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Investigating Problem-Based Learning in Saudi Arabian Mathematics Education: a TIMSS-related study

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Abstract

The aim of this study is to investigate the effectiveness of problem-based learning (PBL) on students' mathematical performance. This includes mathematics achievement and students' attitudes towards mathematics for third and eighth grade students in Saudi Arabia. Mathematics achievement includes, knowing, applying, and reasoning domains, while students' attitudes towards mathematics covers, 'Like learning mathematics', 'value mathematics', and 'a confidence to learn mathematics'. This study goes deeper to examine the interaction of a PBL teaching strategy, with trained face-to-face and self-directed learning teachers, on students' performance (mathematics achievement and attitudes towards mathematics). It also examines the interaction between different ability levels of students (high and low levels) with a PBL teaching strategy (with trained face-to-face or self-directed learning teachers) on students' performance. It draws upon findings and techniques of the TIMSS international benchmarking studies.

Mixed methods are used to analyse the quasi-experimental study data. One -way ANOVA, Mixed ANOVA, and paired t-tests models are used to analyse quantitative data, while a semi-structured interview with teachers, and author's observations are used to enrich understanding of PBL and mathematical performance.

The findings show that the PBL teaching strategy significantly improves students' knowledge application, and is better than the traditional teaching methods among third grade students. This improvement, however, occurred only with the trained face-to-face teacher's group. Furthermore, there is robust evidence that using a PBL teaching strategy could raise significantly students' liking of learning mathematics, and confidence to learn mathematics, more than traditional teaching methods among third grade students. However, there was no evidence that PBL could improve students' performance (mathematics achievement and attitudes towards mathematics), more than traditional teaching methods, among eighth grade students.

In 8th grade, the findings for low achieving students show significant improvement compared to high achieving students, whether PBL is applied or not. However, for 3th grade students, no significant difference in mathematical achievement between high and low achieving students was found. The results were not expected for high achieving students and this is also discussed. The implications of these findings for mathematics education in Saudi Arabia are considered.

Dedication

“I declare that, except where explicit reference is made to the contribution of others, that this dissertation is the result of my own work and has not been submitted for any other degree at the University of Glasgow or any other institution.

Signature -----------------------------

Nawaf Awadh Khallaf Alreshidi

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Chapter One: Introduction

1.1 Introduction

This study aims to investigate the effectiveness of problem based learning (PBL) on the achievements of primary and intermediate school students and analyse the effect of PBL on their attitudes towards mathematics. Firstly, this chapter presents the researcher's background and outlines the study problem. This is followed by a discussion that highlights the importance of problem solving and the important cognitive domains that are required for problem solving. An overview of PBL is also provided, along with an investigation of PBL with self-regulated learning (SRL) skills. Students' attitudes towards mathematics are then discussed, followed by the significance of the study. Finally, a brief summary of the review of some previous studies in this area, the research questions, and the limitations of the study are then presented.

1.2 Researcher's background

The researcher has been teaching mathematics for several years and over this time has noticed that most of the students rely heavily on memorisation techniques. Most students feel that mathematics is difficult and they cannot easily apply it in their daily lives. Mathematics is employed as an integral part of other sciences in many areas; however, it is being taught as a separate learning subject in classrooms which could result in students having a poor level of understanding in this subject (Ronis, 2008). Therefore, showing how mathematics functions in real life, and how it applies in other subjects, could improve students' understanding, and ultimately their attitudes towards learning mathematics.

The researcher's students often ask him what the benefits of learning and studying mathematics are. The researcher believes that this is a question which cannot be sufficiently answered by merely informing students about the importance of mathematics in their lives, but in order for them to fully understand, students need to be shown how mathematics functions in real life, and encounter real-life problems. These observations made the researcher think about PBL, as a possible pedagogical approach for improving this situation. He believes that this strategy may also solve the problem of low achievement levels in mathematics, and students' reluctance towards learning mathematics in Saudi Arabia. This will be discussed next.

1.3 The problem of the study

Some of the main aims of the Ministry of Education in Saudi Arabia are to improve students' abilities to learn, develop students' communication and higher-order thinking skills in mathematics, and to provide a high standard of quality education (Education, 2007). To this end, the Ministry of Education of Saudi Arabia has provided additional training courses for teachers and also implemented an improved curriculum in schools designed to improve students' achievement levels in mathematics (Al-Mutairi 2006; Buthaina, 2006; Almaleki 2010). However, in spite of this, the problem of low achievement levels in mathematics and students' reluctance towards learning mathematics still exists as one of the main problems in Saudi Arabian schools. It is believed that one of the causes of this failing may be the conventional methods of teaching which are used (Almaleki, 2010).

Saudi Arabia has participated in the Trends of International Mathematics and the Science Study (TIMSS) in 2007 and 2011, undertaken by the International Association for the Evaluation of Educational Achievement (IEA) every four years, to evaluate the students' performance in mathematics and science, and the effectiveness of education in the schools of the participating countries in the world. The results shows that the total score that Saudi Arabia gained was 329 for eighth grade students in 2007 and 394 in 2011, and for fourth grade students in 2011 the total score was 410. This was significantly less than the average score of the 500 participating countries and ranks amongst the lowest achievement scores in the list countries. In addition, the majority of fourth and eighth grade students in Saudi Arabia with (93%) and (80%) respectively, were not able to solve problems compared to about (72%) and half of the fourth and eighth grades internationally, respectively (see https://nces.ed.gov/TIMSS/).

Furthermore, the first annual report of the case of education for the academic year 2006/2007, The General Administration of Educational Supervision (2007), indicated that the signs of failure are evident in the education system and it was necessary to keep up to date with mathematics pedagogical developments and the needs of the Kingdom of Saudi Arabia (Ministry of Education, 2007). The report revealed that low results were being experienced by students in Saudi Arabian schools at various stages of study. Moreover, according to some studies, many of the reports produced by supervisors have revealed that the low level is not limited to new teachers but also to veteran teachers, which may reflect the use of conventional methods, and lack of new, innovative, and creative approaches to teaching (Al-Mutairi 2006; Buthaina 2006).

In 2004 Mena indicated that one of the important trends and changes in the future of learning and assessment of mathematics in the Arab world is to give an opportunity for some recent trends in the methods and strategies of mathematics teaching to be implemented. Students' methods of cooperative learning and problem-solving skills need to be examined in order to assess their ability to develop attitudes in mathematics and improve their levels of achievement overall (Faiz, 2002).

Therefore, PBL could possibly improve students' outcomes in mathematics. Teaching students by using problem solving approach aims to improve problem-solving skills. Problem solving will be discussed next.

1.4 Problem solving

One of the goals of solving problems is the learning and studying of mathematics, and problem solving is a major means of doing mathematics (NCTM, 2000). In this section, the importance of problem solving in mathematics education will be discussed, followed by the essential cognitive domains required to solve problems.

1.4.1 Importance of problem solving in mathematics education

The last two decades have seen a marked increase in the use of using problem solving as a main approach in teaching and learning mathematics (NCTM, 2000; Hung et al., 2008; Westwood 2011). The importance of solving problems in the modern curriculum has been highlighted in a number of articles and researches around this topic (NCTM, 2000; Stonewater, 2005; Ronis, 2008; Almaleki, 2010). Arising from this it has been recommended that problem solving is central to education (Schaafstal et al., 2001; Middleton, 2002; Jonassen and Hung, 2008)

The National Council of Supervisors of Mathematics stated "*Learning to solve problems is the principle reason for studying mathematics*" (NCSM, 2000, p.1). In addition, problem-solving was among the six criteria of mathematics from the kindergarten grade up to grade 12 (k-12) which was determined by Standards and Principles of Mathematics (NCTM) in 1995 and 2000. In the USA the revised document Principles and Standards for School Mathematics (NCTM, 2000) states that:

> *"Solving problems is not only a goal of learning mathematics but also a major means of doing so. It is an integral part of mathematics, not an isolated piece of the mathematics program. Students require frequent opportunities to formulate, grapple with, and solve complex problems that involve a significant amount of effort. They are to be encouraged to reflect on their thinking during the problem-solving process so that they can apply and adapt the strategies they develop to other problems and in other contexts. By solving mathematical problems, students acquire ways of thinking, habits of persistence and curiosity, and confidence in unfamiliar situations that serve them well outside the mathematics classroom (NCTM, 2000, p. 52)*

This is reflected by Stonewater (2005) when he describes the best way to provide students with the required skills and attitudes, is through problem-solving and inquiry learning. The next section will investigate the important cognitive domains for problem solving.

1.4.2 Important cognitive domains for problem solving

In order to prepare students for solving problems, Huge (2006) has argued that students should not only acquire knowledge to improve problem solving skills, but they must also be able to understand where, when, and how to apply the knowledge.

According to "Trends in International Mathematics and Science Study" (TIMSS) 2011, Knowledge application is at the heart of problem solving. They point out that the term 'applying' refers to the students' ability to apply knowledge and conceptual understanding in problem situations, for example, how successfully they are able to solve routine problems. However, the term 'reasoning' refers to the students' ability to solve unfamiliar or non-routine problems (Mullis et al. 2012). Therefore, knowledge may need transformation to apply for solving a certain problem. Transfer is involved in new learning when prior relevant knowledge and experience is transferred to a new situation (Bransford et al. 1999).

Transformation of learning can be divided into: knowledge near transfer (almost or immediate application) and knowledge far transfer (novel application). Near transfer is when students almost directly apply their original learned knowledge in an approach that is the same or highly similar to how the knowledge was initially learned (Schunk, 2004). Original knowledge requires a greater degree of modification in a far transfer situation than other levels of transformation which makes applying knowledge more difficult (Hung, 2013). Thus, near transfer knowledge will be applied to routine problems, while far transfer knowledge will be referred to in non-routine problems. Therefore, knowing knowledge and applying knowledge in routine and non-routine situations can help students to improve their problem solving skills. As such, there are three essential cognitive domains that are important in mathematics education to improve students' abilities in solving problems, namely, 'knowing', 'applying', and 'reasoning'.

Practising problem solving processes and gaining knowledge can be achieved through the PBL teaching strategy. Problem solving is at the heart of PBL and problem-based learning (PBL) advocates the belief that problem solving should be the curriculum of intellectual focus (Barrows, 1986; Barrows, 1996; Jonassen and Hung, 2008). In addition, recent cognitive research indicates that the best learning is achieved when learners actively engage in the process of PBL (Ronis, 2008). PBL will be discussed in next section.

1.5 Problem based learning (PBL)

The aim of PBL is to work in small groups to solve real-life problems (Barrows, 1986). PBL is when students work in small groups and use skills to solve problems which will stimulate students to learn knowledge through problem-solving processes (Goodman, 2010). According to Finkle and Torp (1995):

> "*Problem-based learning (PBL) is a curriculum development and instructional system that simultaneously develops both problem-solving strategies and disciplinary knowledge bases and skills by placing students in the active role of problem-solvers confronted with an ill-structured problem that mirrors real-world problems*"(Finkle and Torp, 1995, p.1).

The PBL teaching strategy was implemented for the first time in medical education at the University of McMaster in Canada in the 1960s (Barrett et al., 2005). Since its inception, medical education has been invigorated since being taught by PBL processes. The strategy has spread across many countries and disciplines: some people use PBL in particular modules, and others use it as integrated ways across the programme (Barrett and Moore, 2010).

Although PBL has spread widely, it is not free from criticism by some researchers. For example, Kirschner et al. (2006) criticise PBL from different aspects includes being 'minimally guided instructional' approach and they presents some negative findings related to its effect on content knowledge acquisition. However, Hmelo-Silver et al. (2007) do not agree with the Kirschner et al criticism.

PBL research does show its superiority over traditional teaching methods in some aspects of learning outcomes. However, the literature shows the effects of PBL tend to be similar to the effects of traditional teaching methods in terms of knowledge acquisition (see (Galvao et al., 2014; Bassir et al., 2014; Smits et al., 2002). In addition, there are some challenges related to PBL which include planning for PBL and the time consuming implementation process which subsequently causes a massive shift in the roles of both students and teachers (Ronis, 2008; Monks, 2010).

Barrow (1996) describes the six core characteristics of PBL:

1. Student is the centre of learning.
2. Learning occurs in small groups of students.
3. The role of the tutor is as a facilitator or a guide.
4. At the beginning of the learning the student(s) presents authentic problems.
5. The problems are used as a mean to accomplish the goals of learning subject matter by using problem-solving skills to resolve the problems.
6. New knowledge is gained through self-directed learning (Barrows, 1996).

Therefore, PBL is an instructional strategy that contextualises knowledge. Contextualising knowledge can help students to understand where, when and how to apply knowledge. This in line with the recommendations of principles and standards, the document issued in the United States in 2000 (National Council of Teachers of Mathematics, 2000) and the third principle of teaching which emphasized that effective teaching requires teachers to understand what students know and what they need to learn, then challenge them and support them strongly to learn it well. However, this can occur effectively if teachers have spent the time to improve students' self-regulated learning SRL skills through the PBL process. This will be investigated next.

1.5.1 Self-regulated learning SRL skills through PBL

For effective engagement in PBL, students must be responsible for their own learning and actively participate in constructing knowledge and making meaningful processes (English and Kitsantas, 2013). However, many students cannot be easily shifted to this role because they have developed ingrained habits from typically traditional classroom experiences and they rely on passive receiving of knowledge (Ronis, 2008; Hung, 2011; English and Kitsantas, 2013). In order to shift effectively to this new role, students must develop self-regulated learning (SRL) skills (English and Kitsantas, 2013). SRL refers to the extent to which the learner is motivationally, metacognitively and behaviourally active in their own learning processes (Zimmerman, 1989). Self-regulated learners can set goals, plans, identify appropriate strategies, self-monitor and self-evaluate their learning, as well as being intrinsically motivated to learn. They also demonstrate high levels of self-efficacy for learning and achievement (Zimmerman and Kitsantas, 2005). Thus, for effective learning in PBL, SRL is an essential skill (English and Kitsantas, 2013).

Some researches synonymously use SRL as self-directed learning (SDL). SDR refers to the preparedness of students in engaging in learning activities that have been defined by students rather than the teacher (Schmidt, 2000). SDL and SRL are both considered as requiring the motivation to learn independently and having the ability to do so (English and Kitsantas, 2013). PBL is claimed to develop self-directed learning strategies to help students to apply knowledge to new and non-routine problems (Blumberg 2000, Mergendoller et al. 2006).

Within PBL processes, students often move towards the centre of learning and deduction will be replaced with induction (Ronis, 2008). In such student-centred settings learning is active and requires that teachers observe and respond accordingly to the level of understanding of their students (Ertmer and Simons, 2006). The role of the tutor during the learning process is to listen carefully, facilitate, motivate and direct learners to motivate and ask the correct questions (Barrett et al. 2005). Thus, the tutors often put themselves on the level of student understanding, known as cognitive congruence (Schmidt, 2000). Moreover, teachers can facilitate PBL processes if they are using meta-cognitive skills such as thinking aloud with students and modelling behaviours (Delisle, 1997).

Thus, the role of teachers is to structure activities to stimulate students' motivation, to encourage reflection and facilitate their learning processes through guidance, scaffolding feedback and prompting independent thinking (English and Kitsantas, 2013). Therefore, in PBL, teachers can consciously activate behaviours that lead to SRL. On the other hand, the role of students is to go through the PBL process. Students work in small groups, understand the problem, identify and learn what they need to know and generate hypotheses to solve the problem (Hmelo-Silver, 2004). The role of students also is to question, research and use critical thinking in an active way to solve problems (Cerezo, 2004). In PBL students are required to take responsibility for their own learning and give meaning to their knowledge and the concepts they encounter (English and Kitsantas, 2013). Teacher and student roles appear to be necessary for effective engagement in PBL; however, the effect of PBL problems can also be important. Next, PBL problems will be discussed.

1.5.2 Problems in PBL

PBL problems and their characteristics, such as problem difficulty and length of problem, can be effective factors on students' outcomes. Very little research has given attention to the level of difficulty of the problem (Westwood, 2011; Schunk, 2012; Hung, 2013). Wood defined difficulty as "a gauge of how likely the problem is going to be solved correctly or appropriately" (Wood, 1985, p.45). Instructional designers determine an appropriate difficulty level for a PBL problem based on their intuition and experiences (Jonassen and Hung, 2008).

The difficulty level of the problem will have an effect on students' outcomes; for example, if the level of difficulty of the problem exceeds the readiness of the learner then this can lead to failure (Jonassen and Hung, 2008). Therefore, ensuring an appropriate level of difficulty in the PBL problem which is line with the learners' cognitive readiness will be more effective and produce more reliable results (Jonassen and Hung, 2008). In the current study, problems were set with an appropriate difficulty level. This was based on the researcher and teachers' knowledge, as well as the experts' intuition and experiences. However, more research is needed to measure the effects of the difficulty level of problems.

Regarding length of PBL problems, some studies attempted to adapt PBL strategies in K-12. Achilles and Hoover (1996) found shorter PBL problems could be more effective. They added that regular timetabling (50-minute periods) required creative designing for the PBL process (Achilles and Hoover, 1996). In this current study, PBL problems for the intermediate grade school students were designed for two sessions (90-minute periods); however, problems of primary grade students were designed for one session (45-minute periods). The length of the problem can be an effective factor in students' outcomes, so this needs further research and investigation and this should also controlled in future research.

In this study, four characteristics were adopted in the problems:

1. The role of students as stakeholders. The problem is designed to personalise learning in order to maximise students' motivation (Hung, Jonassen et al., 2008).

2. Ill-structured problems. The problem has more than one answer or can be solved in a number of ways. This kind of problem requires students to research for any missing or further required information, generate possible solutions and make the decision as to which one is best.

3. Real-life problems. Problems are relevant to students' daily lives or their future careers.

4. Age-appropriate problems. Problems are designed to consider students' ages. For example, third grade school students received appropriate difficulty and short problems, and the learning issues were contextualised by their interests. For more details see chapter 3.

Students' attitudes towards mathematics can be a significant factor in successful learning. Problems in PBL can contribute to an increase in students' having positive attitudes towards mathematics. It is the belief of the researcher that attitudes should be considered in all instructional methods.

1.5.3 Attitudes towards mathematics

Problems in PBL can be important in order to improve students' attitudes to become more positive towards learning mathematics. However, not all problems in PBL can play this role. PBL can improve students' attitudes towards mathematics by presenting real life problems, "at an age-appropriate level", which could be of interest and show students the value of the mathematics function (Westwood, 2011).

Creating positive attitudes towards learning mathematics is important primarily to demonstrate the value of mathematics' functions in real life. Ababneh, (1995) reported that the goals of mathematics have become more inclusive. It is no longer only the knowledge domain, which is important; interest now includes the domain of emotion in mathematics, through focusing on appreciating the value of mathematics and its privileged position, aesthetic dimensions, the development of logical thinking, and the precision of expression and awareness of the nature of mathematics and its applications in life (Ababneh, 1995). These trends in mathematics education affect students in their attempts to accept new concepts and understand them in order to apply them efficiently and effectively, therefore it is necessary to develop student's attitudes towards mathematics (Alenizi, 2010).

Secondly, much research shows attitudes towards mathematics have been significant factors in students' levels of mathematics achievement. For example, The Trends in International Mathematics and Science Study (TIMSS) that provides data about participating countries in their educational system, particularly in mathematics and science, and occurs every four years since 1995 reported:

> *"TIMSS routinely presents very powerful evidence showing that, within countries, students with more positive attitudes toward mathematics have substantially higher achievement, and the results from TIMSS 2011 are consistent with previous assessments"(Mullis et al., 2012, p.326).*

The next section will present the importance of the current study.

1.6 Significance of Study

The significance of the study is that it is one of the first studies in Saudi Arabia - according to the investigations of the researcher - especially those interested in studying the impact of using PBL on mathematics achievement and attitudes towards mathematics.

The importance of the study is also highlighted in its employment of PBL teaching methods that may be contributing to addressing weaknesses in students' achievement. This may give the use of the PBL strategy the opportunity to help in resolving the problems of students' reluctance towards mathematics, and their weakness in mathematical thinking. It may also work to improve students' attention and raise their motivation towards learning. The use of PBL may also enhance the confidence of teachers of mathematics to use it for problem-solving. Furthermore, it could also help in improving students' perceptions about the value of mathematics by showing students' the functions of how mathematics is applied in real life situations. It can also help to give an insight into how best improve students' performance in TIMSS mathematics research. Thus the researcher hoped that this study might contribute effectively in understanding this area.

It is hoped that the study will contribute in making some recommendations that may help the authors of mathematics books at the intermediate and primary stages in a way that includes PBL. The results of this study may also help mathematics curriculum planners and designers, as well as educational supervisors, to integrate the PBL strategy in mathematics teaching development programmes. It may also stimulate teachers to apply them in the classroom. In addition, this study may provide a good training programme for teachers of mathematics during their work, or even during the pre-service period. It also could give other researchers insight when conducting further researches in respect of controlling some factors such as students' readiness to learn mathematics. Therefore, I argue that the implications of this study should not be limited to the Saudi Arabian context only, but also can be advantageous for mathematics education in general. However, different important factors that relate to students' learning outcomes including students' background, culture, socioeconomic status and prior knowledge have to be taken into account for generalising purposes. The next section is reviewing the literature of PBL and showing the relationship between the current study and TIMSS research.

1.7 PBL literature review

The current research aimed to investigate the effect of PBL strategies on students' achievement levels and their attitudes towards mathematics. I argue that this strategy helps teachers and students become 'co-investigators' and enables students to practice problem solving.

As discussed previously the 'knowing', 'applying' and reasoning domains appear to be important domains for problem solving. In addition, 'attitudes towards mathematics' was found to have an effect on students' levels of achievement and this also plays an important role in engaging students in SRL processes through PBL. The current study is consistent with TIMSS research in assessing the same aspects of achievements and attitudes. In the following section the researcher explains how this study relates to TIMSS research and provides an analysis of his review of some of the previous studies in PBL in relation to the aspects of assessment which have been addressed.

1.7.1 How this study related to TIMSS

Some studies have suggested that it is necessary to assess the effect of PBL on student outcomes from different angles, (Gijbels et al., 2005; Leary et al., 2009). In order to assess the PBL strategy for this study, the researcher carried out a literature review and analysed the outcomes of recent TIMSS researches which were conducted in 2007 and 2011, as TIMSS international research assesses mathematics education from different perspectives and aspects using valid instruments (Mullis et al., 2012). This study also considered effective factors relating to mathematics class activities that emerged in TIMSS. TIMSS assesses mathematics education from several perspectives, such as students and teachers, and also considers other aspects such as knowing, applying and reasoning domains. This study will attempt to assess students' knowledge acquisition, and ability to apply mathematical knowledge in routine and non-routine situations or problems. In addition, this study will also attempt to examine the effects of PBL on students' attitudes towards mathematics which includes learning mathematics, value mathematics and confidence to learn mathematics.

The most recent TIMSS 2011 research indicates that several factors have an impact on students' mathematics achievement levels. In additional to attitudes towards mathematics, both readiness to learn mathematics and engagement in learning mathematics appeared to be effective factors in students' achievement in mathematics. The current study considered these factors by taking into account the teachers' perspectives.

This study targeted eighth grade students and third grade primary school students. This is also consistent with TIMSS research. However, it should be pointed out that the characteristics of both the primary and intermediate school students are different due to developmental issues (Schunk, 2012). However, TIMSS targets fourth grade students and due to the time when the data collection took place the fourth grade students in Saudi Arabia were at the end of the last semester and were studying new topics which were not covered by TIMSS. This led to the researcher opting to use third grade students rather than fourth grades for this study.

1.7.2 Previous studies in PBL and Research questions

In order to implement this study a literature review was necessary to take advantage of the information available and to attempt to highlight and fill any gaps that exist. Therefore, the current study is limited to assessing PBL from the 'knowing', 'applying' and 'reasoning' achievement levels, and students' attitudes towards mathematics.

The literature review reveals that PBL tends to improve reasoning (Sungur and Tekkaya, 2006; Araz and Sungur, 2007; Gürses et al., 2007; Senocak et al., 2007, Ambo Saeedi and Al Balushi, 2009; Zhang et al., 2011; Hussain, 2012; Kong et al., 2014), and applying abilities (Dochy et al., 2003; Moran, 2004; Pease and Kuhn, 2011; Bassir, et al., 2014) better than traditional teaching methods; however in the knowledge domain, PBL gives similar outcomes to traditional teaching methods (Vernon and Blake, 1993; Colliver 2000; Matthews, 2004; Dobbs, 2008; Sanderson, 2008; Wong and Day, 2009; Bassir et al., 2014). It also shows high achieving students interacted with PBL more than low achieving students (Simons and Klein, 2007). In addition, the previous research shows that the PBL teaching strategy tends to increase positive attitudes among students more than with traditional teaching methods (Albanese and Mitchell, 1993; Vernon and Blake, 1993; Colliver, 2000; Nowak 2001, Smits et al., 2002; Moran, 2004; Goodnough and Cashion, 2006, Lou et al., 2011, Pease and Kuhn, 2011; Borhan, 2012; Hinyard, 2013). This seems to be true for university students in medical schools and other similar institutions because the majority of the studies (see examples: Vernon and Blake, 1993; Colliver, 2000; Smits et al., 2002; Dochy et al., 2003; Al-Azri and Ratnapalan, 2014), were conducted in university and medical and allied medical contexts, however more research is needed for k-

12, particularly in mathematics. Furthermore, it has been suggested that it is necessary for teachers to be trained in implementing PBL teaching strategies (Barrows, 1996; Hmelo-Silver and Barrows, 2006; Leary et al., 2009, Leary et al., 2013). However, there is insufficient evidence to support the necessity of training teachers in implementing PBL. In addition, no single study- as far as the author knows- measured the effects of different professional development (PD) types: teacher training face-to-face and self-directed learning on students' outcomes including mathematics achievement and attitudes towards mathematics.

Despite the power of mixed methods, few studies have used this approach to further investigate the effectiveness of PBL on learning outcomes, (see Shepherd, 1998; Nowak, 2001). In addition, few researchers assess the effectiveness of PBL from different aspects and perspectives, for example, Sungur and Tekkaya (2006), Wong and Day (2009). Also, few studies have considered different ability levels of student achievement and measured its interaction with PBL in students' achievement, (see Elshafei, 1998; Simons and Klein, 2007). However, no single study- as far as the author knows- measured the interaction effects of different ability students with PBL in attitudes towards mathematics. In addition, more research is needed into the perspectives of k-12 teachers about PBL implementation. The available literature related to this is drawn from university tutors. The current study attempts to consider these gaps.

The current study will use quantitative and qualitative methods to describe and explain the phenomenon more accurately. In addition, this study has drawn upon findings and techniques of the TIMSS international benchmarking studies.

TIMSS research shows that three factors have an effect on students' mathematics achievements, namely students' attitudes towards mathematics, students' readiness to learn and engagement of students in learning. Students' attitudes towards mathematics cover the following themes: 'students like learning mathematics', 'value mathematics' and 'confidence to learn mathematics'. All of these areas were considered to be contributory effective factors associated with higher levels of mathematics achievement. This study considered all of these elements because these factors show an impact on students' mathematics achievement in TIMSS research.

In order to consider the different ability levels of student factors, students were divided into two groups comprising high and low achievers based on their school records and pre-test results. This allowed the researcher to investigate the effects of 'interaction of different levels of students (high and low achievers)' whilst using the PBL teaching strategy on students' mathematics achievement. The engagement of students in learning and students' readiness involved the author's own observations [in the classroom] and by conducting interviews with teachers.

The mathematics instrument used in this study is a combination of TIMSS exams from the 'knowing', 'applying' and 'reasoning' domains. The reason for using this instrument is because it is an international test that has been already tested for its reliability and validity. Another reason is to investigate the effectiveness of PBL from more aspects, as mentioned above.

The attitudes test included 'like learning mathematics', 'value mathematics', and 'confidence to learn mathematics'. The aspects of the attitudes in these areas were shown in TIMSS 2011 research to have a strong association with higher achievement in mathematics.

In order to examine and find out the effects of using PBL on mathematics achievement and attitudes towards mathematics among second grade (eighth grade) intermediate students, and third school students in Saudi Arabia, the study will try to answer the following questions:

1. What are the effects of PBL teaching strategies with trained and untrained teachers on male students' achievement levels (knowing, applying, and reasoning) when compared with conventional methods using TIMSS instruments?

2. What are the effects of PBL teaching strategies with trained and untrained teachers on male students' motivation (attitudes towards mathematics, placing value on mathematics, and confidence to learn mathematics) when compared with conventional methods using TIMSS instruments?

3. Is there significant interaction between traditional teaching methods and PBL teaching strategies with trained and untrained teachers and levels of achievement (high and low) in male students' achievement (knowing, applying, and reasoning)?

4. Is there a significant interaction between traditional teaching methods and PBL teaching strategies with trained and untrained teachers and levels of achievement (high and low) in male students' motivation (attitudes towards mathematics, placing value on mathematics, and confidence to learn mathematics)?

5. What is the perspective of teachers of using PBL when compared with conventional methods?

The research questions were developed through reviewing literatures related to PBL studies and TIMSS mathematics education results, to highlight the gaps in which previous studies have neglected to research the interaction of different types of professional development in depth (face-to-face training and self-directed learning) and different ability levels (high and low achievers) with PBL. Similarly, no substantial empirical study conducted in Saudi Arabia, or elsewhere, has assessed the effect of PBL on different aspects of achievement, such as looking at ‘knowing’, ‘applying’ and ‘reasoning’ abilities along with the different aspects of attitudes, such as ‘like learning mathematics’, ‘value mathematics’ and ‘confidence to learning mathematics’, or assessed the teachers’ perspectives about implementing PBL.

The outcomes of PBL studies and TIMSS research are discussed in the third chapter. The second chapter presents the Saudi contexts. The fourth chapter will describe the methods and methodology that will be used to conduct the study. This is then followed by the fifth and sixth chapters which will present the results of the study. Then the seven chapter will discuss the results in light of the literature review. The eighth chapter contains the conclusions and implications.

Chapter Two: Saudi Arabian Contexts

2.1 Saudi Contexts

This section presents the history of Saudi Arabian education policies along with an overview of the current education system in Saudi Arabia. The Saudi Arabian K-12 Education Reform Policy and two initiative programmes for reform - 'The Educational Ten-Year Plan (2004-2014)' and 'The King Abdullah bin Abdulaziz Education Development Project (Tatweer)' - are also discussed. This is followed by discussion about Professional Development Programmes, an overview of The Public Education Evaluation Commission (PEEC) and The Excellence Research Center of Science and Mathematics Education (ECSME). Saudi Arabia's Vision 2030 and education problems are dissected at the end.

2.1.1 Profile of Saudi Arabia

The Kingdom of Saudi Arabia (KSA) was founded in 1932 by King Abdul Aziz Bin Abdul Rahman Al-Saud. The KSA covers an area of 2,149,690 sq. km, is surrounded by the Arabian Gulf, Kuwait, Qatar, United Arab Emirates (East), Red Sea (West), Iraq and Jordan (North) and Yemen and Oman (South), and is considered to be the largest country in the Arab peninsula (Royal embassy of Saudi Arabia, 2011). According to the Central Department of Statistics andInformation, in 2014 the population of the KSA totalled around 30 million and had approximately 10 million expatriates (CDSI, 2016).

The KSA is divided into 13 administrative areas including AL-Riyadh, Makkah AL-Mokaramah, Al-Madinah Al-Monawrah, AL-Qaseem, Eastern Region, ASSER, Tabuk, Hail, Northern Borders, Jazan, Najran AL-Baha, and AL-Jouf. Each administrative area is divided into a number of Governorates, and also each Governorate divided into a number of sub- Governorates, see (CDSI, 2016).

The KSA is the origin of Islam and home to two of the holiest mosques of Islam in Makkah AL-Mokaramah and Medina Al-Monawrah (The World Fact Book, n.d.). The Saudi population has a high degree of homogeneity in culture, language (Arabic), adherence to Islam and strong family tribal relationships (Al-Seghayer, 2011). These characteristics of demography influence the framework of educational context (Almunajjed, 1997). For example, due to religious beliefs, a gender segregation system is adopted in Saudi Arabia.

In KSA all stages of education are free of charge for all citizens, including expatriates. The Saudi education administration system is highly centralized (Ministry of Education: Saudi Arabia, 2004). According to the most recent statistics there were almost 7 million students in public education (primary, intermediate and secondary) with a slightly higher number of male students. For example, the student population of primary schools in 2014 comprised 1,904,792 male students, compared with 1,776,374 female students. In addition around an eighth of the total number of male students (24,565) were studying in private schools but the number of female students in private schools totalled about half of this figure. This indicates that a greater number of male students are supported by their families to study in private schools, which are believed to be of higher quality than public schools. This could be due to the fact that males have more responsibilities than females to financially support their families, including wives and children but this is not the case for females.

2.1.2 History of education in Saudi Arabia

The first formal authority of education (The Council of Education) in Saudi Arabia was established in 1927. This council aimed to provide compulsory primary education for all children in 'Hejas': Makkah and AL Medina. Five years later, after the unification of the KSA, the council expanded to cover the whole of Saudi Arabia (Al-Ansary et al., 2004). Later on in 1953 The Ministry of Education was established and became responsible for supervising public education sectors covering both private and public sectors and including primary, intermediate and secondary schools (Ministry of Education: Saudi Arabia, 2004). All educational policies were supervised by the Supreme Council of Education and controlled by the government. In 1963 the Supreme Committee of Education was led by the King and included Ministers of Education, Ministers of Information Interior, and Defence Ministers and in subsequent years the General Presidency, Labour and Social Affairs, and Ministers of Girls' Education, as members of the Committee. The responsibility of the Supreme Committee was to set out all policies in respect of education in Saudi Arabia (Al-Sonble, 2001,).

Education in the KSA has had a remarkable effect on the reduction of illiteracy. In 1950, for example, it was estimated that more than 90% of the KSA population was illiterate (Al-Romi, 2001). Recently, however, in 2011, this percentage had dramatically reduced to less than 14% (International Human Development Indicators, 2011). These figures may have incentivised the Saudi education policy makers to pay more attention to the quality of education in the KSA. Indeed, Al-Sabti, the Vice Minister of Education, stated that the time has come to focus on quality of education (Chicago Forum: Private Sector to Help Reform Saudi Education Systems, 2012).

2.1.3 System of Saudi education and objectives for each stage

Students study for a total of 12 years in Saudi Arabia; 6 years at primary level, 3 years at intermediate level and 3 years at secondary level, however, pre-school education (Kindergarten) is not compulsory. Kindergartens are delivered for children aged 3-5 years but attendance is not required for enrolment in the first grade. The primary school stage is the real start of general education; it contains six grades. Saudi children start primary school by the age of six and usually leave aged twelve years old. At the age of twelve when students have completed the primary school level they can start intermediate school which they attend for three years and leave by the age of fifteen. Intermediate schools consist of three grades. Following the completion of the intermediate school level students can then start the secondary school stage which also consists of three year levels. Students usually start secondary school at the age of fifteen and leave at the age of eighteen, see Figure2.1.

A gender segregation system is adopted in Saudi Arabia. This adopted system begins from the first year of schooling to the final year of the university. The first nine years of schooling, six years for primary school and three years for intermediate school, is compulsory for both male and female.

The curriculum of subjects for both males and females are similar to each other. In the last two years of school, students have to choose to either study with natural science subjects, such as science and mathematics, or study without natural science but with extensive social science courses. Students who study without natural science would not be accepted to study natural science later on at universities or other higher education institutes; however, all other students can choose to study any subjects they wish without any restrictions relating to their prior education. The school year consist of two semesters; each one last around 16 weeks with 2 more weeks for examination time.

The school day often starts at 7:00 am and ends at about 1:30 pm although this may vary slightly from school to school. There are seven periods or lessons per school day, each lasting for a total of 45 minutes. Students are required to pass exams in order to be promoted to the next grade; however, this does not apply to elementary level students. Failed students are given one more chance to retake the exam. If they do not pass on their second attempt they will then need to repeat the same grade. An on-going evaluation system, which evaluates students in acquiring specified skills for each subject, is applied at the elementary stage (AL-Abdulkareem, 2009).

The same subjects are taught in both semesters. Mathematics is compulsory for all students in school apart from the last two years for students who chose not to study nature science. The mathematics curriculum is the same for both males and females. Male and female schools are supervised under the same education departments and the Ministry of Education. In addition, at the university, the mathematics department teach the same curriculum separately to males and females. About one quarter of Saudi Arabia's budget is spent on education.

Finally, in Saudi Arabia, to become a teacher, a student must be qualified with an educational bachelor's degree in the disciplines required, or an educational Diploma (for one year) if the candidate has a bachelor degree, (non-educational). In addition, a candidate must pass two exams: one assesses the candidate's abilities in education knowledge and skills, while other one is to assess the candidate in the knowledge and skills in their disciplines (ENJ, 2016).

Saudi Arabian officials give special care to education, in particular, for mathematics and science. Attempting to reform education in KSA is described next.

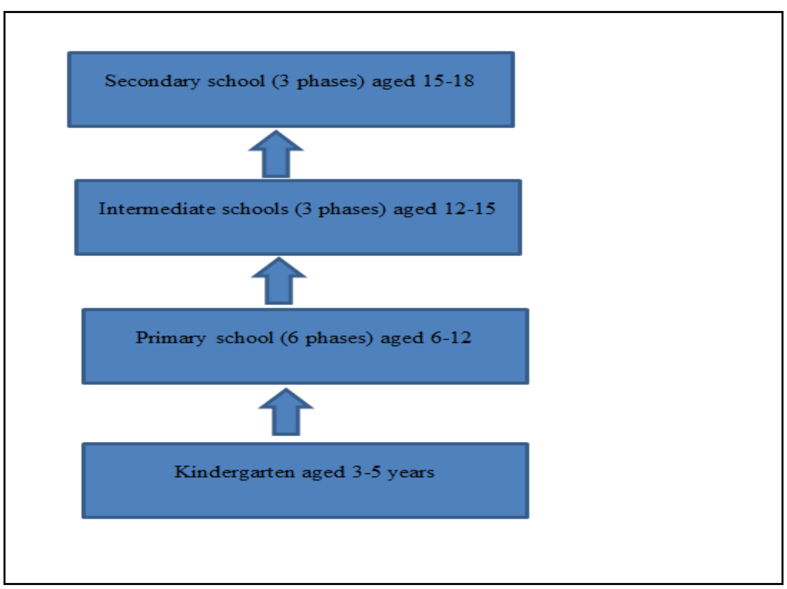


Figure 2.1: the educational system and its stages and phases, and ages in Saudi Arabia

2.2. Saudi Arabian K-12 education Reform

Several economic initiatives have been established by the Saudi government to diversify the country's income resources in an attempt to steer aware from depending heavily on oil production (Jenkins, 2008). Consequently, the acknowledgement of the role that education plays in preparing Saudis for the competitive global market led to the implementation of several educational reforms dating from 2003 (Jenkins, 2008).

The Ministry of Saudi Education reported that "*the world is governed by the economics of knowledge and the power of ever renewing sciences… In addition, we face a world with complex relationships and interactions and those who possess the knowledge, skills and will can join the march of human progress*." (Ministry of Education: Saudi Arabia, 2004, p. 8). This clearly indicates that decision makers in Saudi Arabia were aware of the importance of knowledge and skills to prepare for and face future challenges. It also placed emphasis on the adoption of effective learning and teaching methodologies and combining this with new technologies. In fact, they reported that "*Changes and developments of educational systems, with its methodologies and approaches, are an urgent national strategic requirement*" (Ministry of Education: Saudi Arabia, 2004, p. 8). In response to this, two key significant reforms in Saudi education have recently taken place including the Educational Ten Year Plan (The General Project of Curricular Development) and The Tatweer Programme. These initiatives will now be discussed next.

2.2.1 The Educational Ten-Year Plan (2004-2014)

In 2003 The Ministry of Education adopted a Ten-Year Strategic Plan, covering the period 2004-2014. The overall vision of the Ten-Year Strategic Plan of the Ministry of Education (2004-2014) can be summarised as follows:

> "*The graduation of male and female students with Islamic values and the appropriate knowledge and practice. These students will have acquired practical knowledge, skills, and attitudes; they will be able to positively react to and face modern changes; they will be able to apply advanced technologies with efficiency and flexibility and to deal with international competition in scientific and practical fields. Their positive participation in an efficient educational system will allow them to develop appropriate abilities and attitudes and to spread the positive spirit of work at school environments that encourage learning and social education*.".(Ministry of Education, 2005, p 12).

However, despite the effort to develop, the Saudi education system has unfortunately not shown a great level of improvement (Aba-AlKhail, 2011; Al-Nazeer, 2011, Al-Nefaie, 2010; AL-Abdulkareem, 2009; Al-Sayegh, 2009; Al-Trairy, 2009, Al-Aklobi, 2008; Al-Harthi, 2007; Al-Saadi, 2007).

2.2.2 King Abdullah bin Abdulaziz Education Development Project (Tatweer)

In response to the growing criticism of the Saudi general education, particularly mathematics and science education, King Abdullah established a programme for mathematics and science improvement called the 'King Abdullah bin Abdulaziz Public Education Development Project (Tatweer)'. The Programme aims to conduct researches and provide training for mathematics and science teachers.

Tatweer is an Arabic term meaning 'reform'. The aim of the Programme is "*to make students proficient in subjects such as math, science, and computer skills. This program will encourage young Saudi students to acquire better communication skills and learn to be more flexible and innovative, as well as teaching environmental literacy*" (Chicago forum: Private sector to help reform Saudi education system, 2012, p. 8). The project focuses on teacher requalification, curriculum development and school systems. The project of Tatweer is independent of the Ministry of Education and is directly supervised by and reported to the King, which gives it a strong authority.

Tatweer decentralizes the Saudi education system by giving more authority to education directorates and schools. The programme focuses on adopting a learner-centered approach and learner needs. Tatweer promotes improving professional development, developing educational standards and assessment to fit the needs of the 21st century and enhancing the school environment to promote learning (Hakami, 2010, p. 12).

Tatweer also contributes to reforming the mathematics and science curriculum. For example, in 2009 a new Mathematics and Science Curriculum was launched which used an adapted series of mathematics and science textbooks produced by the American publishing company McGraw-Hill. The texts were translated and modified in order to be appropriate for all student levels. The new mathematics and science curriculum adopted current teaching and learning trends and was expected to adopt a learner-centred approach (Obeikan, for Research and Development, 2010). The project stated a future vision for Saudi education, as follows:

1. The Learner is the focal point of the learning process: working to achieve excellence in learning for all learners, according to their abilities.

2. The Ministry of Education's role is to focus on educational planning, guiding the educational process, development of educational standards, and building quality and motivation systems.

3. Decentralizing the educational process administration and giving more authorities to educational regions and schools.

4. Building capacity and equipment in schools to develop the educational process and direct all its plans and programs to improve learning.

5. Building human and technical capacities at educational regions to guide the development process at their schools and achieve high quality performance. (Strategic plan for public education development in the Kingdom of Saudi Arabia, 2011, p. 3)

Furthermore, the main goals of the Tatweer project cover:

1. Developing a system of education standards, assessment and accountability which will fit for the 21st Century.

2. Implementing the Tatweer major development programs:

3. Developing curriculum and learning materials to meet current and future skill needs.

4. Enhancing the school environment to promote learning.

5. Continuing Professional Development for leaders, managers.

6. Extended School Services in partnership with the wider community. (Hakami, 2010, p. 12)

The results of these initiatives were reflected in Saudi outcomes as TIMSS 2011 reported that some improvements in students' results were found (see TIMSS section). This could be the result of an improvement in teacher training and the reforms which were applied to the mathematics curriculum. However, Saudi students' mathematics results were still lower than the international average (for more details see the TIMSS section).

2.3 Professional development programmes

In 1975, the *General Administration of Teacher Preparation Programs* initiated a teacher professional development programme. Six year later the Programme came under the *General Administration of the Educational Guidance and Training*. Later on in 1998 an independent administration for the training of teachers was launched, named the *General Administration for Educational Training and Scholarships*, which was responsible for professional development programmes including teacher training and scholarships for teachers (Ministry of Education, 2013). Nowadays, the Centre has been expanded across all 45 educational departments and covers the entire country and provides teacher training programmes for all teachers.

In 2009 as part of the Project of Mathematics and Natural Sciences (PMNS) a Secondary Professional Development Programme was developed and provided for all mathematics and science teachers. PMNS trains mathematics and science supervisors so they can then train mathematics and science teachers. The goals of PD Programmes are to identify the competences of teachers and identify the skills needed (Mansour et al., 2013). According to AL-Mazroa and AL-Shamirani "*Although PMNS uses the term 'professional development programmes', it utilizes training workshops as the most common source for science teacher professional development. In fact, the term 'training' is the most prevalent term mentioned when it comes to educational research in Saudi Arabia*" (Mansour et al, 2015, p10). However, no attention was given to learning activities for teachers. According to Mansour et al. (2014) professional development leaders need to design meaningful learning experiences for all teachers as a guiding framework that frames all learning activities. However, these programmes are not free of criticism, one example being the differing views and perceptions between teachers and their supervisors regarding PD needs. (Mansour et al., 2014).

The Tatweer Project, which is mainly focussed on mathematics and science teachers' development needs, subsequently produced a set of goals, as follows:

- improving learning capacity for both teachers and supervisors;
- improving general education outcomes through developing basic teaching skills, and
- improving teachers' leaderships of their classrooms (Tatweer Project, 2014).

However, no evidence of success or outcome results have yet been provided. These researches were conducted and funded by the Excellence Research Center of Science and Mathematics Education (ECSME) which will is described below.

2.4 The Excellence Research Center of Science and Mathematics Education (ECSME)

The Excellence Research Center of Science and Mathematics Education was established 2007 in the University of Kind Saud. The Center provides training courses, seminaries and conducts research. The Center's objectives are summarised as follows:

1. Establish research priorities for science and mathematics education in general and higher education in Saudi Arabia.

2. Conduct research studies and projects to diagnose the status and reality of science and mathematics education which lead to quality science education in both general and higher education in Saudi Arabia.

3. Encourage and guide the researchers to become leaders of future advancements related to science and mathematics education through conducting cooperative programs with various researchers in science and mathematics education for the purpose of developing specialized research and authorship, graduate theses and dissertations, as well as students' projects.

4. Create and disseminate knowledge and information for the purpose of advancing the state-of-the-art in science and mathematics education.

5. Contribute to the professional development of researchers in science and mathematics education in order to generate leaders for future advancements in science and mathematics education.

6. Conduct outreach research work and consultations in science and mathematics education for institutions and government entities.

7. Create partnerships with national, regional, and International related institutions in order to develop quality science and mathematics education and to build effective bridges and networks for the transfer of knowledge and research expertise.

8. Develop a joint intellectual and common scientific vocabulary among science and mathematics education, at the pre-university and university level,(ECSME, 2016).

ECSME has five research groups namely: Professional Development for Mathematics and Science Teachers, Developmental Assessment for Mathematics and Science Teachers, Teaching and Learning Mathematics and Science for Primary School, Assessment and Analysis Curriculum of Mathematics and Science for Public Education and Measure and Development Physics Education in Initial University Curriculum.

These research groups conduct studies which relate to Saudi contexts in mathematics and science education. For example, the Professional Development for Mathematics and Science Teachers Group which is led by Dr. Nasser Mansour, a Senior Lecturer in Science Education at the Graduate School of Education in the University of Exeter in the UK, have recently published a book called 'Science Education in the Arab Gulf States', (see (https://www.sensepublishers.com/catalogs/bookseries/cultural-and-historical-perspectives-on-science-education-distinguished-contributors/science-education-in-the-arab-gulf-states/). The group have also conducted and published four researches.

Another example is the Developmental Assessment for Mathematics and Science Teachers Group which has conducted and published six researches. In addition, the Group has implemented an organised plan which aims to conduct more in-depth studies on the TIMSS results of the participating Saudi Arabia students..

In additional to this the ECSME provides training courses and scientific consultation, and also has a seminar every week related to mathematics and science education. The need for the evaluation of public education has increased due to the need to improve quality of education in the KSA.

2.5 The Public Education Evaluation Commission (PEEC)

The Public Education Evaluation Commission (PEEC) was established in 2013. The PEEC is 'a public organization with an independent corporate personality' which reports directly to the King and is responsible for the evaluation of public and private schools (K-12) in KSA. The objectives of PEEC are presented below:

1. Constructing a system of evaluation to ensure the quality of public education including the main standards and indicators.
2. Building a national framework of qualifications.
3. Building advanced standards for public education of all stages that can be used to measure the performance efficiency on both; institutional and program level.
4. Building standards for general education curricula.
5. Evaluating the performance of both public and private schools and accrediting them periodically.
6. Constructing and implementing standardized national tests for each stage.
7. Setting regulations that ensure the quality of education in all its elements and issuing the suitable guidelines.
8. Setting professional standards and proficiency tests for those working in general education.
9. Building a system for teacher licensing requirements.
10. Evaluating the programs of private and public schools.
11. Conducting and supporting research and studies and in the field of evaluation.
12. Publishing the results of evaluation and accreditation implemented by the PEEC.
13. Issuing scientific journals, periodicals, books, handbooks, and brochures, in its field of specialty.
14. Licensing evaluation- specialized institutions to conduct the evaluation processes (PEEC, 2016).

The PEEC has not yet started its operation but is expected to contribute to improving the quality of public education.

2.6 Saudi Arabia’s Vision 2030

“Saudi Arabia’s Vision 2030” has been recently adopted as a roadmap and methodology for developmental and economic action in the Kingdom of Saudi Arabia. The aim of this vision is to grant Saudi Arabia a leading position in all fields. As part of the vision, the National Transformation Program 2020 was launched across 24 government organizations functioning in the development and economic sectors in its first year (Saudi Arabia’s Vision 2030, 2016).

As a response to the Saudi's vision, the Ministry of Education established eight strategic objectives, presented as follows:

(1) Provide education services for all student levels

(2) Improve recruitment, training and development of teachers

(3) Improve the learning environment to stimulate creativity and innovation

(4) Improve curricula and teaching methods

(5) Improve students' values and core skills

(6) Enhance the educational system's capability to address national development requirements and to meet labour market demands

(7) Develop creative financing methods and improve the educational system's financial efficiency

(8) Increase Private Sector Participation in the Education Sector (Saudi Arabia's Vision 2030, 2016, P 60)

It is clear that the education officials aim to improve the quality of education; this is indicated by the aim of improving professional development of teachers, students' skills, and curricula and teaching methods. For example: the programme[1] objective is to improve students' mathematical achievement in international TIMSS tests as follows:

Table2.1: Key performance Indicators in TIMSS tests for Saudi students

Key performance Indicators	Baseline	2020 Target
Average students results in international TIMSS tests (eighth grade: Math)	394	450
Average students results in international TIMSS tests (eighth grade: Math)	410	460

This study might provide an insight for these objectives in improving students' TIMSS results in Mathematics.

2.7 Educational problems

In spite of the generous budgets allocated to education, jobs in the private sector which require highly qualified employees, are mainly held by expatriates, which constitute approximately a third of the population of the KSA. In the private sector in 2009 only about 10% of the work force were Saudis (Al Bawaba, 2011)

A lack of job skills is one of the main problems faced by Saudi graduates. "One of the main issues that the private sector has is the fact that there aren't enough well-trained Saudis for the kinds of jobs that are needed." (Lindsey, 2010, p. 10).

Saudi Arabia participated in TIMSS research to evaluate mathematics and science education for its fourth and eighth grade students. Results revealed that students' scores were significantly lower than the lowest international benchmark (this will be discussed in detail in the next section). These results warned the whole nation about the quality of education in the KSA and questioned its ability to help students to obtain not only knowledge, but also lifelong skills such as teamwork, critical, social and higher-order thinking and also technological skills (Al-Nazeer, 2011). In order to improve this, Al-Nazeer (2011) stressed the importance of preparing teachers to adopt more student-centered instruction and pay more attention to problem-solving skills.

The next chapter will review literature review of PBL studies, and Saudi education in mathematics in the light of The Trends in International Mathematics and Science Study (TIMSS).

Chapter Three: Literature Review

3.1 Introduction

The aim of this study is to assess whether the problem based learning (PBL) teaching strategy has a positive or negative effect on primary and middle school students' achievement levels in mathematics and determine whether the students' attitudes towards mathematics changed as a result of being taught by PBL. This chapter will outline the contributions PBL has made to teaching in general, identify any gaps with PBL research, and highlight any areas where more research is needed. This study will also attempt to provide solutions and recommendations based on the findings. In addition, the study will review recent international TIMSS research in mathematics education and take advantage of its results.

Thus, this chapter aims to review the literatures on how the PBL teaching strategy affects primary and intermediate school students' mathematics achievements, and their attitudes towards mathematics when compared with traditional teaching methods. The chapter aims also to review research on the effects of PBL on the performance of high and low achieving students by analysing their interaction with trained face-to-face and self-directed learning teachers. Furthermore, research on teachers' perspectives about the effects of implementing PBL in the classroom will also be reviewed.

To date there has been limited research conducted about PBL in the field of mathematics education and also in K-12. This research reviews the effects of PBL in different levels of education (K-university level) and looks at subjects such as science and medicine; however, the majority of the studies were conducted at university level and in the field of medicine education.

In general, the review of empirical studies show that PBL tends to improve students' reasoning skills, such as critical thinking, problem-solving and self-directed learning skills, and also tends to improve knowledge application and support positive attitudes. However, the literature shows a variation in the outcomes of the effects of PBL on content knowledge. These outlined findings could not be applied to all the different ages, disciplines and achievement levels of students; this is due to the different PBL contexts and settings. For example, the majority of studies conducted within Arab contexts having all been carried out using different PBL settings, such as 'Wheatley's Model' in problem-centred learning which was classified as Problem Based Learning (PBL). Wheatley's

Model (Wheatley, 1991), is similar to PBL, however, it does not mention whether the characteristics of the problems used met the criteria for PBL problems, i.e., it does not specify whether ill-structured problems were used or not. The current study has adopted PBL settings which originated in medical education at the McMaster university in Canada (Barrows and Tamblyn, 1980).

Students may respond differently to the PBL strategy due to their differences in prior knowledge and skills. Few studies have investigated the interaction between the different ability levels of students (high and low achieving students) with PBL. The finding revealed that high achievers' scored tend to be better than low achievers in their interaction with PBL. However, the majority of these researches ignored the prior knowledge of students when they analysed the data arising from their studies, and this could have possibly led to less accurate conclusions about the interactions of PBL with the different ability levels of students.

The effect of professional development (PD) of teachers on students' outcomes is important. However, few studies have been conducted to examine the effects of PD on students' performance. The results show that students' learning improved in PBL with well-trained teachers. However, no research has been carried out which assesses the effects of self-directed professional development on students' outcomes.

The majority of research has addressed the students' perspectives, while few researches, particularly in K-12, have been conducted to examine the teachers' perspective about PBL implementation. Generally, teachers tend to feel that PBL is more positive than traditional methods; they found it enjoyable; however, they believed the role of teachers to facilitate students' learning is challengeable.

TIMSS research has been reviewed to investigate the outcomes of fourth and eighth grade Saudi students' performance in mathematics and these results have been compared with the international average. Reviewing such massive international research (TIMSS) was extremely beneficial to this study and helped to improve the research by using its instruments and considering pre-existing contributory factors. Reviewing TIMSS 2007 and 2011 researches highlights some effective factors on student performance, such as readiness to learn mathematics, engagement of students in mathematics lessons, attitudes towards mathematics (including 'like learning mathematics', 'placing value on mathematics' and 'confidence in learning mathematics'). This study takes advantage of these factors by including attitudes towards mathematics with mentioned aspects and makes the researcher consider the engagement and readiness in the interview and his dairy observation. For future researches, more studies are needed in examining the effects of readiness levels to learn PBL and the quality of problems in PBL.

Predominantly, the current study attempts to address the gaps which remain within PBL research. The first gap is to consider the important factors that emerged in the TIMSS research to be effective on the achievements of international mathematics students'; such as readiness to learn mathematics and placing value on mathematics' within PBL settings. The second gap to address is to gain a deeper understanding of the effectiveness of PBL in the Saudi Arabia's contexts for primary and intermediate school students. This will require an investigation into the effect of PBL (using the PBL settings originated in medical education at the McMaster university in Canada) on the different aspects of achievement, such as 'knowing', 'applying' and 'reasoning', and through different aspects of attitudes, such as 'like learning mathematics', 'placing value on mathematics' and 'confidence in learning mathematics', whilst also taking into consideration the teachers' perspectives of PBL.

The third gap is to consider the prior knowledge of students by analysing data by using advanced statistical tests, such as Mixed ANOVA and repeated measures ANOVA, which are more suitable for pre and post quasi-experimental studies. This can help to measure the interaction of different ability levels of students (high and low achievers) more accurately than making comparisons between groups by using only post-test scores. The fourth and final gap is related to professional development, where the study will assess the effects of self-directed professional development on students' outcomes.

In this study, teachers who received face-to-face training in PBL implementation will be referred to as 'trained teachers', while the teachers who were asked to conduct self-directed learning in PBL implementation are referred to as 'untrained teachers'.

. The study attempted to answer the following questions:

1. What are the effects of PBL teaching strategies with trained and untrained teachers on male students' achievement levels (knowing, applying, and reasoning) when compared with conventional methods using TIMSS instruments?
2. What are the effects of PBL teaching strategies with trained and untrained teachers on male students' motivation (attitudes towards mathematics, placing value on mathematics, and confidence to learn mathematics) when compared with conventional methods using TIMSS instruments?

3. Is there significant interaction between traditional teaching methods and PBL teaching strategies with trained and untrained teachers and levels of achievement (high and low) in male students' achievement (knowing, applying, and reasoning)?

4. Is there a significant interaction between traditional teaching methods and PBL teaching strategies with trained and untrained teachers and levels of achievement (high and low) in male students' motivation (attitudes towards mathematics, placing value on mathematics, and confidence to learn mathematics)?

5. What is the perspective of teachers of using PBL when compared with conventional methods?

This chapter consists of two parts: PBL and an evaluation of mathematics education in Saudi Arabia. Part One presents an overall background to PBL, provides empirical evidence for the effectiveness of PBL and then details the different roles of PBL. Problems, problem solving and PBL settings are then presented. Part one concludes by outlining the challenges that both the students and teachers experienced during the process of implementing PBL.

Part Two presents a review of the TIMSS research outcomes. The TIMSS research results include analyse the results of Saudi Arabian student outcomes when compared to the international average in the following areas: quantity of teaching mathematics, quality of teaching and learning mathematics factors and attitudes towards mathematics. This research relates to TIMMS 2007 and 2011 with fourth and eighth grade students.

3.2 An overall background to PBL

In this section the historical background of PBL is briefly discussed, followed by the definition of PBL. The difference between PBL and traditional methods is then highlighted. This is followed by a discussion about the relationship between PBL and the current trends in learning, highlighting the critics of PBL and concludes with the potential advantages of implementing PBL in classrooms.

3.2.1 The history of problem-based learning

PBL was developed in the 1950s and implemented in the 1970s at McMaster University in Canada (Barrows, 1996). The implementation of PBL came as a response to students' unsatisfactory results on clinical performance (Barrows and Tamblyn 1980). According to

Albanese and Mitchell (1993) and Barrows (1996), the poor clinical performance was due to conventional methods which did not provide students with clinical problem-solving and self-directed learning skills, but rather focussed on memorization. Since the inception of PBL, some would argue that medical education has become more exciting through being taught by PBL processes (Barrett et al., 2005). The PBL approach has been implemented by many Asian countries as a result of its claimed success in some Western countries, particularly in medical contexts (Borhan, 2012).

In the 1980s, PBL implementation widely spread in response to the Panel on the General Professional Education of the Physician and College Preparation for Medicine (GPEP) recommendations, (Muller, 1984). The advice given was to promote problem-solving and independent learning and reduce lecturers' hours (Barrows, 1996).

However, in medicine, Albanese and Mitchell 1993 criticised the PBL approach from two aspects: firstly, they reported that PBL is being widely and differently practiced. Secondly, it is difficult to assess PBL success. Despite this, they tended to say that PBL can establish deep learning and help students control their own learning. However, they concluded that there was limited evidence to show that PBL is superior to traditional methods, while Vernon and Blake (1993) argued that PBL failed to give students sufficient content knowledge in 'factual recall professional qualification examinations'.

In the 1990s, PBL was extended outside of medical education into other areas within university or even K-12 settings (Hung et al., 2008). The strategy has spread across many countries and disciplines; nowadays, some people use PBL in particular modules and others use it as integrated ways across the programme (Barrett and Moore, 2010).

Although PBL has spread widely, it is not free from criticism by some researchers. For example, Kirschner et al., (2006) criticise PBL from different aspects includes being 'minimally guided instructional' approach and they presents some negative findings related to its effect on content knowledge acquisition. However, Hmelo-Silver et al. (2007) do not agree with the Kirschner et al criticism.

PBL research does show its superiority over traditional teaching methods in some aspects of learning outcomes. However, the literature shows the effects of PBL tend to be similar to the effects of traditional teaching methods in terms of knowledge acquisition (see, Smits et al., 2002; Galvao et al., 2014; Bassir et al., 2014). In addition, there are some challenges related to PBL which include planning for PBL and the time consuming implementation process which subsequently causes a massive shift in the roles of both students and teachers (Ronis, 2008; Monks, 2010). The next section will define the PBL teaching strategy.

3.2.2 Definition of problem-based learning (PBL)

The aim of problem-based learning (PBL) is to work in small groups to solve real-life problems (Barrows and Tamblyn, 1980). Barrows defines problem-based learning as "*the learning that results from the process of working towards the understanding of a resolution of a problem*" stating that "*the problem is encountered first in the learning process*" (Barrows and Tamblyn, 1980, p.1). According to Finkle and Torp (1995):

> "*Problem-based learning (PBL) is a curriculum development and instructional system that simultaneously develops both problem-solving strategies and disciplinary knowledge bases and skills by placing students in the active role of problem-solvers confronted with an ill-structured problem that mirrors real-world problems*" (Finkle and Torp 1995, p.1).

Problem-based learning is defined when students work in small groups and use skills to solve problems and are stimulated to learn knowledge through problem-solving processes (Goodman, 2010). Therefore, PBL is a learning journey for achieving learning and educational goals which starts from encountering a simulated real-life problem and ends up with a solution. PBL can become clearer when compared with conventional teaching methods. This will be addressed below.

3.2.3 Problem-based learning vs. conventional methods

Traditional and PBL instructions aim to help students to acquire effective knowledge (Morrison, 2004). In addition, problem-solving is part of traditional classrooms (Chall, 2000), while problem-solving is a way of learning in PBL (Chin and Chia, 2006). Some of the other differences associated with both types of instruction relate to the roles of both the teachers and students.

In traditional classrooms, knowledge has been well- defined and organised and students assimilate it with their prior knowledge (Schuh, 2004). Furthermore, problems have been solved by students after they have learned content knowledge (Chall, 2000).

In PBL, students gain knowledge initially through problem-solving (Chin and Chia 2006). The role of students is to question, research and use critical thinking in an active way to solve problems (Cerezo, 2004). Teachers are facilitators instead of content experts (Brown, 2003). Therefore, in PBL the problem is presented at the beginning of the instructional action followed by students searching for useful knowledge in order to solve the problem, while in the conventional method the problem comes after students have acquired content knowledge and skills (Chin and Chia, 2006). It can be stated that in PBL classrooms problems are a vehicle to achieve educational and learning goals, while in conventional methods problems are turned to be exercises to consolidate what students have already learned.

Switching the role of the problem from an exercise to practice of what students have already learned (in conventional methods) into a vehicle to learn new content knowledge and skills, has changed the roles for both teachers and students. PBL has made three changes in the classroom: a) students are initially exposed to ill-structured problems, b) students are responsible for their learning and the teacher works as "a meta-cognitive coach" and c) students are given the role of stakeholders (Gallagher and Stepien, 1996). Therefore, the difference between PBL classrooms and conventional classrooms may be summarised as following (see Table3.1):

Table 3 1: Differences between PBL and conventional classrooms

Differences	PBL classroom	Conventional classroom
Content	Organised around set of problems	Concepts, principles, and exercises
Role of teachers	Facilitators, meta-cognitive coach, guide	Source of knowledge, responsible for learning
Role of students	Responsible for learning, researchers, self-directed learners, problem solvers	Listen to teacher's instructions, applying what they have learned, copying what teachers do

The PBL teaching strategy theoretically is supported by Constructivism Theory. This is investigated below.

3.3 Constructivist Theory

Constructivist Theory could be considered as being the most current theory of learning (Fosnot, 1996). This view originated with Lev Vygotsky et al. (1978) and is based on the premise that new knowledge is constructed within individuals when they interact with the world; when individuals actively engage in the process of learning, the new information synthesises into their prior experiences to construct knowledge (Fosnot, 1996; Wilson, 1996; Yew and Schmidt, 2009). This connection builds solid connected networks of concepts (Marx et al., 1997). Constructive learning (constructivism) is where a learner actively builds his or her own personal knowledge (Loyens and Gijbels, 2008). Learners build their own meaningful constructions by using their own experiences and other cultural factors to organise their ideas into their own cognitive schema (Yackel et al., 1993; Lerman, 1996).

Collaboration between learners is supported by the Constructivist Theory to encourage a community of learners (Abdal-Haqq, 1998). Alternative views challenge other current views to create scenarios that stimulate new learning (von Glaserfeld, 1989). The development of the conceptual understanding of learners is enhanced by discussion (Hoyles, 1985). Therefore, the learning process is as valuable as obtaining a correct solution (de Kock et al., 2004).

Constructivism adopts a learner-centered approach. It encourages teachers to act as facilitators who help students to construct meaningful knowledge form their own experiences (Abdal-Haqq, 1998; Leder, 1993). The role of teachers is to facilitate collaborative knowledge construction by students (Hmelo-Silver and Barrows 2006; Hmelo-Silver and Barrows 2008). This can help learners to enhance knowledge transfer (de Kock et al., 2004). Transfer is involved in new learning when prior relevant knowledge and experience is transferred to a new situation (Bransford, Brown et al., 1999).

According to the social constructivist perspective, knowledge construction can occur by active learning processes, such as social negotiation, which encourages and reflects multiple perspectives. Knowledge construction is the outcome of the learners' interpretation of their interaction with the environment and others that takes place in their social context (Vygotsky, 1978; Blumenfeld et al., 1991; Krajcik et al., 2003).

In order for effective knowledge construction, high-order skills, such as self-regulated learning, problem solving and meta-cognitive thinking, must be given emphasis during students' learning processes (Mason and Rennie, 2006; Brown and Green, 2006; Tynjala et al.,, 2009). For example, metacognitive skills help students to effectively construct their own knowledge and to be aware of the gap between what has been done and what needs to be done next. It can also enhance group dialogue and transfer learning (Fogarty, 1994).

As constructivism supports independent learning with the facilitation of teachers and others, such as peers, the Zone of Proximal Development (ZPD) was emerged as a concept which is concerned with the ability of the learner to learn independently among more capable others (Vygotsky andCole, 1978). Therefore, ZPD can work as a guide for lesson and curricular planning to enhance cooperative learning.

Furthermore, constructivism supports any member of the community learning, such as students, teachers, parents or administrators as they can all play part in the learning network and activities (C. Rogers and Freiberg, 1994, p. 183). Therefore, opportunities should be given to learners to solve real-life problems that are related to their community (Blumenfeld et al., 1991). In addition, providing students with relevant and real-life situations is also supported by situated learning theory.

Situated learning supporters indicate that learning is situated within certain contexts (Lave and Wenger, 1991; Wilson and Meyers, 2000). It assumes that *"...learning is most effective when it is embedded in authentic tasks that are anchored in everyday contexts*."(Hung et al., 2008, p.488). The theory of situated learning underlines that knowledge is tied to the certain context (Anderson et at., 1996); it means that the context of knowledge is important to be learned with knowledge. This view restricts knowledge transfer to other contexts (Anderson et at., 1996). Knowledge transfer (which will be discussed later in this chapter) may be more flexible with the constructivist view than the situated learning view.

Furthermore, prior knowledge is also important for both theories - constructivist and situated learning - in order for knowledge construction. According to Lave and Wenger (1991), situated learning aims to place learners in realistic settings, to increase the probability of application within similar contexts and apply the learner's prior knowledge on a certain subject. Therefore, situated learning or situated cognition can make a connection between the theoretical learning and the real-life application of the knowledge (Resnick, 1987). This idea can be used in formal learning; it can be shaped by embedded meaningful learning in the physical and social contexts (Brown et al., 1989). Thus, situated learning is more grounded in interactions among learners and between learners and their environmental context which is compatible with social constructivist (Yuan and McKelvey, 2004). According to Brown et al. (1989), situated learning is one social constructivist notion where the student plays a part in activities directly relevant to the learning application and that occur within a similar culture to the applied setting (Brown et al. 1989). Therefore, situated learning and constructivism include social constructivist perspectives which are matched in authentic learning, prior knowledge and social dialog. For example, these three learning theories: constructivist, social constructivist, and situated learning, support the idea of presenting the real-life problem at the beginning of a learning situation. According to Jonassen (1999), the problem is presented in the beginning to motivate students to solve it and allow them to link the prior knowledge to the current knowledge by interpreting meaning during solving of the problem. In social constructivism, Perera, N. (2011) argued that the problem allows students to negotiate a solution with different perspectives for deeper understanding and social knowledge construction. He also argued that in situated cognition, an authentic situation is represented by the problem that permits real world problem solving. Therefore, learners actively interacting or engaging with complex and real situations such as real life problems can contribute to their knowledge construction.

3.3.1 PBL as a constructivist teaching strategy

Numerous new teaching and learning strategies fall under the general principles of constructivist learning environments which underline collaborative engagement in real-life problems (Gijbels et al., 2006). PBL is considered to be one of the constructivist teaching strategies and is based on the assumptions that constructivists have about learning. Some of these assumptions, as explained above, state that knowledge is socially and individually constructed when people interact with the environment; knowledge is linked with related contexts, thinking is meaningfully spread out within culture and society and there are multiple perceptions related to every occurrence (Hung et al., 2008).

With the PBL teaching strategy a teaching paradigm has switched to a learning paradigm (Barr and Tagg, 1995). It means that students build their own knowledge through active learning. Active learning has two criteria; the first is the construction of meaningful and new knowledge and the second is integration with appropriate basic knowledge (Mayer, 2005). Through the elaboration of PBL, new knowledge links with old knowledge to produce further new knowledge (van Berkel, 2010). In order to build meaningful knowledge, learning must be contextualised. This means that situations that shape how the learner uses the information they have (Dolmans et al., 1997). In PBL, students are facing problems relevant to their future professional practices (van Berkel, 2010). PBL is a constructive philosophy where students build their knowledge through active instruction. "*Problem-based learning is an example of a constructivist model of teaching*" (Monks, 2010); where "*Constructivism proposes that individuals need to construct their own meaning and derive their own understanding from active engagement with the world through their experiences.*" (Monks 2010, p.458). Therefore, PBL is a constructive teaching strategy which requires students to collaborate in order to build their own knowledge through contextual situations by using their self-directed learning or self-regulated learning skills. Stimulating students to work in small groups is one of the processes of PBL (van Berkel, 2010). This is compatible with the principles of the Constructivist Theory.

Johnson et al., (2007) indicated that the basic aim of collaborative learning is positive interdependence between the members of the group where students work together to achieve their maximum learning potential and motivate each other to interact and exchange knowledge and information relevant to the subject matter. For example, the collaboration of students on mathematical concepts or ideas and generating and presenting solutions should lead to a deeper understanding of mathematical concepts (Clarke et al., 1993). This can occur effectively by promoting the self- regulated learning (SRL) skills of students to make them responsible for their own learning and actively participate in constructing their own knowledge and make meaningful processes (English and Kitsantas, 2013). This will be discussed next.

3.3.2 Role of SRL in PBL

As stated above, in PBL, a teaching paradigm is switched to a learning paradigm (Barr and Tagg, 1995). Students can build their own knowledge construction effectively through self-regulated learning (SRL) strategies. Students cannot be easily shifted to this role because they develop ingrained habits typically from traditional classroom experiences and they rely on the passive receiving of knowledge (Ronis, 2008; Hung, 2011; English and Kitsantas, 2013). In order to shift effectively to this new role, students must develop self-regulated learning (SRL) skills (English and Kitsantas, 2013). SRL refers to the extent to which the learner is motivationally, metacognitively and behaviourally active in their own learning processes (Zimmerman, 1989). Self-regulated learners can set goals, plans, identify appropriate strategies, self-monitor and self-evaluate their learning, as well as being intrinsically motivated to learn. They also demonstrate high levels of self-efficacy for learning and achievement (Zimmerman and Kitsantas, 2005). Thus, for effective learning in PBL, SRL is an essential skill (English and Kitsantas, 2013). Some researches synonymously use SRL as self-directed learning (SDL). SDR refers to the preparedness of students in engaging in learning activities that have been defined by students rather than the teacher (Schmidt, 2000). SDL and SRL are both considered as requiring the motivation to learn independently and having the ability to do so (English and Kitsantas, 2013).

SDL is the process and initiative taken by individuals in identifying their learning needs, setting out learning goals, identifying learning resources, selecting and applying learning strategies and evaluating their learning outcomes, with or without the help of others

(Knowles, 1975). Knowles believes that by 2020, learning will rely on the principles of self-directed learning, for all ages and at all level (Hatcher, 1997). The importance of SDL stems from it being at the heart of lifelong learning skills. SDL skills are believed to be related to lifelong learning (Shokar, Shokar, Romero and Bulik, 2003). SDL becomes increasingly important in light of knowledge explosion, which requires individuals to continuously keep up with new and necessary knowledge and skills; consequently, lifelong learning and SDL are sometimes seen as more important than knowledge transmission (Harvey, 2003; Candy, 1991; Abrahamson, 1978).

PBL is claimed to develop self-directed learning strategies to help students to apply knowledge to new and non-routine problems (Blumberg 2000; Mergendoller et al., 2006). Therefore, SDL or SRL is one of requirements and objectives skill at the same time. SDL is considered as an important process to lean, and it requires of learners to be more responsible for their own learning (Houle, 1980; Boud, 1981; Garrison, 2003).

Within PBL processes, students often move towards the centre of learning and deduction will be replaced with induction (Ronis, 2008). In such student-centred settings learning is active and requires that teachers observe and respond accordingly to the level of understanding of their students (Ertmer and Simons, 2006). The role of the tutor during the learning process is to listen carefully, facilitate, motivate and direct learners to motivate and ask the correct questions (Barrett et al., 2005). Thus, the tutors often put themselves on the level of student understanding, known as cognitive congruence (Schmidt, 2000). Moreover, teachers can facilitate PBL processes if they are using meta-cognitive skills such as thinking aloud with students and modelling behaviours (Delisle, 1997). Thus, the role of teachers is to structure activities to stimulate students' motivation, to encourage reflection and facilitate their learning processes through guidance, scaffolding feedback and prompting independent thinking (English and Kitsantas, 2013). Therefore, in PBL, teachers can consciously activate behaviours that lead to SRL. On the other hand, the role of students is to go through the PBL process. Students work in small groups, understand the problem, identify and learn what they need to know and generate hypotheses to solve the problem (Hmelo-Silver, 2004). The role of students also is to question, research and use critical thinking in an active way to solve problems (Cerezo, 2004). In PBL students are required to take responsibility for their own learning and give meaning to their knowledge and the concepts they encounter (English and Kitsantas, 2013). Therefore, the role of teacher as a meta-cognitive coach can help students to be effective self-regulated learners, to learn effectively and independently through PBL situations. However, some researchers believe that PBL is minimally guided instructions which are incompatible with the structure of the human cognitive architecture. This will be discussed next.

3.4 Is PBL a minimal guided instruction?

Kirschner et al., (2006) classified PBL as a minimally guided instructional approach. They claimed that minimally guided instructions are incompatible with the structure of the human cognitive architecture (Kirschner et al., 2006). Human cognitive architecture is "*the manner in which structures and functions required for human cognitive processes are organized*" (Sweller, 2008, p.370). As a response to the claim of Kirschner et al., Hmelo-Silver et al argued that PBL is not a minimally guided instruction such as discovery. This is because PBL works with scaffolding and facilitating student learning (Hmelo-Silver et al., 2007).

Kirschner et al. (2006) reviewed some meta-analysis studies, such as Albanese and Mitchell (1993), Berkson (1993), and Colliver (2000), to show that using PBL could generate some negative findings. However, their reviews focus on content knowledge, and also on those studies showing no positive effects for PBL.

Therefore, firstly they overlooked some of the other advantages over traditional teaching methods, such as 'softer skills' (Bereiter and Scardamalia, 2006), as mentioned in some of the other studies. Softer skills are some of the required goals of education, such as self-directed learning, epistemic practices and collaboration (Hmelo-Silver et al., 2007). For example, the results of Albanese and Mitchell (1993) study show that students found the PBL teaching strategy more enjoyable and nurturing than traditional instruction, and sometimes, students who had been taught using PBL performed better on faculty evaluations and clinical examinations. It is worth mentioning that the current study reviewed results from several meta-analyses that show that PBL tends to be more positive than traditional teaching methods in improving students' skills such as critical thinking, problem solving, and self-directed learning (see Smits et al., 2002; Dochy et al., 2003; Kong et al., 2014; Galvao et al., 2014; Bassir et al., 2014).

Secondly, they overlooked other reviews that were not negative or more positive to PBL in content knowledge, such as (Galvao et al., 2014; Bassir et al., 2014; Smits et al., 2002). Although they neglected the positive meta-analysis outcomes related to content knowledge, the literature reviewed in the current study shows no clear trends that can be drawn for PBL effects against traditional teaching methods.

Finally, Hmelo-Silver, Duncan et al. (2007) concluded as a response to Kirschner et al. (2006), critics that "*…it is clear that the claim that PBL…'does not work' is not well supported and, in fact, there is support for the alternative*" (Hmelo-Silver et al., 2007, p.105)

In addition, According to Ronis (2008), recent cognitive research indicates that the best learning takes place during the process of engaging learners actively in the process of problem-based learning (PBL). He also added that PBL is considered as an effective method to use in teaching students because it reinforces the brain-compatible learning characteristics.

It seems that the problem-based learning (PBL) process follows a similar process to that of the natural brain when processing information and solving problems. Thus, meaningful activities have long been advocated by educators to be part of students' learning processes (Yew et al., 2011). Therefore implementing PBL in classrooms could have several potential advantages.

3.5 The potential advantages of using PBL

PBL teaching strategies have several potential advantages which could be described as: promoting skills, improving retention, understanding knowledge and improving attitudes and confidence. Firstly, promoting skills, whether related to an academic field, work or social life, PBL helps in developing 'higher- order critical thinking skills' which are analytical skills enabling individuals to think logically by using information which is based on evidence (Ronis, 2008). One of the potential goals of PBL is to develop students' problem-solving skills (Hmelo-Silver, 2004). Hmelo-silver (2004) indicated that the explicit aim of PBL is to develop students' abilities in the skills they need for work or social life such as 'communication, literacy, teamwork, problem-solving and self-assessment'. In addition to acquiring knowledge and skills, PBL makes students become better co-operators. According to Baptiste (2003), there are four principles and values in using PBL: peer collaboration, clarifying roles and goals, appreciation of other people's opinion and raising the level of relationships between members of groups.

Second, in improving retention and understanding of knowledge, PBL helps by increasing retention periods for learning, particularly if a student becomes enthusiastic about a concept or a fact which he or she had discovered by themselves, as it will improve retention and they can use it in creative and meaningful ways (Ronis, 2008). PBL is contributing to producing learners who are more independent and able to learn much deeper than using conventional methods (Deignan, 2009)

Third, increasing students' motivation, is one of the educational goals of PBL (Barrows, 1986). Ronis (2008) reported that one of the principles of PBL is that motivation is explicitly the key to self-directed learning through problem-solving because students will be responsible for their own development and progressing their learning and skills. Self-directed learning is the process in which the learner plays an active role in planning, monitoring and evaluating his or her learning processes (Ertmer and Newby, 1993).

To examine the link between the theories and practice, the empirical studies have reviewed the effectiveness of PBL on students' performance and their attitudes across different levels and disciplines, compared to traditional methods.

3.6 Empirical evidence for effectiveness of PBL

This section will discuss the effectiveness of PBL on students and teachers' performance (achievement and attitudes). Meta-analysis studies are presented, followed by university context findings, and then PBL conducted in K-12 contexts. The effectiveness of trained teachers on students' performance will then be discussed along with the teachers' perspectives about implementation of PBL.

3.6.1 Meta-analysis

Several meta-analyses have been carried out in medical, and allied educational settings, to measure the effects of PBL compared to more traditional methods. These meta-analyses show variations in outcomes. Albanese and Mitchell (1993) conducted a meta-analysis to investigate the effectiveness of PBL on students' outcomes. The results show that students found the PBL teaching strategy more enjoyable and nurturing than traditional instruction, and sometimes, students who had been taught using PBL performed better on faculty evaluations and clinical examinations. However, students who had received PBL instruction viewed themselves as less well prepared in basic science, and also scored less than students who had received conventional instruction (Albanese and Mitchell, 1993). In the same year - 1993, Vernon and Blake conducted a meta-analysis to compare effectiveness between PBL and more traditional methods in medical contexts. The results reveal that PBL supported students' positive attitudes. However, there was no significant difference between the scores of the treatments, PBL and traditional methods, on clinical knowledge and factual knowledge. The interesting point was the differences between the scores reported by the National Board of Medical Examiners (NBME). Step 1 was significant and it was in favour of students who had been taught using more traditional instructions, however, the NBME test data show significant overall heterogeneity and displayed significant differences between programs, which reflected doubt on the generalizability of results among the programs (Vernon and Blake, 1993). It seems that PBL is more enjoyable than traditional teaching methods; however, there is insufficient evidence to suggest that the PBL teaching strategy is superior to traditional teaching methods in improving the learning outcomes of medical students.

In subsequent years Colliver, (2000) reviewed the literature published between 1992 and 1998 and the results were similar to the two previous meta-analysis studies. The findings illustrated that there was not sufficient evidence to show that PBL had improved 'clinical performance' or 'knowledge base', and the relationships between 'basic PBL' and 'applied PBL' is still un-addressed. However, he did note that PBL instruction seemed to be more enjoyable, challenging, and generate more motivation.

Two years later, the study of Smits et al. (2002) reviewed controlled evaluation studies published between 1974 and 2000. The data analysis showed that there was limited evidence to show that PBL improved students' knowledge and performance and patients' health. The study also found moderate evidence that physicians were more satisfied with the PBL approach. Another meta-analysis was conducted by Dochy et al. (2003). The study reviewed 43 articles to investigate the effectiveness of PBL using the 'vote count' and 'combined effect size'. The findings revealed a robust positive effect on knowledge application. However, knowledge acquisition tended to be negative (Dochy et al., 2003). Therefore, there was no clear evidence which indicated that PBL could improve knowledge acquisition more than traditional teaching methods; however, PBL appears to be more effective in improving knowledge application for medical students. This conclusion has been supported more recently by a systematic review conducted by Bassir et al. (2014) who investigated the effectiveness of PBL by comparing it with conventional methods on dental education. The sample consisted of 17 studies. The result of the study shows also an improvement in the application of knowledge for PBL groups and no negative effect on the acquisition of factual knowledge (Bassir et al., 2014).

In addition, a review of randomized controlled trials was conducted to assess the effects of PBL in continuing medical education compared to lectures. The study searched for 'randomized controlled trials' between 2001 and May 2011. The results showed limited evidence that PBL would improve health outcomes or develop the performance of physicians; however, the study found that online PBL is an effective educational approach for physicians (Al-Azri and Ratnapalan, 2014).

In order to assess the effect of PBL in students' critical thinking skills, meta-analysis was carried out in nurse education in 2014 to investigate the effect of PBL on students' critical thinking compared to traditional instruction. The study undertook randomly controlled trials between 1965 and 2012. The findings suggested that PBL could improve nursing students' critical thinking more than traditional instruction (Kong et al., 2014). This study supported the idea that claims that the PBL teaching strategy aims to improve thinking skills. In the same year, Galvao et al. (2014) conducted a systematic meta-analysis in pharmaceutical education. Five controlled studies articles which met the criteria of the study were selected. The purpose of the study was to investigate the effects of PBL on graduate and undergraduate students' outcomes. The findings revealed that students who had received PBL instruction performed better than those who had been taught using conventional instruction in the midterm and final examinations regarding pharmacy knowledge. However, groups were similar in their subjective evaluations (i.e. confidence in learning). The study recommended that pharmaceutical education courses consider the PBL approach (Galvao et al., 2014). Although the study provides evidence which indicates that PBL could improve students' content knowledge more than by using traditional teaching methods, there were other studies which did not come to the same conclusion. Therefore, the effects of PBL on students' knowledge acquisition when compared to traditional teaching methods remain unclear.

It seems that the meta-analyses outlined revealed different PBL outcomes when they tested the effects of PBL from different angles of assessment. Although content knowledge is important, PBL becomes more effective when content knowledge is excluded from the assessment, and in the long-term. A meta-analysis carried out by Gijbels et al. (2005) investigated the effect of the assessment on PBL outcome reports. The study was limited to three levels of knowledge structure a) understanding of concepts, (b) understanding of the principles that link concepts, and (c) linking concepts and principles to conditions and procedures for application'. The results showed that, assessing PBL from the angle of understanding the principles that link concepts, showed positive effects on outcomes (Gijbels et al., 2005). Another meta-analysis was conducted by Walker and Leary (2009). The study found that PBL outcomes were better if its effects were assessed from the angle of application of knowledge, and not concept knowledge (Walker et al., 2009). In the review of Strobel and van Barneveld (2009), they concluded that PBL was more effective for long-term retention, improving skills, and in the satisfaction of teachers and students. However it came slightly lower than traditional methods when it came to short-term retention (Strobel and van Barneveld, 2009).

Overall, several meta-analyses conducted between 1993 and 2014 which covered many researches from the 1960s through to 2014 (which met the standard criteria of those studies), have shown that PBL tends to increase positive attitudes, improve skills, improve clinical performance and the application of knowledge better than more traditional methods in medical or allied medical fields. However, there is no clear trend that PBL can improve clinical knowledge or factual knowledge or increase confidence better than conventional methods. The potential reason may be because assessment of PBL has been applied to short-term outcomes, while PBL becomes more effective when assessing long-term outcomes. However, the result of reviewing the meta-analyses cannot be generalized to other disciplines, or even to different ages, or the achievement of students. This is because the majority of meta-analyses have been limited and have primarily focussed on medical and allied medical fields for university level students. However, in truth, meta-analysis needs to be conducted in a variety of fields and in K-12 contexts in order to more accurately assess secondary sources of research relating to the effectiveness of PBL.

3.6.2 University contexts

Almost all meta-analyses were conducted in the medical or allied medical fields; therefore, this has led the author to review some studies which were not conducted in medical and allied medical schools to see if the trend of PBL effects is still similar or changing in different disciplines.

Moran (2004) examined the effects of PBL on knowledge transfer and the application of problem-solving skills in ‘Aeronautical Safety Science’ discipline in higher education. The findings show that students' survey analysis revealed positive responses in motivation and in increased understanding and application. Final tests show that students' performance significantly increased in the PBL course (Moran, 2004). However, in the same year, in a quantitative study, Matthews (2004) found there was no significant difference in Engineering Graphics Course content knowledge, skills and attitudes between the mean scores of university students who had received instruction using PBL teaching strategies and their counterparts who received traditional instruction (Matthews, 2004). The effect of PBL on students’ performance may be influenced by the kind of the content. Therefore, any decision regarding the general effects of PBL on university students should take into account the findings of prior research conducted in different disciplines.

Recently, a study was conducted to examine the effects of PBL on prospective primary science teachers compared to conventional teaching methods. 101 students were selected and divided into experimental and control groups to be part of the study. Several instruments were used such as attitudes, tests to measure gas concepts and the 'peer evaluation scale'. The results indicated superior results for PBL groups in learning concepts of gases and students' attitudes towards chemistry, and in critical thinking, cooperative learning and self-directed learning skills (Senocak et al., 2007). Similar results were revealed by Gürses et al. 2007, who measured the effectiveness of PBL in a physical chemistry laboratory course. The instruments of the study consisted of two pre-post tests for academic achievement and scientific process skills and questionnaire for attitudes towards a chemistry laboratory course. Forty students were recruited for the fall semester. The outcomes suggested that PBL promotes scientific process skills such as problem-solving, self-directed learning and critical thinking. However, there was no significant difference in attitudes towards a physical chemistry laboratory course (Gürses et al., 2007). It seems that PBL could promote students' thinking skills.

Another study was aimed at examining the effects of PBL on undergraduate students' knowledge, application and critical thinking compared to conventional instruction. Twelve students were selected to present conventional instruction, while 8 students selected to present PBL group. These students were enrolled in an exercise and sport science course. Pre and post tests were applied. The outcomes indicated no significant difference between groups in all abilities mentioned. However, these abilities were observed through PBL classroom discussion and students claimed that PBL helps promote students' independence in learning and improved problem-solving skills (Sanderson, 2008). However, another study was undertaken to investigate the effects of PBL on Turkish university students' beliefs about physics and about learning physics. In addition, it also measured the effects of PBL on their conceptual understanding of 'Newtonian mechanics' and the correlation between their beliefs and conceptual understanding. 124 students participated in this study and were divided into two groups (PBL = 55, conventional = 69). Two instruments were used: attitudes in measuring students' beliefs, and an exam measuring students' conceptual understanding. The repeated test showed that students who were taught using PBL gained scores significantly higher than their counterparts in traditional methods in terms of conceptual understanding. However, there was no significant difference between the groups with regards to students' beliefs. Furthermore, the study found there was a significant relationship between beliefs and conceptual understanding. This correlation indicates that students with more ‘expert-like views’ about physics at the beginning of the study were likely to obtain high scores in the final exam of conceptual understanding (Sahin, 2010). The results on the effect of PBL still show variation when compared to traditional teaching methods. This could possibly be due to the different content and contexts.

For example, in Eastern Asia contexts, a study conducted by Kevin (2010) examined the effectiveness of using PBL on developing meta-cognitive skills among first-year undergraduate students in the University of Hong Kong. The results show that students in experimental groups had significantly developed in metacognition and in their learning experience, which was higher than the control group (Downing et al., 2011). Another study conducted by Yuen Lie Lim, 2011 investigated how students’ reflective thinking develops through the daily practice of PBL in a polytechnic institution in Singapore. This institution had adopted PBL as a method of study. The results indicated that there was a noticeable progression in the development of students' reflective thinking in the first year; however, this development did not continue in the second and third years of study (Lim, 2011).

More recently, in one of two studies carried out by Pease and Kuhn in 2011 at a leading university in Lima, Peru, to investigate PBL over time compared to the lecture / discussion method, multiple assessments were used to achieve the goal of the study. The sample was 127 university students who were enrolled in two concepts of physics: electromagnetic fields taught using PBL and gravitational field taught using the lecture / discussion method). These courses were taught with the same instructor and the results showed superior results for PBL groups in comprehension (understanding the concepts) and in the application of the concept in new situations (Pease and Kuhn, 2011).

Most recently Ertmer et al. (2014) carried out a study aimed at investigating the effect of implementing STEM in 6–12 grade science and mathematics classrooms through PBL units on teachers’ content knowledge and their confidence. 21 teachers were selected, 13 pre-service and seven in-service, to implement a STEM based PBL scenario in their 6-12 grade science and math classrooms for intensive two- week course to create PBL units related to sustainable energy. The tools included pre-post content knowledge tests and two pre-post surveys, one for the implementation of PBL and another in science teaching efficacy. The findings showed significant gains in content knowledge and in confidence in both implementation of PBL and science teaching efficacy (Ertmer et al., 2014).

Following a brief review of the studies in non-medical or allied medical contexts for university level students it can be seen that overall, these show positive trends which indicate that PBL can promote skills such as critical thinking, problem-solving and self-directed learning. However, there is still no clear trend that indicated PBL can improve content knowledge. The effect of PBL on knowledge application and attitudes towards learning tend to be unclear. In addition, different contexts and content seem to have a different effect on student outcomes.

3.6.3 K-12 contexts

It has been seen that PBL tends to promote thinking skills for university students regardless their contents. However, the effect of PBL on knowledge acquisition is still not clear when compared to the effect of using traditional teaching methods. Knowledge application and attitudes seem to improve more with PBL than when students are taught using traditional teaching methods for medical or allied medical students. However, this remains unclear with contexts outside of medical and associated fields. It is necessary to review studies conducted in k-12 settings to assess the effect of PBL on students' outcomes compared to traditional teaching methods.

To examine the effects of PBL compared to conventional methods in K-12 settings, several studies undertook empirical investigations, looking at outcome comparisons between PBL and conventional methods.

Shepherd (1998) examined the effects of PBL on gifted fourth and fifth year social studies students' critical thinking skills and their attitudes towards learning and solving complex problems. This study was conducted in the Midwestern state and lasted for nine months with two groups; one experimental and one control group. The post-tests showed that PBL students' mean scores were significantly greater than their traditional counterparts mean scores. In addition, supporting qualitative measures such as observations, interviews and surveys indicated that students taught using PBL learned as well or better than their counterparts, and PBL students showed more confidence in problem-solving than conventional instruction students (Shepherd, 1998). The study assessed several aspects of PBL effects compared to traditional teaching methods. It used mixed methods of analysis, namely quantitative and qualitative. It was conducting in an elementary school and is a strong study; however, it was conducting using only gifted students. It is worth knowing that the classrooms in Saudi Arabia can include some gifted students, whether or not they are formerly classified as gifted or high achievers. Although not all high achievers are considered as gifted students, in the current study, students were divided into two groups which were classified as either high or low achievers. Similar study conducted by Nowak, (2001) to determine whether students learn as much with PBL teaching strategies as in conventional instruction. The study took place in a Midwest public middle school and targeted gifted eighth grade students in science classes. Observations, tests, interviews and document analyses were used as instruments in the study. The outcomes revealed that students who received the traditional teaching approach learnt significantly more than the students who received PBL teaching strategies in factual content. However, students who were taught using the PBL strategy were better in terms of retention than students who taught using the traditional teaching approach. An analysis of the interviews shows that students favoured learning through PBL and many students suggested that if PBL could be incorporated with teacher-centred teaching units, this would be more beneficial (Nowak, 2001). Therefore, the effect of PBL in students' knowledge acquisition seems to be lower than the effect of traditional teaching methods for gifted students, but on knowledge application it would appear that PBL turned out to be better.

With general education, a study examined the effectiveness PBL on learning content compared to traditional instruction. The study was designed in the form of a quasi-experimental with a non-equivalent control group. 88 elementary school students (5th grade) were selected to be part of the study in science and social studies for half of the academic year at an urban private school in the Southeast United States. The findings indicated all groups improved in learning content. It revealed also that students who had been taught using traditional instruction scored significantly higher than their counterparts in the PBL group. However, after the transformation of data due to a negative skew in social studies classes, the result showed no significant difference between the scores of both groups in learning content (Scott, 2005).

Araz and Sungur (2007) conducted also a study to investigate the effectiveness of PBL and conventional lecture –based instructions for elementary students in genetics knowledge and performance skills with controlling reasoning abilities. Two teachers were selected to teach PBL ($n = 126$) and traditional groups ($n = 91$). The multivariate analysis of covariance revealed that students taught by PBL performed better in knowledge and skills compared to their traditional counterparts (Araz and Sungur, 2007).

Another study was conducted on high school students in Atlanta to investigate the effects of PBL on students' chemistry knowledge of acids and bases compared to traditional teaching methods. A quasi-experimental pre and post-test control group design was used in this study. The post tests showed that there was no significant difference in scores which may be caused by the instructional methods (Dobbs, 2008). It is clear that the effect of PBL on students' content knowledge seems to vary when compared to the effect of traditional teaching methods. It is might due to different contents. A study by Wong and Day (2009) supported this conclusion. They conducted a comparative study between PBL and lecture-based (LBL) learning in middle students' science: human reproduction and density topics in Hong Kong. Two groups were recruited in this study: a group was taught using PBL, while another group was taught using LBL. Pre- test, immediate, post-test and delayed post-tests were used. The findings in the short-term showed that in human reproduction there was no significant difference between the groups in knowledge acquisition; however, PBL students outperformed LBL students in comprehension and application knowledge. In density, they found that PBL students performed better than LBL students in knowledge acquisition, comprehension and application knowledge. The results of this study in the long-term illustrated that PBL students significantly outperformed LBL students in all of the tests mentioned (Wong and Day, 2009).

However, some studies did not find any superior to PBL in improve retention over traditional methods. For example, Hinyard and Brittany S (2013) implemented a study in the northern portion of the East Baton Rouge Parish that compared effectiveness and students' perceptions of PBL compared to traditional based learning (TBL). In this study two instruments were used: test and survey. Four groups of eighth grade students were assigned to take part in the study; two groups were taught using TBL in two earth science concepts, plate tectonics and rocks, against two groups instructed using PBL with the same concepts. The experiment lasted for four weeks and post-tests were reapplied again six months later to investigate the level of retention. The results indicated no significant difference between the groups, whether in post-tests or even in repost-tests, in content retention; however, students taught using PBL enjoyed the activities more than those taught via TBL (Hinyard, 2013). Therefore, different contexts and content seem to affect students' content knowledge outcomes. However, students' retention and knowledge application abilities tend to be improved with PBL more than with traditional instruction.

However, Yew and Schmidt, (2011) reported that the outcomes of PBL in knowledge acquisition effected by earlier stage of learning and self-directed learning skills. They tested learning during the different stages of PBL and looked at whether the learning was cumulative during each learning stage and whether each stage based on the preceding stage or not. The results showed that the learning in each stage of PBL was cumulative and was significantly affected by the earlier stage. The results also indicated that the self-directed learning stage affected students' positively in reiteration and promoted the acquisition of new concepts and the repetition of concepts which they had been previously exposed to. The analysis of the problems revised the previous information and enabled the learner to build new information; also, hearing from other members of the group provided access to knowledge and information which previously would not have been discovered. They did, however, point out that in both the problem analysis and reporting phases, the responsibility also lies with the tutors to guide students' learning (Yew et al., 2011). Therefore, it can be said that students' skills and knowledge and contents can affect PBL's outcomes. As such, it is worth reviewing PBL with mathematics.

Lou, (2011) conducted a study to explore the effect of using PBL strategies on attitudes towards learning in science, technology, engineering, and mathematics (STEM) among tenth grade students at a Taiwanese senior high school. The results indicated that this strategy developed students' attitudes towards learning STEM and also students can gain knowledge of mathematics through learning STEM by using PBL strategies (Lou, Shih et al., 2011). The study did not compare PBL to traditional teaching methods.

The results of other studies show that PBL is superior to traditional methods. For example, a study conducted by Sungur et al. (2006) involved 10th grade biology students in Turkey. Multiple-choice tests (i.e., knowledge and application knowledge) and essays (i.e., organise concepts, articulate uncertainties and interpret information) were used to assess students' academic achievement and students' performance skills. The results showed that students taught using PBL performed better in academic achievement and performance skills compared to their counterparts who received traditional instruction (Sungur et al. 2006). In a more recent study of middle school sixth-grade students, Wirkala and Kuhn (2011) reported that PBL groups significantly outperformed the lecture-based instruction in terms of understanding and application concepts (Wirkala and Kuhn 2011). Also, in the study of Sungur and Tekkaya (2006), the effectiveness of PBL in self-regulated learning and learning strategies were investigated and compared to conventional instruction in 10th grade school students' biology. The PBL group showed superior results to their counterpart group in elaboration learning strategies, critical thinking, intrinsic goal orientation and meta-cognitive approaches (Sungur and Tekkaya, 2006). In addition, a study examined the effects of PBL on 9th grade students' understanding of intermolecular forces (a chemistry topic) and their alternate conceptions, and also students' beliefs about PBL compared to lecture-style teaching. 78 students participated and were split into two groups: PBL = 40 and traditional teaching methods = 38. Analysis of post-test and questionnaires indicated superior results for the PBL group in understanding, alternative conceptions and stoical skills (Tarhan, Ayar-Kayali et al., 2008). Another study curried out by Mergendoller et al. (2000) who found a modest effect on post-tests scores in economics knowledge and few interactions between students' attitudes, ability or preference of style of learning (Mergendoller et al., 2000).

Furthermore, a study investigated the impact of PBL on students' problem-solving skills, their attitudes towards science (chemistry) and students' perceptions about the learning environment. Forty-eight students participated in an all-male Jesuit Catholic high school in a large city in the Midwest. A mixed -methods approach, using a survey, 'journal entries approaches to solving a problem' and observations of the teacher's classroom were used. The results showed that there was a significant increase in problem-solving skills, attitudes towards science, and positive perception of the learning environment (Ferreira and Trudel, 2012). Therefore, it seems that the effect of PBL in performance skills tends to be better than traditional methods. Some studies reported that PBL could raise positive attitudes more than the traditional teaching methods.

For example, a study was carried out on the adoption of PBL strategies as an instructional method and used the curriculum of high school science teachers, a science teacher and the authors (university researchers) to analyse the feasibility and benefits of using PBL strategies from the perspective of the participants. The researchers adopted an 'action-based inquiry method' as the process of investigation. This research included interviews with students, classroom observations, providing feedback and an appropriate assessment approach. The results revealed that students liked this strategy because it encourages active learning, supports working in groups and it also provides students with a variety of learning approaches and methods (Goodnough and Cashion, 2006).

Another study in Italy, conducted by Gutierrez-Perez and Pirrami (2011), demonstrated two different ways of presenting scenarios using PBL in science and these were examined for two hours per week for a total of four weeks. 104 intermediate school students participated in the study and divided into six classes; three classes were taught using the more traditional method (C1), while three classes were taught using PBL (C2). The findings showed that both C1 and C2 students reported that PBL as a technique for learning was better than conventional methods. Teachers and students reported that students' engagement was higher when than traditional methods were used in both C1 and

C2, and students would like the unit not to be too short. The researcher observed that C2 students engaged more than C1 students (Gutierrez-Perez and Pirrami, 2011).

PBL could be used also by younger students, for example, Zhang, Parker et al. (2011) adapted PBL to the kindergarten. The study examined a veteran kindergarten teacher who had experience in using the PBL approach on her 24 students in the context of 'Understanding Earth' materials. The results showed an improvement in students' content understanding and in questioning skills. In addition, the success of this experiment motivated the participating teacher to adopt the PBL strategy in her future teaching (Zhang et al., 2011).

It is necessary to review studies conducted in Saudi Arabia and Arab countries, and in K-12 settings, to assess the effects of PBL on students' outcomes compared to traditional teaching methods within similar contexts and settings.

3.6.4 K-12 settings within similar contexts

It is important to engage critically with the empirical studies carried out in other countries as well as Saudi Arabia that have similar settings and contexts, such as Egypt, Jordan and Oman. The majority of the PBL studies that have been conducted in Saudi Arabia and Arab quarters were conducted in medical or allied medical contexts. Little research has been carried out in K-12, particularly in mathematics. In the Arab world the majority of K-12 studies in relation to PBL focus on investigating the effects of 'Wheatley's Model' in problem-centred learning and are called Problem Based Learning (PBL). Although Wheatley's Model (Wheatley, 1991) is similar to PBL, they did not mention whether the characteristics of problems meet the PBL problems criteria such as for ill-structured problems.

In Saudi Arabia, Al-Saadi's study (2007), conducted in Bisha, aimed to examine the effectiveness of PBL on students' critical thinking skills in science. For the purposes of the study, 125 tenth grade male students were divided into two groups comprising one PBL group and one control group. The results showed that students who were taught using PBL improved significantly more than those who were taught using traditional teaching methods. Despite the positive results for PBL, the sample of the study targeted high school students not intermediate or primary school students and assessed science education not mathematics education.

Another study was carried out by Al Hudhaifi (2002) who investigated the effects of PBL on 147 female eighth grade students' science achievements and attitudes towards science. The results of the quasi-experimental study suggested that the students taught with PBL improved significantly in both science achievements and attitude levels, than those taught using traditional teaching methods. The study was limited to assess science education with female students. Thus, it can be concluded that in Saudi contexts, PBL seems to be more positive in science education than the traditional teaching methods form the available evidence.

Likewise, in mathematics education, Alshhrany, 2010 carried out a study to examine the effects of PBL (Using Wheatley's Model) on students' mathematical achievements and attitudes towards mathematics. 60 male sixth grade Saudi students participated in the quasi-experimental study. The results show that students significantly improved in knowledge acquisitions and attitudes towards mathematics more than when taught using traditional methods. In the study, the researcher did not mention whether he adopted ill-structured problems with PBL or not, and also did not assess applying and reasoning abilities in mathematics.

In the other Arabic contexts, Ali, (2005) carried out a study to examine the effectiveness of PBL on students' geometric achievements and geometric thinking skills. A quasi-experimental study was designed for this purpose. The sample consisted of 62 ninth grade Egyptian students. The results show that there was no significant difference between PBL and traditional teaching methods in the students' knowledge acquisition scores; however, the findings revealed that the PBL group improved significantly in knowledge application and geometric thinking skills. The study did not cover primary school students and reasoning domains.

Another study aimed at investigating the impact of PBL on scientific skills of tenth grade students in biology in the capital of the Oman state, Muscat. Two groups were selected to be part of the study: an experimental group with 62 students and a control group with 62 students. The test of scientific skills consisted of 31 items including nine skills: observation, classification, prediction, reasoning, inference, use of numbers, interpretation, imposition of assumptions and adjusting the variables. The test was applied before and after the study on the two groups The results of the study showed that the performance of the experimental group significantly exceeded the control group in most of the scientific skills (Ambo Saeedi and Al Balushi, 2009). The study did not cover attitudes and knowledge acquisition and application.

Likewise, in 2013, a study was designed by Shaqoura to examine the effects of the PBL teaching strategy on students' thinking skills based on a TIMSS science exam for female eighth grade students in the Gaza Governorate. Seventy six students were divided into two groups: the experimental group with 38 students and the control group with 38 students. In the post-test, the results revealed that PBL significantly improved students' thinking skills more than traditional teaching methods. The researcher also used Wheatley's Model in problem-centred learning and called it PBL. There was, however, a lack of descriptions for the problems used and no indication of any training the teachers had received. Although these studies were not in mathematics education, the results indicate that PBL seem to improve students' thinking skills.

In mathematics education, a study carried out by Al-Khateeb and Ababneh (2011), aimed to examine the effects of a problem solving based teaching strategy on the mathematical thinking and attitudes towards mathematics for seventh grade students in Jordan. 104 male students were randomly divided into two groups. One group was taught via PBL, while another group was taught through traditional teaching methods. The results showed that the scores of the students who were taught via the PBL teaching strategy improved significantly more in mathematical thinking and attitudes towards mathematics than the students who were taught using traditional teaching methods. There was no interaction between the mathematical thinking scores or attitudes towards mathematics and students' achievement levels for high, medium and low achievers. The researchers did not describe the problem characteristics or indicate whether the problems were ill-structured or not. Additionally, the students' prior knowledge and skills in the units used for the study were not checked.

Recently Hussain (2012) conducted a study which was aimed at examining the effectiveness of PBL on mathematical academic achievement and thinking skills at an Egyptian school using ninth grade school students. 78 students participated in the study with 40 selected to represent the conventional group and 38 students assigned to present the PBL group. The results showed that in both critical thinking and academic achievement, students who were instructed by PBL gained mean scores significantly greater than those who received conventional instruction (Hussain, 2012). The study did not assess attitudes towards mathematics and was limited to intermediate school students. It seems that PBL is more effective than traditional teaching methods in teaching mathematics for upper middle school students.

Most recently, a study conducted by Abdalqader (2014) for female tenth grade students in Gaza Governorates examined the effectiveness of PBL on their ability in solving solid geometry problems and their attitudes toward mathematics. A quasi- experimental study with control groups was designed. The results showed that the scores of the students who were taught using the PBL teaching strategy improved significantly more than the students who were taught using traditional teaching methods in the post test of solid geometry and attitudes toward mathematics. Abdalqader used Wheatley's Model in problem-centred learning and he called it PBL. He also did not use pre-tests to establish whether the students in the unit had similar prior knowledge and skills. He mentioned that the teacher was trained in implementing the PBL teaching strategy, however, he did not give description for the training.

To summarise, the empirical studies reviewed carried out on PBL, indicate that this method of teaching tends to be better than conventional methods in terms of thinking skills, such as self-directed learning, critical thinking and problem solving, and attitudes towards learning; however, the effects of PBL on content knowledge seems to suggest that there was no clear trend. PBL tends to increases confidence and applying knowledge skills more than conventional teaching methods. PBL also tends to be more positive for long-term assessment, particularly in knowledge retention. In addition, PBL tends to be more effective for higher achievers. However, the majority of studies did not investigate the interaction of the different type of training teachers had received, and what effect this had on students' outcomes. In fact, some studies did not even mention whether the teachers had actually received any training in PBL or not. In addition, the majority of the available data relating to PBL studies, particularly, with quasi-experimental studies, analysed by statistical models that focus on only post-tests, such as one-way ANOVA and independent T-tests samples, rarely use repeated measures and mixed ANOVA models which are more precise for analysing pre-post quasi-experimental data studies. Thus, the current study attempted to address these gaps.

However, different contexts, self-directed learning skills, prior knowledge and different culture and contents possibly affect PBL's outcomes, all of which should be taken into account in further research. On other hand, the effectiveness of PBL seems influenced by professional development (PD) provided to the tutor.

3.7 Professional development: trained and untrained teachers

The aim of Professional Development (PD) for teachers is to improve their teaching practices in classrooms. Generally, PD refers to the development of an individual in their professional role (Villegas-Reimers, 2003). Specifically, the PD of teachers is defined as "Teacher *development is the professional growth a teacher achieves as result of gaining increased experience and examining his or her teaching systematically*" (Glatthorn, 1995, p.41). Therefore, the purpose of PD is identified by Friedman andWoodhead (2008) as: maintaining and improving knowledge and skills and developing personal qualities for implementing professional and technical responsibilities.

PD is an integral part of many education systems; for example, it is compulsory for teachers in half of the states in the USA and in many of the countries in the European Union (Eurydice, 2003). Professional development in teachers can be classified into two models: organizational partnership (such as professional-development schools and schools' networks), and small group or individual models (such as workshops and self-directed development) (Villegas-Reimers, 2003). The present study is interested in the individual model which ranges from self-directed development to receiving training via a face-to-face training course. Therefore, in the current study, some teachers had received face-to-face training in PBL implementation and others were asked to conduct self-directed learning for the same purpose. Thus, PD should include training courses and design meaningful learning activities (Mansour et al, 2015, Mansour et al, 2014). The combination of training and learning activities in PD can form various types ranging from self-directed study to attending courses (Clark and Hollingsworth, 2002; Ling and Mackenzie, 2001; Craft, 2000).

The goals of PD Programmes are to identify the competences of teachers and identify the skills needed (Mansour et al., 2013). Therefore, views and perceptions between teachers and their supervisors regarding PD needs should not be different. (Mansour et al, 2014). It means that teachers' needs should be recognised by supervisors to work together towards improving teaching practices in classroom. Thus, teachers should identify their needs and develop themselves by either attending face-to-face training courses or conducting self-directed learning. Therefore, face-to-face training for teachers is not only a single model for improving teacher's practices in classrooms; self-directed learning could also be an alternative model. In this section, the face-to-face training programme in PBL implementation and self-directed learning teacher models for teachers will be discussed.

3.7.1 Face-to-face training for teachers in PBL implementation

The role of the tutor in PBL is to facilitate collaborative knowledge construction by students, monitor learning processes, model desired behaviours and concentrate students' efforts on critical thinking (Hmelo-Silver and Barrows 2006; Hmelo-Silver and Barrows, 2008). This could be done through raising awareness among students in their higher cognitive thinking (Barrows, 1998). Effective tutors should know how to facilitate groups' learning processes (Dolmans et al., 2002). In order to enhance cooperation and production within groups, tutors should use intervention strategies, such as making decisions on what, when and how to intervene (Bosse et al. 2010). Tutors may need to be trained to implement such strategies to facilitate tutorial processes as it is the responsibility of tutors is to guide students' learning (Yew et al., 2011). Therefore, tutors should be trained, to be able to help students, within groups, to learn by using intervention strategies.

In the PBL approach, although training tutors is consensually agreed as critical (Leary et al., 2009), the effects of tutor training on students' performance are still ambiguous (Leary et al., 2009, Leary et al., 2013). The agreement of the importance of training is supported by literature outside of PBL where it is stated that the most effective tutors were trained in facilitation skills (Leary et al., 2009). Training tutors on PBL needs more primary research to measure its effects on students' outcomes.

A meta-analysis has been conducted to investigate the relationship between tutor training and students' learning outcomes. 94 studies were chosen to be part of this study. The results show a significant relationship between tutor training and students' achievement. The study suggested that untrained teachers have similar student outcomes to teachers who use traditional teaching methods (Leary et al., 2013). The study concluded that the facilitator may be a key factor on students' outcomes. This study was not an experimental study to show the effectiveness of trained and untrained teachers on students' achievement. In addition, the training programme or the workshops were not constant in form or period of time for each study.

In a primary study, Maxwell et al. (2005) focused on high school contexts. The study examined the effectiveness of PBL on students' knowledge of concepts and principles in macroeconomics compared to traditional methods. The sample comprised 252 students and five teachers at 11 schools in Northern California. All students received pre and post-tests and all teachers attended a week-long training course. Two of the teachers were working as trainers during the training course. The outcomes showed that overall there was modest evidence to indicate that PBL improved learning knowledge more than lecture-discussion instruction. There was robust evidence of instructional interaction with teachers, where with some teachers their students' learning improved with PBL instruction, while with others, their students' learning improved with conventional instruction. The study suggested that PBL instruction can improve learning more than conventional methods with teachers who were well trained in PBL and in economics implementation (Maxwell et al., 2005).

Although many PBL researchers agree that teachers need to be trained in PBL, there is a lack of research studies that have examined the effects of teacher training on students learning (Leary et al., 2013). However, training programmes are different in terms of their content, time and processes. These factors may result in different outcomes on students' performance.

3.7.2 Training programmes in PBL implementation

Most programmes of training in PBL place emphasis on understanding PBL, the importance of PBL and focuses on tutorial processes and developing the content-specific knowledge and skills of the tutors (Holmes and Kaufman, 1994). Some studies have investigated the effectiveness of workshop programmes and the feedback from students and peers.

For example, a study of Van Mook et al. (2007) addressed professional behaviour within the PBL group (tutorial group) as a response to critical incidents. It focused on five factors: lack of effective interaction, lack of thoroughness, lack of effort to find solutions, lack of motivation and failure to confront students. The results show that some students had considered that in general, professional behaviour was a useless exercise and time consuming. In addition, the factors that students' viewed as the more frequent were not always viewed as the highest impediments and vice versa. The findings placed emphasis on the importance of training tutors in how and why, the assessment of professional behaviour and also to encourage tutors to confront students and provide them with appropriate feedback (Van Mook et al., 2007). In another study a faculty development workshop was designed to meet the needs of the tutors. The study examined whether the workshop was effective and if it could effectively improve the teaching skills of the tutors.

Two tools were used to conduct this experiment: (1) tutors' perspectives of the usefulness of the workshop and their improvement in their ability to implement tutorial skills and (2) students' ratings before and after the workshop. The results show that the workshop, which was designed to take into account tutors' needs within teaching units, improved tutors' skills in problem-content knowledge and their ability to guide students' learning (Baroffio et al., 2006).

Some studies were conducted to highlight the challenges that teachers were encountering through PBL situations. In the study of Spronken-Smith and Harland (2009), semi-structured interviews were used to understand (in depth) teacher's experiences of PBL. The teachers showed positive attitudes towards teaching by PBL, however, many found difficulties in acting as facilitators. This was for two reasons: they did not know when and how they should intervene and they were concerned that they had less control in learning activities (Spronken-Smith and Harland, 2009). This difficulty may be addressed by training and providing feedback.

In many studies tutor training has been seen in different types of programs such as one day workshops, one week workshops; some workshops are continued and accompanied by a series of weekly prompts of what establishes good tutoring skills (Leary et al., 2013). Some workshop training ran for four hours divided over two days (Hitchcock and Mylona 2000). However, weekly meetings taking place during the course to provide feedback and resolve unexpected problems is recommended (Hitchcock and Mylona, 2000). Some studies recommend that tutors take advantage of the feedback received from their students and follow this up with their trainers (Hendry 2009, Zhang et al., 2011).

The programme was used in this study to train teachers focusing on how to implement PBL in mathematics classrooms. The programme continued to provide feedback during the implementation after each session. The programme took advantage of the literature recommendations. Therefore, teachers were trained in how to facilitate groups' learning processes and guide students' learning by adopting strategies such as posing meta-cognitive questions and focusing on the process of learning to model students' learning strategies.

Teachers were trained in intervention strategies such as making decision based on what, when and how intervention should occur to enhance cooperation. The training programme was not provided in PBL format due to time issues, and had a small sample size (only one teacher for each stage). However, it included examples of PBL implementations. Teacher training lasted for one week (8-10 hours) and daily meetings took place during the course of the training to provide an opportunity to present feedback and resolve unexpected problems. However, self-directed learning teachers did not receive face-to-face training but were given the programme materials, including PBL materials, and asked to conduct self-directed learning to implement PBL in their classrooms.

3.7.3 Self-directed professional development

Self-directed development is a low-cost method of training when compared to face-to-face training. In addition, it is necessary for continuing professional learning (Houle, 1980; Cavanaugh, 1993). The assumption of self-directed professional development is that adult learners strive toward self-direction (Knowles, 1980; Kasworm, 1992). Self-directed professional development is when the professional development stems from the initiative of the teachers (Van Eekelen et al., 2006). This model requires the effective self-directed learning skills of teachers. Self-directed learning (SDL) is the process whereby individuals take the initiative to increase their knowledge identify their learning needs, set out learning goals, identify learning resources, select and apply learning strategies and evaluate their learning outcomes, with or without the help of others (Knowles, 1975). SDL may also occur when teachers are given more responsibility and are provided with relevant reading materials which encourage them to learn. One of the benefits of teachers having these vital skills is that it may result in a reduction in the cost continuing professional development CPD programmes. SDL is considered as an important learning process as it requires learners to take more responsibility for their own learning (Garrison, 2003; Houle, 1980; Boud, 1981). Therefore, in the self-directed development model, teachers take responsibility for their own development; the teacher or small group can identify one important goal and the activities that can help to achieve the goal, along with the required resources, and end up with an assessment of their own works (Villegas-Reimers, 2003).

Significantly, this is a core reason behind the integration of the question which measures the effects of the teachers that undertook self-directed development on students' outcomes, an area which has never been tested. According to Villegas-Reimers (2003), no study has been conducted related to this model which measures the effects of students' learning or teacher's professional development.

In the current study, some teachers were trained, categorised as 'trained teachers', by attending courses face-to-face in implementing PBL and others, categorised as 'untrained teachers', were given reading materials to learn by themselves. The reasons behind this are to compare the effects that both trained and untrained teachers have on students' learning outcomes using a quantitative approach and assess their teaching practices using qualitative approach. PD can affect students' learning outcomes (Goodall et al., 2005). There is a positive relationship between the amount of professional knowledge that teachers have and students' achievements (Falk, 2001; Grosso de Leon, 2001; Tatto, 1999). PD affects students' achievement in three ways: firstly, PD enhances teacher's knowledge and skills, secondly, this enhancement is reflected in an improvement in the classroom teaching instruction of the teachers and thirdly, the improvement in teaching instructions greatly improves student achievement (Yoon et al., 2007). Under this assumption, this study could examine the effects of the training delivered to teachers face-to-face, and the teachers who undertook self-directed learning on students' achievement. According to Yoon et al (2007), no benefit will occur among students whose teachers fail to apply the new ideas acquired from PD to classroom instruction.

It is anticipated that the implications of this methodology and its results will provide designers with an insight into the importance of self-directed learning skills for teachers and also provide relevant information relating to the content of CPD programmes. It is hoped that it may also pave the way for further research in this promising area.

Teacher's perspectives about PBL are very important to highlight the strengths and weaknesses of PBL from their point of view.

3.8 The perception of teachers about PBL

Many studies have been carried out to investigate students' perspectives about PBL, however, few studies have focused on teachers' perspectives about PBL. Generally, in the studies consulted, teachers tend to feel that PBL is more positive than traditional methods. They found it enjoyable, however, they believed the role of teachers to facilitate students' learning is challengeable. However, the studies located referred exclusively to the university sector.

One study was carried out at Thames Valley University to examine teachers' perspectives about PBL. Semi-structured interviews were conducted with 13 midwifery lecturers. Some of the participants had been teaching for more than two years while others had been teaching for less than two years. The results show that facilitation was the main concern for teachers. This was because they attempted to make a balance between independent learning principles and their supporting role; they found difficulty in asking appropriate questions. Some felt that students should be able to challenge and evaluate each other. A few teachers were uncertain about their role and how much they should intervene. Some teachers felt that the more able students carry the less able students. Teachers saw students who were more motivated gain more benefits, while many teachers felt that students who were weaker would be less effective. In general, teachers felt that PBL is a positive method of education because it teaches students how to learn by themselves (Rowan et al., 2007). However, teachers remain concerned about lower achievers' learning, and they seem to need more training in how to appropriately intervene.

Another study aimed to assess the attitudes of 1,287 faculty members in medicine schools in the Unites States and Canada. A questionnaire was used in the study. The results show more positive attitudes towards PBL than traditional methods. In addition, older faculties were more positive than the newer ones. This was perhaps because the older faculties were less likely to be subjected to administrative problems and were therefore more effective. They felt that students were interested in PBL and were more enthusiastic (Vernon, 1995).

A study conducted by Dahlgren et al. (1998) aimed to evaluate implementation of PBL in an undergraduate education environment from their teachers' perspective. Seven teachers were interviewed after taking part in a special course using PBL. The interview covered the teachers' experiences in planning and implementing PBL, the meaning of PBL and their role in PBL. The results show positive attitudes towards the course; however, they found difficulties and uncertainty during the course. These uncertain experiences lie in how the course was proceeding, whether the important areas were satisfactorily covered and whether they would be allowed to respond to their students in a more traditional way. Thus, they felt that they needed more discussion and collaboration between teachers.

In terms of their perspective of the meaning of PBL, they perceived the PBL strategy either from a learning perspective or a teaching perspective. From the learning viewpoint they believed that PBL can offer students freedom and independence in their learning, deeper knowledge and understanding, oriented learning and personal growth. However, they felt that PBL cannot offer the same breadth and depth of the syllabus and assessment criteria as traditional teaching methods. On the other hand, from the teaching perspective, the teachers believed that PBL is more enjoyable and provides various methods of teaching, however, the competence of the teachers is not fully exploited in PBL and students' knowledge cannot be controlled with PBL.

Regarding the role of the teacher, teachers viewed the role of the teacher in PBL from two different perspectives; (1) being a supportive tutor to focus on the students' learning processes, and (2) being a directive tutor to give instruction on how to work to achieve the goals of the lesson (Dahlgren, Castensson et al., 1998) . It seems that the general concerns of teachers about PBL implementations related to how to intervene. This would become less concern if teachers have been trained well in how to undertake their role effectively.

The next section discusses the roles of both teachers and students in delivering and implementing PBL.

3.9 Roles in PBL

In PBL, the roles for teachers and students differ from those used in traditional teaching methods. This section will highlight this role of the teachers and discusses the skills that teachers should improve to play an effective role in coaching students in PBL sittings. At the end of this section, the role of students will be discussed as well as students' differences levels in achievement.

3.9.1 The role of the tutor in PBL

To be effective in PBL, tutors should know how groups work and how to enhance cooperation, insight and outsight in programmes; how groups develop over time, how to deal with disturbances between members of the group, and how to give notes and instructions about expectations and requirements in respect of personal behaviour for members of the group (van Berkel, 2010). The role of tutor is to help learners to be comfortable with the processes of PBL, and should include, for example, asking some meta-cognitive questions. Questions such as 'what do we need to know more about?' and 'what is going on?' Therefore, over time, students will become self-directed learners and will eventually reach a stage where they require less input from their tutor than they had previously (Ronis, 2008). Teachers can facilitate problem-based learning (PBL) processes if they are using meta-cognitive skills such as thinking aloud with students and modelling behaviours (Delisle, 1997). Furthermore, the role of the teacher is to listen carefully, facilitate, to ask learners to self-motivate and encourage them to ask the correct questions (Barrett et al., 2005). Thus, the tutors should be able to put themselves on the level of student understanding, which is known as cognitive congruence (Schmidt and Moust, 1998).

In addition, according to Barrett and Moore (2011), the role of tutor is also to encourage the challenge of learning, facilitate the processes of PBL, listen to students in groups, observe the students' practices, intervene at the right time, ask questions which encourage critical and creative thinking, ask students to provide evidence for their information, and assess and evaluate the resources they have used. Also, the role of tutor is to challenge students to link theory with practice, motivate students to debate important issues, guide students to becoming responsible for completing their independent learning to high standards, encourage students to reflect their learning and their performance in the group, and develop their skills (Barrett and Moore, 2011). Teachers also have to provide feedback for students as soon as possible following the completion of their work (Ronis, 2008).

According to Asowai (2004), Mathematics teachers should play the role of the guide and the assistant in the education of mathematics, and should not merely dictate knowledge. He added that teachers pose questions and prepare students to move from one topic to another which should provoke thinking in students, and challenge and stimulate them mentally. They should listen to their ideas and opinions and encourage them to justify and defend them and provide opportunities for students for mathematical induction and problem-solving. Teachers should also provide students with the appropriate structure for learning that is required, by satisfying the high expectations of democracy among students in classrooms and provide the tools and means which support learning and verify that tasks are worthwhile and beneficial (Asowai, 2004).

Overall, the tutor in PBL is no longer the sole source of knowledge, but rather he or she becomes a meta-cognitive coach who is able to use his or her intervention strategies at the right time and with the right questions to help students to move through the steps of the PBL processes. Intervention strategies such as making decision on what, when and how intervention should occur to enhance cooperation and production should also take place in group processes (Bosse et al., 2010). Metacognitive questions will be discussed in the next section.

3.9.2 Meta-cognition and PBL

Meta-cognition is defined as 'the knowledge and control one has over one's thinking and learning activities' (Swanson, 1990, p.306). Meta-cognition strategies are the set of processes carried out by the learner for knowing the activities and mental processes and methods of learning and self-control that is used before, during and after learning in order to achieve remembering, planning and management, problem-solving and other cognitive processes (Tantawi 2001). Some believe that not everyone is metacognitive (Whimbey 1976; Sternberg 1982). According to Sternbery and Wagner (1982), some children have no idea of what they are doing when they perform tasks and they cannot explain their problem solving strategies (Sternberg, 1982). Therefore, students should possess and develop their metacognitive skills.

Costa, 1984 states that self-monitoring of inner dialogue to evaluate problem solving processes can be considered as a metacognitive process (Costa, 1984). Rigney (1980) states that self-monitoring skills are necessary for successful performance on intellectual tasks; knowing the sequence of operations, knowing what he/she had achieved and to detect errors and recover them (Rigney, 1980). Fogarty (1994), explains how self-monitoring occurs (Fogarty, 1994). He summarised it into two points: firstly, *looking ahead,* including knowing the structure of the sequence of operations, choosing the effective strategy which can reduce the possible errors, and identifying feedback and evaluating it. Secondly, *looking back* including detecting the previous errors which had been made, knowing what had been done, what should be done next and evaluating the outcomes.

Students' reflections on their learning is crucial in PBL (Hung, 2013). This could improve students' meta-cognitive skills as well as processing their learning transfer and connecting effectively their new learning with prior knowledge (Hung, 2013).

Strategies for developing students' metacognitive abilities must be infused into instructional methods (Costa, 1984). Metacognitive skills help students to effectively construct their own knowledge and to be aware of the gap between what has been done and what needs to be done next. In addition, this ability can enhance group dialog and can also transfer learning. According to Fogarty (1994), there are three clear reasons for including metacognitive classroom instructions; (1) Compatibility with the constructivism's view of learning; (2) Enhancing collaborative learning, and (3) Fostering transfer of learning to non-routine situations (Fogarty, 1994).

Teachers can guide and foster the behaviour of their learners' metacognition (Fogarty 1994). Teachers can ask some meta-cognitive questions such as, 'what do we need to know more about?' and 'what is going on?' (Ronis, 2008) and think aloud with students using modelling behaviours (Delisle, 1997). Therefore, some of the following meta-cognitive strategies can be used in PBL:

1. ‘Higher-order questioning’ such as asking some questions for which the answers depend on analysis or evaluation.

2. ‘Socratic dialogue’ such as questioning that helps students to come to a conclusion.

3. ‘Analytical reading’ such as students critically reading.

4. ‘Strategic writing’ such as following the logical sequence.

5. ‘Cooperative learning’ such as working with groups to allocate each group member a part or task

6. ‘Use of manipulation’ such as using learning materials physically.

7. ‘Graphic organizers’ such as representing data graphically (Ronis, 2008, p.9).

As meta-cognition is to be aware and able to control one’s own cognitive process (Flavell, 1976), and cognitive strategies have a direct effect on learning (McCrindle and Christensen, 1995), meta-cognitive strategies are to useful in helping to improve cognitive strategies.

Therefore, PBL aims to improve cognitive strategies by using meta-cognitive questions and modelling behaviours which can improve learning outcomes, while conventional methods neglect these skills. These strategies can be implemented, within dialogic knowing which is discussed in the next section.

3.9.3 Dialogic knowing in PBL

‘*Dialogic knowing is a concept that is at the heart of problem-based learning and a key idea underpinning all good learning’* (Barrett and Moore, 2011, p.115). The dialectic process is that students are learning from ill-structured problems through a reflective conversation with the processes of a problem and therefore students are required to define the problem, recognise their different perspectives and determine which necessary skills and information are needed to solve the problem (Chin and Chia, 2006).

When students encounter the problem they should question their understanding of the concepts and terminology that come up with the problem, and recall and apply their prior relevant knowledge. This should lead to identification of ‘learning issues’ which means what students need to learn in order to solve the problem. Students then work independently to gather the information or knowledge they need. After that they re-gather and integrate their prior knowledge with the new knowledge to solve the problem (Cockrell, Caplow et al., 2000).

The dialect knowing can be activated by students questioning each other. Questions from students are critical in learning processes (Gallagher, Sher et al., 1995). Students' questions can activate students' prior knowledge, direct their learning efforts, facilitate their new concepts, help them to elaborate on their knowledge and provoke their epistemic curiosity (Schmidt, 1993). However, the discourse among students should reflect their critical thinking (Measure CT in PBL).

Barrett and Moore (2011) suggest three principles to develop dialogic knowledge; generate more democracy and group relations, co-constructing knowledge via co-elaboration and implementing shared control (Barrett and Moore, 2011). In order to involve more democracy they suggest two strategies; (1) making and reviewing ground rules and using the whiteboard to record their ideas and (2) encouraging students' behaviours to co-elaborate and ask questions which can facilitate their learning for co-constructing knowledge. Finally self and peer- assessment can encourage shared control (Barrett and Moore, 2011).

The role of the teacher is to monitor the students' group discussions (Cockrell, Caplow et al., 2000) .This could be done by facilitating students' learning processes and pushing them to think deeply and modelling the kind of questions that they need to ask themselves (Brown, Collins et al. 1989). However, teachers should not control students' knowledge as they need to develop their personal characteristics to be able to relinquish control in the classroom power (Ronis, 2008).

Overall, teachers should facilitate PBL learning processes by using meta-cognitive teaching strategies and enhancing the students' social deluge skills. The next section will address the role of students in PBL.

3.9.4 Different student levels in PBL and the roles for students

The role of students is to go through the PBL process and learn. Students work in small groups, understand the problem, identify and learn what they need to know and generate hypotheses to solve the problem (Hmelo-Silver, 2004). Students may be divided into groups. Each group consists of between five and eight students with a tutor or, if there is a shortage in teachers, one teacher can have responsibility for two or three teams (Barrett and Moore, 2011). Teachers motivate students to learn through interacting with each other when students are discussing problems in small groups (van Berkel, 2010). Each member of the group should have a specific role such as chairperson, recorder, reader or observer. According to Barrett and Moore (2011) who described roles of members of the group, the role of the chairperson is to encourage all members of the team to participate, facilitate the work within agreed rules and control any dominant members of the team, as well as encouraging the quiet members. The role of the recorder or scribe in the team is to record and document the ideas generated by the team and write down the learning approaches that they have decided to conduct. The role of the reader is to read aloud to the group any decisions which have been documented by the recorder. The role of timekeeper is to help the team to manage time whilst the role of observer is to make notes and suggestions (Barrett and Moore, 2011). Commitment and meaningful engagement is required for deep learning of subject matters (Hung, Mehl et al., 2013).

Students are different in terms of achievement level; they are advanced, intermediate, high or low achievers. Therefore students could respond differently to the PBL strategy. The difference between the achievement levels of students may be due to their different abilities and/or their levels of prior knowledge and/or skills. A study by Simons and Klein (2007) revealed that high achievers scored better than low achievers in their interaction with PBL (Simons and Klein, 2007).

Another study used a quasi-experimental design to examine a comparison between PBL and traditional instruction in algebra II (a curve-fitting unit). 342 students (15 classes) from five high schools in a mid-Atlantic state were selected for the purpose of the study; eight classes were instructed using traditional methods while seven classes were instructed using PBL teaching strategies. The treatment lasted for four weeks. In this study, a 20-item test (skills measure) was used to measure basic skills in algebra II, a five-items test (complex problem-solving measure), group problem measure (a single problem to be solved within a group) and a 28-item Constructivist Preference Measure test were used as instruments to obtain the results. The results show that students used a more constructivist approach and high achievers who received PBL instruction to solve problems and generate plausible solutions in groups achieved better results than the high achievers who received traditional instruction. In addition, there was no significant difference between groups in terms of skills (Elshafei, 1998).

Overall, despite the lack of research that investigates the interaction between the different achievement levels of students and the effectiveness of PBL, the overall findings tend to show more positive interaction with PBL and high achieving students. In the next section the problems with PBL will be discussed.

3.10 Problems and problem solving

In this section the relationship between problem solving and literacy and PBL is discussed, followed by problem solving and knowledge transformation. The kind of problems recommended in PBL is then discussed along with adapting problems in curricular PBL.

3.10.1 Problem-solving, PBL and literacy

Problem-solving is considered a necessary part of everyday life; solutions can also create new problems which require problem solvers (Elshafei, 1998). For example, some drugs can cure a patient but produce side effects which create new problems which require solving. Nowadays, these changes and developments are being witnessed and require problem solvers (Nickerson, 1988).

The quantity of experiences significantly affect the ability to solve problems (Elshafei, 1998). For example, experts in any field are likely to solve problems related to their field better than others who have little or no experience in that field. In addition, the more familiar the individual is with a certain topic or if they have previously solved similar problems related to that topic, the higher the probability that those problems will become routine (Elshafei, 1998). Effective problem solvers have many various representations to solve a variety of problems whereas ineffective problem solvers have one strategy to attempt to solve all problems (Elshafei, 1998). "*Mathematical problem solving is a complex cognitive activity involving a number of processes and strategies.*" (Montague, 2005, p.2).

Therefore, in order to be effective problem solvers in mathematics, this would require training on problem-solving in the mathematical field and this can also be true in other cases. This reflects National Council of Teachers of Mathematics (NCTM) suggestions which suggested that problem-solving should be the heart of the mathematics curriculum:

> *"Problem-solving should be the central focus of the mathematics curriculum. As such, it is a primary goal of all mathematics instruction and an integral part of all mathematical activity. Problem-solving is not a distinct topic but a process that should permeate the entire program and provide the context in which concepts and skills can be learned."(NCTM, 1989, p.23).*

PBL could be a good response to the NCTM recommendation, whereby problem-solving is integrated into mathematics activity to gain new knowledge and promote skills such as problem-solving. PBL is an educational approach designed to develop problem-solving and basic learning skills through engaging students in solving ill-structured problems which reflect events and issues which apply in the real-world (Finkle and Torp, 1995). When applying PBL processes, students acquire new concepts through the conflict with problems (Ronis, 2008). Therefore, PBL helps to develop student's literacy (Hmelo-Silver, 2004), and also develops students to be problem-solvers by honing their skills in cooperation, insistence and justifying (Ronis, 2008). Recent cognitive research indicates that the best learning occurs during engaging learners actively in the process of problem-based learning (PBL) (Ronis, 2008).

Overall, PBL can undertake two parallel tasks, promoting skills and gaining new knowledge by solving problems. Thus, problem solving in PBL requires the transformation of knowledge. This is discussed below.

3.10.2 Problem solving and transformation of knowledge

Acquiring domain knowledge only does not improve students' problem solving skills; however, knowledge acquisition and situational knowledge, which refers to understanding where, when and how to apply the knowledge, are improving problem solving skills (Hung 2006). Knowledge application is at the heart of problem solving (Mullis et al., 2012). 'Applying' refers to students' abilities to apply knowledge and conceptual understanding in situations of problem solving, such as solving routine problems, whereas 'reasoning' refers to students' abilities to solve unfamiliar or non-routine problems (Mullis et al., 2012). Therefore, knowledge may need transformation to be applied for solving a certain problem. 'Transfer' is involved in new learning when prior relevant knowledge and experience is transferred to a new situation (Bransford, Brown et al., 1999).

According to Hung, learning transfer could be described as implementation of learned knowledge in order to solve problems or complete a task with some modifications or adaptations (Hung, 2013). Original knowledge requires a greater degree of modification in a far transfer situation than other levels of transformation which makes applying knowledge more difficult (Hung, 2013). The process of transformation therefore requires complex cognitive processing (Schunk, 2004) and further supporting knowledge such as situation knowledge (Hung, 2006), strategic knowledge and higher order cognitive skills (Hung, 2013). As a result of this complexity of the transformation process of learning, Hung, (2013) suggested providing appropriate scaffolding to students which must gradually fade out for developing students' transformation abilities. Thus, students need to improve their ability in knowledge transfer. The cognitive ability for transfer is vital because without it, all learning would be situation specific and much more instructional time could be spent in new situations to teach new skills (Schunk, 2012).

The degree of that transformation can identify the degree of the difficulty of the problem. Abundant transfer entails higher-order thinking skills and beliefs about the utility of knowledge (Schunk, 2012). Transformation of learning can be divided into: knowledge near transfer (immediate application) and knowledge far transfer (novel application). Near transfer is when students directly apply their original learned knowledge in an approach that is the same or highly similar to how the knowledge was initially learned (Schunk, 2004). Therefore, near transfer is almost a direct knowledge application. On the other hand, far transfer is more complex and difficult whereby original learned knowledge cannot be applied on a similar original learned situation. Moreover, there are three types of transfer - positive, zero and negative. Positive transfer is when prior learning facilitates new learning; negative transfer is when prior learning overlaps with new learning or makes it harder, while zero transfer means there is no noticeable influence on subsequent learning (Schunk, 2012).

In traditional classroom instruction students are taught knowledge in "abstract forms" (Hung, 2013) because its advocators believe that gaining the fundamental conceptual knowledge can be achieved through directly teaching theories and principles of the specific topic (Jonassen, 1991). Therefore, this could not show students the function of mathematics in daily life.

Self-directed learning requires students to take responsibility for conducting problem-solving and learning process which could improve students' abilities in the function of knowledge far transfer (Hung, 2013). This could be achieved by practising analytical reasoning (Stolper et al., 2011).

In PBL the acquisition of knowledge and knowledge application occur in one phase (instead of an isolated phase) which could help students to transfer "theoretical principles into practical knowledge" more easily than in conventional instruction (Hung, 2013, P.32). This can occur in PBL processes, however, not all problems are suitable and effective for PBL.

3.10.3 Problems in PBL

The problem is the key element in PBL. Barell, (2006) defined a problem as a challenge that requires a solution (Barell 2006). The design of a problem could affect students' outcomes (Duch 2001; Hung et al., 2013). Therefore, Schmidt, Van der Molen et al. (2009) determined three important roles for problems in PBL:

1. Increasing the level of curiosity in the study field.

2. Providing an experience related to the curriculum.

3. Integrating learning in all of the aspects of the curriculum such as small group dialogue, lectures, skills and training.

However, problems are different in terms of structure, quality and nature. The differences influence the role of the problems.

Regarding problem structure, according to Biggs (2004) there are three types of problems:

1. A problem that also provided all the necessary information to solve it. This kind of problem is not appropriate to PBL.

2. An open problem. It provides no information or guidance and the role of the student is to search the case by themselves. With this type of problem, teachers or problem designers may find it difficult to drive students' attention to learning issues.

3. A problem that is provided with some information and the role of the student is to search for the rest of the information. It encourages students to delve deeper into the source of the given information. This kind of problem is suitable to PBL because it aims to direct students' concentration to learning issues which should be the main objectives of the lesson.

Problems should be designed to suit the PBL strategy. Thus, ill-structured problems are advocated in PBL (Finkle and Torp, 1995). Ill-structured problems present a situation which does not provide the necessary information required reaching a solution and there is no single way to solve it (Chin and Chia, 2006). Hence it makes students require further information and understand what does occur and help them to decide on the required processes to approach a solution (Ronis, 2008).

With respect of the nature of the problem, learning occurs when people frequently practice every-day problem-solving (Barrows and Tamblyn 1980). All life is rich with learning opportunities (Hung et al., 2008). However, According to Eshach (2006), well-structured problems are given in school while ill-structured problems occur in daily life (Eshach 2006). Therefore, PBL acts in a similar way to life actions by presenting problems to students in order for them to learn content and skills. Furthermore, in authentic problems, students would learn intention with meaning (Hung et al., 2008).

In addition, PBL is based on the assumptions of constructivists about learning. Some of these assumptions state that knowledge is socially and individually constructed when people interact with the environment; knowledge is linked with related contexts, thinking is meaningfully spread out within culture and society and there are multiple perceptions related to every occurrence (Hung et al., 2008).

Much of the literature for mathematics education focuses on real life problems which the teachers use, rather than using abstract or contrived examples which may not relate to students (Westwood, 2011).

Real life problems, "at an age-appropriate level", could be of interest and show students the value of the mathematics' functions in real life (Westwood, 2011). Authentic problems would provide an experience related to the curriculum and enhance the role of the problem to capture students' motivation. Therefore, PBL is assumed to be more effective if it is embedded in authentic problems such as ill-structured problems which people encounter in their everyday lives, and have unknown solution, goals or even ways to be solved (Hung et al., 2008).

Concerning quality of the problem, Dronor, (2005) described the problem in PBL, which should include nine characteristics relevant to employers and academics:

1. It has more than one correct solution. This characteristic seems to be found in ill-structured problems or open problems, but not in well-structured ones.
2. It is more complicated than it is easy. It depends on students' reasoning ability; therefore, it seems difficult to design problems that have the similar level of difficulty for all students unless the students' differences could be eliminated in ability and prior knowledge and skills.
3. It is ill structured in nature.
4. It is multidisciplinary in nature. It seems that real life problems can meet this characteristic.

5. It has to concentrate on teamwork and cooperation. The problem should be able to let all students work and cooperate to solve it.

6. It requires planning.
7. It encourages using resources. Resources can be textbook, the Internet, library or even teachers.
8. It requires determining learning issues. It means that solving problems should lead to the objectives of the lesson being achieved.
9. Each one of the students has to think effectively (Drohan 2005). The aim of the problem should not to learn knowledge only but also to gain and improve thinking skills.

Overall, problems in PBL should be ill-structured, have real-life characteristics, and be suitable for groups to play an effective role in PBL. The problem has to be reasonable, relevant and authentic (real world), and it has not to be ambiguous; the aim of the problem-solving is in the discovery and aspects of research rather than the solution, which is expected to discover the mathematical principles in the real-world problems (Ronis, 2008).

Empirical studies show that problems in PBL should be adapted to be suitable for students. Adaptation of problems in PBL is addressed in the next section.

3.10.4 Adapting problems in curricular PBL

Although PBL requires ill-structured and real life problems, it cannot be formulated for all problems in the required form because the curriculum requires teachers to cover the whole learning objectives. It is therefore inevitable that some problems will occur which are contrived and which direct teachers to cover the entire curriculum (Ronis, 2008).

Considering age-appropriate practice with students of different ages is also essential. In a study conducted by Zhang et al. 2011, the study asserted that age-appropriate practice in the kindergarten is vital (Zhang et al., 2011). This illustrated why the teacher who participated in this study used a story to present a problem to students in kindergarten contexts. According to her, the reason was because the story used did not require explicit, or formalised hypotheses. She believed that generating hypotheses in this way is too difficult for younger students, however they will almost certainly seek explanations, and look for solutions to problems that interest them.

Two critical factors are required for students when solving problems; one is that they want to solve it, the other is that they believe they can solve it (Kirkley 2003). Therefore, exposing students to problems which are too difficult will negatively affect students' motivation and confidence (Westwood, 2011). Therefore, when designing lessons in mathematics one must take care not to create excessive cognitive loads for students (Wander and Pierce, 2009). However, Westwood argued that weak fundamental skills among lower primary students may leads to learning difficulties in solving problems (Westwood, 2011).

Hung, (2013) suggested that the curriculum should be organized gradually, starting with problems which are immediately applicable, followed by problems which require knowledge near transfer and ending up with problems which require far transfer.

More recently, Hung, Mehl et al. (2013) conducted a study to investigate the relationship between design problems of PBL and students' and self-directed problems. Two groups were recruited in Midwest University: pure PBL and hybrid PBL. Six pure PBL problems, two solvable and four unsolvable problems were used in one group for one semester, while in another group one unsolved and one extremely difficult problem was used in the third term. The questionnaire and observation form were used in this study. The results show that students found difficulties in identifying objective learning. This could be due to the huge scope of the problem statements or students' weakness in the identification of them. In addition, this confusion may decrease the effect of self-directed learning (Hung, Mehl et al., 2013). The next section will discuss PBL settings.

3.11 PBL settings

This section describes PBL characteristics and processes and how to adapt them for different student's ages and experiences. It then discuses if PBL is suitable for lower primary school students after discussing the difference between third and eighth grade school students. At the end of this section the assessment of PBL will be discussed.

3.11.1 Characteristics of PBL

In PBL students engage in solving authentic problems in small groups in order to gain new knowledge and to improve skills such as problem-solving and self-directed learning skills. Barrows (1996) describes the six core characteristics of problem-based learning, as listed below:

1. Students are the centre of the learning. This means students plan and learn by themselves with some control of the setting. Teachers should not be the centre of learning.

2. The role of the tutor is as a facilitator or a guide. Therefore, teachers help students to learn.

3. Learning occurs in small groups of students. Students cooperate and learn from each other through problem solving.

4. At the beginning of the learning the student(s) present authentic problems. The problems should be real life and presented at the beginning of the lesson to learn the objectives of the lesson.

5. The problems are used as a means to accomplish the goals of learning the subject matter by using problem-solving skills to resolve the problems. Problems are the way of learning and achieving the objectives of the lesson.

6. New knowledge is gained through self-directed learning (Barrows, 1996). The students plan and learn by themselves, through solving real life problems.

It is clear that the six core characteristics are important to be considered in PBL situations. However, not all problems can be real life. It is therefore inevitable that some problems will occur which are contrived and which direct teachers to cover the entire curriculum (Ronis, 2008).

Therefore, the problem is used in the PBL teaching strategy as a vehicle to carry a small group of learners to a certain place. The group members share the same objectives (solving the problem); however, in order to solve the problem the group members must follow the learning objectives (the objectives of the lesson). These learning objectives should be embedded into the problem statement, and become 'knowledge they need to learn', when students plan to solve the problem. The learning objectives (the objectives of the lessons) can be changeable, based on the topics, however PBL objectives should not be changeable. Hmelo-Silver andBarrows, (2006) present four goals for PBL:

1. To keep all the students active in the learning process.

2. To keep the learning process on track.

3. To make the students' thoughts and their depth of understanding apparent.

4. To encourage students to become self-reliant for direction and information.

It is clear that the goals of PBL are not only to gain knowledge but also to improve students' self-directed learning and problem solving skills.

Therefore, learning goals (i.e. obtaining new knowledge related to the subject matter) and educational goals (i.e. skills) plan to be concurrently achieved in PBL settings. It aims also to improve students' motivation and support meaningful experience to learn from using relevant problems. According to Barell (2006), the reasons for implementing PBL are: a) providing an opportunity for students to practice the high-order thinking, b) supporting equity, where students can learn and improve their knowledge and skills, regardless of their backgrounds or cultures, c) improving the motivation of students by challenging them and interaction, d) supporting active learning and e) reinforcing a deeper understanding by learning through meaningful experience (Barell, 2006).

Therefore, it is clear that PBL aims to help students learning from meaningful situations for deeper understanding, and to increase students' motivation towards learning. It also aims to improve students' thinking skills, such as self-directed learning and problem solving, by encountering problems which require solutions. Therefore, the current study aims to assess the effectiveness of PBL on knowledge acquisition and skills (applying and reasoning) and also students' attitudes towards mathematics. The processes of PBL are further discussed below.

3.11.2 Pedagogy of PBL

There is no fixed model to implement the PBL teaching strategy. Ronis (2008) suggests the followings steps:

1. Identifying the problem; students presented with the problem, they work to understand the problem and identify the problem that they should solve.

2. Making precise statements about the problem; students write the 'problem statement' which can clearly highlight how to solve the problem if they know what they need to know.

3. Determining the information that is needed to solve the problem; students determine the missing information that they need in order to solve the problem(s).

4. Determining the resources required to collect the information; students determine which resources they may need to find that information such as Internet, textbooks and library books. These resources should be valid and reliable.

5. Generating possible solutions; as students work to solve ill-structured problems which have more alternative solutions, they should generate all possible solutions.

6. Analysing the solutions; students then make decisions as to which solution can be the best among the possible generated solutions.

7. Providing a presentation whether orally or in writing; once students have agreed on one solution then they will choose how to present it and receive feedback form others (Ronis, 2008).

It seems that the Ronis's steps present clear procedure to PBL implementation. Boud and Feletti (1997) set up some steps of PBL:

1. Presenting a problem; problems are presented to students in any format such as a letter, video or someone outside of the class asks for help.

2. Students work in small groups to organise their own ideas and to understand the problem; once students have received the problem the first step is to attempt to understand the problem in groups.

3. During the discussion students determine what they already know and what they do not know regarding the problem (learning issues); through collaborative discussion students identify what they already know and activate it and then identify what they need to know.

4. Students set up the learning issues to decide on how they will deal with these questions and discuss with tutors how best to find the resources; once students have listed what they need to solve the problem they then set up a plan on how to gain that knowledge and which available resources to use.

5. Students gather information in order to find out about how the previous knowledge connects with the old knowledge and define the new learning issues; the last step is to link new knowledge to prior knowledge to solve that problem (Boud and Feletti 1997)

It is clear that there is some agreement about the ways in which the problems are presented to students, and students determine what they already know about the problem and then identify what they need to know. They then decide on the method of research and co-construct new knowledge and implement the action required to resolve the problem. Each member of the group has to participate effectively (Spronken-Smith and Harland 2009). However, there is more than one model and approach for applying PBL processes because every problem has its own individual and specific set of circumstances; the problem would be different if new information was found (Ronis, 2008).

The model that will be used in this study, for eighth grade students, is to present real-life and ill-structured problems to students in the form of a letter. One of students reads the problem out loud in front of the other students. One of the students explains the problem in their own words and the other students are then asked to give their feedback. This is done with whole class. Then the students identify what they already know and what they need to know. After that, students identify the statement of the problem and the teacher writes the students' responses on the whiteboard. Once students have agreed on what they believe to be the statement of problem, the teacher asks the students to join their groups and set goals for what they need to know. The students then allocate tasks between them and then begin their search for the required knowledge and information. After the students have completed their research and have gathered the new knowledge they re-group to share the new information. They then generate possible solutions for the problem and make a decision as to which is the best solution. Finally, students present their solution to the whole class and the rest of students have the chance to ask questions and give feedback. The teacher facilitates student learning processes by using meta-cognitive teaching strategies, such as asking meta-cognitive questions.

On other hand, the model for younger, third grade students, is to present real-life and ill-structured problems to students in the form of a letter. Then, working in groups, the students are given time to work through the problem together, gain an understanding and formulate a plan. The teacher then assesses whether or not the students fully understand the problem and how they are going to approach it. Specific questions are asked about the process the students are going to take in order to solve the problem. When the teacher is satisfied that the students are clear in their level of understanding and approach, they are then given time to solve the problem. The students are then required to present their work to the rest of the class and receive feedback from the teacher and the other groups.

3.11.3 Assessment of PBL

The assessment of PBL is not always in line with the PBL goals. The tests are being used to assess the content knowledge and not focus on problem solving skills and self-directed learning (Sluijsmans et al., 2001). According to Lockwood (1995) students develop 'test behaviour' where they only focus on the requirement of the assessment.

According to Torp and Sage (1998), assessment in PBL has two functions: assessment *for* learning and assessment *of* learning. Assessment for learning or formative assessment is conducted during the run up to the PBL experience and can be in the form of embedded instructions and coaching. Assessment of learning or summative assessment is carried out during the PBL session where students are required to provide knowledge or skills to be graded on. Additionally, teachers frequently experience difficultly in determining what each student has contributed to the productivity of the group (Sluijsmans et al., 2001).

In this research, embedded instruction is conducted and feedback provided. Teachers should adapt the PBL strategy to be appropriate for student discipline. This is addressed in the next section.

3.11.4 Adapting PBL

PBL principles should be adapted based on the nature of the discipline (Hung 2011). In addition, adaptation should consider the different age and achievement level of study. Students in K-12 may have limited self-directed learning skills (Liu, Williams et al., 2002). Some studies attempted to adapt PBL strategies in K-12. Achilles and Hoover (1996) found shorter PBLs could be more effective. They added that regular timetabling (50-minute periods) required creative designing for the PBL process. They also suggested that students are required to train in PBL group processes before working in PBL instruction (Achilles and Hoover, 1996). Some researchers believe that PBL is not suitable for lower primary school students and this will be discussed next after the discussion on the difference between third and eighth grade school students.

3.11.5 The difference between third and eighth grade school students

The difference in the age of the students (primary school students ranged from age 8 to 9 and intermediate school students ranged from age 13 to 14) could be an important factor on their learning due to their different development stages. Development is defined as changes over time within an orderly shape that enhances survival (Meece, 2002). These changes are progressive and are part of maturation (Schunk, 2012). These changes may also be idiosyncratic, and happen at different rates. Development is linked with learning, for example: young children cannot make the same connections as older ones because older children have more extensive memory networks (Schunk, 2012). Schunk (2012) believes that maturation and learning are elements of development.

It is also difficult to maintain the sustained attention of young children. Therefore, teachers should ask questions and give feedback to help students to focus on important tasks (Meece, 2002). The role of the teacher in PBL is 'to facilitate learning processes through prompting metacognitive questions'. This action also aims to improve students' metacognitive skills. Metacognitive skills improve with development (Kail and Ferrer, 2007), therefore, metacognitive understanding expands between the ages of 5 to 10 (Siegler, 1991).

The current study has considered these factors by giving students age-appropriated problems and models. Development also has an effect on children's motivation (Wigfield and Eccles, 2002). Young children are highly motivated about what they can do, but this decreases with development (Schunk, 2012).

3.11.6 Does PBL suit lower primary school students (elementary school)?

Westwood (2011) argued that the problem-based approach in teaching mathematics for lower primary school students is indefensible. He believed the reason for this to be that students at such a young age do not confidently possess basic computational skills. He disagreed with providing lower primary school students with age-appropriate problems because this approach cannot easily master fundamental number skills (Westwood, 2011). On the other hand, Montague believes that problem-solving strategies and skills began to develop before students had entered schools, "when a child possesses a basic conceptual understanding of the base 10 numerical system". Students continue, however, to apply and refine their strategies and skills when they are being exposed to various real-life problems till middle school levels when they can apply their strategies and skills in effective and efficient ways in and out of school. As understanding the problem requires firstly reading it and then making decisions on how to solve it, most students obtain the strategies and skills needed to read and make decision to both understand and solve problems (Montague 2005, p.1).

A study was carried out to investigate the teaching experiences in the using of PBL to develop decimal concepts for elementary school students. A small group of five to seven year old second grade school children were selected to be part of the study. Eight class sessions totalling 45 minutes for each session were videotaped and analysed for the purpose of the study. The findings showed that students had an informal knowledge of decimals and they could use this knowledge in a problem situation. They could also use discourse with the members of group and their teacher in order to improve their understanding about decimals. The study concluded that the intersection between students' informal knowledge, problem situations and discourse between the students themselves and their teacher could improve learning (McCarthy, 2001). Interesting evidence arose during the study which is a PBL teaching strategy that could be used for younger students.

PBL raises some challenges for both teachers and students. This is discussed in the next section.

3.12 The challenges of implementing PBL

The challenges which would arise during the process of implementing PBL could be divided into two parts: challenges facing students and challenges facing teachers.

3.12.1 Student challenges

According to Ronis (2008), there are some difficulties that students may face when they are engaged in the PBL processes:

1. At the beginning of the implementation of PBL, students may not be comfortable because they have become accustomed to conventional teaching and learning methods; students in PBL are responsible for their learning. The responsibility of their learning requires students to be more active and carry out self-assessment which also requires more energy. This can make students feel uncomfortable, particularly at the beginning.

2. Students may want to know what they have to do in order to gain their grade. The assessment would not be clear for students. Students may then not know what should be done in order to gain their marks.

3. Students who are interested in ‘book learning’ might be uncomfortable with the PBL rules which require coordinating in groups, generating unique productions and conducting research. Students who are accustomed to working with a clear instructional book may feel

frustrated when they are required to deal with other materials which may be outside of their class.

In these cases, the roles of teachers are to familiarise students with the PBL processes and teachers should inform students that they are becoming researchers of information as it is the role of scholars in various fields. Teachers also need to make them aware of their roles which are to prepare them to be successful in life outside school (Ronis, 2008).

3.12.2 Teacher challenges

Teachers may face some difficulties (Monks, 2010), such as:

- Preparing PBL units requires teachers to research and plan in order to develop authentic problems which takes time and effort. This may need a training programme to train teachers how to design problems suitable for PBL. However, teachers can be provided with pre-prepared problems if they are unable to design such problems.

- Teachers need to be familiar with being a guide or a facilitator. Teachers are accustomed to teach using traditional methods, where teachers take control of students' learning. Once teachers have lost their control they may become frustrated and feel their position is threatened. Furthermore, scaffolding learning, adapting new roles and creating an environment of teamwork and interdependence are other challenges that tutors may encounter (Ertmer and Simons, 2006).

One of the difficulties that novice PBL teachers can encounter is retraining to make the transition to PBL more seamless (Irby, 1996). They could experience difficulties during this transition process as the transition to PBL changes the relationships between the tutor and his/her students. Also, this shifting to PBL requires new roles and skills (Wilkerson and Hundert, 1997).

According to the study of Lee and Bae, there were two issues which could concern teachers in using PBL. Firstly, uncovering topics in the textbook and secondly, how much of the knowledge students have fully understood (Lee and Bae 2008). Implementing PBL may need more time and more flexible curricula than with traditional instruction. According to a study by Ingram, (2013), time limitations and curricular restrictions were difficulties facing teachers (Ingram, 2013).

The next section will review Saudi education in mathematics in the light of The Trends in International Mathematics and Science Study (TIMSS). This will evaluate mathematics education in Saudi Arabia and make comparison between Saudi Arabia and the average international performance in detail. In addition, this assessment will highlight the effective factors on students' performance which can raise awareness for drawing an accurate conclusion which can contribute to developing the PBL strategy and the research in education.

3.13 TIMSS

The Trends in International Mathematics and Science Study (TIMSS) provides data about participating countries and their educational system, particularly in mathematics and science, and occurs every four years. The aim of TIMSS is to assess teaching and learning in mathematics and science and make comparisons between participants in order to develop their education in areas such as curriculum and training teachers. TIMSS targets all fourth and eighth grade students. It was done in 1995, 1999, 2003, 2007 and 2011.

TIMSS provides data about participating countries and benchmarking (regional jurisdictions of countries), and compares the data with previous data obtained since the country first participated in TIMSS. Each student that has participated in TIMSS gained overall scores in both mathematics and science and other scores in the 'Content Domain sub-scales and Cognitive Domain sub-scales'.

One of TIMSS goals is to help participating countries to make informal decisions on how to improve their students' teaching and learning in mathematics and science. TIMSS provides massive information about the trends of mathematics knowledge and skills for students all over the world. It assesses mathematics content, concepts and procedures which countries expect primary and lower secondary school students to learn. TIMSS also assesses the progress of students worldwide, over time and makes comparisons within countries and between countries over time in different areas of mathematics, such as Number and Algebra. TIMSS divides levels of students into four benchmarks: Advanced, High, Intermediate and Low. Students' achievements are effected by many factors including home support learning, school resources, school climate, teachers' perspective about instructions and engagement of students in learning. TIMSS is a massive international research programme which assesses students' deeply and understands the effects of policies and practices between countries. TIMSS data is of a very high quality which is arrived at through careful planning, standardized procedures, cooperation among participating countries and rigorous attention to detail (Joncas, 2007).

TIMSS research is not free from criticism by some researchers. Some researchers argued that it is less suited to countries that do not have centralized education systems. They believed the reason is because some students may have not been exposed to all topics that the TIMSS tests covered. Another criticism is related to samples; they believed that not all country samples included disabilities and language learners (Berliner, 2013). However, this could be addressed in the future comparison research by collecting missing data, and controlling them by using possibly multiple regression analysis.

In the next section the overall outcomes of TIMSS 2007 and 2011 are discussed, its framework and the results of participating countries. It is followed by an assessment of Saudi Arabia's performance in TIMSS 2007 and 2011 regarding overall achievements and students' performance in each domain [content and cognitive domains], and the ability of Saudi students in problem solving skills. This is followed by TIMSS quantity and quality factors. Attitudes towards mathematics are then discussed, concluded with other general TIMSS factors.

3.13.1 An overall of TIMSS 2007 and 2011 in Mathematics

More recently, TIMSS 2007 has provided data about 37 countries and seven benchmarking participants for fourth grade students and 49 countries and 7 benchmarking participants for eighth grade students. This data has been compared with the previous data obtained since each country first participated in TIMSS. Each student who participated in TIMSS 2007 has gained overall scores in mathematics and other scores in the 'Content Domain sub-scales and Cognitive Domain sub-scales'(Mullis et al., 2008).

Most recently, TIMSS 2011 has provided data relating to 52 countries and seven benchmarking entitlements for fourth grade students and 45 countries and 14 benchmarking participants for eighth grade students. The data has been compared with the data previously obtained since the country first participated in TIMSS. Each student that has participated in TIMSS 2011 gained scores overall in mathematics and other scores in the 'Content Domain sub-scales and Cognitive Domain sub-scales'(Mullis et al., 2012). The data is drawn from high quality sampling designs which can produce high quality data.

3.13.2 The sample

The sample design is very important for producing high quality data. In TIMSS research, the sample designated is effectively and efficiently broken down into two stages: Stage 1 -

schools are determined randomly and Stage 2 - one or two classes of fourth and eighth grade students are selected (Joncas, 2007).

According to Joncas (2007), the sample selection in TIMSS 2007 utilised school stratification which considered all the different school characteristics, such as urban-public and rural-private schools. He added that TIMSS 2007 also achieved '*...random sampling with a probability proportional to their measures of size*.' (p. 85) which means that if school A is twice as large as school B, then school A is considered as 2 schools and, hence has two chances to be selected. These procedures contributed to the sample design being more efficient.

The framework of mathematics in TIMSS research is reviewed below.

3.13.3. Framework mathematics in TIMSS 2007 and 2011

At the fourth grade, the Content Domain is divided into three categories, as shown in Table 3.2 below:

Table 3 2: The content domain divisions for fourth grades

Content	Percentage in 2011
Number	50
Geometric shapes and measures	35
Data display	15
Total	100

At the eighth grade, the Content Domain is divided into four categories, as shown in Table 3.3 below:

Table 3 3: The Content Domain divisions for eighth grades

Content	Percentage in 2007 and 2011
Number	30
Algebra	30
Geometry	20
Data and chance	20
Total	100

The Cognitive Domain divided also into three categories for all grades and in 2007 and 2011 as it is shown in Table 3.4:

Table 3 4: The Cognitive Domain divisions for fourth and eighth grades

Cognitive Domain	Percentage in 2007 and 2011
Knowing	40
Applying	40
Reasoning	20
Total	100

According to Mullis et al. (2012), TIMSS describes the domains as follows:

1. Knowing

Knowing is to know a knowledge base that recognises, recalls, computes, retrieves, measures, classifies or orders. Mathematical knowing includes the concepts and facts of mathematics, encompassing a factual knowledge, base language and the properties of mathematics which form the foundations of how mathematics is taught. A knowledge base is not learned because of its own sake but because it is necessary for facilitating and applying mathematics and reasoning about mathematical situations (Mullis et al., 2012). Therefore, without accessing a knowledge base of mathematics, mathematical thinking is impossible.

2. Applying

Applying involved that, represent, implement, model, select, and solve routine problem. Applying domain encompasses the application of mathematical tools in various contexts. Routine problem-solving is a heart of applying domain. For example, routine problem-solving includes facts, concepts and procedures. In addition, creation of mathematical representations needs to apply mathematical knowledge, skills, procedures, and understanding concepts.

3. Reasoning

Reasoning comprises that generalise, integrate, synthesise, justify, analyse, and solve non-routine problem. Reasoning requires an ability of observation and makes conjectures, and also logical deduction based on certain rules or assumptions and justifying outcomes. Mathematical Reasoning includes a capacity of systematic and logical thinking. It involves deductive and intuitive reasoning based on regulations and patterns which makes to arrive to solve non-routine problems. The next section presents the overall results of participating countries and Saudi Arabia.

3.14 The results of TIMSS research

In this section the overall result of participating countries in both TIMSS 2007 and 2011 is reviewed followed by the results of Saudi Arabia in TIMSS 2007 and 2011 compared to the average internationally. This section will provide an international assessment for Saudi students in mathematics compared to the international average.

3.14.1 An overall results of participating countries in TIMSS 2007 and 2011

The international average of achievements of fourth grade students was better than the achievements of the students from the eighth grades. TIMSS determined 500 points as ‘the scale average’ and 100 points as ‘standard deviation’ in all tests since 1995 in order to compare between tests (Olsen, 2005). However, this report was limited in TIMSS 2007 and 2011 data. The results of participating countries are shown in Table 3.5.

Table 3 5: The number of participating countries in each score category in TIMSS 2007 and 2011 for fourth and eighth grade students

Grade	TIMSS	Upper Intermediate scores	Intermediate and Almost Intermediate scores	Low Intermediate scores
Eighth	2007	10C 5B	4C 1B	35C 1B
Eighth	2011	13C 9 B	2C 2B	30C 3B
Fourth	2011	24C 5B	4C 0B	10C 2B

Notes: C = participating countries B = benchmarking participants.

Table 3.5 shows that 49 countries and seven benchmarking participants from the eighth grade participated in TIMSS 2007 (see, Mullis et al., 2008). The majority of countries’ students (35 countries and one benchmarking participant) had achieved significantly lower than average scores when compared with the international average scores, while students in 10 countries and five benchmarking participants had achieved average scores which were significantly higher than the international average scores. Four countries and one benchmark participant had achieved an intermediate level. In TIMSS 2011, eighth students in the majority of countries gained average scores which were significantly lower than the international average scores. Conversely, in the majority of countries, students from the fourth grade gained average scores which were significantly higher than the international average scores in TIMSS 2011(Mullis et al., 2012). This may indicate that fourth grade students were better than eighth grade students internationally. The results for Saudi Arabia are reviewed below.

3.14.2 Results of Saudi Arabia in TIMSS 2007 and 2011 - Overall Results

Saudi Arabia has only participated in TIMSS since 2007 with eighth grade students, while it participated with both fourth and eighth grade in 2011. This section will compare the performance of students from Saudi Arabia with other participating countries. The results of Saudi Arabia are shown in Table 3.6 below:

Table 3 6: Overall result of Saudi Arabia for eighth and fourth grades

Country	Average Scale Score
Saudi Arabia 2007 for eighth grade students	329
Saudi Arabia 2011 for eighth grade students	394
Saudi Arabia 2011 for fourth grade students	410
International average for fourth and eighth grade students in TIMSS 2007 and 2011	500

Saudi Arabia had participated in TIMSS 2011 with fourth and eighth grade students, while it participated in 2007 with only eighth grade students (Mullis et al., 2008; Mullis et al., 2012). Students in Saudi Arabia achieved average scores which were significantly lower than the international average scores in both exams (2007 and 2011) and for both grades (fourth and eighth) with 329 and 394 points respectively and with 410 points for fourth grade students in TIMSS 2011. The detailed results in each domain for Saudi Arabia compared with the international average are discussed below.

3.14.3 The results of each domain

The TIMSS 2007 and 2011 tests for eighth grade students included two domains: content and cognitive (Mullis et al., 2008; Mullis et al., 2012).The results show that students received significantly lower scores in both content and cognitive domains, than the international average for both fourth and eighth grade students in Saudi Arabia. For more details see Appendix 3.2. In order to highlight the characteristics of students and give the scores meaning, the scores of students were characterised into four benchmarks.

3.14.4 The benchmarks in TIMSS 2007 and 2011

The TIMSS test measures Content Domain which includes number, algebra, geometry, and data and chance for eighth grades, while it includes numbers, geometric shapes and measures and data display for fourth grades; it also measures Cognitive Domain which involves knowledge, applying and reasoning for both grades.

There are four benchmarks in TIMSS 2007 and 2011, namely:

1. Advanced international benchmark which is 625 or more.
2. High international benchmark which is from 550 to less than 625.
3. Intermediate international benchmark which is from 475 to less than 550.
4. Low intermediate international benchmark which is from 400 to less than 475. (Mullis, Martin et al. 2008; (Mullis et al., 2012)

For more details about the characteristics of students in each benchmark see Appendix 3.1. The results of Saudi Arabian students in each benchmark compared to the international average are reviewed below.

3.14.5 The results of Saudi Arabia in each benchmark

Table 3.7 shows that in TIMSS 2007, there were (0%) of eighth grade students who had reached the advanced international benchmark or even the high international benchmark. However, it slightly improved in the TIMSS 2011, where (1%) and (5%) of students had reached the advanced and the high international benchmark respectively compared to the international median which had slightly increased to (3%) and (17%) respectively. In TIMSS 2007, (3%) and (18%) of students in Saudi Arabia had reached the intermediate international benchmark and the low benchmarks respectively, which is significantly lower than the international median students' percentage which reached the benchmark of (47%) and (75%) respectively. However, there was a remarkable improvement in TIMSS 2011 with (20%) and (47%) of students who had reached the intermediate and low benchmarks respectively. In TIMSS 2007, (82%) of the eighth grade students in Saudi Arabia had not reached the low intermediate international benchmark compared to (25%) of the eighth grade international students. However, in TIMSS 2011, (53%) of the eighth grade students in Saudi Arabia had not reached the low intermediate international benchmark compared to (25%) of the international students.

Table 3 7: The results of Saudi Arabia students in each benchmark

Country	Advanced International Benchmark	High International Benchmark	Intermediate International Benchmark	Low - Intermediate International Benchmark
Saudi Arabia 2007 for the eighth grade	0%	0%	3%	18%
The median of international percentage in 2007 for the eighth grade	2%	15%	47%	75%
Saudi Arabia 2011 for the eighth grade	1%	5%	20%	47%
The median of international percentage in 2011 for the eighth grade	3%	17%	46%	75%
Saudi Arabia 2011 for the fourth grade	2%	7%	24%	55%
The median of international percentage in 2011 for the fourth grade	4%	28%	69%	90%

It can be concluded that (25%) of the eighth grade international students in TIMSS 2007 and 2011 did not have some knowledge of decimals and whole numbers, basic graphs and operations compared to (82%) and (53%) of the students in Saudi Arabia in TIMSS 2007 and TIMSS 2011 respectively.

In respect of the fourth grade students in TIMSS 2011 there were (2%), (7%), (24%) and (55%) of students who had reached the advanced, high, intermediate and the low benchmarks respectively compared to (4%), (28%), (69%) and (90%) of the international students. Therefore, (45%) of fourth grade students in Saudi Arabia compared to only 10% of international students:

- did not know some basic mathematical content knowledge;
- could not add and subtract whole numbers;
- could not recognize perpendicular and parallel lines; and
- were not familiar with coordinate maps and geometric shapes.

It is clear that despite the slight improvement in Saudi students' results in TIMSS 2011, they gained significantly lower scores than the international average in overall results and in each content and cognitive domain for both fourth and eighth grades in 2007 and 2011. From the characteristics of each benchmark crossing students' achievement can we assess students' abilities in problem solving skills. This will be investigated in next section.

3.15 Students' ability in problem-solving

Problems are either routine or non-routine; they can also be real-life or purely mathematical problems (Mullis et al., 2012). Both types of problems require the transformation of knowledge and skills into new situations (Schunk 2004; Schunk 2012). However, non-routine problems require knowledge and skills above what students have learned (depending on their level of education) (Blumberg 2000; Mergendoller et al., 2006), while routine problems require knowledge and skills of what students have already learned (Elshafei, 1998).

The criteria of the benchmarks for eighth grade students can identify the students' abilities in problem-solving skills. Advanced students should be able to solve non-routine problems, high level students should be able to solve complex problem and intermediate level students should be able to solve one-step word problems (Mullis, Martin et al. 2008; (Mullis et al., 2012). It can concluded, therefore, that in TIMSS 2007 only (3%) of the eighth grade students in Saudi Arabia were able to solve one-step word problems compared to (47%) of international students. In TIMSS 2011, (1%) of the eighth grade Saudi students were also to solve non-routine problems compared to (3%) of the eighth grade international students. (5%) of the eighth grade students in Saudi Arabia could solve complex problems compared to (17%) of the international students. (20%) of eighth grade students in Saudi Arabia could solve one-step word problems compared to 46% of the international students.

It can be concluded that in TIMSS 2007, (97%) of the eighth grade students in Saudi Arabia were not able to solve even one-step word problems compared to (53%) of the international students. In TIMSS 2011, (80%) of the eighth grade students in Saudi Arabia were not able to solve one-step word problems compared to (54%) of the international students.

With regards to the fourth grade students in Saudi Arabia, TIMSS 2011 identifies the students' abilities in problem-solving skills. Advanced students could be able to solve multi-step word problems and high level students should be able to solve simple problems. Therefore, (2%) of fourth grade students in Saudi Arabia could be able to solve multi-step word problems compared to (4%) of the international students and (7%) of fourth grade students in Saudi Arabia could be able to solve word problems compared to (28%) of the international students.

It can be concluded that (93%) of fourth grade students in Saudi Arabia were not able to solve problems compared to (72%) of international students.

Overall, the majority of fourth and eighth grade students in Saudi Arabia with (93%) and (80%) respectively, were not able to solve problems compared to about (72%) and half of the fourth and eighth grades internationally, respectively.

Problem solving requires application of knowledge. Therefore, sometimes, a lack of knowledge can negatively affect students' ability to solve problems. The next section will assess the quantity of teaching mathematics for TIMSS topics.

3.16 Quantity of teaching mathematics

This section will review the intended and implemented instructional time for mathematics and devoted time for each area in the content domain. It then highlights the intended TIMSS mathematics topics content at school and how much had been taught. At the end of the section the data in the content domain will be analysed for eighth grade students in TIMSS 2007 and 2011 to assess the effect of the quantity of teaching before the quality of teaching is reviewed. However, assessing the effect of the quantity of teaching mathematics for fourth grade students' achievement was not possible because there were no significant variations between the amount of time spent teaching in each domain.

3.16.1 Intended and implemented instructional time for mathematics

In TIMSS 2007 for eighth grade students, the international average for the intended time indicated in the mathematics curriculum in participating countries was (14%) out of (27) hours of instructional subjects and had implemented (12%) of it. In Saudi Arabia, it had implemented (11%) time out of (27) hours of instructional subjects devoting to mathematics instruction while the intended time was not available in all instructional subjects but (12%) for mathematics (Mullis et al., 2008).

In TIMSS 2011 for the eighth grade students, 134 hours per year had been spent on the instruction of mathematics out of 1050 hours of whole instruction in Saudi schools. The international average for the number of mathematics hours taught per year equated to 138 hours devoted to mathematics and 1031 hours to whole instruction in schools. For the fourth grade, 147 hours per year had been spent on the instruction of mathematics from 977 hours of whole instruction in schools. The international average was 162 mathematics hours out of 897 hours of whole school instruction (Mullis et al., 2012).. It is clear that the time allocated to teach mathematics in Saudi Arabian schools is less than the international average.

3.16.2 Devoted time for each area in Content Domain

In TIMSS 2007 for eighth grade students, teachers' report on how much time is devoted to each area of the Content Domain, as shown in Table 3.8 below:

Table 3 8: Devoted time for each area in Content Domain

Country	Number	Algebra	Geometry	Data and chance	Other
Saudi Arabia	30%	23%	29%	12%	7%
International average	24%	29%	27%	13%	7%

On average, internationally the greatest amount of time devoted to algebra was (29%), followed by geometry at (27%) and numbers at (24%). The lowest amount of time was devoted to data and chance at (13%). The greatest amount of time in Saudi Arabia was devoted to numbers totalling (30%), followed by geometry at 29%. These percentages were higher than the international average of (24%) and (27%) prospectively. However, in Saudi Arabia, algebra and data and chance were given less time than the international average. The data for TIMSS 2011 has not been calculated for all areas.

3.16.3 TIMSS mathematics topics, the intended content at school and how much it had been taught

In the case of eighth grade students

In TIMSS 2007, national coordinators were asked about (39) topics of TIMSS; (10) number, (8) algebra, (14) geometry and (7) data and chance, and how many topics they intended to allocate to the school curriculum. Also, teachers were asked how many topics had actually been taught (See Table 3.9).

In Table 3.9 it is seen that the international average was (31) out of (39) topics were intended to be taught for all or almost all students, two out of (39) topics were intended to be taught for students who were more able and 6 topics were not included in the mathematics curriculum. These numbers of intended topics in almost all participating countries had been taught for (72%) of students.

In Saudi Arabia, (27) topics were intended to be taught for (55%) of students, while (11) topics were not included in the mathematics curriculum. In addition, in Saudi context, there were no extra topics allocated for students who were more able, as indicated at Table 2.9.

Ten number topics were intended to be taught for all or almost all students which included the students of Saudi Arabia. These topics had been taught for (90%) of students in Saudi Arabia. All or almost all students intended to be taught (7) algebra topics out of (8) topics which is compatible with the number of topics that were intended to be taught for students in Saudi Arabia. Furthermore, out of the international average, nearly three quarters of students had been taught about these topics, compared to slightly fewer than half of the students of Saudi Arabia.

In geometry there were (12) out of (14) topics that were intended to be taught for all or almost all students. These topics had been taught for (71%) of international students. In addition, a significantly lower percentage (55%) of students in Saudi Arabia had been taught about (9) topics when compared to the international average.

On average internationally, (4) out of (7) topics were intended to be taught in data and chance. These topics had been taught for (47%) of students. In Saudi Arabia the number of intended topics to be taught was significantly less than the international average and only one topic had been taught for a lower percentage (24%) of students, than the international average percentage.

On the other hand TIMSS 2011 shows that the percentage of eighth grade students in Saudi Arabia who had been taught was higher than international percentage of students in all scales. In addition, all TIMSS topics (19) had been taught in Saudi Arabia compared to 16 topics internationally - see appendix 3.3. With the exception of the number scale, other scales, algebra, geometry and data and chance had been taught for a large percentage of students in Saudi Arabia which was more than the international average

Table 3 9: TIMSS 2007, mathematics topics in intended content at school and how much it had been taught

	Number of TIMSS mathematics topics intended to be taught and average percentage of eighth students who were taught them											
	All TIMSS mathematics topics (39 topics)				Number (10)				Algebra (8)			
Country	For all or almost all students	Only for the students who are more able	Not included in mathematics curriculum	Percentage of students who had been taught	For all or almost all students	Only for the students who are more able	Not included in mathematics curriculum	Percentage of students who had been taught	For all or almost all students	Only for the students who are more able	Not included in mathematics curriculum	Percentage of students who had been taught
Saudi Arabia	27	0	11	55	10	0	0	90	7	0	1	48
International average	31	2	6	72	10	0	0	95	7	0	1	73

Table 3 9: TIMSS 2007, mathematics topics in intended content at school and how much it had been taught (continued)

	Number of TIMSS mathematics topics intended to be taught and average percentage of students who were taught them (continued)							
	Geometry (14)				Data and chance (7)			
Country	For all or almost all students	Only for the students who are more able	Not included in mathematics curriculum	Percentage of students who had been taught	For all or almost all students	Only for the students who are more able	Not included in mathematics curriculum	Percentage of students who had been taught
Saudi Arabia	9	0	4	55	1	0	6	24
International average	11	1	2	71	3	1	3	47

Sources: TIMSS report 2007

3.16.4 The TIMSS 2007 and 2011 Content Domain data for eighth grade students

The TIMSS 2007 results for eighth grade students in all scales (Mullis et al., 2008) show that the percentage of overall number of students taught in Saudi Arabia was lower than the international percentage. Data and chance had less time devoted to it when compared to the average amount of time devoted internationally; it was also covered by fewer topics compared to the international average number of topics. Although overall this subject produced the worst data out of all the factors in the other scales, in the Saudi context, students gained the second best score in this subject, following geometry.

In respect of number, the maximum number of topics taught to students was lower than the international average percentage of students. In addition, the time devoted to it was more than the international average. Again, although number had the best data in the factors, students achieved the lowest scores in this in comparison to the other scales.

Geometry was covered by fewer topics than the international average and had been taught to a lower percentage of students than the international average percentage of students; however, more time was devoted to it than the international average. Although students achieved the highest score in this subject when compared to the other scales, this was still significantly lower than the international average.

Algebra was covered by the same topics as the international average; however, it was lower than international average in the amount of time devoted to it and in the number of students taught.

Overall there were three factors that may be contributed to the achievement of the content domain; first, the amount of time devoted to the scale, second, the number of topics specified in TIMSS that had been covered and three, the percentage of students who had been already taught about the scale. In general, internationally the three scales seem to have a positive effect on student scores although in Saudi Arabia, the results did not reflect this. Furthermore, although Saudi Arabia had devoted the greatest amount of time to 'number' and it had been taught for majority of students with the maximum number of topics, this achieved the lowest score out of all the other scales. It seems that the quality of teaching mathematics was not good enough.

Overall, although there was a reasonable improvement in the results of the eighth grade students' achievement in mathematics, this development was still lower than the international average scores. The improvement may have occurred for at least one reason. This reason could be because the quantity of teaching had increased to that which was above the international average in TIMSS 2011, while in TIMSS 2007 the quantity of teaching was lower than the international average (see, Mullis et al., 2008; Mullis et al., 2012)

In the case of fourth grade students

TIMSS 2011shows that the percentage of fourth grade students in Saudi Arabia who had been taught also was higher than the international percentage of students in all scales, Number, geometric shapes and measures, and data display. In addition, all TIMSS topics (18) had been taught in Saudi Arabia compared to an average of (13) topics taught internationally, as shown in Appendix 3.3.

It is also important to note that in Saudi Arabia, a higher percentage of fourth and eighth grade students were taught the maximum number of TIMSS topics than the average percentage of students internationally. However, despite this, Saudi Arabian students' scores were significantly lower in all areas, namely: knowing, applying and reasoning, than the average scores of the international students. This could be due to the poor quality of teaching, the poor quality of the presentation of the subject matter, or both. The next section will investigate the quality of teaching mathematics in Saudi Arabia and highlight the TIMSS effective factors on students' achievement in relation to environmental classroom activities.

3.17 TIMSS quality of teaching and learning mathematics factors

This section presents the effect of engaging students in learning and readiness to learn mathematics on students' achievement.

3.17.1 Instruction to engage students in learning

In TIMSS 2011, teachers were asked to respond to six statements (Mullis, Martin et al. 2008): i) summarize what students should learned from the class, ii) linking the lesson to their daily lives (for fourth grade only), iii) questioning clarifications, iv) encouragement of students to be improved, v) praising students for good work and vi) bring interesting materials to class (for fourth grade only).

For eighth grade students, linking the lesson to their daily lives and bringing interesting materials to class were dealt with separately.

The results support the positive effective of summarizing, questioning, encouraging, praising, linking the lesson to students' daily lives and bringing interesting materials to class. However, the last two activities had no clear trend for the eighth grade students (see appendix 3.4 for more details). It seems that if each activity is examined separately for its effect on each achievement scale, it may give a clearer vision about their precise effects. For example, if the effects of linking the lesson to students' daily lives had been measured in the 'knowing', 'applying' and 'reasoning' domains, this would have given more precise results.

TIMSS did not only ask teachers about engagement but also asked students to reach more reliable results. This is presented below.

3.17.2 Engagement of students in mathematics lessons

In TIMSS 2011, students were asked to score five statements, according to their degree of agreement (Mullis et al., 2012):

1. "I know what my teacher expects me to do.
2. I think of things not related to the lesson.*
3. My teacher is easy to understand.
4. I am interested in what my teacher says.
5. My teacher gives me interesting things to do.

* Reverse coded"

The results show that internationally, a high level of engagement with students in mathematics lessons was associated with a higher level of achievement. The percentage of students in Saudi Arabia who engaged in mathematics was higher than the international average (see appendix 3.5). Engagement levels may be influenced by students' readiness to learn. The readiness of students to learn mathematics is discussed next.

3.17.3 Readiness to learn mathematics

In TIMSS 2011, teachers reported that students' poor or inferior levels of prior knowledge or skills might negatively affect mathematics instruction for both fourth and eighth grade students (Mullis et al., 2012).

The findings indicate that the majority of teachers found that prerequisites of knowledge or skills for mathematics lessons have an effect on mathematics instruction. A lower percentage of students in Saudi Arabia had no problems at all with their prerequisite knowledge when compared to the international average, whilst a higher percentage of students had a lot of problems. Just under double the percentage of fourth grade students [in Saudi Arabia] and slightly more than one eighth of the percentage of eighth grade international students' encountered a lot of problems in learning mathematics (see appendix 3.6). In addition, the results of TIMSS 2011 shows that being ready to learn mathematics is associated with a higher level of achievement.

Overall high readiness and engagement levels are associated with higher achievement in mathematics. Activities in the mathematics classroom are compared in TIMSS research. It can show the nature of practice being processed in Saudi and international contexts. It is described by TIMSS below.

3.18 Mathematics classroom activities

This section reviews the activities and learning activities of students during mathematics classes and looks at the amount of time spent on those activities and in carrying out mathematics homework. This can highlight the whole picture of Saudi mathematics classes.

3.18.1 Activities of students during mathematics classes

TIMSS 2007 asked both eighth students and teachers about five activities in mathematics classes and requested information on how long these activities lasted, as is shown in appendix 3.8. The results of both the students' and teachers' reports are notably different. However, on average internationally and in Saudi Arabia, more than half of both the students and teachers agreed that students had practised adding, subtracting, multiplying and dividing without using a calculator for half of the lesson or longer. On average internationally, (51%) of students and (42%) of teachers reported that work on fractions and decimals lasted for half of the lesson or longer, while less than this average was reported by the students and teachers in Saudi Arabia. In other activities included, "write equations and functions to present relationships, solve problems about geometric shapes, lines, and angles, and interpret data in tables, charts, or graphs", students and teachers in Saudi Arabia reported a higher allocation of time to these topics than the international average (Mullis, Martin et al. 2008).

Overall in Saudi Arabia, the percentage of students and teachers who reported doing all of the five mathematics activities, mentioned above, for half of the lesson time or more was higher than the international average.

3.18.2 Learning activities in mathematics lessons

Internationally, 70% of teachers and eighth students reported in TIMSS 2007 that doing work which involved 'explaining answers' took around half of the lesson time or longer. In addition, 'working on problems on your own' took up half of the lesson or longer according to around 60% of students and teachers (see appendix 3.9).

In Saudi Arabia, the percentage of teachers and students who reported that work involving 'deciding procedures for solving complex problems' and 'relating what is being learnt in mathematics to their daily lives' lasted for half of the lesson or more, was higher than the average percentage reported by the teachers and students internationally. The percentage of time indicated by Saudi teachers and students spent 'working through problems on their own' was lower than the international average.

'Work on problems for which there is no immediately obvious solution' was reported as taking half of the mathematics lesson or longer by 22% of teachers internationally. The percentage of time spent on this activity was reported as being considerably higher by the teachers in Saudi Arabia at 32%.

In TIMSS 2011, the percentage of time eighth grade students in Saudi Arabia spent on each activity was greater than the international average time spent on each topic, apart from 'working through problems with teacher guidance and 'memorize rules, procedures and facts. It seems that problem-solving practice by students needs to be increased, which may improve students' skills in problem solving.

In terms of the fourth grade, the percentage of time students spent 'working on problems with teacher guidance' and 'explaining their answers' in every or almost every lesson was almost the same as the international average. Time spent on other activities was far greater than the average internationally see appendix 3.10.

3.18.3 Time of lesson spend on variety of activities

TIMSS 2007 asked mathematics teachers about how eighth grade students spent their time in mathematics classes. On average internationally, teachers reported that students had spent one-fifth of mathematics lessons 'listening to lecture-style presentations' compared to 22% of the time spent on this topic in lesson in Saudi Arabia. In addition, 21% of lesson time had been spent on 'working through problems with teacher's guidance' compared to 17% of mathematics time in Saudi Arabia and 11% of lesson time had been spent on 'reviewing homework' which is lower than what students in Saudi Arabia had been spending, with 8 %. 10 % of lesson time had been spent on 'taking tests or quizzes' which is exactly the same amount of time that students in Saudi Arabia had been spending on the same topics. 'Working out problems on their own without teacher's guidance' had taken up 16% of mathematics lesson internationally, which was less in Saudi Arabia with 11%. The lowest amount of time had been spent on 'participating in classroom management tasks not related to the lesson's content / purpose' with 5% and 7% of lesson time in Saudi Arabia and international average respectively (see appendix 3.11). In other words, in Saudi Arabia, students had spent time in mathematics lessons which was higher than the international average in 'listening to lecture-style presentations' and 'participating in classroom management tasks not related to the lesson's content / purpose', whereas they had spent a lower amount of lesson time than the international average on 'working through problems on their own without teacher's guidance. In Saudi Arabia, students had spent less time on 'working problems with teacher's guidance' than the international percentage. In Saudi Arabia, students had spent a higher amount of lesson time than the international average on 'reviewing homework' and 'listening to teacher re-teach and clarify content/procedures' activities and the same amount of time on 'taking tests or quizzes' activities. Overall, in Saudi Arabia, students had spent less time on 'working through problems on their own without teacher's guidance' than international students across all countries. The additional activities given to students to be completed at home are reviewed below.

3.19 Mathematics homework

TIMSS assessed the relationship between homework and the level of achievement in mathematics. In TIMSS 2007, mathematics homework was divided into three categories; high level students who had spent (3) or (4) times at least per week with (30) minutes of study on each occasion; low level students who had done mathematics homework less than (2) times per week and spending no more than (30) minutes on each occasion) and medium level students is all other responses (Mullis et al., 2008). While, in TIMSS 2011, high level was for students to spend 3hours or more in their homework per week, medium level for students to spend less than 3hours but more than 45 minutes per week, and low level for students to spend less than 45 minutes per week in their homework (Mullis et al., 2012).

The results illustrate that more than half of the eighth international students were at the medium level of doing mathematics homework in 2007. The achievement internationally among those who were at the high and medium levels was nearly the same but was higher than students' achievement at low level (see appendix 3.7).

In Saudi Arabia, the majority of eighth grade students were at the medium level with regards to the amount of time spent doing homework. The highest results scored (339) points followed by the medium level with a similar score of (334) points. The lowest level of performance was among students who scored highly in respect of the amount of time spent doing homework with (316) points. Furthermore, in Saudi Arabia, the achievements for students who had spent less than (3) times per week with (30) minutes in each session completing their homework was similar to each other. However, students who had spent much more than this amount achieved considerably lower.

The results indicate that having more homework did not assist the students of Saudi Arabia in achieving higher grades in mathematics. It would seem that having mathematics homework was not beneficial enough to positively affect the achievements of the students of Saudi Arabia.

In TIMSS 2011, although the criteria classifying the levels of mathematics homework had changed, the majority of the eighth grade students were given less mathematics homework than the eighth grade students' allocation in TIMSS 2007 (Mullis et al., 2012). In addition, there is no clear relationship which can be seen between the level of mathematics homework completed and the level of achievement in TIMSS 2007 (Mullis et al., 2008). It seems that those who committed more time to completing homework did not achieve any additional benefits or results.

The next section will review the most effective factors on students' achievement which is students' attitudes towards mathematics.

3.20 Attitudes towards mathematics in TIMMS 2007 and 2011 for fourth and eighth grade students

TIMSS 2007 and 2011 measured students' attitudes towards mathematics in three aspects; i) like learning mathematics (for both fourth and eighth grade students), ii) placing value on mathematics (for only eighth grade students), and iii) confidence in mathematics (for both fourth and eighth grade students) (Mullis, Martin et al. 2008; (Mullis et al., 2012)

3.20.1 like learning mathematics

The like learning mathematics was measured by questionnaires; for example, TIMSS 2007 asked students to respond to three statements (Mullis et al., 2008).

1. I enjoy learning mathematics.
2. Mathematics is boring*.
3. I like mathematics.

* Reverse coded

If students respond to all three statements with 'agree' a little or 'strongly agree' then they will be assigned at the higher level. If a student responds with 'disagree' a little or 'strongly disagree' they will be assigned at the lower level. Others responses will be assigned at the medium level.

In Table 3.10 it can be seen that in TIMSS 2007 more than half of the eighth grade students in all participating countries had a high level of like learning mathematics which was compatible with the percentage of students in Saudi Arabia (54%). Nearly one fourth of students internationally had a low level of like learning mathematics which was also almost the same percentage as the students in Saudi Arabia.

In TIMSS 2011, there was a dramatic decrease in the percentage of the eighth grade international students and the students of Saudi Arabia who had a high level of like learning mathematics, while the amount of students who had a medium or low level of positive attitudes was increased internationally and for student in Saudi Arabia.

In respect of fourth grade students in TIMSS 2011 the percentage of students in Saudi Arabia who had a high level of like learning mathematics was greater than the international average, while the percentage of students who had a medium or low level of positive attitudes was less than the international average.

Apart from eighth grade students who had medium and low levels of positive attitudes and almost had the same achievement rate among students, there is a significant relationship between higher achievement and high 'like learning mathematics'.

Table 3 10: The like learning mathematics for Saudi Arabia and International students

Country	High level of like learning mathematics		Medium level of like learning mathematics		Low level of like learning mathematics	
	Percentage of students	Average achievement	Percentage of students	Average achievement	Percentage of students	Average achievement
Saudi Arabia for eighth grade TIMSS 2007	54	340	22	321	24	323
International average for eighth grade TIMSS 2007	54	471	21	441	26	428
Saudi Arabia for eighth grade TIMSS 2011	29	436	40	389	32	346
International average for eighth grade TIMSS 2011	26	504	42	467	31	443
Saudi Arabia for fourth grade TIMSS 2011	57	433	33	382	10	377
International average for fourth grade TIMSS 2011	48	509	36	478	16	466

3.20.2 Students' valuing mathematics

TIMSS measured the level at which students' value mathematics, as shown in Table 3.11 below:

Table 3 11: Students' valuing mathematics for Saudi Arabia and International students

Country	Students' valuing mathematics as high		Students' valuing mathematics as medium		Students' valuing mathematics as low	
	Percentage of students	Average achievement	Percentage of students	Average achievement	Percentage of students	Average achievement
Saudi Arabia for eighth grade TIMSS 2007	82	334	13	322	5	307
International average for eighth grade TIMSS 2007	78	458	17	438	5	435
Saudi Arabia for eighth grade TIMSS 2011	51	408	35	387	13	363
International average for eighth grade TIMSS 2011	46	482	39	463	15	439

TIMSS asked students to respond to the following four statements:

1. I think learning mathematics will help me in my daily life.
2. I need mathematics to learn other school subjects.
3. I need to do well in mathematics to get into my university of choice.
4. I need to do well in mathematics to get the job I want (Mullis, Martin et al. 2008; (Mullis et al., 2012).

If students respond to all four statements with 'agree' a little or 'strongly agree' then they will be assigned at the higher level and if a student responds with 'disagree' a little or 'strongly disagree' they will be assigned at the lower level. Other responses will be assigned at the medium level.

With regards to the international average number of students and Saudi Arabian students, in 2007 the majority of all students valued mathematics at the high level and scored the highest level of achievement when compared to other levels. A minority of students valued mathematics at the low level and they scored the lowest level of achievement in mathematics. In TIMSS 2011 about half of the international students and the students in

Saudi Arabia valued mathematics at the high level. This indicates that the percentage of students who valued mathematics highly decreased dramatically in 2011, while the percentage of students who valued mathematics as low had increased. However, the relationship between those students who attained a higher level of achievement in mathematics and placed a high value on the subject is still significant. The data for fourth grade students' was not included in TIMSS research.

3.20.3 Students' self-confidence in learning mathematics

TIMSS investigated what the students thought their own level of ability in mathematics; in other words, measured students' levels of self-confidence in learning mathematics. This investigation was based on students' responses to the following four statements:

1. I usually do well in mathematics.

2. Mathematics is harder for me than for many of my classmates.

3. I am just not good at mathematics.

4. I learn things quickly in mathematics. **Notes**: (the response for both statements (2) and (3) were 'reversed in constructing the index') (Mullis et al., 2008; Mullis et al., 2012).

If students respond to all four statements with 'agree' a little or 'strongly agree' then they will be assigned at the higher level and if a student responds with 'disagree' a little or 'strongly disagree' they will be assigned at the lower level. Others responses will be assigned at the medium level.

Table 3 12: Students' self-confidence in learning mathematics for Saudi Arabia and International students

Country	Students with a high level of self-confidence in learning mathematics		Students with a medium level of self-confidence in learning mathematics		Students with a medium level of self-confidence in learning mathematics	
	Percentage of students	Average achievement	Percentage of students	Average achievement	Percentage of students	Average achievement
Saudi Arabia for eighth grade TIMSS 2007	47	361	42	310	11	294
International average for eighth grade TIMSS 2007	43	492	37	433	20	412
Saudi Arabia for eighth grade TIMSS 2011	21	464	52	392	27	348
International average for eighth grade TIMSS 2011	14	539	45	478	41	435
Saudi Arabia for fourth grade TIMSS 2011	40	441	50	396	10	369
International average for fourth grade TIMSS 2011	34	527	46	484	21	452

In Table 3.12 it is seen that in TIMSS 2007, fewer than half of the eighth grade students in all participating countries had a high level of self-confidence in learning mathematics with a total of (43%) compared to (47%) of the students of Saudi Arabia. The number of eighth grade students internationally, including Saudi, who had a high level of self-confidence in learning mathematics dropped dramatically in TIMSS 2011, while the other levels (medium and low), increased.

For fourth grade students in TIMSS 2011, students in Saudi Arabia show higher levels of self-confidence in learning mathematics than their international counterparts. Importantly, higher achievement levels are associated strongly with high levels of self-confidence in learning mathematics for both international and Saudi Arabian students (Mullis et al., 2012). The next section will briefly review other TIMSS factors.

3.21 Other TIMSS factors

In TIMSS 2007, on average internationally, students' achievement of higher scores in mathematics was associated with higher attendance levels at school. However, the statistics for Saudi Arabian eighth grade students show that those students who had a higher attendance rate in mathematics actually achieved lower than average scores Mullis et al., 2008). This might be attributable to a lower standard in the quality of teaching in Saudi Arabia. The majority of students were at the medium level internationally and in Saudi Arabia.

Higher availability of resources for mathematics instruction at school was associated with higher achievement in mathematics internationally and in Saudi Arabia (Mullis et al., 2008). This means that the availability of resources for mathematics instruction within schools is an important factor which should be controlled in educational research and considered to improve environmental instruction. In the current study there was no need to control this factor because the study is based on one school for each stage.

Textbooks have remained as the primary basis of teaching mathematics for teaching (60%) of international students, while (34%) of students were taught using textbook as a supplementary resource. In Saudi Arabia, a higher percentage of students than the international average were taught using textbooks as the primary basis with an average of (77%), while a lower percentage of students were taught using textbook as a supplementary resource internationally with averages of (19%) and (27%) respectively (Mullis, Martin et al. 2008). In TIMSS 2011 more than 90% of Saudi fourth and eighth grade students were taught using textbooks as the primary basis comparing to an average of 70% internationally (Mullis et al., 2012). This may indicate that a higher percentage of students in Saudi Arabia was taught using traditional teaching methods which depend on following textbook instructions.

In TIMSS 2007, around half of the eighth grade students on average internationally had been taught by teachers who had received training on 'mathematics content, mathematics pedagogy / instruction, mathematics curriculum, integrating information technology into mathematics, improving students' critical thinking or problem-solving skills and mathematics assessment' in the previous two years compared to a significantly lower amount of students in Saudi Arabia (Mullis et al., 2008). However, in TIMSS 2011, a higher percentage of fourth and eighth grade students in Saudi Arabia had been taught by teachers who had received training in the previous two years on all the above mentioned topics than the average internationally, apart from 'integrating information technology into mathematics' and 'mathematics assessment' for eighth grade teachers (Mullis et al., 2012). This indicates that there was an improvement in training teachers in Saudi Arabia from between 2007 and 2011.

In TIMSS 2007, teachers' reports indicated that students in Saudi Arabia had a lower percentage than the international average of students whose teachers felt that they had been prepared very well in all mathematics topics (Mullis et al., 2008). However, in TIMSS 2011 the percentage of students whose teachers felt that they had been prepared very well in all mathematics topics was higher than the international average for fourth and eighth grade teachers (Mullis et al., 2012).

TIMSS 2011 outcomes show that generally, a higher percentage of fourth and eighth grade students' teachers felt very confident to teach mathematics than the international average. In Saudi Arabia, the results show that the percentage of students that the teachers felt very confident about in terms of their ability to answer their questions about mathematics and challenge other capable students was slightly less than the international average. However, the percentage of students whose teachers felt very confident about showing their students a variety of problem-solving strategies was noticeably less than the international average respectively (Mullis et al., 2012). This may be one of the reasons that reflect low results being achieved in problem solving ability for Saudi students.

Overall, it seems that Saudi teachers need training in problem solving, giving effective homework and other teaching strategies. This may help to improve their students' outcomes in TIMSS research and the thus, PBL teaching strategy may provide a solution.

3.22 Limitations of the report

This report was limited to the data of Saudi Arabia which was compared with the average of the data obtained from fourth and eighth grade mathematics students in the participating countries. The data was restricted to TIMSS 2007 and 2011 because Saudi Arabia had not previously participated with eighth grade students and fourth grade students had not previously participated in 2007.

This report focused more on important factors related to classroom environment and activities. However, the TIMSS results show other important factors related to 'home environment support for mathematics achievement', 'school resources for teaching mathematics', 'school climate', and 'teacher preparation' on students' learning outcomes.

These important factors such as time, security, access to the Internet and parental education can be different across other countries and places. Therefore, it is worth mentioning that conducting the current study in Saudi contexts can be worthy, and also generalising its results should be done with caution. For example, measuring the effect of PBL should be carried out in different contexts to be able to draw conclusions which are more valid and relevant in different places. *"Many social theories are presented as if the generalizations that they embody are valid for all times and places, when in fact they were arrived at on the basis of limited contemporary Western experience "*(Llobera, 1998,p74).

3.23 Summary of the literature review

PBL supporters claim that PBL could promote reasoning skills, improve knowledge in 'applying' and 'knowing' and increase positive attitudes more than traditional teaching methods among students (Deignan, 2009) over time. It also shows agreement in the necessity of training teachers for PBL implementation (Leary et al., 2009), however, the outcomes of empirical studies could not sufficiently fill the gap between the theories and practices.

The review of empirical studies show that PBL tends to improve students' reasoning skills such as critical thinking, problem-solving and self-directed learning skills (Sungur and Tekkaya 2006; Araz and Sungur 2007; Gürses et al., 2007; Senocak et al., 2007; Ambo Saeedi and Al Balushi, 2009; Zhang et al., 2011; Hussain, 2012; Kong et al., 2014), and tends improve knowledge application (Dochy et al., 2003; Moran 2004; Pease and Kuhn 2011; Bassir et al., 2014), and tends support positive attitudes (Albanese and Mitchell, 1993; Vernon and Blake, 1993; Colliver, 2000; Nowak, 2001; Smits et al., 2002; Moran 2004; Goodnough and Cashion, 2006; Lou et al., 2011; Pease and Kuhn, 2011; Borhan, 2012; Hinyard, 2013). However, the literature outcomes outlined show a variation in the outcomes of the effects of PBL on content knowledge. For example, some studies show no significant difference between PBL and traditional methods (Vernon and Blake, 1993; Colliver, 2000; Matthews, 2004; Dobbs, 2008; Sanderson, 2008; Wong and Day, 2009; Bassir et al., 2014), while other research found PBL more effective (Smits et al., 2002; Maxwell et al., 2005; Wong and Day, 2009; Ertmer et al.. 2014). A few researches, such as (Dochy et al., 2003), found that conventional methods were more effective than PBL on students' achievements in mathematics knowledge.

These outlined findings could not be applied to all different ages, disciplines and different achievement levels of students. The reason behind this is that the majority of researches were conducted in medicine or its allied contexts and university levels, and little research has investigated the different achievement levels of students. Few studies have been conducted in K-12 contexts and even fewer studies have compared the effects of PBL with other methods (Araz and Sungur, 2007). Furthermore, researchers conducted in secondary mathematics education were scarce (Ingram, 2013). More studies are needed (Allen et al., 2011) to investigate the effect of learning outcomes when PBL teaching strategies are used practically, with different disciplines and in K-12 contexts (Strobel and van Barneveld, 2009). Much empirical research is also needed to investigate the effects of PBL on young students' outcomes and also what adaptations could be made (Zhang et al., 2011).

Moreover, the majority of studies are limited to investigating the increasing positive attitudes towards the strategy itself and not the subject matter, such as science and mathematics. Therefore, PBL needs more researches to see if it could increase positive attitudes towards learning the subject matter by students.

Students could respond differently to the PBL strategy. The difference between the achievement levels of students may be due to their different abilities and/or their levels of prior knowledge and/or skills. Few studies investigated the interaction between the different levels of students with types of treatment, including PBL. The finding revealed that high achievers scored better than low achievers in their interaction with PBL (Simons and Klein, 2007). However, more research is still required in this area. Furthermore, there were few studies that were conducted to examine the effects of PBL on PD students' performance. The results show that students' learning improved in PBL with well-trained teachers (Maxwell et al., 2005). However, more research is still required in this area.

The majority of research has addressed the students' perspectives, while few researches have been conducted to examine the teachers' perspective about PBL implementation. Generally, teachers tend to feel that PBL is more positive than traditional methods; they found it enjoyable, however, they believed the role of teachers to facilitate students' learning is challengeable (Dahlgren, et al. 1998).

More research is needed to take advantage of the perceptions of teachers in order to attempt to improve research design and improve the effectiveness of the implementation process. Reviewing TIMSS 2007 and 2011 researches highlights some effective factors on student performance such as readiness to learn mathematics, engagement of students in mathematics lessons, attitudes towards mathematics (including 'like learning mathematics', 'placing value on mathematics' and 'confidence in learning mathematics'). This study takes advantage of these factors by including attitudes towards mathematics with mentioned aspects and makes the researcher consider the engagement and readiness in the interview and his dairy observation.

In addition, using TIMSS instruments may be a good idea to use international high quality tools which covered several aspects of cognitive domains (knowing, applying and reasoning), rather than using local exams or exams created by researchers or other staff.

To address these gaps more research is needed in these areas. One of the main goals of this study is to investigate the effects of PBL on K-12 students' mathematics achievement levels taking into consideration the different achievement levels of students?. This study aims also to fill this gap by examining students' attitudes towards mathematics. This study aims also to fill this gap by examining the effects of trained untrained teachers on students' performance.

Researchers believe that PBL cannot be suitable for lower primary students because they have not yet mastered computation skills. This study could provide evidence that PBL could be implemented in the third grade in schools and provides examples to adapt PBL and problems in PBL to fit different ages and mathematics subjects. In addition, this study could help to improve understanding about the differences between primary and intermediate students after being presented with the PBL teaching strategy.

For future researches, the literature review needs more studies in examining the effects of readiness levels to learn PBL and the quality of problems in PBL. The study attempted to answer the following questions:

1. What are the effects of PBL teaching strategies with trained and untrained teachers on male students' achievement levels (knowing, applying, and reasoning) when compared with conventional methods using TIMSS instruments?
2. What are the effects of PBL teaching strategies with trained and untrained teachers on male students' motivation (attitudes towards mathematics, placing value on mathematics, and confidence to learn mathematics) when compared with conventional methods using TIMSS instruments?
3. Is there significant interaction between traditional teaching methods and PBL teaching strategies with trained and untrained teachers and levels of achievement (high and low) in male students' achievement (knowing, applying, and reasoning)?
4. Is there a significant interaction between traditional teaching methods and PBL teaching strategies with trained and untrained teachers and levels of achievement

(high and low) in male students' motivation (attitudes towards mathematics, placing value on mathematics, and confidence to learn mathematics)?

5. What is the perspective of teachers of using PBL when compared with conventional methods?

The next chapter is the methodology, which shows how to implement this study.

Chapter Four: Paradigms, Methodology and Methods

4.1 Introduction

The aim of this chapter is to present the paradigms of the study, the procedures which have been implemented during the field work study and the methods used to conduct the data collection and data analysis. The ultimate goal of research in education is to improve educational action, such as enhancing the performance or tackling a problem for individuals or originations through changes to the procedures and rules within their operations (Bassey 1999; Denscombe 2002) Thus, the aim of this study is to attempt to enhance students' performance in mathematics. This will be done by investigating the effectiveness of problem based learning (PBL) on students' performance compared to traditional methods.

The process of educational research could be done through five steps: identifying the problem, reviewing information, collecting data, analysing the data and coming drawing the conclusion (William, 2005) Therefore the process of the research will be described in Figure 4.1.

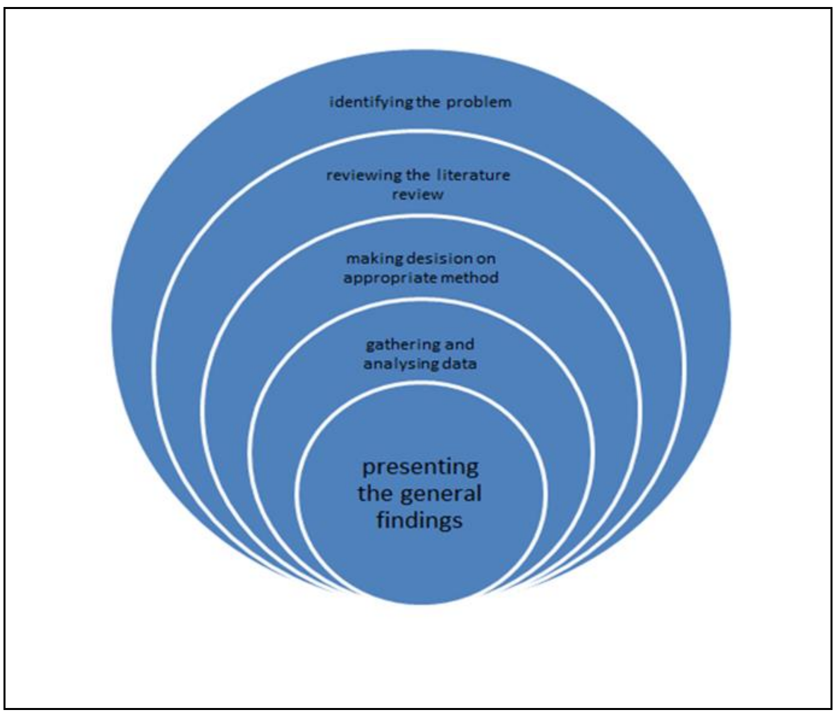


Figure 4 1: The process of the research

The purpose of this study was to investigate whether the achievement and attitude levels of the students were affected by using PBL teaching strategies by trained face to pace (trained teacher) and self-directed learning teachers (untrained teacher). The study also aimed to examine the interactions of both high and low achievers who had been taught using PBL strategies by both trained face to pace and self-directed learning teachers. In addition, the study also attempted to investigate teachers' perspectives on their experiences of implementing PBL strategies in the classroom. The investigations compared the teaching styles of teachers who had been trained in using PBL strategies with those who had not; the teaching styles used with the PBL strategies were also compared to the teaching styles which employed conventional methods. The study attempted to answer the following questions:

1. The study attempts to answer the following questions: What are the effects of PBL teaching strategies, using trained face to pace and self-directed learning teachers, on students' achievement levels (knowing, applying, and reasoning) when compared with conventional methods?

2. What are the effects of PBL teaching strategies, using trained face to pace and self-directed learning teachers on, students' motivation (attitudes towards mathematics, placing value on mathematics, and confidence to learn mathematics) when compared with conventional methods?

3. Is there significant any interaction between treatment and levels of achievement (high and low achievers) in students' achievement levels in 'knowing', 'applying', and 'reasoning'?

4. Is there any significant interaction between treatments and levels of achievement (high and low achievers) in students' motivation (attitudes towards mathematics, placing value on mathematics and confidence to learn mathematics)?

5. What is the perspective of the teachers about PBL after the treatments when compared with conventional teaching methods?

In order to answer the research questions it is important to choose the right research design and use appropriate methods to collect and analyse the data (Muijs, 2010). It could require more than one research method to address the research questions (Yin 1994; Cohen 2000; Cohen and Manion, 2000). In this study, the methods used are divided into two approaches: qualitative (interview and research diary) and quantitative (pre and post-tests and measures). This approach called 'mixed methods'(Teddlie and Tashakkori, 2009). Mixed methods are critical, firstly to understand the pragmatic experimental results, and implementation efforts between the actual practice and evidence. Secondly, both the context and content of an intervention can be examined through this kind of approach; content can be measured by quantitative methods, while context can be understood by qualitative methods (Albright, Gechter et al., 2013). This is believed to be the most appropriate methodology to address the questions of the study. The reason for using more than one research method is to attempt to reach conclusions with more confidence and to provide an holistic view of the outcomes (Cohen and L 1994; Yin 1994), both of which are sought for this study. The holistic view is sought from teachers, students and the researcher by using tests, measures interviews and research dairy.

This chapter covers a discussion of the research paradigms followed by a presentation of the research methodology which includes the study design and a sample selection. The research methods are then explained followed by an overview of Teacher Professional Development training. Finally data analysis and research quality are discussed and ethical considerations are presented.

4.2 Research paradigms

Theoretical views (paradigms) are vital components of study methodology which guide the process of the study (Crotty, 2003). These aspects help the investigators to decide on the research methodology they intend to undertake (Creswell, 2003). The term 'paradigm' is defined as 'a loose collection of logically related assumptions, concepts or propositions that orient thinking and research' (Bogdan and Biklen, 1998, p.22). Denzin and Lincoln, (1998) argued that a paradigm may focus on three basic inquiries: ontology, epistemology and methodology. The ontological inquiry is focused on 'the nature of reality'. The epistemological is concerned with 'how do we know the world?' and 'what is the relationship between the inquirer and the known?'. The methodological inquiry is related to 'how do we gain knowledge about the world?' (p. l85).

There are two key paradigms, namely, positivist and interpretivist (Bryman, 2001; Lincoln and Guba, 1985). Positivist adapts a quantitative approach while interpretivist adopts a qualitative approach. The pragmatist paradigm comes later on as framework to bring the qualitative and quantitative approaches together under a concept called 'mixed methods'. In this section, these paradigms will be discussed, followed by discussing and justifying the use of the 'quasi-experiment' design and qualitative approach in the current study, including semi-structured interviews and a research diary.

4.2.1 Positivism and post-positivism

Positivism was established a century ago by Auguste Comte and Herbert Spencer, (Parahoo, 2006). It underlines the assumption that the world is controlled by the laws of the universe (theories), and discovering these laws allows investigators to understand social phenomena (Creswell, 2003). Therefore, positivism includes *'the belief that the methods of natural sciences are appropriate for the social sciences'* (Bryman, 1988, p.14).

The scientific theories (used with natural sciences) can be tested by statistical and controlled variables through using surveys or experiments (Hammersley and Atkinson, 2007). Therefore, the obtained knowledge is objectively determined which can limit feelings or any subjective experiences (Bryman, 1988).

According to Gall et al. (2003), positivism emphasises that truth exists independently of the observer. Therefore, the role of the researcher is to discover the truth which means that scientific knowledge must be constituted through unbiased observations. However, the positivist perspectives were criticised for being used in social sciences and, as response of this criticism, post-positivism was given rise (Creswell, 2009). Post-positivism is considered as extension to positivism. Ontologically, post-positivism emphasises that truth exists but due to the restrictions of the bias of human beings, it cannot be perfectly recognised (Mertens, 2005). Thus, positivist and post-positivist perspectives both agree that reality exists from the observer's point of view, but they disagree as to the degree in which it is known.

Epistemologically, positivist researchers adopt objective ways (quantitative research) of discovering the truth. Conversely, post-positivist researchers allow for additional qualitative research to understand the social phenomena in light of the researcher's subjective thought because they believe that the subjectivity cannot be eliminated during the data analysis conducted by researchers. This can include the investigation of the context of study and people's perspectives about the social phenomena, whilst positivist researchers only focus on measuring hypotheses which measure the effect of one variable against others (Kim, 2003; May 2001). Although post-positivism is more compatible with positivism it can include qualitative research (Mackenzie and Knipe, 2006; Parahoo, 2006). Therefore, post-positivism takes into account internal and external factors that may affect the positivist researchers' activities, while positivism emphasises the control of such factors (Hammersley and Atkinson, 2007; Denzin and Lincoln, 1998).

According to Gall et al. (2003), the differences between 'positivism and post-positivism are described as follows:

1. *Theory-free observation*: positivism emphasizes that the variables under study should be observed objectively and free from the theory they are designed to test. Post-positivism suggests that this is impossible because any observational strategy is inevitably laden with theory.
2. *Value-free observation*: positivists claim that the observations must be devoid of values, while post-positivists purport that social research is driven mainly by a set of values.
3. *Validity by observation only*: positivists believe that validity can only be achieved by objective observation whereas post-positivists claim that this is insufficient to consider many of the important social factors.
4. *Degree of generalization*: positivists believe that there is no variability between individuals, groups or cultures while post-positivists have an opposing view to this theory.

Thus, this paves the way for the interpretivist paradigm which adapts qualitative research which will be discussed next.

4.2.2 Interpretivist paradigm

The interpretivist paradigm claims that reality is constructed in a subjectively socially manner (Tuli, 2011) for understanding individuals' behaviours, the interpretivist proposes to investigate them within their own social environment (Parahoo, 2006). It means that interpretivist's study the social events within its contexts without controlling any variables which differs from positivists' views in terms of applying control or manipulation. For this reason, some believe that the interpretive investigators are naturalists (Tuli, 2011). The interpretivist approach depends on the interaction of investigators with the subjects under study (Parahoo, 2006). This might lead to different people's perspectives about social events. They perceive different meanings to the same events or phenomena (Williams, 2000).

Investigators engage with subjects and this often leads to rich descriptions being obtained; thus, this makes researchers adopt instruments that permit them to collect intensive data from subjects by giving participants the freedom to talk about their own experiences (Tuli, 2011). Therefore, researchers conduct appropriate strategies for the purpose of collecting data, such as observing, feeling, listening, asking and recording (Decrop, 2004).

The interpretivist approach was criticized for not providing valid and reliable findings as standard (Kelliher, 2005). For example, rigor and validity are '*empirical analytic terms that do not fit into an interpretive research that values insights and creativity*' (Polit andBeck, 2008, p.536).

Positivists and interpretivists fight over incompatible epistemologies and this is known as 'paradigm wars' (Gage, 1989). The ontological difference between positivist and interpretivist paradigms is on how to perceive reality. Positivists suggest that there is only one single reality which exists, whereas interpretivists believe that there are multiple realities or truths which exist; this leads to variety of meanings for various people. The epistemological difference between the two paradigms however, is related to the interaction between the researchers and subjects. Positivism underlines that the researchers should be separated from the subjects under investigation, whilst interpretivsim suggests that the investigators should take advantage of their interaction with the subjects in their investigation (Teddlie andTashakkori, 2009; Mackenzie andKnipe, 2006; Onwuegbuzie andLeech, 2005a).

Howe (1988) responded to paradigm wars by emphasizing that the epistemological incompatibility of paradigms is less important than in what works the best methodologically. Thus, the pragmatist paradigm solves the problem of the incompatibility between positivist and interpretivist paradigms by bringing quantitative and qualitative methods together (mixed methods) (Mackenzie andKnipe, 2006; Tashakkori andTeddlie, 1998).

4.2.3 Pragmatist paradigm

Over the past twenty years, mixed methods have emerged as a third methodological movement combing the two existing movements: qualitative and quantitative (Tashakkori and Teddlie, 2003; Teddlie andTashakkori, 2009). The existence of mixed methods paved the way for the existence of pragmatism. Pragmatism is the theoretical framework for the mixed-method approach (Mackenzie and Knipe, 2006; Feilzer, 2010; Maxcy, 2003). It mixes the '*vision of an ordered and understandable world with a passing glance to plurality and social constructivism*' (Trinder, 1996, p.236). The pragmatism approach focuses on providing insight and has no philosophical loyalty (Mackenzie and Knipe, 2006; Trinder, 1996). The ontological view of pragmatists argues that there are different perspectives about social reality; everyone sees reality or truth based on their own standards and beliefs.

In respect of the epistemological view, this paradigm is either objective or subjective, based on the research phase and inquiry (Creswell andClark, 2011; Teddlie andTashakkori, 2009). For example, investigators can use the quantitative approach as a primary approach to data collection, while qualitative methods involve a secondary approach to collecting data (mixed methods) (Trinder, 1996). The reason for conducting qualitative methods is often to describe quantitative data (Onwuegbuzie andLeech, 2005b). It seems that research design and methods can be identified based on research questions. In order to answer the research questions it is important to choose the right research design and use appropriate methods to collect and analyse the data (Muijs, 2010). It could require more than one research method to address the research questions (Yin 1994, Cohen 2000; Cohen and Manion, 2000). In the current study, mixed methods are used and discussed next.

4.2.3.1 Mixed methods designs

Mixed methods were used in the current study, including: quantitative (pre and post-tests and measures) and qualitative (interview and research diary). Mixed methods are critical, firstly to understand the pragmatic experimental results and implementation efforts between the actual practice and evidence. Secondly, both the context and content of an intervention can be examined through this kind of approach; content can be measured by quantitative methods, while context can be understood by qualitative methods (Albright et al., 2013). This is believed to be the most appropriate methodology to address the questions of the study. The reason for using more than one research method is to attempt to reach conclusions with more confidence and to provide a holistic view of the outcomes (Cohen and L 1994; Yin, 1994), both of which are sought for this study. The holistic view is sought from teachers, students and the researcher by using tests, measures interviews and research dairy.

Mixed methodologies can be applied in different designs. Two factors determine the design of the study: how to order and organize the different methods (i.e. identifying the methods to be used and the order of priority) (Creswell, 2009). Several ways of blending both methods (qualitative and quantitative) together were presented by Creswell and Clark (2011); for example, convergent parallel design, explanatory sequential design, exploratory sequential design, embedded design and multiphase design. The embedded- quasi-experiment design is used in this study. This is discussed below.

4.3 Design of the study

In the current study the embedded quasi-experiment design is used which suggests that the researcher embeds data within and between quasi-experimental research. Any designated research design can be used within or between subject approaches (Edmonds and Kennedy, 2012). Therefore, the design of the present study is a two-phase design (Lee, 1999) which embeds a case study design - exploratory-explanatory - within and between a quasi-experimental design (Cohen and Manion, 1994, p. 259). Thus, in this study the quasi-experiment design will be conducted as the main quantitative approach with a higher priority, and the qualitative approach will be carried out before, during and after the quasi-experiments.

Semi-structured interviews were conducted with both of the teachers (the trained face to pace and self-directed learning teachers) before and after the implementation of the study. This aimed to ensure that all teachers had the same experience, expertise, beliefs and attitudes towards student-centred learning and also to investigate their experiences after the implementation of PBL. After the study was implemented, semi-structured interviews were conducted to investigate the experiences of the teachers who had used PBL teaching strategies. Additionally, between the pre and post measures of the quasi experiment have research diary documenting the researcher's observations has been maintained as a supplement with the aim of being used as part of the triangulation method (see Figure 4.2 below). Each design will be discussed in detail.

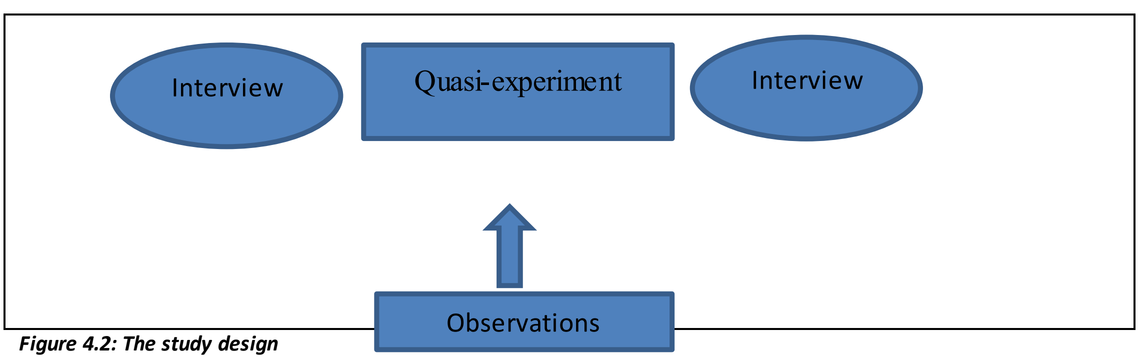


Figure 4.2: The study design

4.4 The design of study for quantitative data

The study was designed along quasi-experimental lines in order to minimize bias in estimating the difference between the conventional instruction and PBL classes. A quasi-experiment is used to test descriptive causal hypotheses about manipulatable causes to support a counterfactual inference about what would have occurred in the nonappearance of manipulation, when sample is not randomly selected (William, 2005). When researchers can be in full control over selection of the scheduling of date collection procedures but cannot randomize exposures, then this situation can be considered as a quasi-experiment (Campbell, Stanley et al., 1963). Although in this study schools were randomized from a limited number of schools (5 private schools) and classrooms, and then randomized from a small number of selected students, this situation is not considered to be fully random. As such, the design of this study is regarded as a quasi-experiment as an alternative to a true experiment. Thus, this design was used because it was not possible to conduct a randomized controlled experiment. This pre-post intervention uses to evaluate the specific interventions benefits (Harris et al., 2006). Thus the reason of using this kind of design is to evaluate the effectiveness of PBL.

In order to reduce bias, plausible alternative explanations such as some students having prior knowledge that other students do not, the same treatment should be considered. To consider this, studies should add pre-tests to disclose maturational trends and compare the trend to the post-tests, and also involve a control group. This study was designed with control groups and pre-tests to reduce bias and to avoid certain threats to validity (Harris et al., 2006).

The combination of qualitative approach is important for two reasons: first to examine the context of study, and secondly to understand implementation efforts between the actual practice and evidence (Albright et al., 2013). The study consists of two cases: intermediate school data and primary school data.

In this section the study designs will be presented for both intermediate and primary schools, followed by a selection of samples and a description of the participating students and teachers. Topics, designing problems, time allocated for instruction, instruments and procedures are then detailed then finally an example of a PBL problem will then be presented.

4.4.1 Intermediate school data design

Two teachers were selected at one large intermediate school "A" in Saudi Arabia to be part of this study. One teacher had undertaken CPD courses in teaching PBL strategies (the trained face-to-face teacher), whereas the other teacher was provided with the materials of PBL (the self-directed learning teacher), such as design problems and guidelines for implementing PBL. The self-directed learning teacher did not attend any CPD training course in PBL implementation, and was asked to conduct self-directed learning in the implementation of PBL. The reason for this was to measure the effects the different types of training had on the teachers and how this affected student outcomes. Four groups participated with a total number of 17, 17, 14 and 16 students in each group. Each teacher taught two groups and used PBL strategies for one group and conventional methods for the other group. Therefore, four groups were selected to be part of this study; group A (the trained face-to-face teacher PBL group), group B (the trained teacher conventional group), group C (the self-directed learning teacher PBL group), and group D (the untrained teacher conventional group). Pre and post-tests in students' achievement and attitudes towards mathematics were applied before and after the study to investigate the effects of PBL on students' outcomes (see study design Table4.1).

Table 4.1: The study design for quantitative data

Teacher	Group	No. of students	Test types	Teaching types	Test Types
Teacher A (The trained teacher)	A	17	Pre-tests	PBL	Post-tests
	B	17	Pre-tests	C	Post-tests
Teacher B (The untrained teacher)	C	14	Pre-tests	PBL	Post-tests
	D	16	Pre-tests	C	Post-tests
Total	64				

4.4.2 Primary school data design

The study design of the primary school is the same as the one used in the study of the intermediate school study accept for the number of teachers, students and groups due to the circumstances of the school. For the primary school, three groups were selected at one large primary school to be part of this study; group A (the trained teacher PBL group), group B (conventional group), and group C (the untrained teacher PBL group). Three teachers were selected. One teacher had undertaken CPD courses in teaching PBL strategies (the trained teacher), whereas the other teacher was provided with the materials of PBL (the untrained teacher) and asked only to conduct self-directed learning in the implementation of PBL. The third teacher was not trained in PBL and asked to teach students using traditional methods. Three groups participated with a total number of 52, 39 and 36 students in each group. Pre and post-tests in students' achievement and attitudes towards mathematics were applied before and after the study to investigate the effects of PBL on students' outcomes (see the study design Table4.2).

Table4.2: The design of study for quantitative data

Teacher	Group	No. of Students	Test Types	Teaching Type	Test Types
Teacher A (The Trained Teacher)	A	52	Pre-tests	PBL	Post-tests
Teacher B (Conventional Methods)	B	39	Pre-tests	C	Post-tests
Teacher C (The Untrained Teacher)	C	36	Pre-tests	PBL	Post-tests
Total		127			

4.5 Selection of sample

This section will describe the sample selection for both the intermediate and primary school data.

4.5.1 Intermediate school data

The school, intermediate school "A", consisted of 210 students and was located in an urban district in a small city, Hail, situated to the North of Saudi Arabia. School "A" had three grades, from seventh grade (first intermediate grade) to ninth grade (third intermediate grade). Each grade taught between five and ten classes and each class contained between 12 and 20 students. The school was randomly selected from five large private schools in Hail City. The classes were instructed by two teachers; one taught three classes (the untrained teacher) and the other taught two classes (the trained teacher).

Out of the five classes, four groups were selected to be part of the study; two groups who had been taught by one teacher and two out of the remaining three groups, who were taught by the other teacher, were then randomly selected (on blind pick), see Table4.3. The reason for this selection process was to attempt to eliminate bias by giving all groups an equal chance to be chosen. However, the selection process was still limited due to the fact that the samples were selected from limited a number of schools and also because every student within the school did not have an equal chance of being selected from the population (Moore and McCabe 2006).

Table4.3: sample selections for intermediate school classroom

Classroom	Group	Types of treatment	Teacher
1	A	PBL	Trained teacher
2	B	C	
3	C	PBL	Untrained teacher
4	D	C	

4.5.2 Primary school data

The school, primary school "B", was located in Hail city (described above). The school "B" consisted of 510 students. It had six grades, from first grade to six grades. Each grade involved from six to ten classes; each class contained from 13 to 20 students. The school was randomly selected among five private large schools in Hail city. The third grade students consisted of seven classes. The classes were instructed by three teachers; one taught three classes and the others taught two classes for each. These classes make up three groups: group A (combining the three classes taught by trained teacher and using PBL teaching strategy), group B (combining the classes taught by untrained teacher and using traditional teaching methods), and group C (combining the two classes taught by untrained teacher using PBL teaching strategy), see Table4.4.

Table4.4: sample selections for primary school classroom

Classroom	Group	Types of treatment	teacher
1	A	PBL	Trained teacher
2			
3			
4	B	C	Untrained teacher
5			
6	C	PBL	Untrained teacher
7			

4.6 Participating

This section will describe the participants of study for the both intermediate school data and the primary school data.

4.6.1 Intermediate students

The majority of students at the school were from Saudi Arabia and each group had 1 or 2 students from Arab backgrounds such as Syria, Egypt and Sudan. All students had a middle-class socioeconomic status and their ages ranged from between 13 and 15. A one-way ANOVA model (Howell, 2012; Field, 2013) was applied to see if there is significant difference between the groups in respect of their academic school records. The results show that there was no significant difference between groups in the ANOVA test; $F (3, 60)$, $p > 0.05$, see the ANOVA Table in Appendix 4. A1. Thus, the groups were similar in terms of mathematical abilities. A wide range of academic achievement was shown by students, from very high to very low achievement levels. There were no special education pupils within the groups.

Table4.5 shows the description of the groups. Each group was divided into two subgroups based on their level of achievement (high and low) to be able to measure the effect of interaction of achievement levels with type of the treatments. This classification was done based on the students' school records. Students who had attained above average scores were classified as high achievers, while students who obtained lower or equal to the average score were classified as low achievers. The reason for this was to be able to assess the effects of the interaction of the different ability levels of students with the types of treatments, comparing PBL and traditional teaching methods on students' mathematics achievement and their attitudes towards mathematics.

Table4.5: Group profiles

Group	Treatment	No. High Achiever	No. Low Achiever	Saudi students	No. Total	Teacher
A	PBL	10	7	16	17	The trained teacher
B	C	9	8	16	17	
C	PBL	7	7	13	14	The untrained teacher
D	C	5	11	14	16	
Total	31		33	59	64	

4.6.2 Primary students

127 pupils were selected from the primary school "B" to be part of the study. The school had seven classrooms in the third grade and each one had between 18 and 20 students. Students' ages ranged from 8 to 9 years old. Pupils were in the last semester of the third

grade. Those classes were instructed by three teachers; one taught three classes and two taught two classes for each. The seven classes were divided into three groups depending on their teachers. The three groups participated, with a number of 52, 39, 36 students in each group respectively. The majority of the students at the school were Saudis and in each group two to four students had Arab backgrounds such as Syria, Egypt and Sudan. All students had a middle-class, socioeconomic status. Academic school records and pre-tests were used to ensuring the groups were similar in terms of mathematical abilities. . One-way ANOVA model was applied to see if there is significant difference between groups in academic school records. The results show that there was no significant difference between groups in ANOVA test; $F (3, 124)$, $p > 0.05$, (see the ANOVA Table in Appendix 4. B1). Thus, the groups were similar in terms of mathematical abilities.

A wide range of academic achievement was shown by students, from very high to very low achievers. There were no special education pupils within the groups. However, some of the students had very weak reading abilities so the teachers recommended that they all read the pre and post-tests in order to try and help prepare the students and assist those who may have an unfair disadvantage. Thus, all pre and post-interventions were read to all students by teachers. Table4.6 shows the description of the groups. Each group was divided into two subgroups based on their level of achievement (high and low).

Table4.6: Group profiles

Group	Treatment	No. High Achiever	No. Low Achiever	Saudi students	No. Total	Teacher
A	PBL	24	28	47	52	The trained teacher
B	C	12	27	34	39	The conventional methods
C	PBL	12	23	34	36	The untrained teacher
Total		49	78	115	127	

4.6.3 Intermediate and primary teachers

The two intermediate veteran teachers were similar in terms of qualifications, experience and expertise and also in their beliefs and perspectives on PBL and traditional teaching methods. Similarly, the primary three veteran teachers were similar in terms of qualification, experience and expertise and also in their beliefs and perspectives on PBL and traditional teaching methods.

All teachers had similar experiences. The intermediate school teachers had been teaching mathematics for intermediate school students for 8 years, while the primary school teachers had been teaching mathematics for primary school students for 10 years. They all had a First Degree in Mathematics. They were all Egyptians and were aged in their late thirties.

According to the teachers and the administration of the school, the teachers had all attended the same training courses in different aspect of education, such as active learning. However, none of them had ever been trained in using PBL teaching strategies. One teacher from each (primary and intermediate) were randomly selected to receive CPD training in PBL and the others were provided with the materials required to teach PBL, such as designed problems and guidelines for implementing PBL. However, according to the information provided by the teachers and school records, all teachers did not receive any CPD training.

4.7 Topics

Topics were chosen because the school's plan was to follow the instructions of the textbook of mathematics that the school had adopted. The subject of the topic was a unit of mathematics from the school textbook. The content was new to the students. This was necessary in order to prevent students' previous knowledge from becoming a variable factor which could affect the outcomes of this study.

4.7.1 Intermediate topics

Rational number units were included Operations on Rational Numbers (Addition, Subtraction, Multiplication and Division of Rational Numbers); comparing Rational Number Orders and the Equivalence of Rational Numbers. Each teacher instructed two groups; one group via PBL teaching strategies and the other group via conventional teaching methods.

4.7.2 Primary Topics

Data display was covered. The topic covered representation through codes, interpretation of representation through codes, representation columns and interpretation of representation columns.

4.8 Designing problems

The problems were designed by the author for both the intermediate and primary schools, the learning goals of the unit were identified. These goals were divided into a set of relevant goals. Each set of goals was organized as learning issues, and then the story of the problem built around them. The problems were ill-structured, real-life, age-appropriate and suitable for the groups (see examples in Appendix 4.A.2 and .B.2). The PBL goals were constant for every problem, see figure2, while the learning goals were changeable based on the lesson. Both teachers were consulted about the problems and only made changes which had been mutually agreed.

The learning subject matter was reformulated to be integrated into the problem-based learning teaching strategy:

a) Determining the units of study, Rational Number.

b) Determining the goals of learning in these units.

c) Reformulating the lessons to use a set of ill-structured and real-life problems to suit the PBL teaching strategy.
d) Presenting it to a set of experts to make sure that it has an acceptable level of credibility to achieve the learning goals. (See learning goals and some problems in Appendix 4. A2 and 4.A3 for intermediate school, and 4. B2 and Appendix 4.B.3 for primary school).

4.9 Time allocated for instruction

The instruction took place during 10 45-minute class sessions for each both the intermediate and primary schools. There were a total of four sessions per week lasting for two and a half weeks with a total of 7.5 hours for each group. All groups, whether PBL or conventional, were given the same amount of time to complete the work, in order to ensure fairness across the groups.

4.10 Research methods

The quantitative methods: Mathematics tests and Attitudes towards mathematics will be described and discussed including their validity and reliability

4.10.1 Mathematics tests

For intermediate school students, 18 multiple-choice questions, short answer questions, fill in table questions, and drawing tests were applied at the beginning of the study (pre-test) and at the end (post-test). The tests consisted of six items measuring the ‘knowing’ domain, seven items covering ‘applying ability’ and five items which assessed reasoning ability. While For primary school students, 16 multiple-choice questions, short answer questions, fill in table questions and drawing tests were applied at the beginning of the study (pre-test) and in the final experiment (post-test). The tests consisted of five items measuring the ‘knowing’ domain, six items covering ‘applying ability’ and five items assessing ‘reasoning ability’, see Table4.7.

Table4.7: Test items

Grade	Scale	Number of items
Intermediate school students	Knowledge	6
	Applying	7
	Reasoning	5
	Total	18
Primary school students	Knowledge	5
	Applying	6
	Reasoning	5
	Total	16

Mathematics items were combined from the TIMSS 2007 for intermediate school students, and from TIMSS 2003, 2007 and 2011 for primary school students. The final version of the exam covered all goals of the unit and was given to 10 veteran teachers to check its credibility (see Appendixes 4.A.4 (intermediate) and 4.B.4 (primary)); they all agreed the exam could be used for measuring what students learn from the “rational number” unit for intermediate, and the “Data display” unit for primary school students. Each item of the exams scored either one point or zero.

Mathematics tests are combined within TIMSS 2003, 2007 and 2011 exams. This was done by posing questions that measure students’ abilities in ‘rational number content’ for intermediate school students, and “Data display content” for primary school students with the cognitive domains ‘knowing’, ‘applying’ and ‘reasoning’. Although TIMSS tests are an international exam and the reliability and validity are supposed to be checked, the validity and reliability of the tests were also tested by the author.

4.10.1.1 Validity of the tests

To evaluate the quality of a measurement procedure, the first criterion is validity (Gravetter and Forzano, 2015). '*The validity of measurement procedure is the degree to which the measurement process measures the variable that it claims to measure'* (Gravetter and Forzano, 2015, p.78).

There are several methods to assess the validity, such as face validity, concurrent validity, and consistency of a relationship. In the current study, the face validity method was used to assess the validity of the measures: tests and attitudes measures. Face validity is defined as the degree of the expert judges' responses to which items of measurement are appropriate to the targeted objectives of assessment and construct (Hardesty and Bearden, 2004).

Thus, after the tests had been prepared and translated from English into Arabic by the author, the tests, which included 18 items for intermediate and 16 items for primary school students, were presented to 10 and 8 arbitrators, respectively, for checking and to give their opinions on the following:

- the clarity of the items;
- the adequacy and relevance of the content of the items;
- to propose any amendments and observations they deem appropriate; and
- to validate the appropriateness of the skills and items for eight grade students.

The opinions of the arbitrators were considered and included in the preparation of the final image of the tests. In addition, the tests were applied to a sample of a pilot study population of around 50 intermediate school students and 40 primary school students. The objective of this was to gather their feedback and use their responses to further improve the tests. However, no changes were reported and the pilot study confirmed the validity of the tests.

4.10.1.2 Reliability of the tests

The second criterion is reliability for evaluating the quality of a measurement procedure (Gravetter and Forzano, 2015). '*A measurement procedure is said to have reliability if it produces identical (or nearly identical) results when it is used repeatedly to measure the same individual under the same conditions'* (Gravetter and Forzano, 2015, p.85).

There are several methods which can be used to assess the reliability of tests, such as test-retest reliability, parallel-forms reliability and split-half reliability. In this study the test-retest reliability and the internal consistency for sub-scale (for the ‘knowing’, ‘applying’, and ‘reasoning’ scales tests along with the attitudes measures: ‘liking learning mathematics’, ‘value mathematics’ and ‘conference to learn mathematics’) were used to assess the reliability of the measures tests and attitudes measures tests.

4.10.1.3 Test-retests for tests

> *‘Test-retest reliability is established by comparing the scores obtained from two successive measurements of the same individuals and calculating a correlation between the two sets of scores’* (Gravetter and Forzano 2015, p.87).

Therefore, the Test-retests were applied after 3 weeks to a sample of a pilot study population and then the correlation between the two groups was calculated in order to ensure the reliability of the test. The levels of reliability were acceptable with a score of .86 for intermediate school students, and .84 for primary school students. The average time spent completing the pilot study tests was calculated and this was the allocated time for all subsequent tests. Thus, the time allocated for the test was 40 minutes for intermediate school students, and 35 minutes for primary school students.

4.10.1.4 Internal consistency for sub-scale of tests

Cronbach Alpha was used to measure the internal consistency of scales for the tests. Cronbach Alpha states that “*Internal consistency describes the extent to which all the items in a test measure the same concept or construct and hence it is connected to the inter-relatedness of the items within the test*” (Tavakol and Dennick, 2011, p53). The test scores range from 0 to 1 and the acceptable level is between 0.70 and 0.95.

This test was necessary in order to ensure the reliability of the scales of the tests. The reason behind this was because the items of the tests were selected from different TIMSS exams and this may have affected the reliability of the scales or the whole tests.

Both the tests for the intermediate and primary school students were employed to measure the constructs for all scales (‘knowing’, ‘applying’ and ‘reasoning’). All scales in each test had the internal consistency acceptance level (see Table4.8).

Table 4.8: Cronbach's Alpha Test

Grade	Scale	Number of items	Cronbach's Alpha	Number of students
Intermediate	Knowing	6	.716	64
	Applying	7	.709	
	Reasoning	5	.736	
	Total	18	.804	
Primary	Knowing	5	.745	127
	Applying	6	.747	
	Reasoning	5	.732	
	Total	16	.802	

The mathematics test for the intermediate school students was employed to measure the construct and the test consisted of 18 items which were divided to measure three domains or scales, namely 'knowing', 'applying' and 'reasoning'. The 'knowing' scale consists of 6 items, the 'applying' scale contains 7 items and the 'reasoning' domain consists of 5 items all of which were found to be at an acceptable level of internal consistency with scores of .716, .709, and .736 respectively. The total exam had a high level of internal consistency with a total score of .804.

For the mathematics tests for the primary school students, the test consists of 16 items which were also divided to measure three domains or scales ('knowing', 'applying' and 'reasoning'). The 'knowing' scale consists of 5 items, the 'applying' scale contains 6 items and the 'reasoning' domain consists of 5 items, all of which were found to be at an acceptable level of internal consistency with scores of .745, .747and .732 respectively. All the items correlated with good total scales (no items scored less than .3). The final exam, which included 16 items, had a high level of internal consistency with a total score of .802.

The results of Cronbach Alpha shows that for both intermediate and primary school students, for all scales ('knowing', 'applying' and 'reasoning'), and the exams were reliable and valid for this study (see the final version in appendices 4.A.4 for intermediate and 4.B.4 for primary).

4.10.2 Attitudes towards mathematics

Attitudes were assessed using 12 items for intermediate school students, and 8 items for primary school students applied twice as pre and post measures. Each item with 4 Likert-Scales was used, namely: agree a little, agree a lot, disagree a little and disagree a lot. Likert scales are a range of pre-defined responses to statement to given question, using to measure attitude (Cohen, 2000). These items were used covering three aspects of attitudes, namely: like learning mathematics (4 items), placing value on mathematics (4 items) (not included for primary school students) and confidence to learn mathematics (4 items). The items used to measure the 'attitudes towards mathematics' were taken from the TIMSS 2007 and 2011. Each item was scored from 1 to 4. The total marks ranged from the number of items of the measure to multiply them by 4; for example, like learning mathematics measure consisted of 4 items, so the total scores ranged from 4 to 16 scores meaning 4 scores was the lowest mark and 16 was the highest marks. Some items were reverse coded; for example, 'mathematics is boring' means that to disagree a lot takes 4 scores, whereas to agree a lot takes 1 score (see Table4.9).

Table4.9: Attitudes items

Grade	Scale	Number of items
Intermediate	Like learning mathematics	4
	Value mathematics	4
	Confidence to learn mathematics	4
	Total	12
Primary	Like learning mathematics	4
	Confidence to learn mathematics	4
	Total	8

Although the measures of attitudes were taken from an international research (TIMSS) which meant that the reliability and validity are supposed to be checked, the validity and reliability of tests were also tested by the author.

4.10.2.1 Validity of the measures

For greater confidence in the validity of the measure, after the preparation of the measure of attitudes towards mathematics the exam was translated from English into Arabic by the author. It was included in 12 items (for intermediate school students) and 8 items (for primary schools students). Face validity (discussed above) was used - the measures were presented to 10 arbitrators to get their opinions on the following:

- the extent of the clarity of the items in each scale;
- the accuracy of the items in each scale; and
- To propose any amendments and observations they deem appropriate.

Then, the opinions of the arbitrators were considered and input into the preparation of the final version of the measures.

In addition, the tests were applied to a sample of a pilot study population of around 50 intermediate students and 40 primary school students. The purpose of this was to gain feedback and use their responses to implement any necessary modifications and improvements to the tests. However, no changes were reported and the pilot study confirmed the validity of the tests.

4.10.2.2 Reliability of the measures

The measures were applied to a sample of a pilot study population of around 50 for intermediate school students, and 40 for primary school students and their responses were used to improve the measures. The Test-retests (discussed above) were conducted for each measure, after 3 weeks with a sample of a pilot study of the population and the correlation between the two measures was then calculated in order to ensure the reliability of the measure. The level of reliability was acceptable with a score of 88 for intermediate school students, and .85 for primary school.

The internal consistency for sub-scale for the attitudes measures: 'liking learning mathematics', 'value mathematics' and 'confidence to learn mathematics' scales were used to assess the reliability of the measures.

4.10.2.3 Internal consistency for sub-scale of attitudes

For both the intermediate and primary school students measures both tests were employed to measure the construct for all scales ('liking learning mathematics', 'value mathematics' and 'confidence to learn mathematics' scales). All scales in each measure had an acceptable level of internal consistency (see Table4.10).

Table4.10: Cronbach's Alpha Test

Grade	Scale	Number of items	Cronbach's Alpha	Number of students
Intermediate	Like learning mathematics	4	.802	64
	Value mathematics	4	.806	
	Confidence to learn mathematics	4	.810	
	Total	12	.891	
Primary	Like learning mathematics	4	.808	127
	Confidence to learn mathematics	4	.820	
	Total	8	.848	

The attitudes for intermediate school students were employed to measure the construct; the test consists of 16 items which were divided to measure three domains or scales: ('liking learning mathematics', 'value mathematics' and 'confidence to learn mathematics'). Each scale consists of 4 items and were all found to be at a high level of internal consistency with scores totalling .802, .806, and .810 respectively. The total measure had a high level of internal consistency with a score of .891.

For the attitudes of primary school students, the measure consists of 8 items which were also divided to measure two domains or scales: ('like learning mathematics' and 'confidence to learn mathematics'). Each scale consists of 4 items which were all found to be at a high level of internal consistency with scores of .808, and .820 respectively. All items correlated with a good degree of total scales (no items scored less than .3). The total measure, which included 8 items, had a high level of internal consistency with a score of .848.

The results of Cronbach Alpha shows that for all scales, the measures for both the intermediate and primary school students ('liking learning mathematics', 'value mathematics' and 'confidence to learn mathematics') were reliable and valid for the purposes of this study (see the final version of the measure in appendices 4.A.5 and 4.B 5).

4.11 The design of the qualitative dimension to the study

Qualitative research is '*a systematic, subjective approach used to describe life experiences and give them meaning*' (Bums andGrove, 2003, p.356). It is flexible and open which can help provide access to information that could be difficult to access using the quantitative approach (Bryman, 1988). The data is collected within the context of the study from selected participants who have experienced the issue being investigated (Creswell, 2009).

Data can also be collected from different sources and from more than a single resource, such as interviews and observations, to analyse the data and eventually identify the themes (Creswell, 2009; Bums andGrove, 2003).

There are several qualitative research designs, such as phenomenology, grounded theory, narrative research, ethnography and case study (Blenner, 1995, Creswell, 2009, Chase, 2005, Polit andBeck, 2008).

For the qualitative data the present study adopted the case study design. A case study is described as an "*empirical inquiry that investigates a contemporary phenomenon within its real-life context, especially when the boundaries between phenomenon and context are not clearly evident*." (Yin, 2003b, p13).

With the case study design the researcher investigates one person or a group of people; it can include more than one method, such as interview and observation, (Polit and,Beck, 2008). According to Yin, (1994), one of the most important resources of a case study is interviews.

Case studies can be used with a single source or multiple sources (Schell, 1992). Multiple sources can include more than one method for collecting data, such as interview and observation. In the current study, two methods were used, namely: interview and researcher's observation. This can be called 'multiple triangulations' (Schell, 1992), and can use the researcher's work and observations as a supplemental to the triangulation method. This design was described by Yin (1984) as 'embedded cases'. Therefore, the design of this study is considered as an embedded case of observations between interviews.

For the purposes of the current study teachers were interviewed to obtain information about their experiences in implementing PBL and the researcher' observations were used as a supplement to the triangulation method which was applied during the quasi-experimental intervention study for more understanding. A case study strategy is beneficial to obtain a rich understanding of the phenomenon inside its context (Punch, 1998; Saunders et al., 2003). In addition, the selective case study is the methodology used for a holistic and in-depth investigation and it may offer a deeper understanding of causal processes (Feagin et al., 1991; Catharine Hakim, 1987). Case studies may be classified into three categories – first is the exploratory category which relates to the 'what' questions, second is the explanatory category which focuses on the 'how' questions and the third category is descriptive and focuses on the 'why' questions (Schell, 1992). According to Yin, (1984) all the three categories can be used in one strategy. The case study used in the current study focuses on the ‘what’ and the ‘how’ (see the interview questions below) and therefore adopted the exploratory-explanatory case study strategy. The data collected is related to the subject experience and contexts (Polit andBeck, 2008; Eisenhardt, 1989).

In this study, semi-structured interviews and a research diary will be used for enriching and understanding the context and actual practice of the study. The research diary or researchers’ observations will also be undertaken to add to credibility of the data. This method is called ‘triangulation’ which uses different methods to look at convergent and divergent findings for more accurate interpretations (Mariano, 1995; Lincon and Guba, 1985).

4.11.1 Interviewing teachers

The interview method is a very powerful tool for obtaining qualitative data (Punch, 1998; Walliman, 2001). An interview is when an interviewer conducts a conversation with one or more people with the substance of what is said being recorded, analysed and reported (Powney and Watts, 1984). The interview has three main forms: structured, unstructured and semi-structured, all of which can be applied in the form of either one-to-one (individual) or group interviews (Fontana and Frey's, 2000; Dawson, 2009). Additionally, these forms can be either face-to-face interviews, telephone interviews or e-mail interviews (Walliman, 2006; Meho, 2006). In the present study, to achieve its purpose, individual, face-to-face, semi-structured interviews were selected.

Semi-structured interviews were conducted with both of the teachers (the trained teacher and the untrained teacher) before and after the implementation of the study. This aimed to ensure that all teachers had the same experience, expertise, beliefs and attitudes towards student-centred learning and also to investigate their experiences after the implementation of PBL.

In the semi-structured interviews (see the interviews’ questions below), interviewer had already prepared lists of questions before conducting the interviews, however, if necessary, the questions could be modified based on the investigator’s perceptions of what appeared most suitable to the context (Wisker, 2001). Using semi-structured interviews allows respondents to say what they want and does not include leading questions (Stringer, 2004). Tape-recordings and transcriptions are used for the interviews (Reid, 2006). In the present study tape-recordings were used and the interviews lasted for about 30 minutes with each teacher. The interviews were conducted in Arabic, transcribed and then subsequently translated into English by the researcher.

4.11.1.1 Semi-structured interviews

Semi-structured interviews were conducted with five teachers; two from the intermediate school and three from the primary school. In the intermediate school, one teacher had received face-to-face training in implementing PBL whilst the other had received PBL materials and training materials, and was asked to conduct self-directed learning. Both teachers were interviewed twice, once before and then once after the implementation of PBL. This aimed to ensure that all teachers had the same experience, expertise, beliefs and attitudes towards student-centred learning, and also to investigate their experiences after the implementation of PBL. The following six main questions were asked in the pre-implementation interview:

1. What motivated you to become a mathematics teacher?
2. Can you tell me about your experience in mathematics?
3. Can you talk about your expertise in the field of mathematics?
4. What do you think about the teacher-centred and student-centred teaching approach?
5. What are the benefits of learning mathematics?
6. Can you take about any training that you have received?

All teachers in the third and eighth grades had similar results (see 4.5.3 intermediate and primary teachers for more details).

Follow up, semi-structured interviews were conducted following the implementation of the study in order to investigate the experiences of the teachers who had used the PBL teaching strategies. Similarly, three primary teachers were interviewed before the implementation of PBL and two of them were interviewed after the study. Using semi-structured interviews allows respondents to say what they want and do not include leading questions (Stringer, 2004). Tape-recording and transcriptions were used for the interviews (Reid 2006). This is shown in Table4.11.

Table4.11: Interview timeline

School	Teacher	Pre-interview		Teaching methods	Post-interview	
		Time by minutes	Data		Time by minutes	Data
Intermediate	The trained teacher-face-to-face	22	Sep 2013	PBL and traditional teaching methods	21	Oct 2013
	The self-directed learning teacher	15		PBL and traditional teaching methods	16	
Primary	The trained teacher-face-to-face	21	May 2014	PBL	23	Jan 2014
	Traditional teacher	14		Traditional teaching methods	No need	
	The self-directed learning teacher	13		PBL	17	Jan 2014

The following six main questions were asked:

1. How was PBL implemented in your teaching strategies?
2. What are the advantages of using PBL teaching strategies?
3. What are the disadvantages of using PBL teaching strategies?
4. What challenges did you face during the process of implementing the PBL teaching strategies?
5. To what extent do the students who lack prerequisite knowledge or skills affect how you teach this class?
6. How well do students engagement in PBL learning processes?

In Glasgow, the semi-structured interview was applied in 'G' School for five intermediate school teachers as a pilot study to make sure that the interview could achieve its goals. The comments of the teachers were taken into account (see letter of school in Appendix 4. A6). The author had also taken a training course in how to conduct semi-structured interviews for two days at the University of Glasgow.

4.11.1.2 Field observation notes (methodological triangulation)

According to Denzin (1978), there are four applications of triangulation: methodological triangulation, theory triangulation, researcher triangulation and data triangulation. In the current study the research diary was used as a supplement for the methodological triangulation of the semi-structured interviews. Methodological triangulation is when a researcher uses various methods to collect data, such as observation and interview, and aims to understand the phenomenon deeply (Neuman, 2000; Flick, 2004). Therefore, combining observation and interviews to understand social events could result in deeper understanding and enhance the credibility of the results. Using multiple methods allows for each method to assist in the strengthening and development of the other (Creswell, 2009). In this study, field observation notes were used to gain a deep understanding and enhance credibility. Field observation notes can be used to collect data (Moen, 2006). Conducting methodological triangulation does not only increase validity, but also reduces bias and brings objectivity to the research (Fielding and Fielding, 1986). The analysed data notes were compared with analysed semi-structured interview for deeper understanding and credibility and then the results of interview were given to the teachers for confirming their perspectives. This has, in my view, given the findings of interview more credibility.

A research diary (field observation notes) was kept throughout the project. The field observation notes are a supplement to the main data sources (Ary et al., 2013). The research diary was taken during the implementation of the study. As the researcher, I moved between groups to make sure everything was proceeding very well; my intention was to monitor the implementation of the study, and I had a diary that I used to document my observations, particularly the observations which took place during lessons and were made inside mathematics classrooms. The field observation notes used in this study consists of two parts: firstly, descriptive, followed by reflective information (Patton, 2015). Therefore, after documenting the factual data obtained from inside the classrooms, the researcher then reflects on the meaning of the observations as initial interpretations. This was outside of the classrooms in order to be more accurate, organised and focused on the research problems.

The main focus was on teachers’ performance with particular concern in respect of teacher intervention and student practices, both individually and collectively, students responses, group interaction and PBL processes. In addition, these topics were not exclusive but this made the observation easier. I mainly focused on teachers’ performance and was particularly concerned with teacher intervention, student practices, both individually and collectively, students responses, group interaction and PBL processes.

4.12 Validity and reliability in mixed methods research

Although terms of validity and reliability engage with positivism and are related to the quantitative approach, they have also been used for interpretive research with the qualitative approach. These convergences have been criticized because both approaches are divergences in purpose and philosophical assumptions (Burns and Grove, 2003). Rigour and validity are '*empirical analytic terms that do not fit into an interpretive research that values insights and creativity*' (Polit and Beck, 2008, p.536). However, Lincoln and Guba (1985) proposed the following appraising criteria for studies adopting mixed methods approaches described in Table4.12 below.

Table4.12: Appraising criteria for studies adopting mixed methods approaches

Concept	Quantitative Methods	Qualitative Methods
Truth value	Internal Validity	Credibility
Applicability	External Validity	Transferability
Consistency	Reliability	Dependability
Neutrality	Objectivity	Confirmability

4.12.1 Truth value

Truth value can be tested for both quantitative and qualitative approaches. This can be done by examining internal validity for quantitative approach and credibility for qualitative approach.

4.12.1.1 Internal validity

Internal validity is "*to what extent findings reflect the phenomena under investigation*." (Denzin and Lincoln, 1998, p.l86). It refers to causal relationships and does not relate to descriptive or observational studies (William, 2006). The presence of confounding variables might reduce the chance of establishing a cause and effect relationship and hence threaten internal validity (Bums and Grove, 2007; Blenner, 1995). The present study adopted quasi-experimental design with pre-post-tests, and control groups. A quasi-experiment is used to test 'descriptive causal hypotheses' about manipulatable causes to support a counterfactual inference about what would have occurred in the nonappearance of manipulation, when sample is not randomly selected (William, 2005).

Therefore, in order to reduce bias, avoid threats to internal validity, confounding variables plausible alternative explanations or such as some students having prior knowledge that other students do not, the same treatment should be considered. To consider this, studies should add pre-tests to disclose maturational trends and compare the trend to the post-tests, and also involve a control group. Control group and pre-tests can avoid threats to internal validity (Harris et al., 2006).

4.12.1.2 Credibility

'Credibility' is considered as 'internal validity' in quantitative research (Guba and Lincoln, 1985). Credibility purposes to find "*isomorphism between constructed realities of respondents and the reconstructions attributed to them*" (Guba and Lincoln, 1989, p. 237). To achieve credibility is to confirm the accuracy of gathered and interpreted data from specific subjects by conducting the study in a way that permits for increasing the believability of results (Polit and Beck, 2008). There are several methods that have been used to achieve credibility such as triangulation, member checks and peer review (Creswell, 2007; Creswell andPlano Clark, 2011, Mariano, 1995; Lincon and Guba, 1985).

In the present study, triangulation was used with different methods to confirm and analyse the data collected. According to Creswell (2007, p. 208) the triangulation process involves "*…corroborating evidence from different sources to shed light on a theme or perspective*."

In this study, field observation notes used for deep understanding and credibility, as discussed previously. The list of notes was compared with semi-structured interview for deeper understanding and credibility and then the results of interview were given to the teachers for confirming their perspectives. This has given the findings of interview more credibility.

4.12.2 Applicability

Applicability can be tested for both quantitative and qualitative approaches. This can be done by examining external validity for quantitative approach and transferability for qualitative approach.

4.12.2.1 External validity

External validity "*refers to the degree to which the results can be generalized to the wider population, cases or situations*" (Cohen et al., 2007, p 136). External validity can relate to sample size and selections. "*The main reason for random sampling is to enhance the* *generalizability of the results, or the extent to which the results can be applied to people and contexts outside of the study*." (Collingridge and Gantt, 2008, p 391). Therefore, there are two approaches for generalization: the 'Sampling Model' and the 'Proximal Similarity Model' (William, 2006).

The sampling model is used to select a representative sample from the population with the intention of receiving a range of generalised results back (Collingridge and Gantt, 2008; William, 2006). This approach may be impossible because it cannot be able to take samples from future times that you intend to generalise to. Therefore, this kind of approach (the Sampling Model) was not adopted in the current study. Additionally, the sampling size in this study is not representative. However, probability sampling theory cannot limit generalization (Collingridge and Gantt, 2008). Alternatively, analytical generalization can be adopted; it makes a "*reasoned judgment about the extent to which the findings in one study can be used as a guide to what might occur in another situation*" (Kvale, 1996, p.231). In analytical generalization, researchers support their generalization claims through developing appropriate theoretical frameworks for interpretive understanding by identifying similarities and differences between situations (Collingridge and Gantt, 2008).

The proximal similarity model is an example of the analytical generalization approach (Campbell, 1986). This model uses what is called 'gradient of similarity criterion' which includes judging the degree of similarity between the place, time, people and setting both inside and outside groups (Collingridge and Gantt, 2008; William, 2006). Analytical generalization was therefore appropriate for this study. Therefore, the combination of quantitative and qualitative approaches is important to examine the context of the study (Albright, Gechter et al., 2013). This might enhance generalization claims.

Generalizability or external validity threats also may take place. According to Campbell andStanley, (1963), there are two external validity threats, namely: the '*Reactive Effect' and the 'Hawthorne Effect'. The Reactive Effect can occur as a response to a new intervention while the Hawthorne Effect can create unnatural responses from participants simply because they are a research participant* (Campbell andStanley, 1963). However, as the current study was conducted over a period of 2-3 weeks, this would more than likely decrease the possibility of both Reactive and Hawthorne factors.

4.12.2.2Transferability

Although generalizations for qualitative results cannot be justified based on the random sampling model due to purposive sampling, they can be generalized under the term 'Transferability' (Collingridge and Gantt, 2008). In qualitative research, 'transferability' is considered as 'external validity' (Guba and Lincoln, 1989). Transferability refers to 'the extent to which the findings can be transferred to other settings or groups' (Polit and Hungler, 1999, p.717). To achieve transferability is to give a more detailed description to the participants of the research settings (Creswell, 2007; Guba and Lincoln, 1989, Schofield, 1990), and provide suggestions for transferring the results to another setting (Graneheim and Laundman, 2004).

In order to achieve transferability, in the current study more details were given about the context of the study, such as type of school, age, qualifications, experiences and expertise of participants,.

4.12.3 Consistency

Consistency can be tested for both quantitative and qualitative methods. This can be done by examining reliability for quantitative method and dependability for qualitative method.

4.12.3.1 Reliability

Reliability is "*replication of the study findings by another researcher*" (Denzin and Lincoln, 1998, p.l86). The reliability for quantitative methods: the mathematics tests and attitudes measures were discussed (as detailed above) and checked by using the test-re-test reliability measure and the internal consistency for sub-scale of tests for quantitative data.

4.12.3.2 Dependability

In qualitative research, dependability is parallel to the reliability of quantitative research (Guba and Lincoln, 1989). Dependability means obtaining the same result from the same subjects located within the same environment (Polit and Beck, 2008). This can be achieved through "external audits" which allows an external consultant to "*examine both the process and the product of the account, assessing their accuracy… whether or not the findings, interpretations and conclusions are supported by the data*." (Creswell, 2007, p.209). Another suggestion for achieving is for the researcher to revisit their respondents and ask them to check the findings (Bloor, 1978; Cohen et al., 2007). In the current study the findings of qualitative data (semi-structured interviews) were checked by the respondents (the teachers) to make sure they were accurate and dependable.

4.12.4 Neutrality

Neutrality can be tested for both quantitative and qualitative methods. This can be done by examining objectivity for quantitative methods and Confirmability for qualitative methods.

4.12.4.1 Objectivity

Objectivity refers to whether the findings of quantitative data are 'free from bias' (Denzin and Lincoln, 1998, p.186). In this study the answers and responses of the participants responsible for providing the quantitative data (mathematics tests and attitude measures) were objective, (see research methods section for more details).

4.12.4.2 Confirmation

In qualitative research, confirmation corresponds with objectivity in the quantitative research; it is similar to dependability, where the findings of the study are not affected by the researcher's subjectivity and are embedded in the data (Guba and Lincoln, 1989; Miles and Huberman, 1994). To achieve confirmation an external audit can be applied which is similar to dependability (Guba and Lincoln, 1989). Thus, the interviewees in the current study checked their responses to ensure they were accurate.

4.13 Teacher professional development

All the teachers who were asked to teach using PBL provided with PBL materials such as designed problems and guidelines for implementing PBL. However, as discussed in the literature review, CPD can occur either using the face-to-face training approach or by using the self-directed learning approach whereby reading materials are provided to assist in developing teaching practices. The aim of the study is to assess the effects of the different types of CPD on students' outcomes. In this study trained teachers were allocated to the teachers who were trained using the face-to-face approach and untrained teachers were allocated to the teachers who were trained using the self-directed learning approach.

4.13.1 Training on applying PBL using face-to-face training approach

The program of training teachers for implementing PBL in their class was developed by the author. For each stage of the study one teacher was selected to undertake the face-to-face training approach and, following completion of the programme, these teachers should be able to:

1. be familiar with PBL as a teaching strategy;
2. be familiar with the role of teachers and students in PBL settings;
3. assess and coach students during PBL processes by using meta-cognitive teaching skills;
4. keep all the students active and on track in the PBL learning process by monitoring and guiding them;
5. make the students' thoughts and their depth of understanding apparent; and
6. encourage students to become self-directed learners.

The programme included three real-life sessions with each one lasting 45 minutes. Teachers were asked to implement the PBL strategy using an ill-structured problem which was taken from a mathematics textbook and related to the topics that the students had been studying. A group of students from outside the study sample was selected in order to assess the teachers' performance and establish whether they were able to implement PBL effectively. This was followed by providing them with extensive feedback which lasted for more than an hour for each session.

The CPD training totalled approximately10 hours for the intermediate teachers and 8 hours for the primary teachers and was scheduled to take place within timescales. The training was scheduled to fit delivered in a flexible time scale, based on the amount of time and availability the teacher had. Table4.13can describes the process of implementing the programme.

Table4.13: the process of implementing the programme

N	Time by hours	process	Details
1	4 (for intermediate teacher) 2 (for primary teacher)	Face-to-face discussion	Explanation and discussion about how to implement PBL
2	2 for both teachers	Session 1- followed by feedback	Teachers implemented PBL on a group of students using an ill-structured problem related to topics that students had been studying, taken from a mathematics textbook. This allowed the researcher to assess the teachers' performance
3	2 for both teacher	Session 2- followed by feedback	
4	2 for both teachers	Session 3- followed by feedback	
Total	10 hours		

4.13.1.1 Assessment of the program

The program was presented to a set of professors in the University of Glasgow through a briefing and debriefing method and was then applied in 'G' School for five teachers as a pilot study to make sure that the program could achieve its goals. The comments of the supervisors, professors and teachers were taken into account (see the programme in Appendix 3. A7).

The pilot study for developing the programme lasted for one day. The teachers found the programme had achieved its goals; however, they recommend further training for teachers within their relative contexts. This was considered and teachers were subsequently given more practical work set in real life classrooms.

The programme was translated from English into Arabic in Saudi Arabia, and was given to three teachers to check that the language had been accurately translated. All three teachers found the translation to be satisfactory and agreed that the language of the programme was clear and appropriate.

4.13.2 Applying PBL using self-learning training

One teacher was selected from the intermediate and primary schools for each stage of the study. They were provided with the materials required to teach PBL, namely: designed problems, the programme materials and guidelines for implementing PBL, and were asked to research PBL implementation and train themselves using a self-directed learning approach. As the selected teachers were not formally trained in implementing PBL by a third party they were classified as 'untrained teachers' by the researcher.

4.13.2.1 Assessment of teachers in PBL implementation

The trained teachers were asked to implement PBL in a mathematics classroom that was not related to the study sample and were given feedback as necessary. The trained teachers were also given feedback as needed after each session during the study. However, both the trained and untrained teachers were assessed using semi-structured interviews and field observation notes. The effect they had on their students' outcomes was also measured using the quantitative approach, as discussed previously.

4.14 Procedures for both intermediate and primary school

Ethical approval has been received from the University's College of Social Sciences Ethics Committee to implement the study in Saudi Arabia (see Sample of consent Form and Plain Language Statement taken from ethical approval: University of Glasgow in Appendix4.A.9). It followed by receiving approval from the Ministry of Education to implement the study in Hail City schools (see the letter in Appendix 4. A8). The study was conducted in the following stages:

1. Meeting the administration of the school to assign groups of study (4 groups) and two mathematics teachers.

2. Conducting semi-structured interviews, each lasting around 30 minutes, with the two assigned teachers before conducting CPD.

3. Conducting CPD with one of those teachers. This took about 10 hours and was done in a flexible time scale, based on the amount of time and availability the teacher had.

4. Checking students' records for students in mathematics and analysing it to make sure all groups were similar in terms of their ability in mathematics.

5. Identifying the content of the subject matter to be taught

6. Applying a pre-test (a measure of attitudes towards mathematics and an exam to measure mathematics achievement, all taken from TIMSS)

7. Conducting the study which took about 2 and a half weeks.

8. Applying a post-test (a measure of attitudes towards mathematics and an exam to measure mathematics achievement, all of which were taken from TIMSS)

9. Again conducting semi-structured interviews, each lasting around 30 minutes, with the two assigned teachers.

10. The students received training in PBL instruction before embarking on the study. They received two short interesting problems about travelling for holiday and poverty. The students worked within groups to prepare for the PBL sessions. They were encouraged to ask open questions, listening to others and thinking critically.

Table 4.14 explains the timelines of the study starting from receiving confirmation of ethical approval from the University of Glasgow through to the completion of data collection.

Table4.14: The timelines of the study

N	Activity	Timeline
1	Ethical approval from the University's College of Social Sciences Ethics Committee	March 2013
2	School 'G' approval	
3	The pilot study in Scotland for developing professional development CPD	May 2013
4	Approval from the Ministry of Education to implement the study in Hail City schools	July 2013
5	The pilot study in Saudi Arabia for intermediate schools	August 2013
6	Teachers' pre-interviews	September2013
7	Implementation of study for intermediate schools in including quasi-experimental studies and observations	September and October 2013
8	Teachers post-interviews	October 2013
9	Ethical approval from the University's College of Social Sciences Ethics Committee	March 2014
10	The pilot study in Saudi Arabia for primary schools	April 2014
11	Teachers' pre-interviews	May 2014
12	Implementation of study for primary schools in including quasi-experimental studies and observations	May and June 2014
13	Teachers post-interviews	June 2014

4.15 Problem-Based Learning materials and activities

The PBL instruction contained rational number (for intermediate school) and data display (for primary school) units reformulated into a set of ill-structured problems to suit PBL instruction whilst maintaining its learning unit goals. The author designed the problems and he considered any changes suggested by the teachers. Four characteristics were adopted in the problems:

1. The role of students as stakeholders. The problem is designed to personalise learning in order to maximise students' motivation (Hung et al., 2008). Therefore, students are asked to solve the problem as if they are the stakeholders, i.e. consultants, researchers or engineers.

2. Ill-structured problems. The problem has more than one answer or can be solved in a number of ways. This kind of problem requires students to research for any missing or further required information, generate possible solutions and make the decision as to which one is best.

3. Real-life problems. Problems are relevant to students' daily lives or their future carers.
4. Age-appropriate problems. Problems are designed to consider students' ages. For example, third grade school students received easy, clear and short problems and the learning issues were contextualised by their interests. See Figure4.4.

In addition, one more characteristic was added to the list of problems for primary school students only. The fifth characteristic, 'clear and short problems' was added after implementation and feedback had been received from intermediate school study to attempt to provide more suitable problems, see Figure4.5.

The teachers who were asked to implement PBL were given the programme, including PBL materials, such as 'Model of what know and need to know and ideas to solve problem', 'model of the information gathering process' and the 'decision-making matrix' (see the programme in appendix 4. A.7). The teachers were permitted to use these materials during the PBL sessions. Furthermore, the designed problems were given to the teachers who were asked to implement PBL with learning and PBL goals (see Table4.15). PBL groups were kept constant throughout all problems, while learning goals changed depending on the subject matter (see Figure 4 2: A problem example).

Table4.15: PBL materials given to teachers

<table>
<tr><th>Grade</th><th>Teacher</th><th>Materials Given</th></tr>
<tr><td rowspan="2">Intermediate</td><td>The trained face-to-face teacher</td><td rowspan="4">- The programme including PBL materials
- The designed problems including learning and PBL goals
- Mathematic textbooks</td></tr>
<tr><td>The self-directed learning teacher</td></tr>
<tr><td rowspan="3">Primary</td><td>The trained face-to-face teacher</td></tr>
<tr><td>The self-directed learning teacher</td></tr>
<tr><td>The traditional teacher</td><td>- Mathematic textbooks</td></tr>
</table>

In this study the six core characteristics of PBL mentioned by Barrow (1996) were adopted:

1. The student is the centre of the learning. The students work under the guidance of their teacher. Students must be responsible for their own learning, identifying what they need to know and where they will get the information they need, i.e. from books and via the Internet.

2. Learning occurs in small groups of students. The students are divided into small groups with between 4 and 6 members in each group. They were not homogenous and contained both high and low achieving students; group members were also changed randomly from one problem to another.

3. The role of the tutor is as a facilitator or a guide. The teacher's role is not to be the source of knowledge but to guide students by asking metacognitive questions. The teachers cannot inform students whether they are right or wrong and the teacher cannot tell them what they should study or read.

4. At the beginning of the learning the student(s) are presented with authentic problems. The problems are presented to students in the form of a written case study. This challenges students and motivates them for learning. Students then identify what they need to learn to link this with what they have already learned in order to solve the problem(s).

5. The problems are used as a means to developing problem-solving skills. To do so, problems have to be presented in the same way as they would occur in real world.

6. New knowledge is gained through self-directed learning. The students work together, to review, discuss, debate and compare what they have learned (Barrows, 1996).

Generally, to implement problems via the PBL teaching strategy, nine steps were adopted, as follows:

1. Meeting a problem.
2. Understanding the problem.
3. Identifying what students know, what they need to know in order to solve the problem, and their ideas about initially solving the problem.
4. Defining the problem statement.
5. Gathering and sharing information with groups.
6. Generating possible solutions.
7. Choosing the best solution.
8. Presenting the problem.
9. Debriefing the problem.

Specifically, for the intermediate school, in this example (Figure 4. 3), the teacher reads the problem and asks students to try to understand the problem. The teacher then assigns one of his students to explain it in his own words and encourages the other students to comment. Once the teacher is assured that the students have understood the problem, he then asks students to identify what they know and what they need to know in order to solve the problem. After that he asks students to define the problem statement. Once they have agreed on the problem statement he asks students to sit in groups and set a plan to gather the information that they need to know and divide the task between them. When the students have gathered the new information they share this information within their groups. They then generate possible solutions, choose the best solution and then present the solution in front of the other students and finally debrief the problem.

For primary school, in this example (Figure 4 4), the teacher reads the problem and asks students to understand it within their small groups. Students cooperate to understand the problem and determine what they know and what they need to know in order to solve the problem. Then the teacher asks them to explain the problems in their own words, questions their understanding with whole class and discusses what they know and what they need to know in order to solve the problem. This is followed by the teacher asking students to make a plan to solve the problem. The teacher facilitates their learning with metacognitive questions and he acts as an outstanding student. Students gather information and once they have solved the problem, students present their solutions and received feedback from the other groups and the teacher. Finally, the teacher asks the students to summarize what they have learned from today's lesson as homework.

Example: A problem

Due to the success in providing wonderful consulting with the manufacturing company, we in turn, are honoured to join our team in order to give us advice on how much should sell TVs that are measured by screens in inches pricing, as follows: $\frac{40}{1}$, 3, $\frac{270}{9}$, $\frac{300}{8}$, $\frac{180}{5}$, 55.77, 43, 30.7, 33.6, $\frac{6}{7}$

Note that the final cost of the price is ascending from smallest to largest by the capacity of the screen:

100,150,200,250,350,400,450 SR

Note: that profit must be at least 30% and not exceed 70%.

Learning goal:

Making comparisons between rational numbers.

PBL goals:

The following goals are likely to be fixed in every problem being taught by PBL (Hmelo-Silver andBarrows, 2006):

5. To keep all the students active in the learning process.
6. To keep the learning process on track.
7. To make the students' thoughts and their depth of understanding apparent.
8. To encourage students to become self-reliant for direction and information.

Figure 4 3: A problem example

Example: problem

As you are a consultant of the school, work with your group and present the results of some of the students' favourite games from your classroom in Table, in order to make it easy for others to understand.

Learning goals:

Present data in table

Figure 4 4: An example of problem for primary school students

4.16 Traditional approach

A traditional approach was used in normal classes at the school. It started with concepts and principles and ended up with exercises. It was teacher-centred instruction with the teachers as the source. The teachers identify the learning goals and use lectures and discussions to achieve them, and then provide students with exercises, such as problems, to practice what they have learned. The students work individually, and listen to the teacher, and they follow the teacher's instructions. The students can receive answers for their questions from the teacher. The teacher does not pose any metacognitive questions, or let students work within groups. The teacher leads students to achieve the learning goals but not guide them. The allocated time was discuses above see (4. B7 Time allocated for instructions).

4.17 Quantitative analysis: Statistical analysis

One-way ANOVA models (Howell, 2012; Field, 2013) between groups were applied to ensure the equality of students' prior knowledge across the groups. Mixed-factor ANOVA models (Howell, 2012; Field, 2013) within one factor (time: pre and post-tests) and between two factors, (group factor [4 levels for intermediate school data and 3 levels for primary school data] and achievement level factor, [2 levels] as the main factor along with a possible interaction factor). Only the changes in the group achievement levels were. Models such as the ANOVA model are robust and avoid making parametric assumptions; however, the constant variance assumption was monitored and was found to be at acceptable levels. The assumption of sphericity was tested and used and Mauchly's test was also used to test the assumption of the sphericity. It became apparent whilst using Levin's test for one-way-ANOVA that this produced homogenous of variances. However, this test was used for repeated-subject design to test the hypothesis that the different variances between conditions (different levels of independent variables) were equal. If the assumption was violated then the Greenhouse-Geisser correction was be used. In addition, some outliers were found which were modified to the nearest scores. Tukey's post hoc test (Howell 2012, Field 2013) was applied when appropriate and where significant results were observed, i.e. an Effect Size [Partial Eta Squared]. The effect size classified as Cohen's suggested was small .01, medium, .06, and large .14. All analysis was performed on IBM SPSS v22 and at a 5% level of significance.

One-way ANOVA models can make a comparison between several groups to check whether they are equal or not. It is an alternative test to two t-test independent samples. However, carrying out two t-tests to compare all combinations of groups can increase the probability of making a Type I error (rejection of null hypotheses). As this study has more than two groups in each stage (primary and intermediate school data), ANOVA models are more suitable to decrease the probability of making a Type I error to less than 5% (0.05) as social scientists agreed this to be the acceptable.

An ANOVA produces an F-statistic which is 'the ratio of the model to its error'. It compares the systematic variance amount (the ratio of the model) to the unsystematic variance amount (the model error). However, an ANOVA cannot tell which groups were affected. To identify which groups have been affected Post hoc tests can be applied. Post hoc tests can make a comparison between each pair of groups to find out which groups were affected. There are many post hoc procedures such as Tukey and REGWQ which can be used. In this study, Tukey's post hoc test was applied when appropriate and where significant results were observed. This procedure has tight control over the Type error rate with a good power.

A mixed-factor ANOVA model is used to examine if there are differences between groups while subjecting participants to repeated measures. It is combined repeated-measure designs and independent designs; namely: 'two between-subjects variables and one within-subjects variable'. Two between-subjects variables are type of treatment and achievement level (independent designs), while the within-subjects variable is a time factor (repeated-measure designs).

Repeated-measure designs are when the same participants play a part in all conditions of the experiment. It uses a common subject pool to reduce overall variability and remove the differences of subjects from the error term to leave the error components independent from manipulation to manipulation (Howell, 2012).

The author had taken Social Science Statistic 1 and 2 at the University of Glasgow and then began Teaching Social Science Statistic 1 to postgraduate students at the University of Glasgow as a tutor. The reason for this was to improve his statistical skills in order to use statistic in analysis his study more effectively.

4.18 Qualitative analysis

Tape-recordings were used for the interviews which ranged from 13 to 23 minutes with each teacher. The interviews were conducted in Arabic, transcribed and subsequently translated into English by the researcher. The data obtained from the semi-structured interview was then manually coded in line with interview questions to six themes. The thematic analysis aims to describe and interpret the participants' perspectives (Firth, 2011).

Field observation notes were also analysed thematically. In this study, the field observation notes, and the semi-structured interview analyses were mixed for deeper view of the event. Observations and interview methods could be combined to enhance the validity of the study and to gain a deeper understanding of about the social events. "*Looking at something from several different points gives a more accurate view of it*." (Neuman, 2000, p: 521). This can be done by applying triangulation.

The analysed field observation notes were compared with the outcomes of the semi-structured interview analysis to gain a deeper understanding and enhance credibility. The summary of the interview was then given to the teachers for confirmation of accuracy. This gave the findings more credibility and made them more reliable (see 'Validity and Reliability in the 'Mixed Methods Research' section for more details).

4.18.1 Thematic analysis

Thematic analysis is a generic skill across qualitative analysis (Holloway and Todres, 2003) which is considered as a tool to use with through different methods (Boyatzis, 1998). For example, it can be a method to identify, analyse and report themes within data (Braun and Clarke, 2006). A theme presents something important about the data related to the research question and can have multiple aspects.

Themes within data can be recognised in one of two main ways in thematic analysis: in an inductive or a deductive approach. An inductive or data-driven way, themes are driven only by the data itself without necessarily having to engage with the prior analysis of literature (Patton, 1990; Braun and Clarke, 2006). A deductive or a theoretical way is driven by the researcher's analytic or theoretical interest in the area (Braun and Clarke, 2006).

In the current study, the themes are driven by researcher' theoretical interest in PBL settings, which was influenced by the literatures reviewed about the area; this requires coding for specific research questions.

There are two levels of identifying themes: sematic (explicit) or latent (interpretative) (Boyatzis, 1998). The themes in the sematic level is to identify data with an explicit meaning, while with the latent level, the analyst goes beyond the explicit data (Braun and Clarke, 2006). In fact, in this study, these levels were mixed. For example, the first question of the interview was 'How was PBL implemented in your teaching strategies?'. This question was aimed, not at describing the process of how PBL implementation was applied by the different teachers, but to go beyond the description and establish whether the teacher implemented PBL appropriately or not. Other questions in the interviews can be attributed to the sematic level, such as 'What are the disadvantages of using PBL teaching strategies?'

In the present study the semi-structured interview data was analysed in six phases, as suggested by Braun and Clarke, (2006). After the data was conducted in Arabic, transcribed and translated into English by the researcher the first step was for the researcher to familiarise himself with the data. The researcher collected the data himself and he repeatedly read it and searched for meaning and made notes about expected codes. As the researcher followed a deductive approach he was only concerned with the codes which related to the research questions.

The second step was to generate the initial codes. In this stage the researcher begins coding being mindful of the fact that the themes are more theory-driven, and contain mixed levels: sematic and latent, as discussed above. This made the coding processes clearer and easier. The coding was carried out manually by making notes on the texts and highlighting potential themes.

The third step was to search for themes which involved the researcher sorting the different codes into possible themes. This was done by using tables with two columns: the data extracts and code, see Table 4.16 as an example of the theme of identifying the disadvantage of implementing PBL, from the trained primary school teacher. This helped to shape the potential themes by playing around with and organizing themes.

Table: 4:16: example of analysing and coding the interview for the trained primary teacher

the data extracts	code
With traditional methods the time is controlled by the teacher, whereas with PBL teaching strategies the time is controlled by students.	Time-consuming
Some of the low achieving students were depending on the high achievers to solve problems which meant that they did not learn." In order to avoid this problem he suggested that: "Students should be given exercises and assessed individually.	Depending on others

The fourth step was to review the themes and divide them into two levels, as suggested by Braun and Clarke, (2006), assessing the collated extracts for each theme ensuring they were coherent and assessing the validity of the meaning of each theme in relation to the whole data set. Therefore, the researcher firstly read through the collated extracts for each theme to make sure a coherent pattern was formed and secondly, ensured the themes had meaningful relationships with each other.

The fifth step was to define and name the themes; in this stage, the researcher defined and refined the themes and analysed the data within them and then determined what aspect of the data each theme included. Six final themes emerged, namely: PBL implementation, advantage of using PBL, disadvantages of using PBL, challenges of using PBL, students with a lack of perquisite knowledge or skills and engagement in the PBL process. The sixth step was to produce a report that provided sufficient evidence for each theme.

In field observation notes, the analysis processes were similar to those for the semi-structured interview data. After describing the situations from inside the classrooms by taking notes, the researcher then reflects on the data outside of the classrooms in order to be more accurate, organised and focused on the research problems. When the data was completed, the six phases suggested by Braun and Clarke, (2006) were applied. Starting from familiarising the researcher with the data by reading and searching for meaning and making notes about expected codes related to the research questions. The second step was to generate the initial codes manually. The third step was to search for themes.

The fourth step was to review the themes. The fifth step was to define and name the themes. Three final themes emerged, namely: Teachers' implementation of PBL, disadvantages of implementing PBL, and advantages of implementing PBL. The sixth step was to produce a report that provided sufficient evidence for each theme.

4.19 Ethical Considerations

The study was subject to the ethical procedures of the University of Glasgow. It had been reviewed and approved by the College of Social Sciences Research Ethics Committee. All participants and children's parents were provided with plain language statements to illustrate the aim of the study and detail the procedures in respect of collecting the data. They were all willing to participate and signed the consent letter provided.

All the information collected has been kept strictly confidential. The participants are identified by an ID number or false name and no personal information has been used. They were also informed that once the data has achieved its purpose it would be destroyed.

All participants were informed that they were able to withdraw from the research at any time without having to give any reason. The teachers were informed that all interviews would be recorded and gave their consent for audio recording to be used.

A significant aspect of the research design was to ensure that, for both quasi-experiments, all groups were treated equally. This was done by exchanging the treatments: PBL and traditional teaching methods. However, in this thesis, the author has presented only data of the first stage of the experiments (before exchanging treatments between groups), to answer the questions of the study, while the other data were kept to be analysed and publishing later.

The schools "A and B" in Saudi Arabia were selected based on the expression of assistance and cooperation received from the administration and teachers of the school.

Pupils who participated were given a consent form which was also be signed by their parents. This was done after they have been provided with a plain language plain statement to ensure that they understood what the research is about, how they will participate and be assessed, and how long the implementation of the study will last. They were also informed that they can withdraw at any time from participation if they wish without the necessity to give a reason, and this is not going to affect their school marks or their relationship with teachers or with others. The researcher is not a teacher in either of the schools. Therefore, the teachers' and pupils' decision to participate or not to participate in this study was not affected by their relationship to the researcher. The researcher monitored the implementation of the research.

4.20 Conclusion

This chapter has presented the approach of the research undertaken in this study. The field work has been done within the guidance of the ethical procedures employed by the University of Glasgow. Mixed methods were used to enhance the reliability and validity of the conclusions. The participants, instruments, topics, designing problems, time allocated, CPD workshops and procedures were described in detail. The validity and reliability were tested for each instrument. Statistical tests were selected to answer the questions of the research and they are described in this chapter. In the next two chapters the results of the study in the intermediate and primary school will be presented.

Chapter Five: the result of the intermediate school data

5.1 Introduction

The main purpose of this study was to investigate the effects on achievement and Attitudes towards Mathematics levels, of students taught using PBL teaching strategies, by trained (trained face-to-face) and untrained (self-directed learning) teachers. The study also aimed to examine the interactions of both high and low achievers who had been taught using PBL strategies by both trained teachers and untrained teachers. These data are primarily quantitative. In addition, and supplementary to the quantitative data, the study also investigated the teachers' perspectives on their experiences of implementing PBL strategies in the classroom, using qualitative approaches, more specifically semi-structured interviews. These data were also triangulated with field observation notes of the teachers actually working in the classroom. Furthermore, the quantitative investigations also compared the effects upon achievement and attitudes, of the teaching styles of teachers who had been trained in using PBL strategies with those who had conducted self-directed learning (and were not trained). A comparison of pupils' outcomes with the PBL teaching styles was also made with that of conventionally taught pupils.

The aim of this chapter is to present the results of the data that has been collected from the field work study for intermediate school students. However, the primary schools student data will be presented in chapter 6. The procedure of implementing the study has been fully discussed in Chapter 4.

For the principal quantitative findings, all assessment outcome variables are presented as summary statistics. One-way ANOVA models (Howell, 2012; Field, 2013) between groups are applied to check the equality of all the students' prior knowledge across the groups. Mixed-factor ANOVA models (Howell, 2012; Field, 2013) within one factor (time: pre and post) and between two factors, group factor [4 levels] and achievement level factor [2 levels] are the main factors, along with a possible interaction factor. Change in achievement was analysed by group only. Such models are robust to depart from parametric assumptions; however, the constant variance assumption was monitored and was found to be at acceptable levels. Tukey's post hoc test (Howell, 2012; Field, 2013) was applied when appropriate and where significant results were observed; an Effect Size [Partial Eta Squared ($\eta p2$)] is also reported. All analyses were performed on IBM SPSS v22 and at a 5% ($p = 0.05$) level of significance. For the additional qualitative findings, teachers were interviewed about their experiences of implementing PBL and the results are presented later in this chapter. A research diary was kept which recorded a detailed commentary with regards to implementing the study. Observations from this diary are included in this chapter. These data are summarised in Table 5.28. Finally, qualitative and quantitative findings are integrated with respect to the research questions. This integration is presented in section 5.10 and Table 5.29.

5.2 Intermediate School Students

The aim of this study was to investigate the effects of PBL teaching strategy on students' achievement levels (knowing, applying and reasoning achievement) and students' Attitudes towards Mathematics levels (Like Learning Mathematics, placing value on mathematics and confidence to learn mathematics). In addition, the study examined whether the achievements and attitudes towards mathematics levels were affected in the students who had been taught both by the teachers who had undertaken face-to-face CPD courses or by the teachers who were asked to conduct self-directed learning in teaching PBL strategies, or both.

This study then went deeper to investigate the interactions of high and low achievers using students who had been taught using PBL strategies by trained teacher and untrained teachers in terms of their achievement and Attitudes towards Mathematics. The study also examined the teachers' perspective of their experience of implementing PBL in their classrooms. The investigations compared the teaching styles of teachers who had been trained in using PBL strategies with those who had not, and the teaching styles used with the PBL strategies were also compared to the teaching styles which used conventional methods.

18 multiple-choice questions (short answer questions, fill in table questions, and drawing tests) were applied at the beginning of the study (pre-test) and in the final experiment (post-test). The tests consisted of six items measuring the knowing domain, seven items covering applying ability, and five items assessing reasoning ability, see (appendix 4.A.4).

Attitudes towards Mathematics were assessed using 12 items applied twice as pre and post measures. 12 items 4 Likert-Scales were used, covering three aspects of Attitudes towards Mathematics: Like Learning Mathematics (4 items), placing value on mathematics (4 items) and confidence to learn mathematics (4 items) see appendix4.A.5.

Semi-structured interviews were conducted with all teachers (the trained face-to-face teacher and the untrained teacher) before and after the implementation of the study. This aimed to ensure that all teachers had the same experience, expertise, beliefs and attitudes towards student-centred learning and also to investigate their experiences after the implementation of PBL. These instruments and procedures have been discussed in detail in chapter 4.

Four groups were selected to be part of this study; group A (the trained teacher PBL group), group B (the trained teacher conventional group), group C (the untrained teacher PBL group), and group D (the untrained teacher conventional group). The teachers were similar in terms of qualification, experience and expertise and also in their beliefs and perspectives on PBL and traditional teaching methods. However, one teacher was selected randomly to receive CPD training in PBL and another was provided with the materials of PBL, such as design problems and guidelines for implementing PBL to conduct self-directed learning. However, he did not receive any CPD training. Students were equal between all groups and were chosen based on school records, as explained in Chapter 4.

The study attempted to answer the following questions:

1. What are the effects of PBL teaching strategies, using trained and untrained teachers, on students' achievement levels (knowing, applying, and reasoning) when compared with conventional methods?
2. What are the effects of PBL teaching strategies, using trained and untrained teachers on, students' motivation (attitudes towards mathematics, placing value on mathematics, and confidence to learn mathematics) when compared with conventional methods?
3. Is there significant any interaction between treatment and levels of achievement (high and low achievers) in students' achievement levels in 'knowing', 'applying', and 'reasoning'?
4. Is there any significant interaction between treatments and levels of achievement (high and low achievers) in students' motivation (attitudes towards mathematics, placing value on mathematics and confidence to learn mathematics)?
5. What is the perspective of the teachers about PBL after the treatments when compared with conventional teaching methods?

This chapter details the assumptions of Mixed between-within subjects ANOVA, and will be discussed first and, then the data of mathematics achievements and attitudes towards mathematics will be followed. Finally, the qualitative data will be analysed at the end.

5.3 Assumptions of Mixed Between-Within Subjects ANOVA

There are main three assumptions which were applied to the Mixed Measures ANOVA model, namely: '*Homogeneity of Variance', 'Normality' and 'Sphericity' (*Cardinal and Aitken, 2013; Field, 2013; Howell, 2012). It is important to remind the reader that, as discussed previously, the Mixed Measures ANOVA model is a combination of two approaches: repeated measures and independent design and therefore, data have to meet the assumptions of each design. This means that if the data meets the assumptions of the Mixed Measures ANOVA model, the assumptions for each design have already been met. The data for this study has met all the necessary assumptions for all the statistical tests used. This indicates that using the Mixed Measures ANOVA Model is appropriate for this study. In the following section, Normality, Sphericity and Homogeneity of Variance will be discussed and tested.

5.3.1 Normality

For each condition it is assumed that the scores meet normal distribution around the mean; it is the same to say that within each condition, error is normally distributed (Cardinal and Aitken, 2013). In order to test the normality there are several methods, such as histograms, skewness and kurtosis values, and tests, such as Kolmogorov-Smirnov (K-S) Test, Shapiro-Wilk test and Anderson-Darling test. These tests are used to determine whether the sample data is normally distributed or not. It is common to stick with only one main type of normality test (Ghasemi and Zahediasl, 2012; Howell 2012; Field 2013; Cardinal, and Aitken, 2013).

The tests compare the sample scores to a set of scores that are normally distributed using the same mean and standard deviation. In other words, it tests the null hypothesis assuming that the sample scores are normally distributed, so if the result is significant (less than .05) then the sample scores are not normal (Ghasemi and Zahediasl, 2012). The Shapiro–Wilk test (Shapiro andWilk, 1965) is recommended as the best choice for checking the normality of sample data tests (Ghasemi, and Zahediasl, 2012; Howell, 2012; Field, 2013; Cardinal and Aitken, 2013).

Although ANOVA is a robust test which can lead to valid results, even if the data has violated the normality, it is not known how a violation can be tolerated, and it is more reliable for the results of the data analysis to establish normality in the data before carrying on with its analysis (Howell, 2012; Field, 2013). The Shapiro–Wilk test is used in this study to test the normality of the data. The results of the Shapiro–Wilk test for each cell of data (condition) should not be significant (Field, 2013).

The main statistical model has been used in this study (Mixed Between-Within Subjects ANOVA), with two approaches being combined in the one study. One approach is the repeated measures design (one independent variable within-subjects variable with two levels: pre and post) and other independent variables between-subjects (groups with four levels, and the achievement ability levels with two levels). Therefore, there are eight cells (conditions) [2 times×4 groups = 8 conditions]. In addition, there are two conditions, low and high levels of students' abilities. Therefore, 10 conditions were tested for normality by using the Shapiro–Wilk test. The results show that the data met the assumption of normality, see Table5.1.

5.3.2 Sphericity

Sphericity should be met in repeated subject ANOVA tests to avoid making Type I errors. It can be tested by using Mauchly's Test of Sphericity and, if the result is significant ($p < .05$), it means that the Sphericity has been violated and then the Greenhouse–Geisser test can be used. Sphericity assumes that different variances within groups are equal; it is similar to the homogeneity of variances, but the difference between them is that the homogeneity assumes the equality of variances between groups while Sphericity assumes the equality of variances within groups.

For the purposes of this study there is no need to test the assumption of Sphericity because the factor of within subjects has only two levels (time with pre and post). Thus, the Sphericity assumption is already met for a within-subjects factor that has only two levels (Field, 2013; Cardinal and Aitken, 2013).

Table5.1: Shapiro-Wilk test for knowing scores (intermediate school students)

Test	group	Statistic	df	sig	Test	group	Statistic	df	sig
Pre-knowing	A	.899	17	.065	Post-knowing	A	.913	17	.112
	B	.911	17	.103		B	.920	17	.147
	C	.900	14	.111		C	.892	14	.086
	D	.902	16	.085		D	.908	16	.108
	high	.859	31	.061		high	.868	31	.076
	Low	.802	33	.052		low	.845	33	.092
Pre-applying	A	.906	17	.086	Post-applying	A	.908	17	.094
	B	.897	17	.060		B	.919	17	.142
	C	.878	14	.054		C	.906	14	.140
	D	.906	16	.100		D	.895	16	.067
	high	.897	31	.077		high	.868	31	.058
	Low	.798	33	.051		low	.844	33	.098
Pre-reasoning	A	.920	17	.147	Post-reasoning	A	.901	17	.071
	B	.911	17	.103		B	.930	17	.217
	C	.900	14	.111		C	.916	14	.190
	D	.902	16	.085		D	.891	16	.058
	high	.913	31	.055		high	.879	31	.062
	Low	.829	33	.101		low	.865	33	.081
Pre-like learning mathematics	A	.924	17	.170	post-like learning mathematics	A	.957	17	.576
	B	.943	17	.355		B	.952	17	.490
	C	.881	14	.061		C	.881	14	.060
	D	.971	16	.853		D	.932	16	.262
	high	.921	31	.066		high	.925	31	.052
	Low	.917	33	.075		low	.960	33	.253
Pre-value mathematics	A	.929	17	.207	Post-value mathematics	A	.957	17	.584
	B	.940	17	.322		B	.906	17	.085
	C	.944	14	.470		C	.884	14	.066
	D	.896	16	.070		D	.923	16	.188
	high	.680	31	.089		high	.776	31	.090
	Low	.938	33	.058		Low	.933	33	.051
Pre-confidence to learn mathematics	A	.933	17	.242	Post-confidence to learn mathematics	A	.969	17	.808
	B	.919	17	.141		B	.894	17	.054
	C	.934	14	.343		C	.913	14	.176
	D	.899	16	.076		D	.913	16	.128
	high	.855	31	.101		high	.915	31	.058
	Low	.949	33	.125		Low	.961	33	.278

A= PBL with trained teacher's group, **B**= conventional method with trained teacher's group, **C**= PBL with untrained teacher's group, and **D**= conventional method with untrained teacher's group. **High** =high achievers, and **low**= low achievers

5.3.3 Homogeneity of Variance

The homogeneity assumes the equality of variances between groups. Levene ' s test (Levene, 1960) tests this assumption. If the result of the test is significant ($p < .05$), the assumption is violated (Howell, 2012; Cardinal and Aitken, 2013; Field, 2013). In the present study the assumptions for homogeneity of variance between groups were tested using Levene's test. No significant results were found. (See Table5.2).

Table5.2: Levene's Test of Equality of Error Variances for intermediate school students

Groups between	F	df1	df2	Sig.
Pre-knowing	2.229	7	56	.145
Post-knowing	2.708	7	56	.117
Pre-applying	.642	7	56	.719
Post-applying	.526	7	56	.811
Pre-reasoning	1.065	7	56	.398
Post-reasoning	.847	7	56	.554
Pre-like learning mathematics	1.604	7	56	.153
Post-like learning mathematics	2.119	7	56	.056
Pre-value mathematics	4.409	7	56	.067
Post-value mathematics	1.022	7	56	.426
Pre-confidence to learn mathematics	2.294	7	56	.051
Post-confidence to learn mathematics	1.875	7	56	.091

The data of study is met with three main assumptions of Mixed Between-Within Subjects ANOVA: Homogeneity of Variance, Normality and Sphericity; therefore it is appropriate and valid to analysis the data of the study.

5.4 Mathematics Achievement

Three domains were selected to assess the students' abilities in 'Mathematics Achievement. These were: 'Knowing Achievement', 'Applying Achievement' and 'Reasoning Achievement'.

One-way ANOVA had been applied on pre-test of Knowing Mathematics, Applying mathematics, and Reasoning mathematics achievements to ensure that all students across the groups are similar before the treatment.

The test shows that there is no statistically significant difference in the pre-tests of Knowing Mathematics, Applying mathematics, and Reasoning mathematics achievements between groups, F (3, 60), p <0.05, see ANOVA Table in Appendix 5.1. Therefore, all groups were equal for implementation of the treatment.

In this section the ANOVA model was used to analyse each domain separately; this was considered to be the most appropriate method to adequately measure the effectiveness of PBL on 'Mathematics Achievement' with trained and untrained teachers for high achievers, low achievers and a combination of all students.

5.4.1 Knowledge

Table 5 3: Summary statistics for 'Knowledge' scores and achievement levels by groups and within specified time

Knowing Achievement	A (training and PBL)		B (training and tradition)		C (non-training and PBL)		D (non-training and tradition)	
Student ability levels	High	Low	High	Low	High	Low	High	Low
Pre-score Mean	2.30	0.71	1.89	0.63	2.14	0.29	2.60	0.82
SD	0.48	0.49	0.93	0.52	0.90	0.49	0.55	0.60
Mean	1.65		1.29		1.21		1.38	
SD	0.93		0.96		1.19		1.03	
Post-score Mean	2.90	1.57	1.67	1.00	1.29	1.00	2.40	1.18
SD	0.99	0.54	1.50	0.76	0.76	0.58	1.14	1.17
Mean	2.35		1.35		1.14		1.56	
SD	1.06		1.22		0.66		1.26	

From Table 5.3it can be seen that the improvements in the 'Knowing Achievement' scores were small, with three of the four groups (groups A, B and D) experiencing an increase in their mean score, while one of the four groups' scores (group C), slightly decreased. In addition, the mean pre score was in general higher for the high achievers within each group. The improvement was more marked in the lower achiever scores and for three of the groups whilst the average achievement scores in the higher achievers' groups were slightly decreased.

From the ANOVA analysis Table 5.4, it can be seen that, despite the significant difference between the groups (the difference between groups in the combination of pre-and post-tests), there was no significant overall group effect which was observed over time ($F(3, 56) = 1.88$, $p = .140$, partial $\eta^2 = .09$). This means that there was no significant difference between the groups attributed to the types of treatment in 'Knowing Mathematics Achievement'. It also shows no significant interaction effect between groups and their levels of achievement over time ($F(3, 56) = 1.10$, $p =.355$, partial $\eta 2 = .056$). This implies that in 'Knowing Mathematics Achievement' the students' results were not significantly affected by the interaction of the types of treatment with different levels of students (high and low achievers). In other word, the trends of the high and low achievers within each group were similar across all groups, (see Figure 5.1). In addition, there was no significant difference between the students' average 'Knowing Achievement' mean scores over time, with estimated mean scores of 1.42 and 1.63 for pre and post-test scores respectively, ($F(1, 56) = 2.339$, $p =.132$, partial $\eta 2 = .040$). This indicates that overall, students' achievement in 'Knowing' did not significantly improve. However, there was a very significant difference between the overall level effect over time, ($F(1, 56) = 1.88$, $p =.007$), with increasing low level and decreasing high level scores. The partial eta square effect size for this significant result was medium at 0.123, (see Table 5.3and 5.4 and Figure 5.1). This means that the average change in scores for all low achievers was significantly greater than the average change in the scores of the high achievers in 'Knowledge Achievement'. Furthermore, the average increase in the 'Knowledge Achievement' scores of all low achievers was significant ($F(1, 29) = 12.487$, $p =.001$) with estimate scores of pre-test .611 and post-test 1.188 being achieved. The partial eta square effect size for this significant result was large at 0.301, (see Table 5.5). This improvement was not significantly interacted with the groups ($F(1, 29) = .577$, $p =.635$). However, the decrease in the average scores for 'Knowledge Achievement' for all high achievers was not significant ($F(1, 279) = .632$, $p =.434$) with estimate scores of pre-test 2.233 and post-test 2.063 being achieved, (see Table 5.6). This decline was also not significantly interacted with the groups ($F(1, 27) = 2.299$, $p =.100$. Therefore, it can be said that the average scores for the low achieving students was significantly improved, with a large size effect being achieved in students' 'Knowledge Achievement' scores, although there was no significant deterioration in the scores of the high achievers'.

It would be not be advisable to investigate the changes of high and low achievers within groups because this might lead to unreliable results, particularly as there was no noticeable effects in respect of the types of the treatments on the levels of achievement with both the high and low achievers. In addition, this research is interested in establishing any significant results in achievement between groups rather than within groups.

Table 5.4: ANOVA results for all students (Mixed ANOVA outcomes for Knowing achievement)

Test	df	F	p-value	Partial Eta Squared
Time	1	2.339	.132	.040
Groups	3	3.908	.013*	.173
Time * groups	3	1.876	.144	.091
Time * level achievement	1	7.860	.007**	.123
Time * levels of achievement * groups	3	1.104	.355	.056
Error (time)	56			

Note: p* is significant < 0.05, p** is significant >0.01

Table 5.5: Low achievers by groups in Knowing

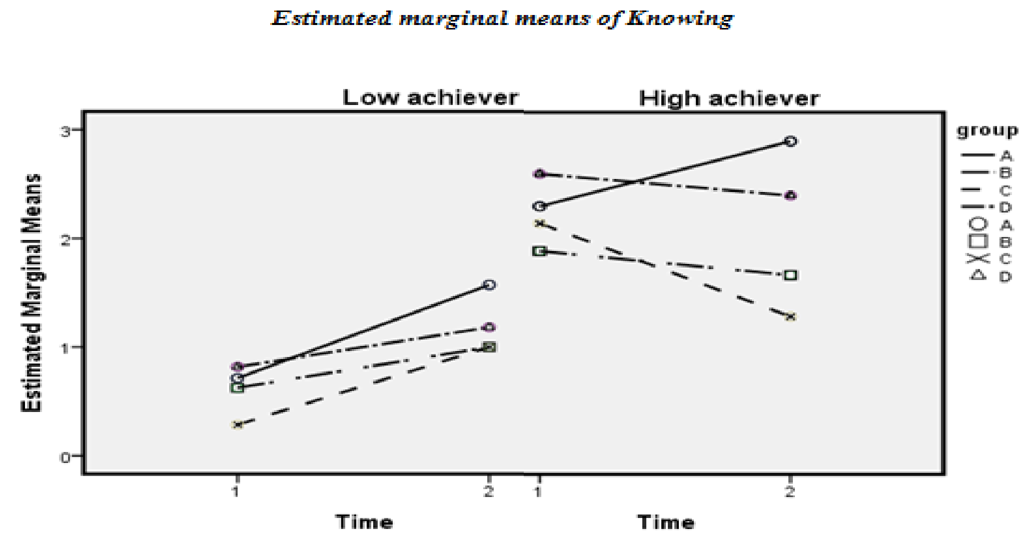
Test	df	F	p-value	Partial Eta Squared
Time	1	12.487	.001**	.301
Time * groups	3	.577	.635	.056
Error (time)	29			

Note: p* is significant < 0.05, p** is significant >0.01

Table 5.6: High achievers by groups in Knowing

Test	df	F	p-value	Partial Eta Squared
Time	1	.632	.434	.023
Time * groups	3	2.299	.100	.203
Error (time)	27			

Note: p* is significant < 0.05, p** is significant >0.01



A is the trained teacher's PBL group

B is the trained teacher's traditional group

C is the untrained teacher's PBL group

D is the untrained teacher's traditional group

Figure 5 1: High and low achievers' average achievement scores in knowledge

As Figure 5.1 and Table 5.3show, the low achiever group's mean scores all increased whilst for the high achiever groups, the mean 'Knowledge' score decreased for three of the groups. Only group A's scores (the trained teacher's PBL group) increased for both high and low achievers. On average, the high and low achievers' scores changed in opposite directions, however, only the increase in the low achiever scores was large enough to be statistically significant. However, the overall significant difference in changes in the 'Knowledge Achievement' scores between high and low achievers over time was not affected by the types of treatment.

Overall, students' 'Knowing Achievement' scores did not significantly improve. The low achievers' scores significantly improved and the high achievers' scores did not significantly deteriorate in 'Knowledge Achievement'. This might explain why the average scores of all students did not significantly improve in the 'Knowledge Achievement' post-tests scores. The difference between the high and low achievers scores in 'Knowledge Achievement' over time was not significantly interacted by the types of the treatment. In addition, there was no significant difference between groups attributed to the types of treatment in 'Knowing Mathematics Achievement'. This indicates that using PBL is unlikely to improve achievement in 'Knowledge Mathematics' any more than when using traditional teaching methods. In addition, training teachers in PBL implementation could not have any effect on students' knowledge mathematics achievement. Finally, it can be concluded that in respect of mathematics achievement the different ability levels of students is unlikely to have any effect on their performance in 'knowing mathematics achievement' when using the PBL teaching strategy.

5.4.2 Applying

Table 5.7: Summary statistics for Applying scores within time and by groups and achievement levels

Applying Achievement	**A (training and PBL**		**B (training and tradition)**		**C (non-training and PBL)**		**D (non-training and tradition)**	
Student ability levels	High	Low	High	Low	High	Low	High	Low
Pre-score Mean SD	 3.00 0.67	 1.00 0.58	 2.44 0.53	 1.13 0.35	 2.43 0.54	 1.00 0.57	 2.60 0.55	 1.01 0.54
Mean SD	2.18 1.19		1.82 0.81		1.71 0.91		1.56 0.89	
Post-score Mean SD	 2.60 0.97	 2.14 1.07	 2.33 1.00	 1.88 1.13	 2.00 1.52	 1.43 1.13	 2.40 1.34	 1.82 1.25
Mean SD	2.41 1.00		2.12 1.05		1.71 1.33		2.00 1.27	

From Table 5.7 it can be seen that the improvements in "Applying Achievement" mean scores were small, with three of the four groups experiencing an increase in their mean score, while one of the four groups' scores (group C), remained the same. In addition, the mean pre score was in general higher for the high achievers within each group. The improvement was more marked in the lower achiever scores and for all groups whilst the average achievement scores in the higher achievers' groups were slightly decreased.

From the ANOVA analysis (Table 5.8) it can be seen that, there was no significant difference between the students' average 'Applying Achievement' mean scores over time, with estimated mean scores of 1.84 and 2.08 for pre and post-test respectively, $F(1, 56) = 2.61$, $p = .112$, partial $\eta 2 = .045$. This indicates that overall, students' achievement in 'Applying' did not significantly improve. Furthermore, there was no significant overall group effect which was observed over time, $F(3, 56) = 0.303$, $p = .823$, partial $\eta 2 = .016$. This means that there was no significant difference between the groups attributed to the types of treatment in 'Applying Mathematics Achievement'. However, there was a very significant difference between the overall level effect over time $F (1, 56) = 12.57$ $p =.001$, with increasing low level and decreasing high level scores. The partial eta square effect size for this significant result was large at 0.183, see Table 5.7 and 5.8, and Figure 5.2. This means that the average change in scores for all low achievers was significantly greater than the average change in the scores of the high achievers in 'Applying Achievement'. It also shows no significant interaction effect between groups and their levels of achievement over time $F (3, 56) = .336$, $p =.800$, partial $\eta 2 = .018$. This implies that in 'Applying Mathematics Achievement' the students' results were not significantly affected by the interaction of the types of treatment with different levels of students (high and low achievers). In other word, the trends of the high and low achievers within each group were similar across all groups, see (Table 5.8 and Figure5.2).

Furthermore, the average increase in the 'Applying Achievement' scores of all low achievers was significant, $F (1, 29) = 16.660$, $p =.000$ with estimate scores of pre-test 1.054 and post-test 1.816 being achieved. The partial eta square effect size for this significant result was large, .365, (see Table 5.9). This improvement was not significantly interacted with the groups, $F (1, 29) = .542$, $p =.658$. However, the decrease in the average scores for 'Applying Achievement' for all high achievers was not significant, $F (1, 279) = 1.514$, $p =.229$ with estimate pre-test 2.618 and post-test 2.333 being achieved. This decline was also not significantly interacted with the groups, $F (1, 27) = .126$, $p =.944$, (see Table 5.10). Therefore, it can be said that the average scores for the low achieving students was significantly improved, with a large size effect being achieved in students' 'Applying Achievement' scores, although there was no significant deterioration in the scores of the high achievers'.

Table 5.8: Applying (Mixed ANOVA outcomes for Applying achievement)

Test	df	F	p-value	Partial Eta Squared
Time	1	2.61	.112	.045
Groups	3	1.116	.350	.056
Time *Groups	3	.303	.823	.016
Time * level achievement	1	12.57	.001**	.183
Time * levels of achievement * groups	3	.336	.800	.018
Error (time)	56			

Note: p* is significant < 0.05, p** is significant >0.01

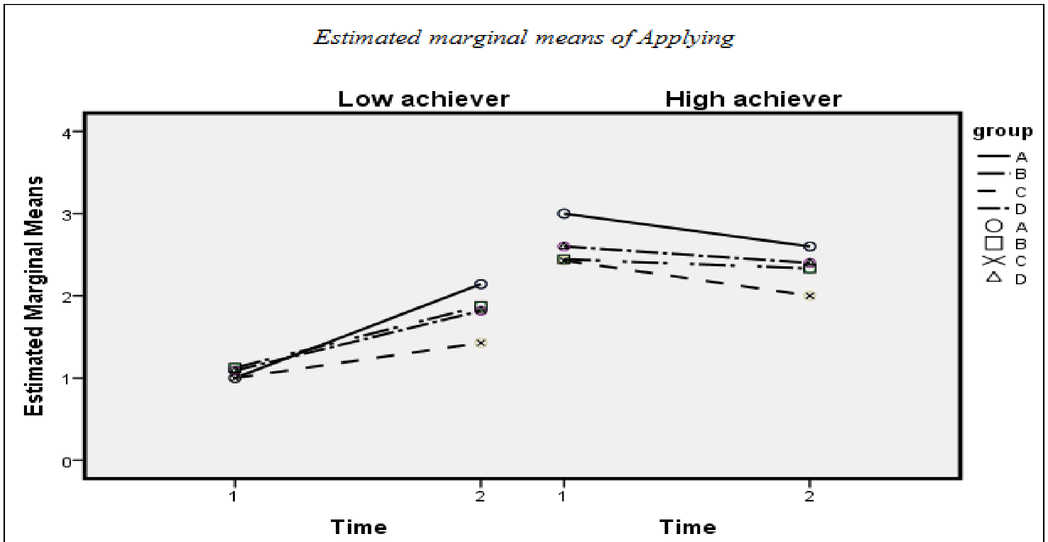
Table 5.9: Low achievers for all students by groups in Applying

Test	df	F	Sig.	Partial Eta Squared
Time	1	16.660	.000**	.365
Time * groups	3	.542	.658	.053
Error (time)	29			

Table 5.10: High achievers for all students by groups in Applying

Test	df	F	p-value	Partial Eta Squared
Time	1	1.514	.229	.053
Time * groups	3	.126	.944	.014
Error (time)	27			

Note: p* is significant < 0.05, p** is significant >0.01



A is the trained teacher's PBL group

B is the trained teacher's traditional group

C is the untrained teacher's PBL group

D is the untrained teacher's traditional group

Figure 5 2: High and low achievers' average achievement scores in 'Applying' for each group

As Figure 5.2 and Table 5.7 indicate, the low achiever group's mean scores all increased whilst for the high achiever groups the mean 'Applying' score decreased for all groups. The significant difference between high and low achievers over time was not affected by the groups.

On average, the high and low achievers' scores changed in opposite directions, however, only the increase in the low achiever scores was large enough to be statistically significant. However, the overall significant difference in changes in the 'Applying Achievement' scores between high and low achievers over time was not affected by the types of treatment.

Overall students' 'Applying Achievement' scores did not improve. The low achievers' scores significantly improved and the high achievers did not significantly deteriorate in 'Applying Achievement'. This might explain why the average scores of all students did not significant improve in 'Applying Achievement' post-tests scores. The difference between the high and low achievers in 'Applying Achievement' over time was not significantly interacted by the types of the treatment. In addition, there was no significant difference between groups attributed to the types of treatment in 'Applying Mathematics Achievement'. This indicates that using PBL is unlikely to improve achievement in 'Applying Mathematics' any more than when using traditional teaching methods. In addition, training teachers in PBL implementation could not have any effect on students' applying mathematics achievement. Finally, it can be concluded that in respect of mathematics achievement the different ability levels of students is unlikely to have any effect on their performance in 'applying mathematics achievement' when using the PBL teaching strategy.

5.4.3 Reasoning

From Table 5.11the improvements in 'Reasoning Achievement' were small, with three of the four groups increasing their mean score, while one of the four groups' mean scores decreased. In addition, the mean pre score was in general higher for the high achievers within each group. The improvement was more marked in the lower achiever scores and for all groups whilst the average achievement scores in the higher achievers' groups were slightly decreased.

Table 5.11: Summary statistics for Reasoning scores within time and by groups and achievement levels

Reasoning Achievement	**A (training and PBL**		**B (training and tradition)**		**C (non-training and PBL)**		**D (non-training and tradition)**	
Student ability levels	High	Low	High	Low	High	Low	High	Low
Pre-score								
Mean	1.80	0.14	1.44	0.38	2.14	0.57	2.20	0.55
SD	0.63	0.38	0.53	0.52	0.69	0.54	0.45	0.52
Mean	1.12		0.94		1.36		1.06	
SD	0.99		0.75		1.01		0.93	
Post-score								
Mean	1.70	0.86	0.89	0.50	2.00	1.14	1.60	1.00
SD	0.82	0.69	0.93	0.76	1.00	0.69	1.14	0.74
Mean	1.35		0.71		1.57		1.19	
SD	0.87		0.85		0.94		0.91	

From the ANOVA analysis Table 5.12 it can be seen that, despite the significant difference between the groups (the difference between groups in the combination of pre-and post-tests), there was no significant overall group effect which was observed over time, $F(3, 56) = 1.275$, $p = .292$, partial $\eta 2 = .064$. This means that there was no significant difference between the groups attributed to the types of treatment in 'Reasoning Mathematics Achievement'. It also shows no significant interaction effect between groups and their levels of achievement over time $F(3, 56) = .137$, $p = .937$, partial $\eta 2 = .007$. This implies that in 'Reasoning Mathematics Achievement' the students' results were not significantly affected by the interaction of the types of treatment with different levels of students (high and low achievers). In other word, the trends of the high and low achievers within each group were similar across all groups, (see Figure 5.3). In addition, there was no significant difference between the students' average 'Reasoning Achievement' mean scores over time, with estimated mean scores of 1.15 and 1.21 for pre and post-test scores respectively, $F(1, 56) = .276$, $p = .602$, partial $\eta 2 = .005$. This indicates that overall, students' achievement in 'Reasoning' did not significantly improve. However, there was a very significant difference between the overall level effect over time, $F(1, 56) = 13.48$ $p = .001$, with increasing low level and decreasing high level scores. The partial eta square effect size for this significant result was large at 0.194, (see Table 5.11and 5.12and Figure 5.3). This means that the average change in scores for all low achievers was significantly greater than the average change in the scores of the high achievers in 'Reasoning Achievement'.

Furthermore, the average increase in the 'Reasoning Achievement' scores of all low achievers was significant F (1, 29) = 8.843, p =.006 with estimate scores of pre-test.409 and post-test .875 being achieved. The partial eta square effect size for this significant result was large, .234, (see Table 5.13). This improvement was not significantly interacted with the groups, F (1, 29) = .611, p =.614. In addition, the decrease in the average scores for 'Reasoning Achievement' for all high achievers was significant, F (1, 27) = 4.970, p =.034 with estimate scores of pre-test 1.897 and post-test 1.547. The partial eta square effect size for this significant result was large, .155. This decline was not significantly interacted with the groups, F (1, 27) = .748, p =.533, (see Table 5.14). Therefore, it can be said that the average scores for the low achieving students was significantly improved, with a large size effect being achieved in students' 'Reasoning Achievement' scores, and there was significant deterioration in the scores of the high achievers'.

Table 5.12: Reasoning (Mixed ANOVA outcomes for reasoning achievement)

Test	df	F	p-value	Partial Eta Squared
Time	1	.276	.602	.005
Groups	3	4.106	.011*	.180
Time * groups	3	1.275	.292	.064
Time * levels of achievement * groups	3	.137	.937	.007
Time * level achievement	1	13.478	.001**	.194
Error(time)	56			

Note: p* is significant < 0.05, p** is significant >0.01

Table 5.13: Low achievers for all students by groups in reasoning

Test	df	F	p-value	Partial Eta Squared
Time	1	8.843	.006**	.234
Time * groups	3	.611	.614	.059
Error (time)	29			

Note: p* is significant < 0.05, p** is significant >0.01

Table 5.14: High achievers for all students by groups in reasoning Achievement

Test	df	F	p-value	Partial Eta Squared
Time	1	4.970	.034*	.155
Time * groups	3	.748	.533	.077
Error (time)	27			

Note: p* is significant < 0.05, p** is significant >0.01

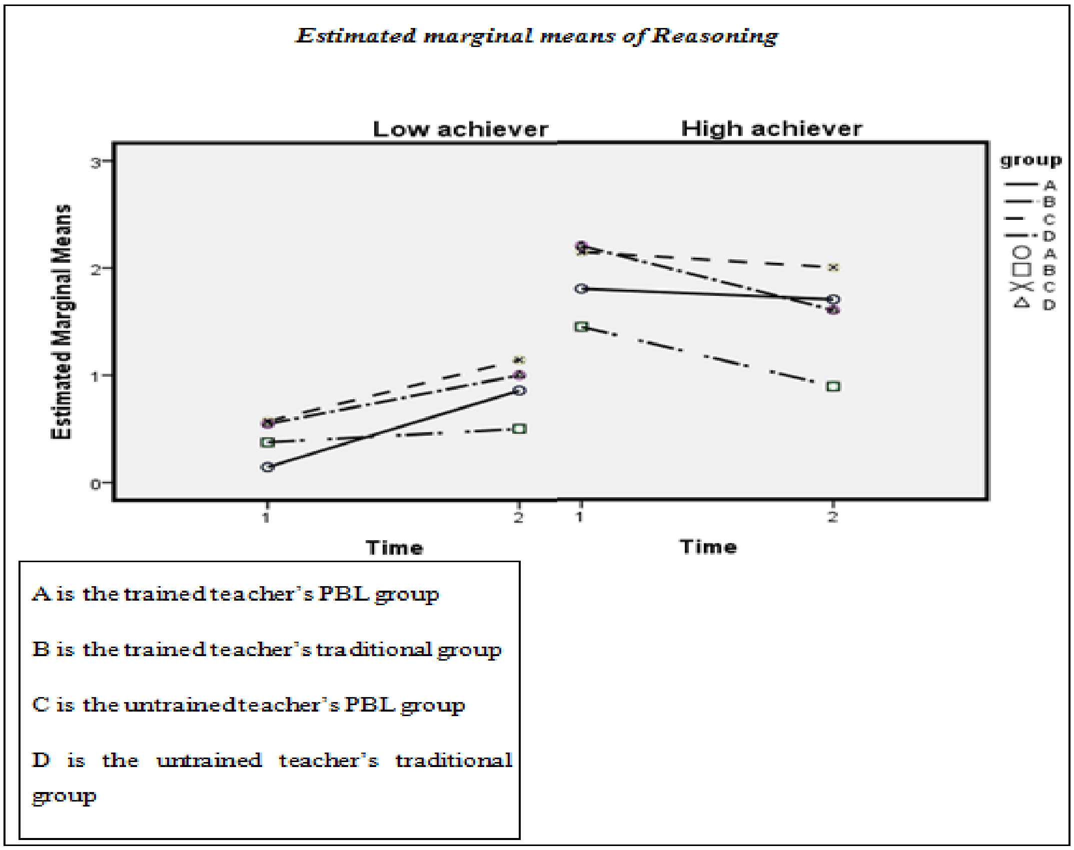


Figure 5 3: High and low achievers' average achievement scores in reasoning

As Figure 5.3 and Table 5.11 illustrate, the low achiever group mean scores all increased whilst for the high achiever groups the mean 'Reasoning' score decreased for all groups. The significant difference between high and low achievers over time was not affected by the groups. On average, the high and low achievers' scores significantly changed in opposite directions. However, the overall significant difference in changes in the 'Reasoning Achievement' scores between high and low achievers over time was not affected by the types of treatment.

Overall students’ ‘Reasoning Achievement’ scores did not significantly improve. The low achievers’ scores significantly improved, and the high achievers’ scores significantly deteriorated in ‘Reasoning Achievement’. This might explain why the average scores of all students did not significantly improve in ‘Reasoning Achievement’ post-tests scores. The difference between the high and low achievers scores in ‘Reasoning Achievement’ over time was not significantly interacted by the types of the treatment. In addition, there was no significant difference between groups attributed to the types of treatment in ‘Reasoning Mathematics Achievement’. This indicates that using PBL is unlikely to improve achievement in ‘Reasoning Mathematics’ any more than when using traditional teaching methods. In addition, training teachers in PBL implementation could not have any effect on students’ reasoning mathematics achievement. Finally, it can be concluded that in respect of mathematics achievement the different ability levels of students is unlikely to have any effect on their performance in ‘reasoning mathematics achievement’ when using the PBL teaching strategy.

5.5 Attitudes towards Mathematics

One-way ANOVA had been applied on pre-measured Like Learning Mathematics, placing value on mathematics and confidence to learn mathematics to ensure that all students across the groups are similar before the treatment.

The test shows that there is no statistically significant difference in the pre-measure of Like Learning Mathematics, placing value on mathematics, and confidence to learn mathematics between groups, $F\ (3, 60)$, $p < 0.05$, see ANOVA Table in Appendix 5.2. Therefore, all groups were equal for implementation of the treatment.

5.5.1 Like learning Mathematics

From Table 5.15 it can be seen that the ‘Like Learning Mathematics’ score means decreased for two of the four groups (groups B and D), while one of the four groups (group C) scores increased and one (group A) remained the same. Furthermore, the mean pre score was in general higher for the high achievers within each group. The improvement was marked in two of the four groups for the lower achiever scores, while the other two groups’ scores slightly decreased. For all groups the results in the higher achiever’s average score was slightly decreased.

Table 5.15: Summary statistics for Like learning Mathematics scores within time and by groups and achievement levels

Like learning Mathematics measures	A (training and PBL		B (training and tradition)		C (non-training and PBL)		D (non-training and tradition)	
Student ability levels	High	Low	High	Low	High	Low	High	Low
Pre-score Mean SD	13.80 1.48	8.14 2.85	13.78 1.72	8.50 2.33	13.86 1.07	6.43 1.62	13.80 1.64	8.73 2.42
Mean SD	11.47 3.54		11.29 3.35		10.14 4.07		10.31 3.26	
Post-score Mean SD	12.80 2.20	9.57 1.62	12.78 2.05	7.75 2.38	12.71 2.87	9.57 4.24	12.00 3.94	8.36 2.94
Mean SD	11.47 2.53		10.41 3.36		11.14 3.84		9.50 3.35	

From the ANOVA analysis Table 5.15it can be seen that there was no significant difference between the students' average 'Like Learning Mathematics' scores over time, with estimated mean scores of 10.88 and 10.69 for pre and post-measure scores respectively, F (1, 56) = .276, p =.602, partial η2 = .005. This indicates that overall, students' scores in 'Like Learning Mathematics' did not significantly improve.

Furthermore, there was no significant overall group effect which was observed over time, F (3, 56) = 1.821, p =.154, partial η2 = .089. This means that there was no significant difference between the groups attributed to the types of treatment in 'Like Learning Mathematics'. However, there was a very significant difference between the overall level effect over time, F (1, 56) = 8.824 p =.004, with increasing low level and decreasing high level scores. The partial eta square effect size for this significant result was medium at 0.136, (see Table 5.15and 5.16, and Figure 5.4 and). This means that the average change in scores for all low achievers was significantly greater than the average change in the scores of the high achievers in 'Like Learning Mathematics'. It also shows no significant interaction effect between groups and their levels of achievement over time F (3, 56) = 1.456, p =.236, partial η2 = .072. This implies that in 'Like Learning Mathematics' the students' results were not significantly affected by the interaction of the types of treatment with different levels of students (high and low achievers). In other words, the trends of the high and low achievers within each group were similar across all groups (see Table 5.16 and Figure5.4).

Moreover, the average increase in the 'Like Learning Mathematics' scores of all low achievers was not significant $F\ (1,\ 29) = 2.284$, $p = .142$ with estimate scores of pre-measure 7.950 and post- measure 8.814 being achieved, (see Table 5.17). This improvement was not significantly interacted with the groups $F\ (1, 29) = 2.387$, $p = .904$. In addition, the decrease in the average scores for 'Like Learning Mathematics' for all high achievers was significant, $F\ (1, 27) = 9.788$, $p = .004$ with estimate scores of pre-measure 13.809 and post-measure 12.573 being achieved. The partial eta square effect size for this significant result was large, .266. This decline was not significantly interacted with the groups $F\ (1, 27) = .188$, $p = .904$, (see Table 5.18). Therefore, it can be said that the average scores for the low achieving students was not significantly improved being achieved in students' 'Like Learning Mathematics' scores, however there was a significant deterioration in the scores of the high achievers' with a large size effect.

Table 5.16: Like learning Mathematics (Mixed ANOVA outcomes for Like Learning Mathematics)

Test	df	F	p-value	Partial Eta Squared
Time	1	.276	.602	.005
Groups	3	.155	.926	.008
Time * groups	3	1.821	.154	.089
Time * levels of achievement * groups	3	1.456	.236	.072
Time * level achievement	1	8.824	.004**	.136
Error (time)	56			

Note: p* is significant < 0.05, p** is significant >0.01

Table 5.17: Low achievers for all students by groups in like learning math

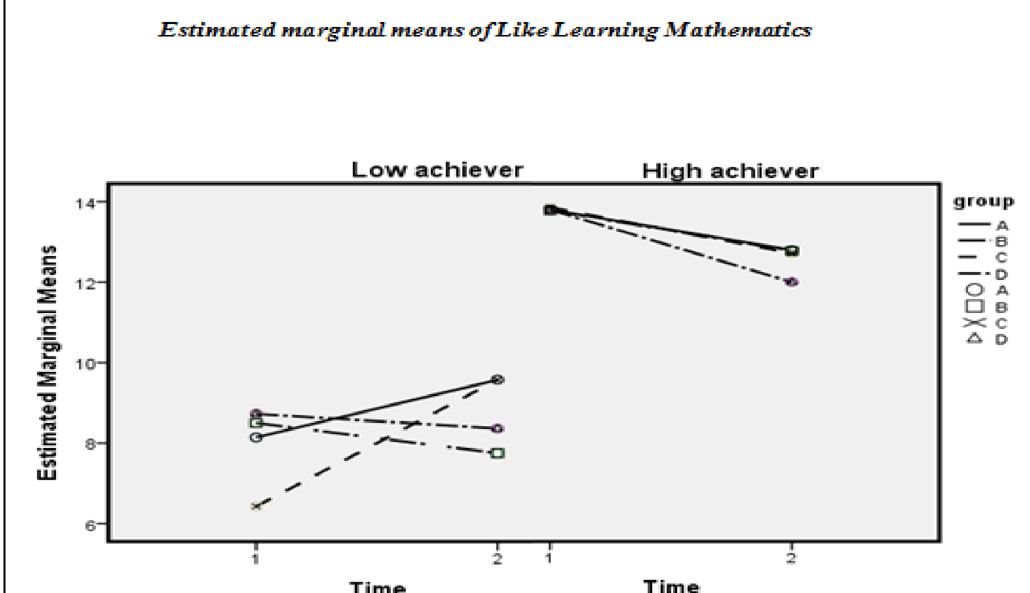
Test	df	F	p-value	Partial Eta Squared
Time	1	2.284	.142	.073
Time * groups	3	2.387	.089	.198
Error (time)	29			

Note: p* is significant < 0.05, p** is significant >0.01

Table 5.18: High achievers for all students by groups in like learning math

Test	df	F	p-value	Partial Eta Squared
Time	1	9.788	.004**	.266
Time * groups	3	.188	.904	.020
Error (time)	27			

Note: p* is significant < 0.05, p** is significant >0.01



A is the trained teacher's PBL group

B is the trained teacher's traditional group

C is the untrained teacher's PBL group

D is the untrained teacher's traditional group

Figure 5 4: High and low achievers' average scores in 'Like Learning Mathematics' for each group

As Figure 5.4 and Table 5.15 show, the low achiever group means in two of the four groups increased (group A and C), while the means of two groups decreased. For the high achiever groups the mean 'Like Learning Mathematics' score decreased for all groups. The significant difference between high and low achievers over time was not affected by the groups. On average, the high and low achievers' scores changed in opposite directions, however, only the decrease in the high achiever scores was large enough to be statistically significant. However, the overall significant difference in changes in the 'Like Learning Mathematics' scores between high and low achievers over time was not affected by the types of treatment.

From Figure 5.4 it is clear that PBL groups, A and C, increased for low achievers while decreased for traditional groups, B and D. further analysis indicates that on average the low achievers' scores changed in opposite directions for PBL groups and traditional groups, these changes were large enough to be statistically significant between PBL and traditional groups, with increasing the PBL groups' scores and decreasing the traditional groups' scores, (see Table 5.19). This means that the PBL teaching strategy could help to improve low achievers more than traditional teaching methods in 'Like Learning Mathematics'

Table 5.19: Low achievers by groups in 'Like learning math' (PBL groups against traditional group)

Test for low achievers	df	F	p-value	Partial Eta Squared
Time	1	2.467	.126	.074
Groups	1	.007	.935	.000
Time * groups	1	6.301	.017*	.169
Error (time)	31			

Note: p* is significant < 0.05, p** is significant >0.01

Overall students' 'Like Learning Mathematics' scores did not significantly improve. The high achievers scores significantly deteriorated in 'Like Learning Mathematics' scores. This might explain why the average scores of all students did not significantly improve in 'Like Learning Mathematics' post-tests scores. The difference between the high and low achievers scores in 'Like Learning Mathematics' scores over time was not significantly interacted by the types of the treatment. In addition, there was no significant difference between groups attributed to the types of treatment in 'Like Learning Mathematics' scores accept for superiority of low achievers within PBL groups. This indicates that using PBL is unlikely to improve scores in 'Like Learning Mathematics' any more than when using traditional teaching methods accept for low achievers. In addition, training teachers in PBL implementation could not have any effect on students' like learning mathematics scores. Finally, it can be concluded that in respect of mathematics achievement the different ability levels of students is unlikely to have any effect on their scores in 'Like learning mathematics' when using the PBL teaching strategy.

5.5.2 Value on Mathematics

Table 5.20: Summary statistics for Value Score within time and by groups and achievement levels

Value on Mathematics measures	A (training and PBL		B (training and tradition)		C (non-training and PBL)		D (non-training and tradition)	
Student ability levels	**High**	**Low**	**High**	**Low**	**High**	**Low**	**High**	**Low**
Pre-score Mean SD	 15.20 0.92	 10.71 2.36	 15.67 0.71	 11.50 2.62	 15.00 1.00	 12.57 1.40	 15.80 0.45	 12.18 2.68
Mean SD	13.35 2.78		13.71 2.80		13.79 1.72		13.31 2.80	
Post-score Mean SD	 15.20 1.32	 11.57 3.00	 14.44 1.74	 12.50 2.33	 14.57 1.90	 13.57 2.37	 14.20 2.17	 13.00 2.49
Mean SD	13.71 2.78		13.53 2.21		14.07 2.13		13..38 2.39	

From Table 5.20 it can be seen that the 'Value on Mathematics' means scores slightly increased for three of the four groups (groups A, C, and D), while the mean scores of one of the four groups (group B) slightly decreased. In addition, the mean pre score was in general higher for the high achievers within each group. The improvement was marked in all groups of the lower achiever scores. Apart from group A which remained the same, the results in the higher achievers average score for all groups were decreased.

From the ANOVA analysis Table 5.21 it can be seen that there was no significant difference between the students' average 'Value Mathematics' scores over time, with estimated mean scores of 13.58 and 13.63 for pre and post-measure scores respectively, $F (1, 56) = .044$, $p =.835$, partial $\eta 2 = .001$. This indicates that overall, students' scores in 'Value Mathematics' did not significantly improve. Furthermore, there was no significant overall group effect which was observed over time, $F (3, 56) = .532$, $p =.662$, partial $\eta 2 = .028$. This means that there was no significant difference between the groups attributed to the types of treatment in 'Like Learning Mathematics. However, there was a very significant difference between the overall level effect over time, $F (1, 56) = 11.623$ $p =.001$, with increasing low level and decreasing high level scores. The partial eta square effect size for this significant result was large at 0.172, (see Table 5.21, 4.20 and 4.21, and Figure 5.5). This means that the average change in scores for all low achievers was significantly greater than the average change in the scores of the high achievers in 'Value Mathematics'. It also shows no significant interaction effect between groups and their levels of achievement over time $F(3, 56) = .521$, $p = .670$, partial $\eta 2 = .027$. This implies that in 'Value Mathematics' the students' results were not significantly affected by the interaction of the types of treatment with different levels of students (high and low achievers). In other word, the trends of the high and low achievers within each group were similar across all groups, (see Table 5.21 and Figure5.5).

Furthermore, the average increase in the 'Value Mathematics' scores of all low achievers was significant $F(1, 29) = 5.331$, $p = .028$ with estimate scores of pre-measure 11.742 and post-measure 12.661being achieved. The partial eta square effect size for this significant result was large, .155, (see Table 5.21). This improvement was not significantly interacted with the groups $F(1, 29) = .015$, $p = .997$. In addition, the decrease in the average scores for 'Value Mathematics' for all high achievers was significant $F(1, 27) = 7.107$, $p = .013$ with estimate scores of pre-measure 15.417 and post-test 14.604 being achieved. The partial eta square effect size for this significant result was large, .208. This decline was not significantly interacted with the groups, $F(1, 27) = 1.480$, $p = .242$, (see Table 5.23). Therefore, it can be said that the average scores for the low achieving students was significantly improved, with a large size effect being achieved in students' 'Value Mathematics' scores, and there was significant deterioration in the scores of the high achievers' with a large size effect too.

Table 5.21: Mixed ANOVA outcomes for Value on mathematics

Test	df	F	p-value	Partial Eta Squared
Time	1	.044	.835	.001
Groups	3	.561	.643	.029
Time * groups	3	.532	.662	.028
Time * levels of achievement * groups	3	.521	.670	.027
Time * level achievement	1	11.623	.001**	.172
Error (time)	56			

Note: p* is significant < 0.05, p** is significant >0.01

Table 5.22: Low achievers for all students by groups in Value mathematics

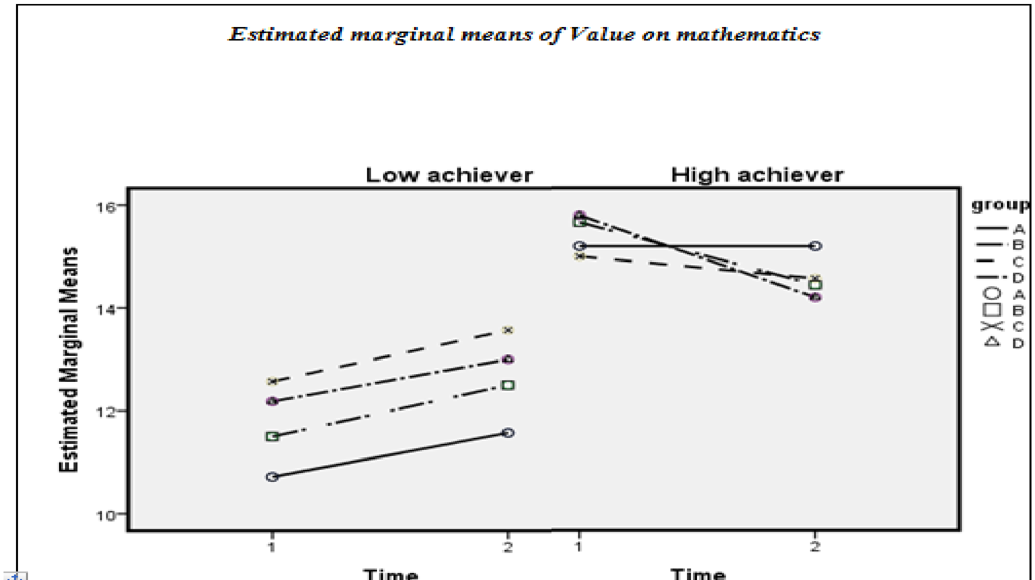
Test	df	F	p-value	Partial Eta Squared
Time	1	5.331	.028*	.155
Time * groups	3	.015	.997	.002
Error (time)	29			

Note: p* is significant < 0.05, p** is significant >0.01

Table 5.23: High achievers for all students by groups in Value mathematics

Test	df	F	p-value	Partial Eta Squared
Time	1	7.107	.013*	.208
Time * groups	3	1.480	.242	.141
Error (time)	27			

Note: p* is significant < 0.05, p** is significant >0.01



A is the trained teacher's PBL group

B is the trained teacher's traditional group

C is the untrained teacher's PBL group

D is the untrained teacher's traditional group

Figure 5 5: High and low achievers' average scores in 'Value Mathematics' for each group

As Figure 5.5 and Table 5.20 illustrate, the low achiever group mean scores in all four groups increased. For the high achiever groups the mean ‘Value Mathematics’ score decreased for three groups out of four, with one group remaining the same. The significant difference between high and low achievers over time was not affected by the groups. On average, the high and low achievers’ scores significantly changed in opposite directions. However, the overall significant difference in changes in the ‘Value Mathematics’ scores between high and low achievers over time was not affected by the types of treatment

Overall students’ ‘Value Mathematics’ scores did not significantly improve. The low achievers significantly improved and the high achievers significantly deteriorated in ‘Value Mathematics’ scores. This might explain why the average scores of all students did not significantly improve in ‘Value Mathematics’ post-tests scores. The difference between the high and low achievers scores in ‘Value Mathematics’ scores over time was not significantly interacted by the types of the treatment. In addition, there was no significant difference between the groups attributed to the types of treatment in ‘Value Mathematics’ scores. This indicates that using PBL is unlikely to improve scores in ‘Value Mathematics’ any more than when using traditional teaching methods. In addition, training teachers in PBL implementation could not have any effect on students’ value mathematics scores. Finally, it can be concluded that in respect of mathematics achievement the different ability levels of students is unlikely to have any effect on their scores in ‘value mathematics achievement’ when using the PBL teaching strategy.

5.5.3 Confidence to Learn Mathematics

Table 5.24: Summary statistics for Confidence scores within time and by groups and achievement levels

Confidence to Learn Mathematics Measures	**A (training and PBL**		**B (training and tradition)**		**C (non-training and PBL)**		**D (non-training and tradition)**	
Student ability levels	**High**	**Low**	**High**	**Low**	**High**	**Low**	**High**	**Low**
Pre-score								
Mean	14.30	9.86	14.78	10.75	13.57	10.00	14.40	11.09
SD	1.57	1.22	1.30	1.04	1.27	1.53	0.55	2.59
Mean	12.47		12.88		11.79		12.12	
SD	2.65		2.37		2.29		2.66	
Post-score	13.10	11.86	14.00	11.63	13.00	12.14	14.20	11.00
Mean	1.97	1.35	2.24	2.67	2.08	1.77	1.10	2.90
SD								
Mean	12.59		12.88		12.57		12.00	
SD	1.81		2.67		1.91		2.90	

From Table 5.24 it can be seen that the 'Confidence to Learn Mathematics' mean score slightly increased for one of the four groups (group A) and remained the same for one group (group B), while two of the four groups (groups C and D) slightly decreased. In addition, the mean pre score was in general higher for the high achievers within each group. The improvement was marked in three of four groups (groups A, B, and C) of the lower achiever scores. For all groups the results in the higher achievers average score was decreased.

From the ANOVA analysis Table 5.25, it can be seen that there was no significant difference between the students' average 'Confidence to learn Mathematics' scores over time, with estimated mean scores of 13.58 and 13.63 for pre and post-measure scores respectively, $F(1, 56) = .997$, $p = .322$, partial $\eta 2 = .017$. This indicates that overall, students' scores in 'Confidence to learn Mathematics' did not significantly improve. Furthermore, there was no significant overall group effect which was observed over time, $F(3, 56) = .533$, $p = .661$, partial $\eta 2 = .028$. This means that there was no significant difference between the groups attributed to the types of treatment in 'Confidence to Learn Mathematics'. However, there was a very significant difference between the overall level effect over time, $F(1, 56) = 12.389$ $p = .001$, with increasing low level and decreasing high level scores. The partial eta square effect size for this significant result was large at 0.181, (see Table 5.25 and Figure 5.6). This means that the average change in scores for all low achievers was significantly greater than the average change in the scores of the high achievers in 'Confidence to Learn Mathematics'. It also shows no significant interaction effect between groups and their levels of achievement over time $F(3, 56) = 1.517$, $p = .220$, partial $\eta 2 = .075$. This implies that in 'Confidence to Learn Mathematics' the students' results were not significantly affected by the interaction of the types of treatment with different levels of students (high and low achievers). In other word, the trends of the high and low achievers within each group were similar across all groups, (see Table 5.25 and Figure5.6).

Furthermore, the average increase in the 'Confidence to Learn Mathematics' scores of all low achievers was significant, $F(1, 29) = 9.075$, $p = .005$ with estimate scores of pre-measure 10.425 and post-measure 11.656 being achieved. The partial eta square effect size for this significant result was medium, .123, (see Table 5.26). This improvement was not significantly interacted with the groups $F(1, 29) = 1.828$, $p = .164$. In addition, the decrease in the average scores for 'Confidence to Learn Mathematics' for all high achievers was not significant $F(1, 27) = 3.772$, $p = .063$ with estimate scores of pre-measure 14.262 and post-test 13.575 being achieved. The partial eta square effect size for this significant result was medium, .123. This decline was also not significantly interacted with the groups F (1, 27) =.346, p =.793, (see Table 5.27). Therefore, it can be said that the average scores for the low achieving students was significantly improved, with a medium size effect being achieved in students' 'Confidence to Learn Mathematics'' scores, although there was no significant deterioration in the scores of the high achievers'

Table 5.25: Mixed ANOVA outcomes for Confidence to learn mathematics

Test	**df**	**F**	**p-value**	**Partial Eta Squared**
Time	1	.997	.322	.017
Groups	3	.524	.667	.027
Time * groups	3	.533	.661	.028
Time * levels of achievement * groups	3	1.517	.220	.075
Time * level achievement	1	12.389	.001**	.181
Error (time)	56			

Note: p* is significant < 0.05, p** is significant >0.01

Table 5.26: Low achievers for all students by groups in confidence of mathematics

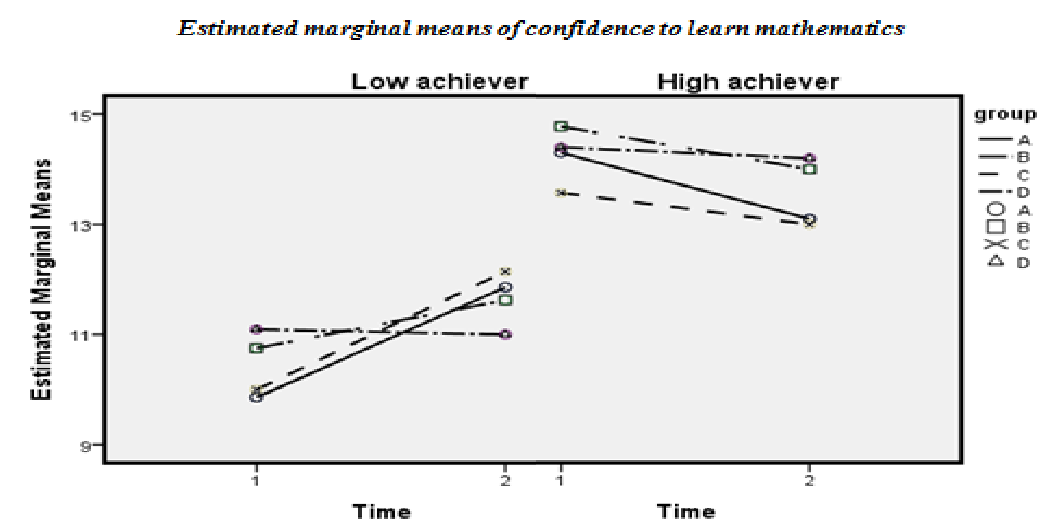
Test	Df	F	p-value	Partial Eta Squared
Time	1	9.075	.005**	.238
Time * groups	3	1.828	.164	.159
Error (time)	29			

Note: p* is significant < 0.05, p** is significant >0.01

Table 5.27: High achievers for all students by groups in confidence of mathematics

Test	Df	F	p-value	Partial Eta Squared
Time	1	3.772	.063	.123
Time * groups	3	.346	.793	.037
Error (time)	27			

Note: p* is significant < 0.05, p** is significant >0.01



A is the trained teacher's PBL group

B is the trained teacher's traditional group

C is the untrained teacher's PBL group

D is the untrained teacher's traditional group

Figure 5 6: High and low achievers' average scores in 'Confidence to Learn Mathematics' for each group

As Figure 5.6 and Table 5.24 indicate, three of the four groups of the low achiever group mean scores increased. For the high achiever groups the mean 'Confidence to Learn Mathematics' score decreased for all the groups. The significant difference between high and low achievers over time was not affected by the groups. On average, the high and low achievers' scores changed in opposite directions, however, only the increase in the low achiever scores was large enough to be statistically significant. However, the overall significant difference in changes in the 'Confidence to Learn Mathematics' scores between high and low achievers over time was not affected by the types of treatment.

Overall, students' 'Confidence to Learn Mathematics' scores did not significantly improve. However, the low achievers' scores significantly improved whereas the high achievers' scores did not significantly deteriorate in 'Value Mathematics' scores. This could explain why the average scores of all students did not significantly improve in 'Confidence to Learn Mathematics' post-tests scores. The difference between the high and low achievers scores in 'Confidence to Learn Mathematics' scores over time was not significantly interacted by the types of the treatment. In addition, there was no significant difference between the groups attributed to the types of treatment in 'Confidence to Learn

Mathematics' scores. This indicates that using PBL is unlikely to improve scores in Confidence to Learn Mathematics' any more than using traditional teaching methods. In addition, training teachers in PBL implementation could not have any effect on students' confidence to learn mathematics scores. Finally, it can be concluded that in respect of mathematics achievement the different ability levels of students is unlikely to have any effect on their scores in 'confidence to learn mathematics' when using the PBL teaching strategy.

5.6 Teachers' Interviews

Semi-structured interviews were conducted to investigate the experiences of teachers who had used PBL teaching strategies. Six main questions were asked, as follows:

1. How was PBL implemented in your teaching strategies?

2. What are the advantages of using PBL teaching strategies?

3. What are the disadvantages of using PBL teaching strategies?

4. What challenges did you face during the process of implementing the PBL teaching strategies?

5. To what extent do the students who lack prerequisite knowledge or skills affect how you teach this class?

6. How well do students engagement in PBL learning processes?

The teachers' responses to six questions were analysed (please see Chapter 3 for more details). Six final themes emerged, namely: PBL implementation, advantage of using PBL, disadvantages of using PBL, challenges of using PBL, students with a lack of prerequisite knowledge or skills and engagement in the PBL process. The themes were then presented to each teacher with the results (both the trained and the untrained teacher) – (see the transcripts of the interview in Appendix 5.3).

5.6.1 The trained teacher A (Ahmed)

1. Implementation of PBL in class

As requested, Ahmed, a trained teacher, implemented the PBL teaching strategy using meta-cognitive teaching skills to guide students through PBL learning processes. Ahmed stated:

> "*I present a problem to the students; they read, then discuss it and after this, one of them reads out the problem to the rest of the students who then explain it in their own words. The students then give their feedback on their understanding of the problem, determine the problem statement then ascertain what they know and what they need to know in order to solve the problem while I record their notes on the blackboard. The students then join their groups and make a plan of how to gather the information they need by allocating specific tasks to each member of the group. The students will then collect the required information and exchange their findings with one another. Collectively they then select the best and most suitable ideas and generate all the possible solutions to the problem. Finally, each group presents their work to the rest of their classmates who will then provide them with their feedback. My role here is to help them learn by asking meta-cognitive questions*."

The trained teacher (Ahmed) explains how he implemented PBL in class. He starts by presenting the problem to students. One of students reads the problem out loud in front of the other students. One of the students explains the problem in their own words and the other students are then asked to give their feedback. This is done with whole class. Then the students identify what they already know and what they need to know. After that, students identify the statement of the problem and the teacher writes the students' responses on the whiteboard. Once students have agreed on what they believe to be the statement of problem, the teacher asks the students to join their groups and set goals for what they need to know. The students then allocate tasks between them and then begin their search for the required knowledge and information. After the students have completed their research and have gathered the new knowledge they re-group to share the new information. They then generate possible solutions for the problem and make a decision as to which is the best solution. Finally, students present their solution to the whole class and the rest of students have the chance to ask questions and give feedback. This process enables the students to learn from others. Ahmed concludes that he facilities students' learning processes by asking meta-cognitive questions. Thus, Ahmed had done what he had been asked to do in guiding students from one process to another by asking meta-cognitive questions.

2. Advantages of using PBL

Four advantages of using PBL were mentioned by the trained teacher:

1) PBL improves self-directed learning,
2) PBL improves problem solving skills;
3) PBL improves cooperation skills; and
4) Students may like the PBL teaching strategy at much as traditional teaching methods when they become familiar with it.

- ***Self-directed learning skills***

Teacher A (the trained teacher) noticed that students' self-directed learning skills improved over time. Ahmed asserted:

"*In the beginning the students found PBL weird because they were accustomed to conventional methods, but after three lessons they were able to learn by themselves without relying on the teacher as they had previously*".

He believed that this was a great achievement which would help students in the future when they began studying at university. Therefore, it can be argued that PBL seems to have a positive impact on improving students' self-directed learning skills.

- ***Problem solving skills***

Teacher A believes that PBL improves students' thinking skills; he stated that "*PBL improves students' thinking skills to solve problems*". He believes that it is extremely important to improve students thinking skills.

- ***Team skills***

Ahmed noticed that PBL improves students' cooperation skills within groups. He mentioned that "*PBL improves learning based on cooperation where each student has a certain role*."

- ***Like learning mathematics***

The trained teacher found that when the students became more familiar with the PBL teaching strategy, the more they began to like it. He asserted:

"*In the beginning students stated that they liked conventional teaching methods more than PBL but at the end of the experiment they had changed their view stating that they liked both methods of teaching instructions*".

3. Disadvantage of PBL

The trained teacher believes that PBL causes noise in classrooms due to the group discussions taking place. He also commented that generally, some Saudi students were not interested or serious about their education because they believe that having an education is not important or necessary for their future.

- ***Noise***

The teacher felt that using PBL meant the classroom was noisy. He felt that this would be a problem for those teachers who were accustomed to using conventional teaching methods, while he sees that is ok as long as the noise is beneficial for students.

- ***Uninterested students***

Ahmed believes that many students are of the view that Saudi Arabia has a strong economy and this view negatively influences their attitudes towards education and the importance of learning. Thus, these students do not take their education seriously and this, in turn, has a detrimental effect on the effectiveness of teaching practices, regardless of the method used, The teacher states that "*some Saudi students were uninterested in learning in general because they thought that being good in education would not have an effect on their future*". He believes that ultimately, this perception could be problematic for some Saudi students' in the future.

4. The challenges in implementing PBL

Several challenges in implementing PBL were mentioned by the trained teacher including: designing problems, teachers' beliefs, assessment types, time, characteristics of students and the instructions regarding the administration of school.

- ***Designing problems***

The trained teacher believes that in order to support the integration of PBL in mathematics classrooms, mathematics textbooks need to be adapted to include PBL teaching strategies and include examples of clear and short problems. Ahmed stated: "*If we are to effectively implement the PBL strategy in mathematics classrooms, mathematics textbooks must be* *adapted and include designed problems and adequate training could even be made available to teachers to enable them to design problems for PBL.*"

He found that designing problems were difficult for him and he believes it would be difficult for other teachers as well. He argued that if this strategy (PBL) aimed to be applied in mathematics classes in Saudi Arabia, teachers must be trained to design problems or problems must be designed by experts. To improve PBL practice he suggests that "*designing short and clear problems*". He believes this could reflect a better outcome. He argued that difficult problems could require too much clarification and explanation from teachers and it also may be too difficult for students to gain new knowledge.

- ***Restrictions in implementing PBL***

Ahmed felt that the implementation of PBL could be affected by the instructions given by the school's administration, as well as the content of mathematics textbooks. Ahmed thought that the strategy could be more comfortable than conventional methods if certain obstacles could be overcome. According to him the main obstacles are: the textbook of mathematics which does not adapt well with PBL (discussed previously). He also felt that the administration of the school went against the strategy and did not marry with the textbook of mathematics. He said that "*The problem which could restrict implement PBL is the administration of the education as they need us to follow the instructions of standard textbooks*." He thinks that if the textbook of mathematics were to adapt to incorporate the PBL strategy, then the administration of the school and the Ministry would not present any more obstacles because teachers would be required to fill in the book and be strict with it

- ***Teacher's belief***

Ahmed thinks that teachers' beliefs should be changed by convincing them to implement PBL in their lessons stating that: "*Teachers need to be convinced to implement PBL.*"

- ***Assessment of PBL***

The trained teacher suggested that students should be assessed in the same way as when they were taught through the PBL strategy. He commented: "*In order for PBL practices to be effective, the assessment of mathematics should be changed to contain problems which students are asked to solve collectively (in groups)*." The teacher found that in conventional method of teaching he can assess students by giving exercises at the end of the lessons, but with PBL there is no way of guaranteeing that they have understood the lesson. Therefore, he suggested that mathematics tests should contain at least one problem which is required to be solved collectively, rather than individually.

- ***Adjusting to PBL***

Ahmed felt that students tend to prefer to be taught using methods that place less responsibility upon them. The trained teacher noticed that students tend to be lazy and this is why students initially prefer to be taught using the teacher-centered approach. Ahmed indicated that "*students need time to become accustomed to using the PBL strategy*". He went on to say that "*if this strategy were to be implemented at the beginning of the intermediate school level for students who have just come from primary school, students would adapt to it more easily and also accept it because they might think this is the system of the level of intermediate school and they wouldn't know any different*". He argued that this approach would mean that students would be unable to compare PBL with traditional teaching methods and so could not then prefer the traditional way of teaching. According to him, the reason that students might prefer traditional methods is because the students tend to be lazy.

- ***Time***

Ahmed recommended PBL problems should be designed for one session. The trained teacher mentioned that the allocated time for each session is 45-minutes (five sessions per week) and suggested that "*to combine 2 sessions and have two 90-minute sessions and one 45-mintue session, rather than having 5 sessions lasting 45-minutes each, would be more suitable for teaching with the PBL strategy*". Combing two sessions (i.e. increasing the length of time for each PBL lesson), would give more time for both the teachers and students for discussion and learning.

5. Readiness to learn mathematics

The trained teacher asserted that prerequisite knowledge should be considered for more effective learning in PBL. Ahmed noticed that some students relied on others because they had no prerequisite knowledge or skills. He stated that: "*Working in groups causes some less able students to rely on more able students and this may affect my performance as a teacher, as well as have a negative effect on all students*." He found that students with a lack of prerequisite knowledge or skills restrict the learning processes and this has a negative effect on all the other students. This problem may particularly affect high achievers who are forced to wait for the low achievers to learn the basic knowledge or other students who were not ready to learn the new knowledge.

6. Engagement in learning mathematics

Ahmed believes that the characteristics of the PBL problems (length and clarity) and the characteristics of students (readiness to learn new knowledge) seem to be contributory factors which affect how well students engage in PBL learning processes. The trained teacher asserted that "*the more able students and those with more prerequisite knowledge or skills were more engaged than others*". He believed this is because they felt that they were more responsible for solving problems than the others. He believes also that the type of problems is a key factor in students' levels of engagement. He said that "*when a problem is clearer, shorter, and considered students' prior knowledge then the engagement level would be raised*".

5.6.2 The untrained teacher B (Nasser): Self-directed learning teacher

1. Implementation of PBL in class

The untrained teacher (self-directed learning) did not implement PBL in the proper way. The untrained teacher (Nasser) explains how he implemented PBL with his students by saying: "*I present the problem to the students, they read and understand it, then they identify what they already know and what is required while I record their comments on the whiteboard. I then ask them to learn from the mathematics textbook and we then discuss what they have learnt. I will answer any questions and explain anything they have found difficult to understand. They then carry out exercises around what they have learnt*." He explained any difficult issues and answered any questions students asked. He also gives them feedback and asks some students to practice what they know on the whiteboard. Students sit with groups but they also work individually (field work).

Nasser did not do what he was asked to do in the proper way. He assesses each step by asking students to show their understanding on the whiteboard and practice it, then he gives them feedback with some explanations. In other words, he leads students and adopts some traditional principles, such as correcting, explaining and practising their mistakes. This indicates that the self-directed learning approach is insufficient and that face-to-face training may be required in order for teachers to obtain effective meta-cognitive teaching skills.

2. Advantages of PBL

The untrained teacher noticed that the students interacted with each other within groups because they liked working with groups. Additionally, he believes that PBL can be appropriate for all levels of education in schools.

- ***Interaction of students***

Nasser noted that because students are asked to work with collectively, the interaction between students is one of the advantages of PBL. Teacher B (the untrained teacher) said that "*the advantage of using PBL is the interaction students have with each other, this started from identifying the problem, extracting data from the problem, identifying the requirements and then solving the problem*".

- ***Like learning mathematics***

The self-directed learning teacher noticed that the students were interested in working within groups. Nasser stated that "*the majority of students were happy with PBL because they like working in groups*". He also thinks any teacher likes the transfer from being at the centre of the learning to being a facilitator.

- ***Flexibility of PBL***

The untrained teacher believes that PBL is appropriate for all levels of education systems. Nasser suggested that "*PBL should be introduced to primary schools right through to university levels*".

3. Disadvantage of PBL

One of the disadvantages of PBL is that the students who are not interested in their education see working within groups as an opportunity to make noise and cause chaos and disruption in the classroom. This is very disruptive for the other students and can have a detrimental effect on their studies.

- ***Noise***

Nasser found that the excessive noise and chaos in the classroom is one of the disadvantages of PBL, particularly for the teachers who are accustomed to quiet and passive classrooms.

- ***Uninterested students***

Nasser believed that uninterested students may affect their own learning, as well as negatively affecting other students. The self-directed learning teacher added that "*some students who are uninterested in the learning work against interested students in a noisy and chaos environment*". This problem, however, is not necessarily the result of PBL and occurs generally in a limited number of students.

4. The challenge of implementing PBL

Several challenges for PBL implementation raised by the untrained (self-directed learning) teacher includes training teacher how to help students to coach their learning process, designing problems for PBL or even train teachers to so, train teacher to deal with typical number of students with PBL settings. Some challenges may not only related to PBL could also be important include a lack of some students in perquisite knowledge or skills and not placing high value on education.

- ***Teacher training***

The untrained teacher felt that in order for teachers to implement PBL effectively, this requires face-to-face training on how to coach students' thinking in order to improve their self-directed learning skills through PBL learning processes. The self-directed development teacher found that the difficult part of PBL implementation is "*how to make students learn by themselves and also how to let students move from one process to another*". He added that "*teachers should be trained to overcome this problem*".

This view clearly indicates that teachers needs to be trained in implementing PBL implementation to help them to effectively use meta-cognitive teaching skills to coach students' learning processes.

- ***Adjusting to PBL***

Adapting to teaching using PBL takes time for teachers. The untrained teacher said that "*teachers need time to adapt to using the PBL strategy*". This is, perhaps, due to the fact that both students and teachers have become accustomed to the teacher-centered approach as it has been used for such a long time. However, the feedback received from teachers indicates that, whilst they find it difficult initially, this becomes less difficult over time.

- ***Uninterested students***

The untrained teacher believes that the achievements of students who are uninterested in education may be effected as a result of their disinterest. He states that "*some Saudi students are uninterested in education and they are forced to go to the school*". He feels that this causes problems in respect of any improvement process in the education strategy. He commented that a number of students do not place any value on education and this may be a cultural problem.

- ***Designing problems***

Nasser thought that clear and short problems might be more effective for improving students' performance. To improve PBL practice, Nasser suggested that "*designing shorter and clearer problems could reflect a good outcome*". This kind of problem may be more effective when applied at the outset of implementing PBL.

- ***Class size***

Training may be required for teachers in order to prepare them for dealing with the number of students typically encountered when using the PBL teaching strategy. The self-directed learning teacher mentioned that "*small classroom sizes would produce better outcomes as a reduced number of students in class create more opportunities for teachers to be able to make sure every group is doing very well*".

- ***Restrictions in using PBL***

The mathematics textbooks do not align with PBL teaching strategies. Nasser therefore suggested that "*Textbooks should be adapted to incorporate PBL teaching styles*." He also suggested that teachers should receive training in how to design problems for PBL. This is an important issue if PBL is planned to be fully integrated into the education system in the future

- ***Assessment of PBL***

Teachers also need training to be able to deal with groups effectively. The untrained teacher suggested that "*Every student should work individually as well as working within groups as this would give better outcomes*."

5. Readiness to learn mathematics

Readiness to learn mathematics appears to be very important and can be problematic for all students. The self-directed development teacher stated that "*I spent a great part of the lesson dealing with students who had no per-requisite knowledge or skills*". He added "*working with groups would hide those students and their problems would never be solved*". He suggests to "*work individually within groups*". The lack of prerequisite knowledge or skills seems to present additional problems for teachers and students alike; it makes the learning more difficult for the students who lack this prior knowledge and causes frustration for the students who feel held back by these less able students. Thus, this is a serious problem which needs to be addressed.

6. Engagement in learning mathematics

The underestimation of the value of education and readiness to learn appear to be important factors in students' engagement in PBL learning processes. The untrained teacher said that "*some students do not feel education is important and they would not engage in learning*". However, some students could not engage because they lacked per-requisite knowledge or skills.

5.7 Research Diary

The study was observed by the author. The author played a great part in this study by training and preparing teachers and students for the implementation of the PBL strategy. He also monitored the implementation process and provided all participants with what they needed to complete the study. In this research diary, the author has discusses what has been noticed during the field work exercise. He mainly focused on teachers' performance and was particularly concerned with teacher intervention, student practices, both individually and collectively, students responses, group interaction and PBL processes.

5.7.1 School and staff

The school is a large private school which is considered to be three public schools. Every grade was ranged between 5 and 8 and each classroom has between 14 and 20 students. The school contains intermediate grades only (first (7th grade), second (8th grade), and third (9th grade)). The students ranged from the medium to high class. The condition of the school and its setting is good. The school offers a bus transportation service for students and is considered to be rated as one of the best schools in Hail City. It has competition with other private schools. The majority of staff are not local but the majority of students are from Saudi. The head master was also from Saudi but the monitors are not – they are Arab staff.

Contradictions between monitors and administrators were observed; local monitors (in school) encouraged teachers to use traditional methods, while the administrators of the school and education asked teachers to use active learning instructions. Teachers used traditional methods in general. It is thought by the author that the reason for the contradiction was the book of subjects. The textbooks were designed for traditional teaching methods and teachers required to follow the instruction of the textbooks. However, in reality, teachers were asked to use active learning instructions. The teachers were confused as to which approach they should follow. This became clear during the process of implementing the study. It was noted that teachers were blamed and reprimanded when they did not follow the instructions of the textbook although it was made clear from the outset that the PBL strategy would need to be used for this study. Despite this, however, the local monitors were reluctant to give teachers the chance to try the PBL strategy.

The head master of the school welcomed the implementation of PBL to the school and he was interested in PBL when the idea was explained to him. He also attended some of the CPD sessions and expressed his satisfaction at what he saw. Teachers also welcomed the idea and they were very willing to be volunteers to take part in the study. One teacher taught 3 classes and another taught 2 classes in the 8th grade.

5.7.2 Implementation of the study

The administration of the school employed 4 teachers to monitor the students while students were exposed to the pre-tests and pre-measures. As the researcher, I moved between groups to make sure everything was proceeding very well; my intention was to monitor the implementation of the study, and I had a diary that I used to document my observations, particularly the observations which took place during lessons and were made inside mathematics classrooms (see, an example of hand written from my research dairy in appendix 5.4). Three themes emerged from the observation: Teachers' implementation of PBL, disadvantages of implementing PBL, and advantages of implementing PBL.

1. *Teachers' implementation of PBL*

Although the trained teacher had received intensive CPD training, sometimes he still returned to traditional methods to explain problems and to lead students. However, it was noted that teachers changed their approach when they realized that they had reverted back to traditional teaching methods. This is perhaps because the teachers had been using traditional methods for several years and they also had been taught using traditional methods.

Although the untrained teacher had been provided with materials to explain how to implement PBL, he still explains and leads students in the traditional way and he thought that was ok. The trained teacher coached students' thinking by posing mate-cognitive questions while the self-directed learning teacher not. Therefore, it became clear that untrained teachers did need to receive CPD training to assist them in the implementation process.

2. *Disadvantages with PBL implementation*

The teachers and students need time for adapting PBL and students with a lack of prior knowledge caused problems.

- ***Teachers' adaptation to PBL***

The teachers were very frustrated initially, but after about 3 sessions, they were satisfied with it. This was expected for teachers who had been accustomed to traditional teaching methods.

- ***Students' adaptation to PBL***

The students who took part in this study received training in PBL instruction before embarking on the study, however, this was only for a short period of time over two sessions. They received two short interesting problems about travelling for holiday and poverty. The students worked within groups to prepare for the PBL sessions. They were encouraged to ask open questions, listening to others and thinking critically. On reflection, however, the training did not seem to be adequate for students who have been accustomed to traditional teaching methods for a long time.

- ***Students' readiness to learning by PBL***

Some students had lack of prerequisite knowledge and skills and this unfortunately caused restrictions in implementing PBL learning processes for all. Students' engagement levels seem to depend on some factors such as readiness to learn, type of problems and students' ability.

3. ***Advantages of implementing PBL***

Some students like PBL and their presentation skills were improved by using PBL.

- ***Students' attitudes towards PBL***

When the PBL strategy was introduced to the participants of the study, it became clear that some of the students were enthusiastic about the PBL process and worked effectively to solve problems, however, other students were uninterested in the process and used the group sessions as an opportunity to chat to their classmates. It was noted that a few students did not even try to learn. The teachers told me that there was a selection of students who did not care about any strategy or subject and they only came to school because they had to.

- ***Students' presentation skills***

Some students seemed to have problems with making presentations because they had not tried it before. However, the trained teacher encouraged them and asked others to assess them and them to assess others. It was noticed that these students started to become more confident in presenting their work verbally.

5.8 Comparison between the Intermediate School trained and the untrained teachers in their perspectives and field observation notes

From Table 5.28 it would seem that the self-directed learning teacher needs training face-to-face in PBL implementation, particularly in how use meta-cognitive teaching skills to guide students' learning processes; the untrained teacher involved some traditional practices, while the trained teacher coached students' thinking by posing metacognitive questions. As a result of this, the trained teacher noticed that students' thinking, self-directed learning and cooperative skills improved, whereas the untrained teacher did not express this. This confirmed by the research diary.

Students appeared to need time to become accustomed to PBL as one of the student-centred strategies. This also noted by the author. This may be because they were accustomed teacher-centred methods. This could not be the case for the primary school students and this will be discussed in the next chapter (chapter 6).

It seems that characteristics of students may look different from one country to another based on students' perspectives about the value of education in their future. In Saudi Arabia the socioeconomic status is high; this may make students feel that education is not important to survive. However, this view would be different in other countries where education is the key to securing good career prospects and thus, a prosperous future. In fact, this was one point that was raised by some of the teachers who had previously taught in different countries, i.e. Egypt. Therefore, as the PBL teaching strategy should show students how mathematics functions in real life and future careers, it may become more effective than more traditional teaching methods with students who are coming from lower socioeconomic status. The reason is because the lower socioeconomic students may feel more responsible, and they would give more attention to education in order to easily find a job.

It seems that the trained teacher focussed on the challenges of how to develop PBL while the untrained teacher focussed on how to implement PBL well. This could imply the need for training teachers in implementing PBL. Another indication is that the trained teacher required more time, while the untrained teacher did not require as much, possibly because the trained teacher gave students more time to discuss and think within PBL sessions and also had a better understanding of the PBL process.

In addition, it appears that both teachers found the embedded assessment is not enough to assess students' achievement. The trained teacher suggested that assessing learning in PBL should be collective, as the format in which they were taught, whereas the untrained teacher suggested that students work individually for improving students' performance.

Both teachers expressed that incorporating PBL in mathematics classrooms needs the adaptation of mathematics textbooks. Furthermore, both of them also expressed concerned about low achievers who had a lack of prerequisite knowledge and/or less ability than the other students. The teachers believed that the readiness of students and the characteristics of problem affected the students' engagement. The result of the semi-structured interviews and field observation notes for intermediate school teachers is summarised in Table 5.28.

Table 5.28: Summary of results of semi-structured interview for intermediate school teachers with field observation notes

Theme	The trained face-to-face teacher	The untrained teacher (self-directed learning teacher)	Notes and observations
PBL implementation	Implemented PBL as requested	Included some traditional practices such as leading and explanations	It seems that untrained teachers need training in PBL implementation
Advantages of using PBL	- Self -directed learning skills appeared to be improved - Students' thinking skills to solve problems seemed to be improved - Students' cooperation skills within groups looked to be improved	- High level of students interaction - Students and the teacher are happy with PBL - Believed that it could be applied to students of all ages	Students' thinking, self-directed learning and cooperation skills seem to improve with trained teachers because the trained teachers coached students' thinking by suing mate-cognitive questions while the self-directed learning not.
	Over time students start liking the strategy		Students appear that need time to like PBL, particularly if they were accustomed to teacher-centred methods
Disadvantage of PBL	- Noisy and chaos - Uninterested students generally, regardless of the strategy		The characteristics of students may different from one country to another based on their perspective about the value of education in their future
	Time pressures		It seems that the trained teacher need more time, possibly because he gave the students time to discuss and think
The challenges in implementing PBL	- Teachers' belief - Assessing learning should be collectively	- Needs training to help students to learn independently and move from process to another - PBL is possibly better with small sized classrooms - Students should work individually through PBL for better outcomes	It seems that trained teachers would focus on the challenges of how to develop PBL while untrained teachers focus on how to implement PBL itself. It also appears that both teachers found the embedded assessment is not enough to assess students' achievement
	- Mathematics textbooks are not adapted with PBL - Designing problems Problems should be short and easy and clear		It seems that incorporating PBL in mathematics classrooms needs adaptation with mathematics textbooks
Readiness to Learn Mathematics	- Less able students rely on others - students with a lack of prerequisite knowledge or skills have limited instructions in classroom		It seems that less able students, whether with a lack of prerequisite knowledge or not, concern teachers
Engagement in Learning Mathematics	Problem solving and prior knowledge and skills could play an effective role on students' engagement		It appears student engagement results are affected by several factors, such as readiness and nature of the problem

5.9 Summary of result of the Intermediate School

5.9.1 Academic Achievement

Pre and post-tests were applied to examine the effects of PBL on students' academic achievement in three domains: Knowing, Applying and Reasoning abilities. Four groups were assigned with two teachers to be part of the study. Each teacher taught two groups and for each teacher one group was instructed using the PBL strategy whilst the other group was taught using conventional teaching methods. One teacher received PBL CPD training while the other teacher received no training at all. The reason was to examine the effects of PBL with the trained teacher and with the untrained teacher. The results show that there was no significant difference between the groups in terms of their achievements and no significant interaction between the students with different levels of ability, i.e. high and low achievers, with types the treatment in all domains ('knowing' 'applying' and 'reasoning'. This indicates that the outcomes of implementing PBL teaching strategies in the classroom, whether taught using trained or untrained teachers, is likely to be similar to conventional methods in improving mathematics achievement for intermediate school students. In addition, it is unlikely that PBL will interact with effect of different ability levels of students (high and low achievers) in respect of their overall mathematics achievement.

5.9.2 Attitudes Towards Mathematics in Learning Mathematics

Pre and post-measures were applied to examine the effects of PBL on students' Attitudes towards Mathematics levels in three domains: Like Learning Mathematics, placing Value on Mathematics and Confidence to learn Mathematics. Four groups were assigned with two teachers to be part of the study. Each teacher taught two groups; one was instructed using the PBL strategy and the other group was taught using conventional methods. In addition, one teacher had received CPD training in using PBL teaching strategies while the other teacher had received no training at all. The reason for this was to examine the effects of implementing PBL by trained and untrained teachers. The results show that there was no significant difference between the groups and there was no significant interaction between the different ability levels of students (high and low achievers) with the types of treatment in all domains ('knowing' 'applying' and 'reasoning') in their scores in relation to 'like learning mathematics', 'placing value on mathematics' and with their 'confidence to learn mathematics'. This indicates that the effects of implementing PBL teaching strategies, either with trained or untrained teachers, is likely to be similar to using conventional methods in improving Attitudes towards Mathematics in Learning Mathematics for intermediate school students. In addition, it is unlikely that PBL will interact with effect of different ability levels of students (high and low achievers) in respect of their overall mathematics achievement.

5.9.3 Teachers Perspectives

The trained teacher guided students from one learning process to another by posing meta-cognitive questions, while the untrained teacher could not completely switch from traditional practices into the PBL process. The untrained teacher still used some traditional principles such as correcting students' mistakes and practising what students have just learned. He clearly did not coach their thinking by using meta-cognitive questions.

The trained teacher noticed that self-directed learning, problem solving and team skills seemed to be improved among his students, while the untrained teacher noticed that only the interaction among students was observed. The reason for these outcomes is perhaps explained due to different teachers' practices, where the trained teacher coached students' thinking, while the untrained teacher did not.

In respect of Like Learning Mathematics, the trained teacher noticed that there was no difference between using the PBL strategy and using traditional methods among students, while the untrained teacher noticed that the majority of students liked PBL more than traditional methods. The reason may be because the untrained teacher's students found no problems with acquiring new knowledge as the teacher explains and gives examples, while their counterparts were required to think and gain new knowledge by themselves.

Both teachers noted that teaching using PBL could make the classroom noisy; the trained teacher felt that was no problem, while the trained teacher felt this was annoying. A good explanation for this may because the shift for the untrained teachers was not completed. The teachers also agreed that there were some uninterested students and they had an effect on the other students. They explained that the uninterested students' perspective towards education was negative; students thought being good in education did not bring any extra benefits to them, despite what the teachers said.

Both teachers found students with no per-requisite knowledge or skills restricted PBL instruction. They also believe that engagement depends on the type of problem and students' readiness to learn. Both teachers also believed that designing the problems for PBL is difficult. They suggested that all teachers needed to be trained on this to become better skilled in this area or that the problems should be previously designed by experts. They also agreed that the textbooks of mathematics were not adapted to teaching using PBL. In addition, they believe teachers and students need time to adjust to using PBL. Both teachers found the embedded assessment is not enough to assess students' achievement. The trained teacher suggested containing mathematics problem solving tests and that problems should be solved collectively, while the untrained teacher believed that students should be working individually to show their understanding.

The trained teacher suggested combining two 45 minute sessions to give enough time to successfully implement PBL in class, as the current session time of 45-minutes is too short, while the untrained teacher did not mentioned the current lesson time was a problem. The trained teacher believed that teachers' beliefs may cause an obstacle which would prevent them from being convinced to use PBL. He suggested including CPD training for all teachers in order to explain the reasons behind it and what requirements are needed in order to implement PBL.

The untrained teacher felt that he was not good at teaching students in how to practice self-directed learning skills. He also recommended that PBL should be implemented in smaller sized classes. In the following chapter, primary school data will be analysed and presented.

5.9.4 Research diary

Teachers seemed to need to receive CPD training in order for them to implement PBL effectively. Problems may be more effective if they were short, not exceeded 45 minutes, and clear not mess. Finally, it appeared that the training the students received to prepare them for the introduction of PBL did not seem to be adequate for many students who had been accustomed to traditional teaching methods for many years.

It is important to briefly present the qualitative findings in relation to quantitative findings. This will be presented below.

5.10 Presentations of qualitative findings in relation to quantitative findings

Question 1, 4, and 5

Table 5.29 shows that PBL seems to produce similar results as traditional teaching methods on the achievements and attitudes towards mathematics of the intermediate school student. However, the qualitative findings show that PBL seems to improve students' self-directed learning and cooperation and thinking skills when taught by a trained teacher. This is possibly because the trained teachers were able to use meta-cognitive teaching skills to guide students' learning processes, whereas the untrained (self-directed learning teacher) could not. Although the qualitative results showed positive improvement for the trained teacher's group, the quantitative results did not show significant positive for PBL with the trained teacher over traditional teaching methods; this is perhaps because the improvement was not significant enough to be shown by the statistical test.

Question 2

Students like learning via PBL instruction once they become familiar with it. This may be due to fact that they had become accustomed to traditional teaching methods and needed time to get used to the new method of learning.

Question 3

Low achieving students learned significantly more than high achievers, regardless the teaching instructional methods. This could be the result of them learning some perquisite knowledge in additional to the new knowledge whereas the high achievers only acquired new knowledge. The teachers gave more attention to low achievers in order to ensure that they were able to keep up with other students. This could be one of the reasons which contributed to them improving more than the other students.

Table 5.29: presentation of qualitative in relation to quantitative findings

Research questions	Ability	Quantitative findings	Interview and Field observation note
1	Knowing Applying Reasoning	No sig difference between groups	In discussion with the teachers, the researcher found generally that the trained teacher thought that his students' thinking was improved. Their conversation did not separate knowing, applying, and reasoning abilities. The researcher also observed that the appeared to be the case. This observation applied to the trained teachers only.
2	Like learning mathematics Value mathematics Confidence to learn mathematics		The researcher's discussion with teachers, and field observation both indicated that students began to like PBL over time. This liking was not instant, but developed during the research.
3	Different ability levels for students	No sig interaction with teaching instructions Sig difference in favour of low achievers	In discussion with the teachers, the researcher found that the teachers indicated that some students were suffering from a lack of prerequisite knowledge or skills which led to limited instructions in their classrooms, and they paid more attention to them to keep up with other students. The researcher also observed that this appeared to be the case
4 and 5	Different type of CPD	No sig difference between groups	The researcher's discussion with teachers, and field observation both indicated that training face-to-face is important for improving meta-cognitive teaching skills and intervention strategies

This Table integrates the principal quantitative findings with the additional qualitative data for intermediate school students. It is clear that the qualitative findings illuminate some subtle aspects of pupils' outcomes that are not revealed by the quantitative testing. Together, these data provide a robust basis for understanding the power and limitations of PBL in this intermediate school, and some indications of where further qualitative work might be undertaken – for example in relation to self-directed learning, cooperation, and thinking skills.

Chapter Six: The results of primary school data

6.1 Introduction

The main purpose of this study was to investigate the effects on achievement and Attitudes towards Mathematics levels, of students taught using PBL teaching strategies, by trained (trained face-to-face) and untrained (self-directed learning) teachers. The study also aimed to examine the interactions of both high and low achievers who had been taught using PBL strategies by both trained teachers and untrained teachers. These data are primarily quantitative. In addition, and supplementary to the quantitative data, the study also investigated the teachers' perspectives on their experiences of implementing PBL strategies in the classroom, using qualitative approaches, more specifically semi-structured interviews. These data were also triangulated with field observation notes of the teachers actually working in the classroom. Furthermore, the quantitative investigations also compared the effects upon achievement and attitudes, of the teaching styles of teachers who had been trained in using PBL strategies with those who had conducted self-directed learning (and were not trained). A comparison of pupils' outcomes with the PBL teaching styles was also made with that of conventionally taught pupils.

The aim of this chapter is to present the results of the data that has been collected from the field work study for primary school students. The procedure of implementing the study has been fully discussed in Chapter 4.

For the principal quantitative findings, all assessment outcome variables are presented as summary statistics. One-way ANOVA models (Howell, 2012; Field, 2013) between groups are applied to check the equality of all the students' prior knowledge across the groups. Mixed-factor ANOVA models (Howell, 2012; Field, 2013) within one factor (time: pre and post) and between two factors, group factor [3 levels] and achievement level factor [2 levels] are the main factors, along with a possible interaction factor. Change in achievement was analysed by group only. Such models are robust to depart from parametric assumptions; however, the constant variance assumption was monitored and was found to be at acceptable levels. Tukey's post hoc test (Howell, 2012; Field, 2013) was applied when appropriate and where significant results were observed; an Effect Size [Partial Eta Squared ($\eta p2$)] is also reported. All analyses were performed on IBM SPSS v22 and at a 5% ($p = 0.05$) level of significance. For the additional qualitative findings, teachers were interviewed about their experiences of implementing PBL and the results are presented later in this chapter. A research diary was kept which recorded a detailed commentary with regards to implementing the study. Observations from this diary are included in this chapter. These data are summarised in Table 5.28. Finally, qualitative and quantitative findings are integrated with respect to the research questions. This integration is presented in section 6.10 and Table 6.14.

All assessment outcome variables are presented as summary statistics. One-way ANOVA models (Howell, 2012; Field, 2013) between groups are applied to check the equality of all the students' prior knowledge across the groups. Mixed-factor ANOVA models (Howell, 2012; Field, 2013) within one factor (time: pre and post) and between two factors, group factor [3 levels] and achievement level factor [2 levels] are the main factors, along with a possible interaction factor. Change in achievement was analysed by group only. Such models are robust to depart from parametric assumptions; however, the constant variance assumption was monitored and was found to be at acceptable levels. Tukey's post hoc test (Howell, 2012; Field, 2013) was applied when appropriate and where significant results were observed; an Effect Size [Partial Eta Squared ($\eta p2$)] is also reported. All analyses were performed on IBM SPSS v22 and at a 5% ($p = 0.05$) level of significance. Teachers were interviewed about their experiences of implementing PBL and the results are presented later in this chapter. The research diary is presented which gives a detailed commentary with regards to implementing the study. Finally, qualitative and quantitative findings are integrated with respect to the research questions.

6.2 Primary school students

The aim of this study is to investigate the effects of the PBL teaching strategy on students' achievement (knowing, applying and reasoning achievement) and students' Attitudes towards Mathematics (Like learning mathematics and confidence to learn mathematics) in primary school students. In addition, the study examined whether the achievements and attitudes towards mathematics levels were affected in the students who had been taught both by the teachers who had undertaken face-to-face CPD courses or by the teachers who were asked to conduct self-directed learning in teaching PBL strategies, or both. This study went deeper to investigate the interactions of high and low achievers taught with PBL strategies by trained teacher and untrained teachers and their students' achievement and Attitudes towards Mathematics levels. The study also examined the teachers' perspective about their experience of implementing PBL. The investigations compared the teaching styles of teachers who had been trained in using PBL strategies with those who had not and the teaching styles used with the PBL strategies were also compared to the teaching styles which used conventional methods.

16 multiple-choice questions, short answer questions, fill in Table and drawing tests were applied at the beginning of the study (pre-test) and during the final experiment (post-test).

The tests consisted of five items which measured the knowing domain, six items covering applying ability and five items assessing reasoning ability.

Attitudes towards Mathematics were assessed using seven items applied twice as pre and post measures. Seven items, 4 Likert-scales were used which covered three aspects of Attitudes towards Mathematics: Like Learning Mathematics (3 items) and confidence to learn mathematics (4 items).

Semi-structured interviews were also conducted with both trained teachers and untrained teachers before and after the implementation of the study. This aimed to ensure that all teachers had the same experience, expertise, beliefs and attitudes towards student-centred learning and also to investigate their experience after the implementation of PBL. These instruments and procedures had been discussed in detail in chapter 3.

Three groups were selected to be part of this study; group A (the trained teacher PBL group), group B (the conventional group), and group C (the untrained teacher PBL group). The teachers were similar in terms of qualifications, experience and expertise and also beliefs and perspectives on PBL and traditional methods. However, one teacher was selected randomly to receive CPD training in PBL strategies and another was provided with the materials of PBL such as designed problems and guidelines for implementing PBL. This teacher did not receive CPD training. Students were equal between the groups based on school records, as explained in Chapter 3.

The study attempts to answer the following questions:

1. What are the effects of PBL teaching strategies, using trained and untrained teachers, on students' achievement levels (knowing, applying, and reasoning) when compared with conventional methods?
2. What are the effects of PBL teaching strategies, using trained and untrained teachers on, students' motivation (attitudes towards mathematics, placing value on mathematics, and confidence to learn mathematics) when compared with conventional methods?
3. Is there significant any interaction between treatment and levels of achievement (high and low achievers) in students' achievement levels in 'knowing', 'applying', and 'reasoning'?
4. Is there any significant interaction between treatments and levels of achievement (high and low achievers) in students' motivation (attitudes towards mathematics, placing value on mathematics and confidence to learn mathematics)?

5. What is the perspective of the teachers about PBL after the treatments when compared with conventional teaching methods?

This chapter details the assumptions of Mixed between-within subjects ANOVA, and will be discussed first and, then the data of mathematics achievements and attitudes towards mathematics will be followed. Finally, the qualitative data will be analysed at the end.

6.3 Assumptions of Mixed Between-Within Subjects ANOVA

The data for this study has met all the necessary assumptions for all the statistical tests used. This indicates that using the Mixed Measures ANOVA Model is appropriate for this study. In the following section, Normality, Sphericity and Homogeneity of Variance will be discussed and tested (see Chapter 5 for more details)

6.3.1 Normality

10 conditions were tested for normality by using the Shapiro–Wilk test (for more details see chapter 5). The results show that the data met the assumption of normality, see Table6.1.

Table6.1: Shapiro-Wilk test for scores (primary school students)

Test	group	Statistic	df	sig	Test	group	Statistic	df	sig
Pre-knowing	A	.897	52	.061	Post-knowing	A	.910	52	.100
	B	.915	39	.123		B	.920	39	.146
	C	.909	36	.152		C	.914	36	.177
	high	.866	26	.073		high	.873	26	.054
	Low	.844	22	.093		low	.877	22	.060
Pre-applying	A	.919	52	.142	Post-applying	A	.901	52	.071
	B	.915	39	.124		B	.908	39	.091
	C	.900	36	.111		C	.923	36	.246
	high	.907	26	.052		high	.873	26	.064
	Low	.844	22	.093		low	.867	22	.067
Pre-reasoning	A	.919	52	.142	Post-reasoning	A	.905	52	.083
	B	.915	39	.124		B	.927	39	.193
	C	.906	36	.140		C	.914	36	.177
	high	.924	26	.056		high	.880	26	.066
	Low	.853	22	.104		low	.896	22	.075
Pre-like learning mathematics	A	.945	52	.388	post-like learning mathematics	A	.920	52	.146
	B	.943	39	.355		B	.952	39	.482
	C	.881	36	.061		C	.901	36	.115
	high	.921	26	.057		high	.916	26	.067
	Low	.936	22	.166		low	.939	22	.189
Pre-confidence to learn mathematics	A	.916	52	.128	Post-confidence to learn mathematics	A	.957	52	.574
	B	.927	39	.192		B	.897	39	.061
	C	.932	36	.328		C	.902	36	.119
	high	.885	26	.088		high	.902	26	.097
	Low	.943	22	.223		Low	.949	22	.297

A= PBL with trained teacher's group, **B=** conventional method group, and **C=** PBL with untrained teacher's group. **High** =high achievers, and **low**= low achievers

6.3.2 Sphericity

For the purposes of this study there is no need to test the assumption of Sphericity because the factor of within subjects has only two levels (time with pre and post) (for more details see chapter 5). Thus, the Sphericity assumption is already met for a within-subjects factor that has only two levels (Field 2013; Cardinal and Aitken, 2013).

6.3.3 Homogeneity of Variance

In the present study the assumptions for homogeneity of variance between groups were tested using Levene's test (for more details see chapter 5). No significant results were found (See Table6.2).

Table6.2 Levene's Test of Equality of Error Variances for primary school students

Groups between	F	df1	df2	Sig.
Pre-knowing	.832	5	121	.530
Post-knowing	.409	5	121	.842
Pre-applying	1.425	5	121	.220
Post-applying	1.503	5	121	.194
Pre-reasoning	3.773	5	121	.053
Post-reasoning	2.173	5	121	.061
Pre-like learning mathematics	4.884	5	121	.060
Post-like learning mathematics	20.379	5	121	.071
Pre-confidence to learn mathematics	5.628	5	121	.083
Post-confidence to learn mathematics	20.304	5	121	.170

The data of study is met with three main assumptions of Mixed Between-Within Subjects ANOVA: Homogeneity of Variance, Normality and Sphericity; therefore it is appropriate and valid to analysis the data of the study.

6.4 Mathematics Achievements

In order to assess the students' 'Mathematics Achievement', three domains were considered, namely 'Knowing Achievement', 'Applying Achievement' and 'Reasoning Achievement'.

One-way ANOVA had been applied on pre-test of Knowing Mathematics, Applying mathematics, and Reasoning mathematics achievements to ensure that all students across the groups are similar before the treatment.

The test shows that there is no statistically significant difference in the pre-tests of Knowing Mathematics, Applying mathematics, and Reasoning mathematics achievements between groups, $F(2, 124)$, $p < 0.05$, see ANOVA Table in Appendix 6.1. Therefore, all groups were equal for implementation of the treatment.

In this section the ANOVA model was used to analyse each domain separately. This approach was considered as the most reliable and effective to assess the effectiveness of PBL on students' 'Mathematics Achievement' with trained or untrained teachers for high achievers, low achievers and a combination of all students.

6.4.1 Knowledge

Table 6.3: Summary statistics for the Knowledge score within time and by groups and achievement levels

Knowing Achievement	A (training and PBL)		B (training and tradition)		C (non-training and PBL)	
Student ability levels	High	Low	High	Low	High	Low
Pre-score Mean SD	2.29 0.75	0.75 0.84	1.17 0.39	0.93 0.39	2.31 0.95	0.65 0.71
Mean SD	1.46 1.11		1.00 0.40		1.25 1.13	
Post-score Mean SD	3.50 1.38	1.93 1.37	2.67 1.50	2.11 1.37	2.54 1.27	1.65 1.30
Mean SD	2.65 1.52		2.28 1.41		1.97 1.34	

From Table 6.3, it can be seen that the improvement in the ‘Knowing Achievement’ mean score increased in all the groups. In addition, the mean pre score was in general higher for the high achievers within each group. The improvement was less marked in the higher achiever scores and for group C, the untrained teacher’s PBL group. In addition, the average achievement scores in the higher achievers’ group were increased.

From the ANOVA analysis there was no significant overall group effect which was observed over time, $F(3, 121) = 2.601$, $p = .078$, partial $\eta 2 = .041$. This means that there was no significant difference between the groups attributed to the types of treatment in ‘Knowing Mathematics Achievement’. In addition, there was no significant interaction effect between the groups and their levels of achievement over time $F(3, 121) = 1.377$, $p = .256$, partial $\eta 2 = .022$. This implies that in ‘Knowing Mathematics Achievement’ the students’ results were not significantly affected by the interaction of the types of treatment with different levels of students (high and low achievers). In other word, the trends of the high and low achievers within each group behaved similarly across all groups (see Table 6.1).

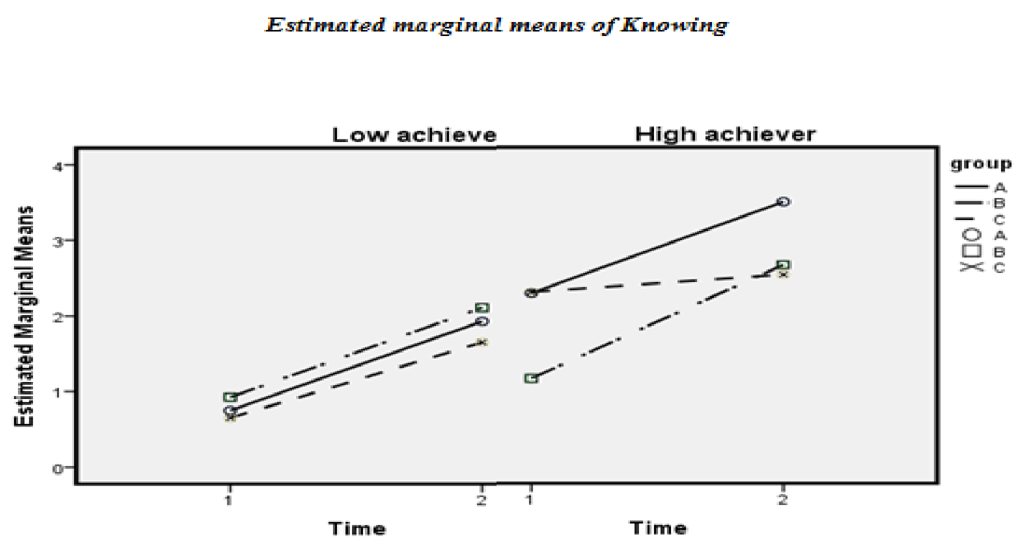
However, there was a significant difference between the average all students’ Knowing achievement over time, with estimated mean scores of 1.35 and 2.40 for pre and post-tests respectively, $F(1, 121) = 64.170$, $p = .000$. The partial eta square effect size for this significant result was large at 0.347. This indicates that overall, students’ achievement in

‘Knowing’ significantly improved. Furthermore, there was no significant difference between the overall level effect over time F (1, 121) = .291, p =.590, partial η2 = .002, (see Table 6.4and Figure 6.1).

Table 6.4: Mixed ANOVA outcomes for Knowing achievement

Test	df	F	p-vlaue	Partial Eta Squared
Time	1	64.170	.000**	0.347
Groups	2	3.035	.052	0.048
Time * groups	2	2.601	.078	0.041
Time * levels of achievement * groups	2	1.377	.256	0.022
Time * level achievement	1	.291	.590	0.002
Error (time)	121			

Note: p* is significant < 0.05, p** is significant >0.01



A is the trained teacher’s PBL group

B is the untrainedteacher’s traditional group

C is the untrainedteacher’s PBL group

Figure 6 1: High and low achievers’ average achievement scores in ‘Knowing’ for each group

As Figure 6.1and Table 6.3illustrate, the low and high achiever group mean scores increased in all the groups. In addition, there was no significant difference between high and low achievers over time. Moreover, the difference between the high and low achievers over time was also not affected by the groups.

Overall, there was no significant difference overall in the Knowing achievement scores over time. The interaction between the levels of achievement and time is insignificant. It was also not affected by the type of the treatments. In addition, there was no significant difference between the groups over time. This indicates that using PBL is unlikely to improve achievement levels in 'Knowledge Mathematics Achievement' any more than when using traditional teaching methods. In addition, training teachers in PBL implementation could not have any effect on students' knowledge mathematics achievement. Finally, it can be concluded that in respect of mathematics achievement the different ability levels of students is unlikely to have any effect on their performance in 'knowing mathematics achievement' when using the PBL teaching strategy.

6.4.2 Applying

Table 6.5: Summary statistics for Applying scores within time and by groups and achievement levels

Applying Achievement	A (training and PBL)		B (training and tradition)		C (non-training and PBL)	
Student ability levels	**High**	**Low**	**High**	**Low**	**High**	**Low**
Pre-score						
Mean	1.79	0.50	1.75	0.52	2.15	0.30
SD	0.78	0.64	1.10	0.64	0.80	0.47
Mean	1.10		0.90		.97	
SD	0.96		0.97		1.10	
Post-score						
Mean	3.37	2.04	2.25	1.52	2.77	1.61
SD	1.47	0.89	1.66	1.29	1.64	1.56
Mean	2.65		1.74		2.03	
SD	1.36		1.43		1.67	

From Table 6.5, it can be seen that the improvement in the 'Applying Achievement' mean scores increased in all the groups. In addition, the mean pre score was in general higher for the high achievers within each group. The lower achiever and the higher achievers average scores were increased within all groups.

From the ANOVA analysis there was a significant overall group effect which was observed over time, $F(3, 121) = 4.333$, $p = .015$. The partial eta square effect size for this significant result was medium at .067. Tukey's post hoc test was applied to determine which any of the groups were significantly different from the others. This test found that the mean scores of the students taught using PBL by the trained teachers group were significantly different from the scores of the students taught using conventional methods but were no different to the scores of the PBL students taught by the untrained teachers group, $P = .009$, see Appendix 6.2. This implies that in 'Applying Mathematics Achievement' the students' results were significantly affected by the interaction of the types of treatment. This means that there was a significant difference between the groups attributed to the types of treatment in 'Applying Mathematics Achievement', which indicates that the average of the PBL group's scores with the trained teacher significantly improved more than the average of the traditional group's scores in 'Applying Mathematics'. However, there was no significant interaction effect between the groups and levels of achievement over time $F(3, 121) = .899$, $p = .410$, partial $\eta 2 = .015$. This means that the trends of the high and low achievers within each group behaved similarly across all groups, (see Figure 6.2). In addition, there was a significant difference between the average students' applying achievement mean scores over time, with estimated mean scores of 1.17 and 2.26 for pre and post-tests respectively, $F(1, 121) = 76.795$, $p = .000$. The partial eta square effect size for this significant result was large at .388. Furthermore, there was no significant difference between the overall level effect over time $F(1, 121) = 2.340$, $p = .129$, partial $\eta 2 = .019$, (see Table 6.6 and Figure 6.2). This indicates that overall, students' achievement in 'Applying' significantly improved.

Table 6.6: Mixed ANOVA outcomes for Applying Achievement

Test	df	F	p-value	Partial Eta Squared
Time	1	76.795	.000**	0.388
Groups	2	2.351	.100	0.037
time * groups	2	4.333	.015*	0.67
time * levels of achievement * groups	2	.899	.410	0.015
time * level achievement	1	2.340	.129	0.19
error (time)	121			

Note: p* is significant < 0.05, p** is significant >0.01

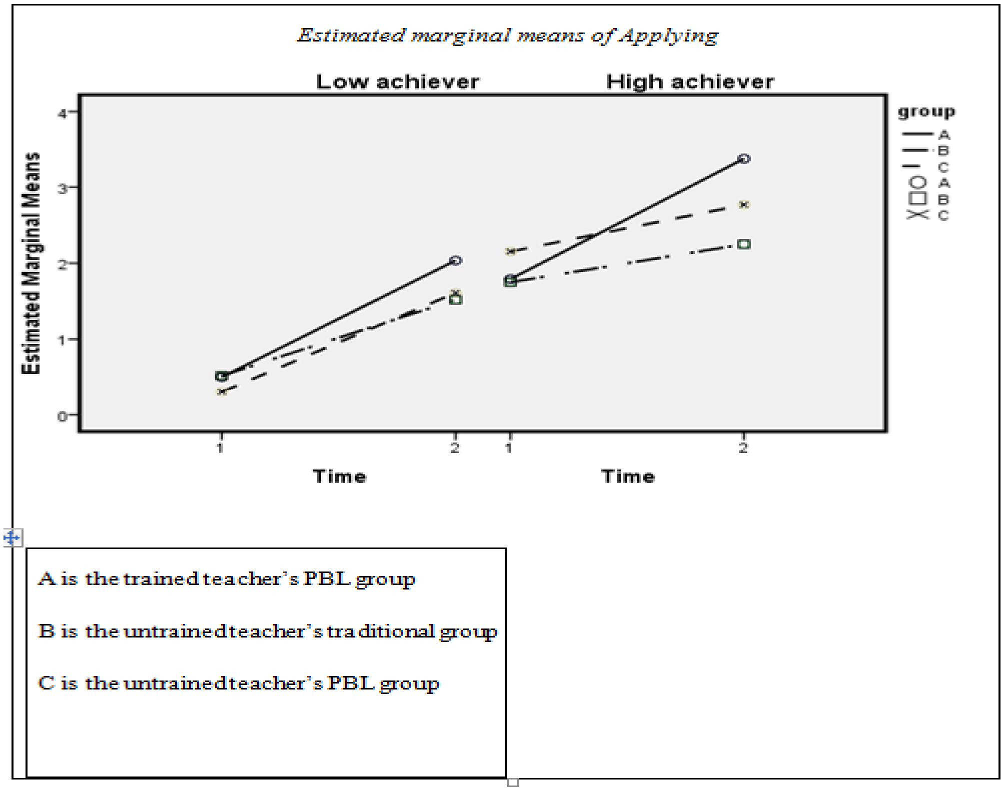


Figure 6 2: High and low achievers' average achievement scores in 'Applying for each group

As Figure 6.2 and Table 6.5 illustrate the low and high achiever group mean scores increased within all the groups. Thus, there was no significant difference between the high and low achievers over time. Moreover, the difference between the high and low achievers over time was also not affected by the groups. Moreover, the difference between group A and group B is significant and this can be seen from the illustration.

Overall, there was a significant difference between the groups over time in favour of the trained teacher's PBL group when compared with the conventional group. In addition, there was a significant impartment overall in the Applying achievement scores over time. The interaction between the levels of achievement and time was insignificant. It was also not affected by the type of the treatments. This indicates that using PBL with trained teachers is likely to improve achievement in 'Applying Mathematics Achievement' more than when using traditional teaching methods. Finally, it can be concluded that in respect of mathematics achievement the different ability levels of students is unlikely to have any effect on their performance in 'applying mathematics achievement' when using the PBL teaching strategy.

6.4.3 Reasoning

Table 6.7: Summary statistics for Reasoning scores within time and by groups and achievement levels

Reasoning Achievement	A (training and PBL)		B (training and tradition)		C (non-training and PBL)	
Student ability levels	High	Low	High	Low	High	Low
Pre-score Mean SD	1.38 0.92	0.75 0.70	1.50 0.52	0.59 0.64	1.46 1.13	0.57 0.73
Mean SD	1.04 0.86		0.87 0.73		.89 .98	
Post-score Mean SD	2.25 1.48	1.14 0.89	1.75 0.87	1.11 0.89	2.15 1.52	1.43 0.99
Mean SD	1.65 1.31		1.31 0.92		1.69 1.24	

From Table 6.7, it can be seen that the improvement in 'Reasoning Achievement' mean scores increased in all the groups. In addition, the mean pre score was in general higher for the high achievers within each group. The lower achiever and the higher achievers average scores were increased within all groups.

From the ANOVA analysis there was no significant overall group effect which was observed over time, F (3, 121) = 1.102, p =.335, partial η2 = .018. This means that there was no significant difference between the groups attributed to the types of treatment in 'Reasoning Mathematics Achievement'. In addition, there was no significant interaction effect between the groups and their levels of achievement over time F (3, 121) = 1.494, p =.228, partial η2 = .024. This implies that in 'Reasoning Mathematics Achievement' the students' results were not significantly affected by the interaction of the types of treatment with different levels of students (high and low achievers). In other word, the trends of the high and low achievers within each group were similar across all groups, (see Figure 6.3). In addition, there was a significant difference between the average students' Reasoning achievement scores over time, with estimated mean scores of 1.04 and 1.64 for pre and post-test scores respectively, F (1, 121) = 33.345, p =.000. The partial eta square effect size for this significant result was large at 0.216. This indicates that overall, students' achievement in 'Reasoning significantly improved Furthermore, there was no significant difference between the overall level effect over time F (1, 121) = .003, p =.954, partial η2 = .000, (see Table 6.8and Figure 6.3).

Table 6.8: Mixed ANOVA outcomes for reasoning achievement

Test	df	F	p-value	Partial Eta Squared
Time	1	33.345	.000**	.216
Groups	2	.448	.640	.007
Time * groups	2	1.102	.335	.018
Time * levels of achievement * group	2	1.494	.228	.024
Time * level achievement	1	.003	.954	.000
Error (time)	121			

Note: p* is significant < 0.05, p** is significant >0.01

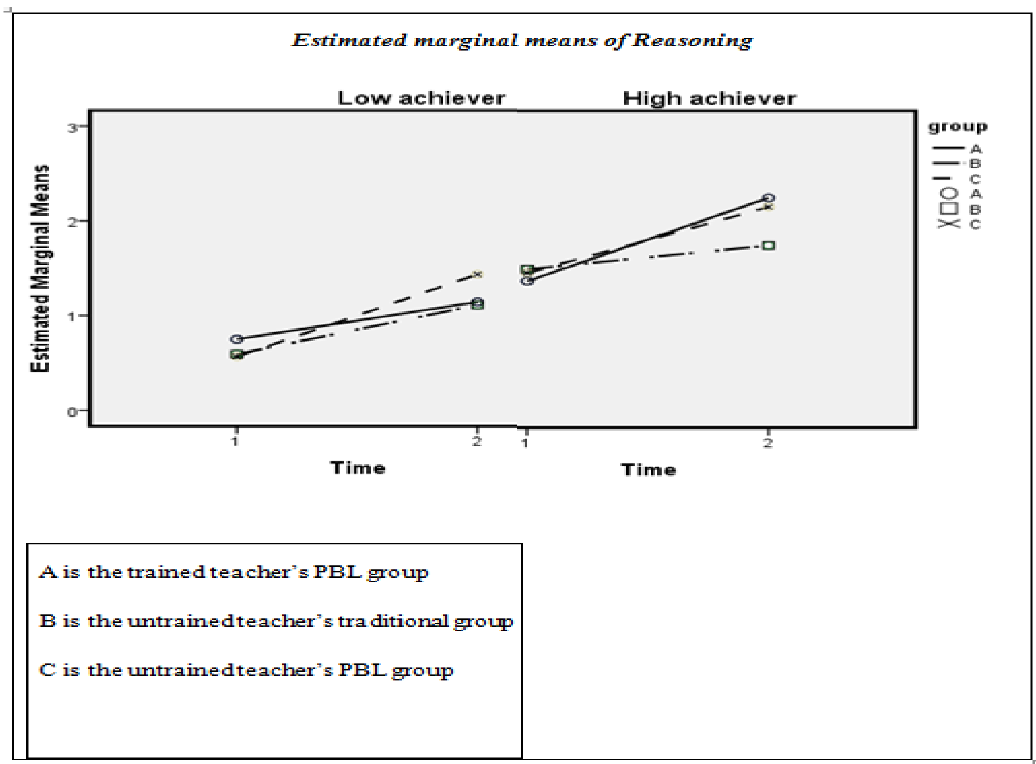


Figure 6 3: High and low achievers' average achievement scores in 'Reasoning for each group

As Figure 6.3 and Table 6.7 illustrate, the low and high achiever group mean scores increased within all the groups. In addition, there were no significant differences between the high and low achievers scores over time. Moreover, the significant difference between the high and low achievers over time was also not affected by the groups.

Overall, there was a significant difference overall in the Reasoning achievement over time. The interaction between the levels of achievement and time is insignificant. It was also not affected by the type of the treatments. In addition, there was no significant difference between groups over time. This indicates that using PBL is unlikely to improve achievement in ‘Reasoning Mathematics Achievement’ any more than when using traditional teaching methods. In addition, training teachers in PBL implementation could not have any effect on students’ Reasoning mathematics achievement. Finally, it can be concluded that in respect of mathematics achievement the different ability levels of students is unlikely to have any effect on their performance in ‘reasoning mathematics achievement’ when using the PBL teaching strategy.

6.5 Attitudes Towards Mathematics

One-way ANOVA had been applied on the pre-measure Like Learning Mathematics and confidence to learn mathematics tests to ensure that all students across the groups were similar before the treatment. The tests show that there was no statistical significant difference in the pre-measure of Like Learning Mathematics and confidence to learn mathematics between groups, $F (2, 124)$, $p < 0.05$, see the ANOVA Table in Appendix 6.3. Therefore, all the groups were equal prior to the implementation of the treatment.

6.5.1 Like Learning Mathematics Scores

Table 6.9: Summary statistics for Like Learning Mathematics scores within time and by groups and achievement levels

Like Learning Mathematics	A (training and PBL)		B (training and tradition)		C (non-training and PBL)	
Student ability levels	High	Low	High	Low	High	Low
Pre-score						
Mean	10.17	10.86	10.25	10.11	10.15	10.35
SD	2.14	1.30	2.26	1.81	1.82	2.23
Mean	10.54		10.15		10.28	
SD	1.75		1.93		2.07	
Post-score						
Mean	11.38	11.32	8.83	8.70	11.85	10.70
SD	1.41	1.72	2.82	3.18	0.56	2.77
Mean	11.35		8.74		11.11	
SD	1.57		3.04		2.53	

In Table 6.9 it can be seen that the mean score of the ‘like learning mathematics’ increased in the PBL Groups A and C, while the scores of Group B, the traditional group, decreased.

Both the lower and higher achievers' average scores were increased with two of the three PBL groups, (A and C), and the average scores Group B, the traditional group.

From the ANOVA analysis there was a significant overall group effect which was observed over time, $F(3, 121) = 12.486$, $p = .000$. The partial eta square effect size for this significant result was large at .171. Tukey's post hoc test was applied to determine which any of the groups was significantly different from the others. This test found that using PBL with the trained teachers group was significantly different from the conventional group P=.000, and using PBL with the untrained teachers group was also significantly different from the conventional group P=.008. However, there was no significant difference between using PBL, whether with the trained or untrained teacher, (see Table 6.10 and figure 6.4). This means that there was significant difference between the groups attributed to the types of treatment in 'Like Learning Mathematics'. The average scores of both PBL groups with the trained and untrained teachers significantly improved more than the average scores of the students taught using traditional teaching methods. However, there was no significant interaction effect between the groups and their levels of achievement over time $F(3, 121) = .739$, $p = .480$, partial $\eta2 = .012$. This implies that in 'Like Learning Mathematics' the students' results were not significantly affected by the interaction of the types of treatment with different levels of students (high and low achievers). In other word, the trends of the high and low achievers behaved similarly across all groups (see Figure 6.4).

In addition, there was no significant difference between the average students Like Learning Mathematics scores over time, with an estimated mean score of 10.31 and 10.46 for pre and post-tests respectively, $F(1, 121) = .480$, $p = .490$, partial $\eta2 = .004$. This indicates that overall, students' scores in 'Like Learning Mathematics' did not significantly improve. Furthermore, there was no significant difference between the overall level effect over time $F(1, 121) = 2.625$, $p = .108$, partial $\eta2 = .021$, (see Table 6.10and Figure 6.4).

Table 6.10: Mixed ANOVA outcomes for Like learning mathematics results

Test	df	F	P-value	Partial Eta Squared
Time	1	.480	.490	.004
Groups	2	7.501	.001**	.110
Time * groups	3	12.486	.000**	.171
Time * levels of achievement * groups	3	.739	.480	.012
Time * level achievement	1	2.625	.108	.021
Error (time)	121			

Note: p* is significant < 0.05, p** is significant >0.01

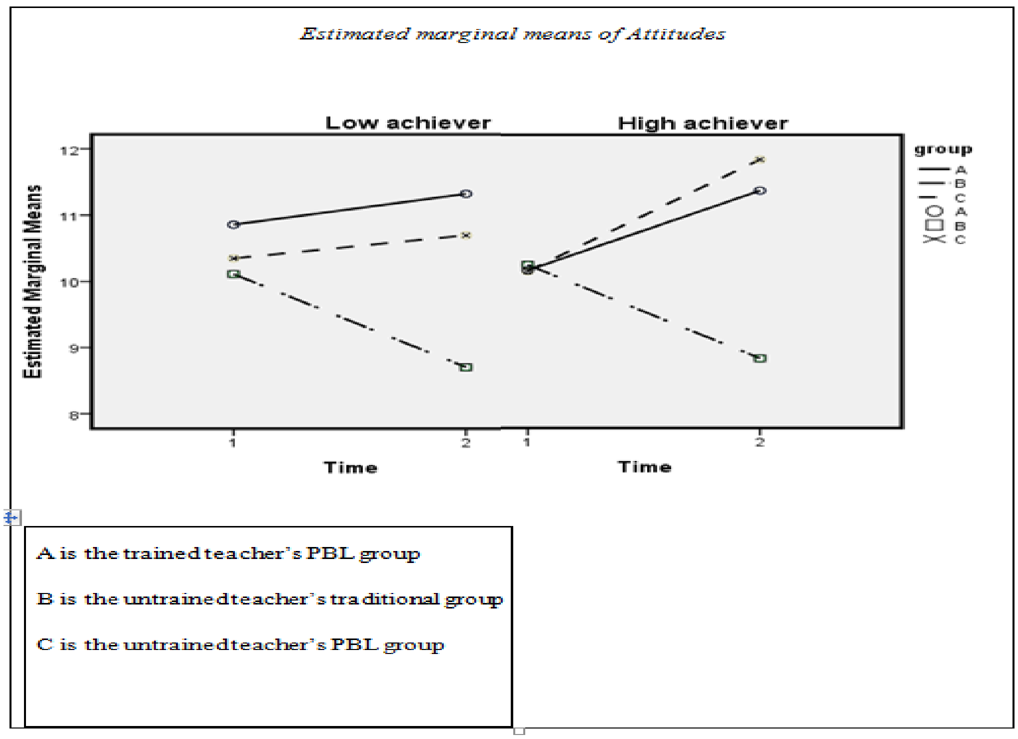


Figure 6 4: High and low achievers' average scores in 'Like Learning Mathematics' for each group

As Figure 6.4 and Table 6.9 illustrate, the differences between group A and group B are significant, and there are also significant differences between group B and group C. The low and high achiever group mean scores increased with groups A and C, and significantly decreased for group B, (see T-test Table in Appendix6.4). Thus, there is no significant difference between high and low achievers over time. Moreover, the difference between the high and low achievers over time was also not affected by the groups.

Overall there is a significant difference between the groups over time in favour of PBL. In addition, there was no significant difference overall in the Like Learning Mathematics scores over time. This may be due to the decreasing of group B. The interaction between the levels of achievement and time is insignificant. It is also not affected by the type of the treatments. This indicates that using PBL, whether with trained or untrained teachers, is likely to lead to higher scores in ‘like learning mathematics’ more than when using traditional teaching methods. In addition, training teachers in PBL implementation could not have any effect on students’ Like Learning Mathematics’. Finally, the different ability levels of students in mathematics achievement are unlikely to have an effect on the PBL teaching strategy on ‘like learning mathematics’ scores.

6.5.2 Confidences to Learn Mathematics Scores

Table 6.11: Summary statistics for Confidence score within time and by groups and achievement levels

Confidence to learn Mathematics	A (training and PBL)		B (training and tradition)		C (non-training and PBL)	
Student ability levels	High	Low	High	Low	High	Low
Pre-score Mean SD	14.17 2.01	14.79 1.29	14.08 2.20	14.11 1.81	14.15 1.82	14.30 2.10
Mean SD	14.50 1.67		14.10 1.90		14.25 1.95	
Post-score Mean SD	15.46 1.02	15.25 1.72	13.33 2.23	12.67 3.15	15.85 0.56	14.65 2.55
Mean SD	15.35 1.43		12.87 2.89		15.08 2.41	

From Table 6.11 it can be seen that the mean scores relating to ‘confidence to learn mathematics’ increased in PBL groups A and C, while the scores of the traditional group, Group B decreased. Both the lower and higher achievers average scores were increased with two of three PBL groups (A and C), whereas the scores decreased in Group B, the traditional group. From the ANOVA analysis there was a significant overall group effect which was observed over time, $F(3, 121) = 10.163$, $p = .000$. The partial eta square effect size for this significant result was large at .144. Tukey’s post hoc test was applied to determine which any of the groups were significantly different from the others. This test found that the results of using PBL with the trained teacher group were significantly different from the results of the conventional group $P=.000$, and the scores of the untrained teachers group who used PBL were also significantly different from the scores of the conventional group $P=.008$, (see Table 6.12 and figure 6.6). This means that there was significant difference between the groups attributed to the types of treatment in

‘Confidence to Learn Mathematics’. The average scores of both PBL groups with the trained and untrained teachers significantly improved more than traditional group’s average scores. However, there was no significant difference between using PBL, whether with the trained or untrained teacher. There was no significant interaction effect between the groups and their levels of achievement over time F (3, 121) = .208, p =.813, partial η2 = .003. This implies that in ‘Confidence to Learn Mathematics’ the students’ results were not significantly affected by the interaction of the types of treatment with different levels of students (high and low achievers). In other word, the trends of the high and low achievers within each group were similar across all groups, (see Figure 6.5). In addition, there was no significant difference between the average students confidence to learn mathematics scores over time, with estimated mean scores of 14.27 and 14.53 for the pre and post-tests respectively, F (1, 121) = 1.657, p =.200, partial η2 = .014. This indicates that overall, students’ scores in ‘Confidence to Learn’ Mathematics’ did not significantly improve. Furthermore, there was a significant difference between the overall level effect over time F (1, 121) = 5.307, p =.023, partial η2 = .042, with an increase in the high achievers mean scores and decreased mean scores for the low level achievers group,(See Table 6.12and Figure 6.5). This indicates that regardless the type of treatment students received, the higher achieving students felt more confident than lower achieving students.

Table 6.12: Mixed ANOVA outcomes for Confidence results

Test	Df	F	p-value	Partial Eta Squared
Time	1	1.657	.200	.014
Groups	2	7.305	.001**	.108
Time * groups	3	10.163	.000**	.144
Time * levels of achievement * groups	3	.208	.813	.003
Time * level achievement	1	5.307	.023*	.042
Error (time)	121			

Note: p* is significant < 0.05, p** is significant >0.01

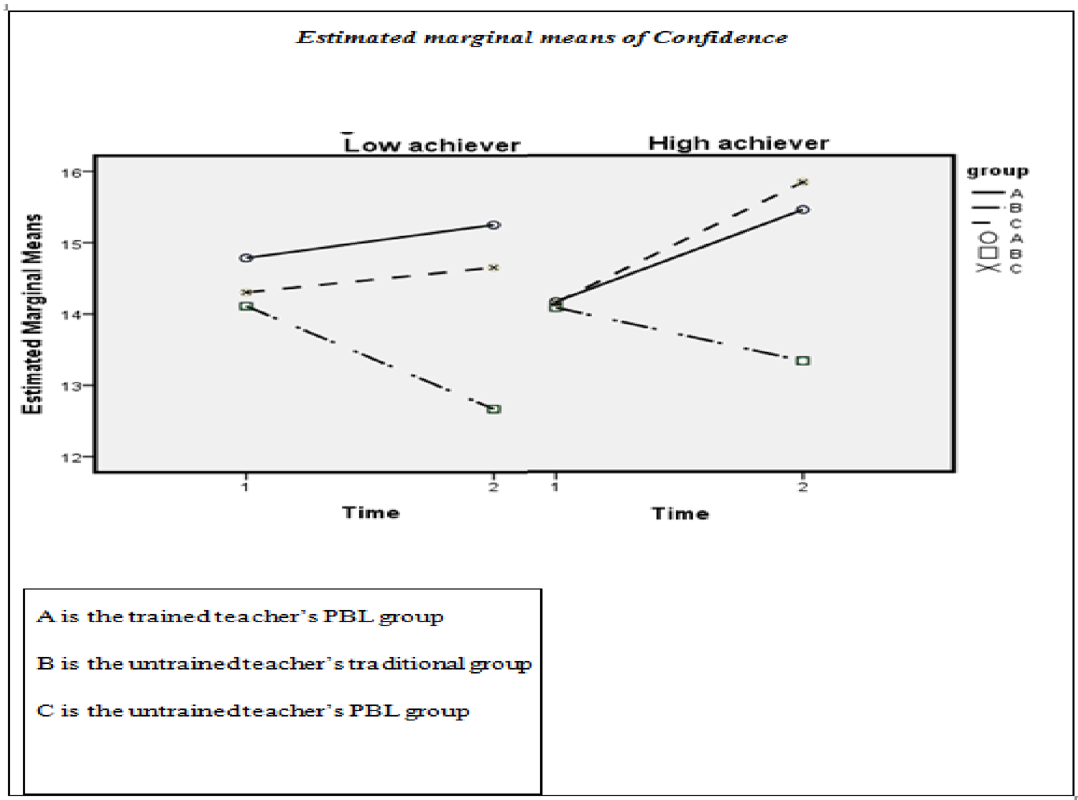


Figure 6 5: High and low achievers' average scores in 'Confidence' for each group

As Figure 6.5 and Table 6.11 illustrate that the difference between group A and group B is significant, and also with group B and group C. The low and high achiever group mean scores increased within groups A and C, and decreased significantly for group B, (see T-test Table in Appendix6.5. In addition, there was a significant difference between the high and low achievers' mean scores over time. However, the difference between high and low achievers over time was not affected by the groups.

Overall, there is a significant difference between the groups over time in favour of PBL. In addition, there was no significant difference overall in the Confidence to Learn Mathematics scores over time. This may be due to the decreasing of group B. The interaction between levels of achievement and time is significant with an increase in the estimated mean score for the high achievers and a decrease in the estimated mean score of the low achievers. However, the scores were not affected by the type of the treatments. This indicates that using PBL, whether with trained or untrained teachers, is likely to lead to higher scores in 'confidence to learn mathematics' more than when using traditional teaching methods. In addition, training teachers in PBL implementation could not have any effect on students' Like Learning Mathematics'. Finally, the different ability levels of students in mathematics achievement are unlikely to have an effect on the PBL teaching strategy on 'confidence to learn mathematics' scores.

6.6 Teachers' Interviews

Semi-structured interviews were conducted to investigate the experience of teachers in using PBL strategies. Six main questions were asked; How was PBL implemented in class? What were the advantages of using PBL? What were the disadvantages of using PBL? What challenges did you face when implementing PBL in the classroom? To what extent do the students lacking prerequisite knowledge or skills limit how you teach this class? How do students engage in PBL learning processes? The teachers' responses to six questions were analysed (please see Chapter 3 for more details). Six final themes emerged, namely: PBL implementation, advantage of using PBL, disadvantages of using PBL, challenges of using PBL, students with a lack of prerequisite knowledge or skills and engagement in the PBL process. The themes were then presented to each teacher with the results (both the trained and the untrained teacher) – (see the transcripts of the interview in Appendix 6.6).

6.6.1 The trained teacher (Ali)

1. ***Implementation of PBL in class***

Ali felt that face-to-face training seemed to improve the effectiveness of teachers in implementing PBL. Following his training, Ali was extremely keen to ensure that his students understood PBL problems very well and implemented PBL as he was asked. He commented that: "*Once students had understood the problem, their interest in learning mathematics immediately increased and they had a great desire to solve the problem*." Ali felt that any student who did not appear to like mathematics or have the desire to solve the problem, this was the result of them not fully understanding the problem. He continued by saying that "*They* [the students] *work within groups to solve the problem and I monitor them and coach their thinking with meta-cognitive questions*." Finally, Ali added: "*I discuss the solution with whole class*."

Ali emphasised that the students' understanding of the problem was a trigger to raise their Like Learning Mathematics. Meta-cognitive questions were used by Ali to coach students' thinking and to move students from one learning process to another. Ali implemented PBL as it was requested.

2. *Advantages of implementing PBL*

The trained teacher of the experimental group was asked about the most important advantage of using the PBL teaching strategy in the classroom. Ali found that students like learning mathematics when taught using PBL. In addition their concentration increased and their critical thinking skills improved.

- ***Like learning mathematics***

Ali noticed that his students' motivation increased once they began to understand the problems and what they needed to do to solve it with less input and explanation from their teacher. Ali stated that "*PBL remarkably increased Like Learning Mathematics among students*". He explained that "*students enjoyed learning using PBL"*. He added more explanation: "*the lesson becomes enjoyable with PBL and students began to look forward to mathematics lessons*". He added that "*many students ranked mathematics as their most second favourite subject after a sport lesson"*. He noted that this positive attitude towards mathematics was due to the problems that students encountered.

According to the teacher, "*when students encountered the problem they tried to solve it and this increased the students' Like Learning Mathematics to solve the problem. If students could not solve the problem then they become motivated to know the solution; if they were able to resolve it then the solution becomes a prize for them*". He found that the PBL teaching strategy was the best strategy that he ever had known in terms of increasing students' Like Learning Mathematics to learn. He said that "*I used to think that, as I made more effort in the classroom, students would be more motivated, but after I had experienced PBL I found the correct relationship between the effort required from teachers to explain everything for students and students' Like Learning Mathematics is negatively linked*". This means that if teachers reduce their efforts to explain everything to students and let them learn things by themselves then their Like Learning Mathematics towards learning is increased. This resulted in a change in his initial feelings about implementing PBL in favour of the student-centred approach rather than the teacher-centred approach.

Ali clearly believes that understanding the problem motivated students to solve it or to learn the solution. He also found reducing teacher's explanations could motivate students and increase their willingness to learn.

- ***Learning***

The self-directed learning in PBL situations increases students' concentration which may ultimately lead to an improvement in their learning. Ali stated: "*My students' levels of concentration became increased when learning via the PBL strategy.*" He noticed that when his students were taught via PBL they would concentrate for more than 40 minutes when previously their period of concentration was never longer than 15 minutes when taught using traditional methods. He argued that: "*The reason is because when the students learn with PBL they study by themselves and this makes them focus for a longer period of time. When the students learn by themselves over a longer period of time they also have a greater level of retention of the knowledge learned*." This indicates that when students become responsible for their learning, they spend much more time studying than if they are not. Ali confirmed this by adding: "*PBL strategies can expand the time students spend because they take over the responsibility of learning*." However, this may only be true with the students who like learning mathematics. Therefore, shifting the responsibility of learning from teachers to students may not be the only the reason for an increase in their levels of concentration and learning, it could also be due to the fact that they actually enjoy learning mathematics through real life situations.

- ***Critical thinking skills***

Ali noted that his students' critical thinking skills improved over time and they began to critically analyse their own ideas and his answers.

Ali commented: "*As well as teaching mathematics, I also taught critical thinking skills. The students had started to practise self-assessment skills and had begun to assess the ideas of others. Eventually they assessed me.*" Ali gave the following example: "*There were some occasions where I purposefully gave students an incorrect answer to see how they responded. I was pleased to see that they did not automatically accept my answer without first carrying out their own assessments; they would then agree or disagree with my answer based on their own level of understanding following their own assessment of the problem*." This indicates that students have shown some improvement in their critical thinking skills. This may be because the practice of receiving information from their teachers, without questioning its validity or carrying out their own assessment had changed, and they were required to come up with their own solutions.

- ***Class size***

Ali believes that the PBL strategy could be implemented on large class sizes of up to 40 students, but the stressed that: *"The classroom area must be large enough to allow teachers to easily access all groups*." This indicates that the trained teacher felt comfortable with dealing with groups.

- ***Implementing the PBL strategy on other subjects***

Ali recommended implementing PBL teaching strategies in a range of different subjects. This indicates that the trained teacher feels that PBL teaching strategy is worthwhile and should be used with other subjects.

3. ***Disadvantages of using PBL***

The trained teacher was asked to outline what he felt were the main disadvantages of using the PBL teaching strategy with the experimental group. Ali found PBL to be more time-consuming for the students when compared to traditional methods. He also believes that working with groups meant that some of the less able students relied on the stronger students so consequently did not learn as much.

- ***Time-consuming***

Ali found that teaching using PBL strategies takes much more time than teaching using traditional methods. He argued that "*with traditional methods the time is controlled by the teacher, whereas with PBL teaching strategies the time is controlled by students*". As such he felt it would be more beneficial if lesson times were extended from 45 minutes to 60 minutes. He also felt that lessons should be split over two classes of 45 minutes with one class being allocated to learning how to use PBL and another to recap and test what has been learned. With PBL, students need more time to practice their thinking skills and search for missing information, which is not the case for traditional teaching methods. However, as this increases their self-directed learning and critical thinking skills, this may ultimately justify to be beneficial for their development.

- ***Depending on others***

Low achieving students appear to rely on high achieving students in PBL sessions, so it may be prudent to assess students individually as well as within groups. Ali highlighted another disadvantage and said that: "*Some of the low achieving students were depending* *on the high achievers to solve problems which meant that they did not learn*." In order to avoid this problem he suggested that: "*Students should be given exercises and assessed individually*." He believes that if the students know they will be assessed individually then they would be more willing to learn.

4. *Challenges of implementing PBL*

The trained teacher of the experimental group was asked about the most challenges of using the PBL teaching strategy in the classroom. Ali believes that convince teachers to adopt the PBL strategy and adapting mathematics textbook of to ensure they support PBL the main challenges in implementing PBL in classrooms.

- ***Adjusting to PBL***

Ali thinks that new teachers would find PBL difficult to implement initially. He stated that: *"Inexperienced or new teachers may not believe that giving students more responsibility and control of their learning would have a positive effect and increase their ability to learn*". He added: "*Once they had realised and mastered this new way of teaching they would then become more comfortable with this strategy*." It seems that initially, the problem of adjusting to PBL is related to the teachers' apprehension about changing their roles and their lack of confidence that their students will learn using the new strategy. Therefore, Ali believes that teachers should be trained in how to implement PBL which would help to convince them to use it.

- ***Restrictions of using PBL***

Ali argued that adaptation of mathematics textbook would help both teachers and students to embrace PBL more easily. He asserted that: "*Student's mathematics textbooks need to be adapted to incorporate the PBL settings*."

5. *Readiness to learn mathematics*

Ali found that PBL could not be beneficial for extremely low achievers because they did not have the necessary pre-requisite knowledge. He recommended that students who lacked prerequisite knowledge should be given additional teaching outside of classroom before embarking on a PBL session. He stated that: *"Students should be taught the necessary skills needed separately and prior to joining the groups and this would solve the problem of students having insufficient prior knowledge or skills*."

6. Engagement in learning mathematics

Ali found some that students relied on each other. This is because the assessment is not taken individually and some had no pre-requisite knowledge or skills. The ability to understand problems is very important in order to ensure that all students are fully engaged. He added that: "*Once students had a clear understanding and when the problems were easy they would be highly engaged in learning processes*." Therefore, he believes that it is necessary to ensure that all students understand the problems to improve their learning. In addition, individual assessments for students could have a positive impact on students' outcomes.

6.6.2 The untrained teacher (Khalid)

1. Implementation of PBL in class

Self-directed development does not appear to improve teacher's abilities in implementing PBL as much as face-to-face training.

The untrained teacher (Khalid) explained how he implemented PBL in his class. He stated that "*I present the problem to students and then give them time to discuss the problem within groups, and then they work with their groups to solve the problem and I help them to solve the problem by explaining any difficulties indirectly, for example, by giving them some examples*".

Khalid explains things indirectly for students and gives them examples to help them to understand any difficult issues. He did not mention understanding the problem, so it seems that this is not very important to him. In addition, it appears that he did not use meta-cognitive questions to coach students' thinking.

2. Advantages of PBL

After undertaking PBL implementation, Khalid, the untrained teacher, was asked what he felt were the main advantages of using the PBL teaching strategy in his classroom. Khalid felt comfortable implementing PBL and noticed that some students' self-directed learning skills improved and their interest in learning mathematics increased with PBL.

- ***Self-directed learning***

Self-directed learning appears to be one of the advantages of the PBL strategy. Khalid stated that "*PBL is the best way to improve students' self-directed learning skills*". He explained the reason is because the students encountered the problem and were able to answer 20% of the problem without any help from him, after this they then needed help to solve the problem. He noticed that "*students could learn by themselves, even if only a little*".

- ***Like Learning Mathematics***

Khalid mentioned that students liked participating and cooperating with each other within groups and this was clear in the PBL settings. When he was asked whether PBL could improve students' Like Learning Mathematics, he responded that "*students generally like working in groups and they like competition*". He found PBL is better than traditional method and he was satisfied with it.

- ***Class size***

Khalid believes that the PBL strategy could be implemented on large class sizes of up to 40 students. This might show how comfortable he felt with PBL implementation.

- ***Teacher training***

Khalid found PBL easy and did not need any training. This might be true if he tends to implement PBL without using meta-cognitive teaching skills, however, he may require training in PBL implementation if he intends to implement PBL in the proper way.

3. ***Disadvantages of using PBL***

After undertaking PBL implementation, Khalid, the untrained teacher, was asked what he felt were the main disadvantages of using the PBL teaching strategy in his classroom. Khalid found that some of the students with weaker reading abilities encountered more problems than the more competent students.

- ***Weakness in reading***

One problem which came to light in implementing PBL is the poor standard of reading skills in some of the students. He found that: "*Students with weaker reading abilities could be negatively affected as this would hamper their ability to read the problem*." However, he thinks this problem could be solved by encouraging students to cooperate and said: "*This issue could be counteracted by asking the students with better reading skills to read the problem to the rest of the group*."

4. Challenges of using PBL

After undertaking PBL implementation, Khalid, the untrained teacher, was asked to describe the challenges he had encountered when implementing the PBL teaching strategy in his classroom. Khalid found the main challenge was the use of inappropriate mathematics textbooks which he felt needed to be adapted to incorporate strategies to support PBL implementation.

- ***Restrictions of using PBL***

Khalid noticed that the Saudi mathematics textbooks were inappropriate and recommended they should be adapted to include guidelines for implementing the PBL teaching strategy. He did, however, feel that PBL is worth using in the classroom.

5. Readiness to learn mathematics

It would appear that the low achieving students rely upon the high achievers in the PBL setting. Khalid noted that "*some low achieving students were depending on high achievers to solve the problems"*. This means that if the teacher did not address this problem, some low achieving students did not learn. He suggested that to avoid this, "*more care should be taken of the low achievers and teachers should keep asking them questions*". This could be advantageous for low achieving students but may be frustrating for the high achieving students. He commented: "*If the strategy could be implemented more efficiently, this would help to counteract the problems encountered by the low achievers*." This indicates that Khalid required face-to-face in order being more effective in implementing the PBL teaching strategy.

6. Engagement in learning mathematics

Khalid found PBL increased the students' levels of engagement. He also felt that "*implementing PBL effectively would increase levels of engagement*." This implies Khalid would benefit from attending training course to learn how to implement PBL effectively and help students to engage in PBL learning processes.

6.7 Research diary

The study had been observed by the author. The author played a great part in this study by training a teacher and preparing teachers and students for the implementation of the PBL strategy. He also monitored the implementation process and provided all participants with what they needed to complete the study. In this research diary the author has discussed what he noticed during the field work study. He mainly focused on teachers' performance and was particularly concerned with teacher intervention, student practices, both individually and collectively, students responses, group interaction and PBL processes. In the next section he discusses the school and the staff and also the implementation of PBL.

6.7.1 School and staff

The school was a large private school which is considered to be four public schools. Each grade ranged from between 7 and 10 and each classroom had between 14 and 20 students. The school contained primary grades only (from the first to the sixth grade). The students ranged from middle to high class backgrounds. The condition of the school and its settings were good. The school offers a bus transportation service for students and is considered to be one of the best schools in Hail City. The school was in competition with other private schools in education. The majority of the staff was not local and the majority of the students were from Saudi. The principle was from Saudi Arabia but the local education supervisors in the school were not from Saudi but were Arabic.

Teachers were encouraged to use the learning instructions provided by the administration of the school and education. It was noticed that some teachers practised teaching in school whereby they divided students into groups, asked students to read out loud and encouraged them to actively participate in the lesson; however, the teachers led the students, and corrected students' mistakes and explained everything to them immediately. The author recalls that when he first visited the school at the beginning of the study, he was invited by the administration of the school to attend an optimal lesson which took place in the sixth grade. At the end of the session he was asked to give them feedback. The author asked the teacher which strategy he had used and the teacher said he had used the active learning instruction which is student-centred. The author commented that the form of the session implied the strategy was student-centred, however, the teacher explains everything to the students and the core of teaching is still the same. The author felt that the teaching had been applied in this way in order to satisfy both administrations and educational supervisors. This insight helped to convince the author to try a new strategy which was to implement PBL.

When the principle idea of PBL was explained to the head teacher, he expressed his interest and welcomed its implementation in the school. Teachers also welcomed the idea and many, if not all the teachers were willing to be volunteers. In the third grade, three teachers taught eight classes; two teachers taught three classes and while one teacher taught two classes. From the seven classes, three groups were made.

6.7.2 Implementation of the study

The administration of the school employed seven teachers to monitor students while students were exposed to the pre-tests and pre-measures. As the researcher, I moved between groups to make sure everything was proceeding very well; my intention was to monitor the implementation of the study, and I had a diary that I used to document my observations, particularly the observations which took place during lessons and were made inside mathematics classrooms. The same approach was used with the post-tests and post-monitoring process.

Teachers were encouraged to use active learning instructions; however, they did not implement it in the proper way. They still needed more training to shift their teaching styles to become completely student-centred. They needed to be trained in how and when they should intervene with meta-cognitive questions during the students' learning process.

Three themes emerged from the observation: Teachers' implementation of PBL, disadvantages of implementing PBL, and advantages of implementing PBL

1. ***Teachers' implementation of PBL***

One of teachers who had attended the training and received intensive CPD implemented PBL very well and, in particular, his last two sessions was amazing. In the last two sessions he shows a noticeable improvement in posing and modelling meta-cognitive questions to students and it was noticed that students were positively affected by his questions. For example, sometimes he wondered why the students had given a particular answer to a question and why they had not given a different answer, the students enthusiastically responded by explaining the reason behind their answer and why the answer did not need to be different. As the researcher monitored the session he observed that some students did not understand the problem and the teacher encouraged them to move on to the next process. The researcher suggested that he give the students more time and to make sure that they all fully understand the problem. Once he did this it could be seen that the students' enthusiasm to solve problem increased immensely. After this the teacher started to place a lot more emphasis on understanding the problem and spent time a lot more time on this part. In fact, he did not move on to the next stage of the process until he was sure that his students had demonstrated their desire to solve the problem. This really was what the author had been looking for and he wished that this approach could have been applied from the beginning.

The untrained teacher is provided with the necessary materials needed to explain how to implement PBL in class. He sometimes explains things and lead students and he thought this was necessary. Therefore, it was clear to the researcher that the teacher needs to receive CPD training in implementing PBL strategies. At the end of the session, each teacher discussed the solution to their students in a comprehensive way.

2. Disadvantages with PBL implementation

The students had problems with prior knowledge and skills.

- ***Students' readiness to learning by PBL***

Some students had problems in respect of their prior knowledge or a lack of skills which prevented them from working well with other students. For example, some students could not read and so needed someone else to read for them. Another example was that some students were unable to write numbers properly. This affected their outcomes and made them unable to cope with PBL sessions. The researcher observed that teachers spent what he considered to be too much time on these low achievers which then had a knock on effect in respect of the advancement of the high achievers.

3. Advantages of implementing PBL

Some students like PBL and their engagement level improved once they had understood the problem.

- ***Students' attitudes towards PBL***

During implementation of the study the majority of students liked the idea of PBL and worked effectively to solve problems. The young students really liked working in groups and liked the challenge of completing the problems.

- ***Students' engagement with PBL***

In fact the younger students turned out to be incredibly enthusiastic once they understood the problem. Engagement levels seem to depend mostly on understanding the problem for the majority of students who had no problem with prerequisite knowledge or skills.

Overall, teachers seem to need to receive CPD to implement PBL. Understanding problem seems vital to improve students' positive attitudes. Working with groups seemed to improve students' scores in 'liking learning mathematics'.

6.8 Comparison between the primary school trained and the untrained teachers with interview and field observation notes

From Table 6.13, it would seem that the teachers who undertook self-directed learning would benefit from receiving face-to-face training in PBL implementation, in particular, in how to guide students' learning processes by using meta-cognitive teaching skills. The untrained teachers included some traditional practices in their PBL lessons, while the trained teachers coached students' thinking by posing metacognitive questions. This was noted by the author. As a result of this, the trained teacher noticed that students' thinking skills, such as critical thinking, improved, whereas the untrained teacher did not express this.

It would seem that the third grade students like learning mathematics through PBL, possibly because they like working within groups and they like active learning. This was noted by the author. The trained teacher believes that they would, perhaps, like PBL more if they understood the problem very well. According to the author' research diary, students showed high levels of motivation when they fully understood the problem. He also observed that the teacher held the students attention during the lessons and kept the majority of students motivated and interested in solving the problems. This was not the case with the untrained teacher. It also appears that students' thinking skills seemed to improve only when taught by the trained teacher as the trained teacher coached their thinking by posing meta-cognitive questions. In addition, the third grade students' self-directed learning seemed to improve with PBL. Both teachers believed that they could implement PBL in large classes. This implies that both teachers felt comfortable with implementing PBL.

Table 6.13: The results of the semi-structured interviews for primary school teachers

Theme	The trained teacher	The untrained teacher	Notes and observations
PBL implementation	Implemented PBL as asked	Included some traditional practices such as leading and explanations	It seems that untrained teachers needs training in PBL implementation
Advantages of using PBL	PBL remarkably increased' Like Learning Mathematics' scores among students because they like learning independently and understanding the problem is the key point of their motivation Students' levels of concentration became increased and this would increase their learning Students' critical thinking skills improved	Students like the PBL strategy because they like active learning and working within groups Self -directed learning improved No need for training in PBL	It would seem that students like learning mathematics through PBL because they like working in groups and they like active learning. They also indicated that they could like PBL more if they understood problems more easily and have a trained teacher. It also appears that students thinking skills improved by using trained teachers It appears that students' self-directed learning improved with PBL
	The PBL strategy could be implemented on large class sizes		This implies that the teachers felt comfortable with PBL implementation.
Disadvantage of using PBL	Time-consuming Less able students depend on others	Less able students with inferior reading skills were restricted and found it harder to cope than others	It seems that less able students need support to cope with the PBL strategy more than the other students
The Challenges in implementing PBL	Teachers' belief Assessing learning could be better if students receive problems to solve individually after the PBL session		It appears that embedded assessment that was being used through PBL was not enough to achieve better outcomes
	Mathematics textbooks are not adapted PBL		It seems that incorporating PBL in mathematics classroom needs adaptation with mathematics textbooks
Readiness to Learn Mathematics	Students with a lack of prerequisite knowledge or skills were limited in the instructions in classroom	Less able students depended more on other students and the teacher but if PBL is implemented very well it could solve this problem	It appears that less able students, whether with a lack of prerequisite knowledge or not, concern teachers
Engagement in Learning Mathematics	The type of problem, prior knowledge and skills and the ability of students could play an effective role on students' engagement also understanding problem helps for high engagement	He found PBL increased engagement and if PBL was implemented better it would increase engagement further	It seems that student engagement results were affected by several factors, such as readiness, ability, problem nature, understanding the problem and the ability of teachers to implement PBL

6.9 Summary of the results for primary schools

6.9.1 Academic Achievement

Pre and post-tests were applied to examine the effects of PBL on students' academic achievement in three domains: Knowing, Applying and Reasoning abilities. Three groups were assigned with three teachers to be part of the study. Each teacher taught one group; group A were instructed using the PBL strategy with a trained teacher, group B were taught using conventional teaching methods and group C were instructed using PBL but with an untrained teacher. In addition, the trained teacher received CPD training in PBL while the other teachers did not received any training in PBL. The reason for this was to examine the effects using PBL with trained teachers and with untrained teachers. The results illustrate that there was no significant difference between the groups and no significant interaction between the different ability levels and achievement in the groups (high and low achievers) and the types of treatment in 'knowing' and 'reasoning'. However, the result shows that there was a significant difference between using PBL with the trained teacher and the conventional group in Applying ability but no difference with the untrained teacher. In addition, there is no significant difference between using PBL with the untrained teachers and the other groups. This indicates that implementing PBL with either trained or untrained teachers is likely to be similar to using conventional methods in improving Mathematics Achievement in Knowing and Reasoning domains for primary school students. However using the PBL strategy with trained teachers could be better than using conventional methods in improving Applying Knowledge in Mathematics for primary school students. In addition, it is unlikely that PBL will interact with effect of different ability levels of students (high and low achievers) in respect of their overall mathematics achievement.

6.9.2 Attitudes towards Mathematics in learning Mathematics

Pre and post-measures were applied to examine the effects of PBL on students' Attitudes towards Mathematics in two domains: Like Learning Mathematics and Confidence to Learn Mathematics. Three groups were assigned with three teachers to be part of the study. Each teacher taught a different group; group A was instructed using the PBL strategy with a trained teacher, group B were taught using conventional methods and group C were taught using the PBL strategy with an untrained teacher. Therefore, one teacher received PBL CPD training while the other teachers did not receive any CPD training. The reason for this was to examine the effects of PBL with a trained teacher and with an untrained teacher. The result shows that there was a significant difference between the groups in their levels of Attitudes towards Mathematics. The PBL groups' Attitudes towards Mathematics levels were increased and were significantly higher than the conventional group, while there was no significant difference between the unconventional group's Attitudes towards Mathematics levels. However, there was no significant interaction between the different ability levels of the groups with the high and low achievers and the types of treatment in their scores relating to 'attitudes towards mathematics' However, when the both PBL groups, the trained teacher's group and the untrained teachers' group, were combined, and examined against the traditional group, the interaction between the groups and the different ability levels of students was significant in relation to the 'confidence to learn mathematics' scores for high achievers. This indicates that using the PBL strategy is likely to be better than using conventional teaching methods in Attitudes towards Mathematics in learning Mathematics for primary school students. In addition, it is unlikely that PBL will interact with effect of different ability levels of students (high and low achievers) in respect of their overall mathematics achievement. However, it seems that PBL is likely to raise students' confidence more than traditional teaching methods.

6.9.3 Teachers' Perspectives

The trained teacher noticed that the problem solving element of PBL motivated students to learn, while the untrained teacher believes any instructional strategy which involved working in groups and active learning can motivate students to learn. They seemed to both right. The difference between their perspectives is perhaps because the trained teacher used to give students plenty of time to understand the problem and then discuss the problem with whole class, while the untrained teacher asks his students if they understood it or not and then ask them to solve the problem. Therefore, the problem would lose its role of inspiring like learning mathematics, if some or all students did not understand it very well.

"Understanding the problem is the trigger of students' Like Learning Mathematics" said Ali, the trained teacher.

Both teachers found problems with students who had limited or no prerequisite knowledge or skills. Both of the teachers believed that PBL is valid for large class size of up to 40 students if the class area is large enough and the teacher can easily access each group. This may support the fact that the teachers felt more comfortable with PBL. However, the difference between teachers practise is that the trained teacher used meta-cognitive questions while the untrained teacher used explanations and gave examples for the difficult parts.

The trained teacher found PBL needed much more time than traditional methods to implement. He seemed more concerned about time than the untrained teacher. This may be explained by the fact that the trained teacher transferred the majority of the control of learning on to his students, while the untrained teacher shared some of this responsibility with them. The trained teacher noticed that PBL improved students' critical thinking skills, while the untrained teacher did not mention this. The potential reason is that the trained teacher coaches students' meta–cognitive thinking skills, while the untrained teacher focused on cognitive issues. Both agreed that low achievers could depend on the high achievers. The trained teacher also believed that the solution to this is to assess students individually.

Both also agreed that the mathematics curriculum and textbooks need to be adapted for the PBL teaching strategy and without this the use of PBL would be difficult. The trained teacher added that the strategy would be difficult for new teachers to implement while the untrained teacher thought the strategy was easy. This could explain why the untrained teacher had no problem with leading students to the right answer which seems that the challenge he faced was only to solve the problem, while the trained teacher guided them to move from one process to another which required meta-cognitive questions be asked at right time.

6.9.4 Research diary

Teachers seem to need to receive CPD to implement PBL effectively. Understanding the problem seems vital to improve students' positive attitudes. Active learning, working within groups, and asking questions from the teacher and between students were all things which helped to improve students' Like Learning Mathematics. Teachers seemed to need solutions for students with a lack of prerequisite knowledge or skills.

It is important to briefly present the qualitative findings in relation to quantitative findings. This will be presented below.

6.10 Presentations of qualitative findings in relation to quantitative findings

Question 1, 4, and 5

As Table 6.14shows, PBL seems to produce similar results as traditional teaching methods on the achievements and attitudes towards mathematics of the intermediate school students' but not for their knowledge application. The trained teacher's PBL group improved significantly in knowledge application more than the group was taught using traditional teaching methods. In addition, students' critical thinking skills improved when they were taught using the PBL strategy by a trained teacher. This is possibly because the trained teachers were able to use meta-cognitive teaching skills to coach students' thinking processes, whereas the untrained (the self-directed learning teacher) could not. The qualitative results show that PBL seems to improve students' self-directed learning skills, irrespective of whether they are taught by trained or untrained teachers.

Question 2

The students like PBL and feel more confident to learn mathematics when using PBL more than when they are taught via traditional teaching methods. This may be because they like working in groups and enjoy active learning. They also indicated that they seem to like PBL even more if they are given the time to gain a deeper understanding of the problems.

Question 3

The low achieving students learned at a similar rate to the high achievers, regardless of the teaching instructional method used. However, teachers did give the low achievers more attention so that they were able to keep up with the other students. Thus, the high achievers may have improved even more if they had received a similar amount of attention from the teacher as the low achievers.

Table 6.14: presentation of qualitative findings in relation to quantitative findings

Research questions	Ability	Quantitative findings	Interview and Field observation note
1	Knowing	No sig difference between groups	In discussion with the teachers, the researcher found that teachers thought that their students' self-directed learning was improved. The trained teacher also indicated that his students' critical thinking skills improved. Their conversation did not separate knowing, applying, and reasoning abilities. The researcher also observed that the appeared to be the case.
	Applying	Sig difference between groups in favour of trained teacher's group	
	Reasoning	No sig difference between groups	
2	Like learning mathematics	Sig difference between groups in favour of PBL groups	The researcher's discussion with teachers, and field observation both indicated that students like learning mathematics through PBL because they like working in groups and they like active learning. The trained teacher also indicated that they could like PBL more if they are given time to understand problems better.
	Confidence to learn mathematics		
3	Different ability levels for students	No sig interaction with teaching instructions	In discussion with the teachers, the researcher found that the teachers indicated that some students were suffering from a lack of prerequisite knowledge or skills which led to limited instructions in their classrooms, and they paid more attention to them to keep up with other students. The researcher also observed that this appeared to be the case
		No Sig difference in favour of low achievers	
4 and 5	Different type of CPD	Sig difference between groups in favour of trained teacher in improving students' knowledge application	The researcher's discussion with teachers, and field observation both indicated that training face-to-face is important for improving meta-cognitive teaching skills and intervention strategies

This Table integrates the principal quantitative findings with the additional qualitative data for primary school students. It is clear that the qualitative findings illuminate some subtle aspects of pupils' outcomes that are not revealed by the quantitative testing. Together, these data provide a robust basis for understanding the power and limitations of PBL in this primary school, and some indications of where further qualitative work might be undertaken – for example in relation to self-directed learning, cooperation, and thinking skills.

Chapter Seven: Discussion

7.1 Introduction

This study aimed to investigate the effectiveness of problem based learning (PBL) on primary and intermediate school students' achievements and their attitudes towards mathematics in two Saudi Arabian schools when compared to traditional teaching methods.

In PBL, students learn actively through meaningful processes and teachers coach students' meta-cognitive learning skills. With traditional teaching methods however, students passively receive knowledge from their teachers. Based on the theoretical learning differences between PBL and traditional teaching instructions, student outcomes may be affected. Student outcomes include mathematical achievements and attitudes towards mathematics. Mathematics achievements covers: 'knowing', 'applying' and 'reasoning' domains, while attitudes towards mathematics include: 'like learning mathematics', 'value mathematics' and 'confidence to learn mathematics'. With these dependent variables the students' results can be inducted by several factors, including the abilities of both teachers and students. The study also assessed the teacher's abilities by using teachers who had received face-to-face training in the implementation of PBL (classified as 'trained teacher'), and teachers who had undertaken self-directed learning (classified as 'untrained teacher'). Student abilities are categorised by low and high achieving students. In this chapter therefore, the results of investigating five main questions, conducted in Saudi Arabia for third and eighth grade students, were discussed in light of the literature review. The five main questions addressed in this study are as follows:

1. What are the effects of PBL teaching strategies with trained and untrained teachers on students' achievement levels in mathematics (knowing, applying and reasoning) when compared with conventional teaching methods?

2. What are the effects of PBL teaching strategies with trained and untrained teachers on students' attitudes (like learning mathematics, placing value on mathematics and confidence to learn mathematics) when compared with conventional teaching methods?

3. Is there significant interaction between treatment and levels of achievement (high and low) in students' achievement (knowing, applying and reasoning)?

4. Is there a significant interaction between treatment and levels of achievement (high and low) in students' attitudes (like learning mathematics, placing value on mathematics and confidence to learn mathematics)?

5. What is the perspective of teachers about PBL, after the treatment comparing with conventional methods?

In this chapter, the findings of the study will be briefly presented in tables, followed by a detailed discussion and engagement with the literature. Therefore, the effectiveness of PBL on students' achievements in 'knowing', 'applying' and 'reasoning' will be discussed. This is followed by an investigation of the effects of PBL on students' attitudes towards mathematics in 'like learning mathematics, 'value of mathematics' and 'confidence to learn mathematics'. For each section (achievement and attitudes towards mathematics) the effects of CPD (training teacher and self-directed development in PBL) on students' achievement will be discussed along with how this affects the different ability levels of students.

Before proceeding with the extended discussion, the researcher will very briefly identify the significance of the study and the contribution it makes. This is as follows, and will be elaborated in detail in this chapter, and the significance further discussed in Chapter 8:

The study has researched the interaction of different types of professional development in depth (face-to-face training and self-directed learning) with different types of treatment (PBL and traditional teaching methods).

The study was conducted in Saudi Arabia, and has considered all of the important factors and looked at the different abilities of students and teachers in PBL settings. It has assessed the effect of PBL on different aspects of achievement, such as looking at 'knowing', 'applying' and 'reasoning' abilities along with the different aspects of attitudes, such as 'like learning mathematics', 'value mathematics' and 'confidence to learning mathematics', and assessed the teachers' perspectives, qualitatively, about implementing PBL. Linkages between the quantitative findings and the qualitative findings have been made.

7.2 Study findings

It is reasonable to summarise the important findings of the study in tables before discussing the findings in detail. This could be useful to avoid repetition and also to easily refer to the data. Tables 7.1 and 7.2 briefly present the qualitative data in relation to quantitative findings, while Table 7.3 highlights the most important differences between the third and eighth grade characteristics.

Table 7.1: Presentation of qualitative data in relation to quantitative findings

Grade	Ability	Quantitative findings	Interview and Field observation Notes
Eighth	Knowing	No sig difference between groups ($p > 0.05$)	Students' thinking, self-directed learning and cooperation skills seem to improve with trained teachers because the trained teachers coached students' thinking by posing meta-cognitive questions while the self-directed learning teacher did not.
	Applying		
	Reasoning		
	Like learning mathematics		Over time students start liking PBL till they eventually like both strategies similarly
	Value mathematics		
	Confidence to learn mathematics		
	Different ability levels for students	No sig interaction with teaching instructions ($p > 0.05$)	Students with a lack of prerequisite knowledge or skills have limited instructions in classroom and teacher paid more attention to them to keep up with others
		Sig difference in favour of low achievers ($p < 0.05$)	
	Different type of CPD	No sig difference between groups ($p > 0.05$)	Training face-to-face seems important for improving meta-cognitive teaching skills
Third	Knowing	No sig difference between groups ($p > 0.05$)	It appears that students' critical thinking skills improved by using trained teachers It appears that students' self-directed learning improved with PBL
	Applying	Sig difference between groups in favour of trained teacher's group ($p < 0.05$)	
	Reasoning	No sig difference between groups ($p > 0.05$)	
	Like learning mathematics	Sig difference between groups in favour of PBL groups ($p < 0.05$)	It would seem that students like learning mathematics through PBL because they like working in groups and they like active learning. They also indicated that they could like PBL more if they are given time to understand problems better.
	Confidence to learn mathematics		
	Different ability levels for students	No sig interaction with teaching instructions ($p > 0.05$)	It appears that less able students, with a lack of prerequisite knowledge concern teachers
		No Sig difference in favour of low achievers ($p > 0.05$)	
	Different type of CPD	Sig difference between groups in favour of trained teacher in improving students' knowledge application ($p < 0.05$)	Training face-to-face seems important for improving meta-cognitive teaching skills

Table 7 2: Summary of the general findings arising from the interviews with teachers

<table>
<tr><th>Theme</th><th>Intermediate teachers, N= 2</th><th>Primary teachers, N=2</th><th>Trained teachers, N=2</th><th>Untrained teachers, N=2</th></tr>
<tr><td>PBL implementation</td><td>-</td><td>-</td><td>Implemented PBL as requested</td><td>Included some traditional practices such as leading and explanations; they did not know when or how they should intervene in order to keep students’ discussions flowing</td></tr>
<tr><td>Advantages of using PBL</td><td>Over time students start liking PBL till they eventually like both strategies similar</td><td>The PBL strategy could be implemented on large class sizes</td><td>Students’ thinking skills seem to be improved</td><td>Students like the PBL teaching strategy</td></tr>
<tr><td>Disadvantage of PBL</td><td>Noisy
There were some uninterested students generally, regardless of the strategy that was used</td><td></td><td>Time pressures</td><td></td></tr>
<tr><td rowspan="2">The challenges in implementing PBL</td><td>Designing problems
Assessment
They suggest problems should be easier, shorter, and clearer</td><td></td><td>Teacher’ belief
Assessment</td><td></td></tr>
<tr><td colspan="4">Mathematics textbooks are not adapted with PBL</td></tr>
<tr><td>Readiness to learn mathematics</td><td colspan="3">Students with lack prerequisite knowledge or skills limited instructions in classroom</td><td></td></tr>
<tr><td>Engagement in learning mathematics</td><td>Type of problem and prior knowledge and skills and ability of students could play an effective role on students’ engagement</td><td></td><td>Type of problem and prior knowledge and skills and ability of students could play an effective role in students’ engagement</td><td></td></tr>
</table>

Table 7.3: Highlight the main differences between third and eighth grades

<table>
<tr><th>Characteristics</th><th>Third grade</th><th>Eighth grade</th></tr>
<tr><td>Age</td><td>8-9</td><td>13-14</td></tr>
<tr><td rowspan="2">Developmental issues</td><td colspan="2">According to Siegler (1991), metacognitive understanding expands between the ages of 5 and 10</td></tr>
<tr><td colspan="2">Young children are highly motivated about what they can do, but this decreases with development (Schunk 2012)</td></tr>
<tr><td>Background of teaching methods received</td><td>Accustomed to student-centred teaching methods</td><td>Accustomed to teacher-centred teaching methods</td></tr>
<tr><td>Design of problems</td><td>Fit in one session</td><td>Fit in more than one session</td></tr>
</table>

The following sections will discuss the above findings in further detail.

7.2.1 The effectiveness of PBL on students' achievement levels

This section will discuss the effectiveness of PBL, in the two study schools, on students' achievement in 'knowing', 'applying' and 'reasoning', and will also address the effects of CPD (training teacher in PBL, and self-directed development) on students' achievement along with how this interacts with the different ability levels of students.

7.2.1.1 Knowledge acquisition

The results of the pre and post tests conducted in intermediate and primary school contexts show no significant difference ($P > 0.05$) between the groups on the 'knowing mathematics achievement' scores over time (see Table 5.4, Table 6.4and Table 7.1). This indicates that using the PBL teaching strategy, whether with a trained teacher (this teacher had received face-to-face training in PBL implementation) or an untrained teacher (this teacher was asked to conduct self-directed learning in how to implementing PBL), is likely to lead to similar results in 'knowing mathematics achievement' as those attained using conventional teaching methods among eighth and third grade students. In addition, no qualitative findings were reported in this study in respect of knowledge content. The reason for this may be because knowledge acquisition is perhaps less visual for the teachers and researcher's observations than with other domains, such as applying and reasoning skills.

PBL is concerned with meaningful processes (English and Kitsantas, 2013) and not memorising processes. Therefore, the students were not expected to improve more than with traditional teaching methods in knowledge acquisitions and the results achieved were expected. The literature review shows that the effect of teaching using the PBL strategy tends to be similar to traditional methods on the acquisition of knowledge (Vernon and Blake, 1993; Colliver, 2000; Matthews, 2004; Dobbs, 2008; Sanderson, 2008; Wong and Day, 2009; Hinyard and Brittany, 2013; Bassir et al., 2014). For example, the results of this study are supported by Ali, (2005) who found no significant difference between the outcomes of using PBL and traditional teaching methods in improving students' knowledge acquisition for ninth grade students in Egypt. In addition, the results also supported a study carried out by Scott, (2005) who found no difference in learning content for social studies for 5th grade students in an urban private school in the Southeast of the United States of America. However, the results disagreed with the results of Alshahrani, (2010) who conducted a study in mathematics for sixth grade Saudi students and found that PBL significantly improved students' knowledge acquisition more than when taught using traditional teaching methods. Therefore, the variations in the results pertaining to knowledge acquisitions may be due to the topic of the study. For example, Wong and Day (2009) found no significant difference in the short-term between the post-test scores in human reproduction for the treatments of PBL and traditional teaching methods on knowledge acquisition in middle students in Hong Kong. However, in contrast, they found a significant difference between these groups in density topics in favour of the PBL teaching strategy.

In fact, in a PBL classroom, teachers act as facilitators instead of content experts (Brown, 2003). Therefore, theoretically, what students learn by themselves could remain longer than what they are taught by teachers. PBL helps in increasing retention periods for learning, particularly if a student becomes enthusiastic about a concept or a fact which he or she had discovered by themselves, as it will be better in retention (Ronis, 2008).

Empirically, some studies show that PBL is superior to traditional teaching methods in knowledge retention. For example, in the review of Strobel and van Barneveld (2009), they concluded that PBL was more effective for long-term retention, and it came slightly lower than traditional methods in respect of short-term retention (Strobel and van Barneveld, 2009). Thus, PBL tends to be similar to traditional methods in term of acquisition of knowledge in a short-term period of assessment. However, assessing the effectiveness of PBL on content knowledge over a longer term could show superior results for PBL than traditional methods. The current study has assessed the effects of the PBL teaching strategy on students over a short -term period only. Further research is needed to measure the effect of PBL on students' mathematics knowledge content and retention within Saudi and similar contexts.

Nevertheless, although, a meta-analysis study carried out by Walker et al. (2009) suggests that assessing PBL from angles other than knowledge acquisition could show its effects, this suggestion did not consider assessing knowledge acquisition in the long-term. This may be because the ultimate goal of learning mathematics is to apply mathematical knowledge in the real world. Therefore, a knowledge base is not learned for its own sake, rather, because it is necessary for eventually facilitating and applying mathematics and reasoning about mathematical situations in the real world (Mullis et al., 2012). Therefore, applying and reasoning are important and are discussed next.

7.2.1.2 Applying achievement

The results of this study show no significant difference ($P > 0.5$) between the groups achievement scores over time in 'applying mathematics' for intermediate school students (see Table 5.8 and Table7.1). This indicates that using the PBL teaching strategy, whether with trained or untrained teachers may lead to similar results in 'applying achievement' to those attained using conventional teaching methods among intermediate school students. The findings from the primary school results however, illustrate that there was a significant difference between the groups (PBL with trained teachers, traditional teaching methods, and PBL with untrained teachers) over time, in favour of PBL with the trained teachers against the conventional group with medium effect size. However, no significant difference was found with the untrained teachers' PBL group against other groups (see Tables 6.6 and 7.1).

PBL supporters claim that PBL can improve knowledge application over traditional teaching methods (Hmelo-Silver, 2004). This is because in PBL as a constructivist instructional methods, students engage in self-directed learning by using their meta-cognitive learning skills to solve real-life and ill-structured problem as a way of learning (Chin and Chia, 2006). This should reflect some improvement in students' applying ability over traditional teaching methods, where in traditional teaching methods students solve well-structured problems as exercises to practice what they have already learned (Chall 2000; Schuh, 2004).

According to the qualitative findings in the current study, both the intermediate and primary school students taught with PBL showed some improvement in self-directed learning skills through PBL sessions. However, only the groups that were taught PBL by the trained teachers showed some improvement in their thinking skills, such as critical thinking, for both primary and intermediate school students. This is perhaps because the trained teachers coached students' thinking by posing meta-cognitive questions while the self-directed learning (untrained teacher) teacher did not (see Tables 7.1 and 7.2). The professional development (PD) teacher will be discussed in further detail later in the chapter.

In addition, several studies supported this claim that PBL could improve students' knowledge application, such as (Dochy et al., 2003; Moran, 2004; Pease and Kuhn, 2011; Bassir et al., 2014). For example, Ali, (2005) found Egyptian ninth grade students' knowledge application improved with PBL when compared with traditional teaching methods.

The results of primary school data supported the conclusions of Wong and Day (2009) which suggests that students taught with PBL out-performed the students taught by traditional teaching methods in 'application knowledge' in middle students' science in Hong Kong. It also supports the results of Wirkala and Kuhn (2011) in middle American school sixth-grade students which reported that PBL groups significantly outperformed the lecture-based instruction in terms of understanding and application concepts (Wirkala and Kuhn, 2011). The available studies, which were conducted in Arab and Saudi contexts, measured mathematics achievements by combining knowledge acquisition and application (Al Hudhaifi, 2002 and Hussain, 2012). Therefore, in future research in Saudi and Arab study contexts in mathematics education, researchers should measure knowing and applying separately to give a more accurate assessment of the effects of PBL.

Although the quantitative results of the intermediate school data did not support the trend of the literature review outcomes, there are, in fact, two factors which may contribute to this, namely: background teaching methods being used before implementation of the current study, and the design of the problems which were used for PBL.

- ***Background teaching methods***

As mentioned above, one of the possible factors which has an effect on students' outcomes relates to the teaching method(s) which had been used prior to implementation of the PBL teaching strategy. In this case, the primary school students were familiar with active learning, while the intermediate school students were accustomed to traditional teaching methods (see Table 7.3). As a result, the intermediate school teachers felt that, for them, the implementation of PBL became comfortable over time and their students were initially frustrated at the outset of PBL implementation. This also was noticed by the researcher but was not noticeable with the primary school teachers (see Tables 7.1 and 7.2). Therefore, the previous teaching styles received by the students may affect their knowledge application. This is something which needs to be considered in any future research.

- ***The problem design***

The second possible factor which could affect student outcomes related to how the problems are designed. Problems are not equal in terms of how they affect students' outcomes (Duch, 2001; Hung et al., 2013). In the current study, the intermediate teachers suggest that problems should be shorter, clearer and easier rather than being messy, taking a long time (more than a session) to solve, or difficult (Table 7.2). In the case of this study, the problems presented were not considered to be too difficult, too long or too messy (see Appendix4.A.2). The problems which were used by the intermediate school students were not designed to fit into one session (45 minutes) but rather, they were designed to be taught over more than one session (2-3 sessions). Conversely, however, the problems given to the primary school students were designed to fit into one session (see Table 7.3).

As results of the length of problems, the intermediate school trained teacher suggests that, rather than having five 45-mintue sessions per week, combining 2 sessions to have two 90-minute sessions and one 45-mintue session could be more suitable for PBL implementation, while the primary school trained teacher suggests that extending the sessions to be 60 minutes rather than 45 minutes would be more suitable for PBL implementation (see the qualitative results in chapters 5 and 6). Therefore, short problems could bring both teachers to an agreement. This kind of problem may require creative designing. Achilles and Hoover (1996) believe that regular timetabling (50-minute periods) required creative designing for the PBL process.

Time pressures are agreed to be one the main concerns of the trained teachers, however, the untrained teachers did not express this (see Table 7.2). This may be because the trained teachers gave students more time to discuss, think and ask questions than the untrained teachers. Time limitations were difficulties which the teachers faced when implementing PBL in their classrooms (Ingram, 2013).

Furthermore, the intermediate students had been accustomed to traditional teaching methods, as discussed above, so the process of transferring students from teacher-centred to student-centred instruction might add more 'difficulty' to the situation. In addition, teachers may need time to become experts in PBL implementation. These potential factors would support the requests of the teachers for easier, shorter and clearer problems. Thus it would have been better if students had received shorter, clearer and easier problems from the outset of the implementation process, at least until teachers and students became accustomed to using PBL.

Considering the time taken to shift the students' learning style from teacher-centred to student-centred instruction, and the teacher's meta-cognitive teaching skills, the problem characteristics (designed to fit one session) may have contributed to the effectiveness of the students' knowledge application.

Some suggestions were recommended by the teachers which could potentially increase student engagement levels and lead to better outcomes for students. For example, the intermediate school trained teacher suggests that tests should contain problems that require students to work together and solve them collectively (see the qualitative results in Chapter 5). The tests which are being used assess content knowledge and do not focus on problem solving skills or self-directed learning (Sluijsmans et al., 2001). However, the primary school trained teacher suggests assessing students individually and giving each student one or more exercises after PBL has been implemented in order to increase their responsibility for their own learning (see the qualitative results in Chapter 6). According to Lockwood (1995), students develop 'test behaviour' as they only focus on the requirement of the assessment. Therefore, students may work backwards according to the assessment.

Knowledge application is at the heart of problem solving where 'applying' refers to students' abilities in applying knowledge and their conceptual understanding in situations such as solving routine problems (Mullis et al., 2012). Problem solving is at the heart of PBL, therefore, improving knowledge application could improve students' problem solving results in the TIMSS research.

7.2.1.3 Reasoning achievement

TIMSS describes the 'reasoning domain'(Mullis et al., 2012), and states that reasoning comprises generalising, integrating, synthesising, justifying, analysing and solving non-routine problems. Reasoning requires the ability of observation, making conjectures, and also logical deduction based on certain rules or assumptions and justifying outcomes. Therefore, reasoning ability is required for higher-order thinking skills in order to analyse and synthesis knowledge and be able to solve non-routine problems. PBL helps in developing 'higher-order critical thinking skills' which are analytical skills enabling individuals to think logically by using information which is based on evidence (Ronis, 2008).

‘Reasoning’ achievement levels were assessed for mathematics students taught using PBL and then compared to the achievement levels of students taught using traditional teaching methods. The finding indicates that there is no significant difference ($P > 0.5$) between groups over time on intermediate and primary school students’ ‘reasoning mathematics achievement’ scores (see Table 5.12, Table 6.8and Table 7.1). This indicates that using the PBL teaching strategy, whether with trained or untrained teachers, is likely to lead to similar results in ‘reasoning mathematics achievement’ when compared with conventional teaching methods among intermediate and primary school students.

Reasoning ability can be improved by involving meta-cognitive coaching within mathematics classrooms. According to Fogarty (1994), one of the clear reasons for including meta-cognitive coaching in classroom instructions is fostering the transfer of learning to non-routine situations (Fogarty, 1994). As meta-cognition is to be aware and able to control one’s own cognitive process (Flavell, 1976), and cognitive strategies have a direct effect on learning (McCrindle and Christensen, 1995), meta-cognitive strategies are used in helping to improve cognitive strategies. With the PBL teaching strategy, students engage in self-directed learning and, in conjunction, receive coaching from their teachers for their meta-cognitive learning skills. Therefore, students’ meta-cognitive learning skills are expected to improve more with PBL than when they receive traditional teaching methods.

This study involved meta-cognitive coaching by trained teachers and it was noticed that students’ thinking skills seemed to improve, particularly with the trained teachers’ groups (see Tables 7.1 and 7.2). However, this was not supported by quantitative results. A possible reason for this could be that in order to improve reasoning skills a high level of ability is needed to transform knowledge into new situations such us working on non-routine problems. This study supported Elshafei (1998) who found no significant difference between PBL and traditional methods in terms of skills (higher level thinking in solving algebra problems for high school students (Elshafei, 1998). More research is needed in Saudi Arabian contexts to measure the effect of PBL on k-12 students’ higher order thinking skills in mathematics.

However, the problems provided in this study, particularly for primary school students, did not require far transfer knowledge for the students were too young to be presented with problems that required far transfer knowledge.

Age-appropriate problems in PBL are vital (Zhang, Parker et al., 2011). From around the age of 8, students begin to show basic skills in inductive reasoning which means that they can be developed to reason faster and are able with deal with more complex material (Schunk, 2012).

The difference in the age of the students (primary school students ranged from age 8 to 9 and intermediate school students ranged from age 13 to 14) could also be a contributory factor on their learning due to their different developmental stages (see, Table 7.3). Development is defined as changes over time within an orderly shape and it enhances survival (Meece, 2002). These changes are progressive and occur within the life duration (Schunk, 2012). Development is linked with learning, for example: young children cannot make the same connections as older ones because older children have more extensive memory networks (Schunk, 2012); Schunk believes that maturation and learning are elements of development.

One role of the teacher in PBL is to facilitate students' learning processes through posing metacognitive questions (Delisle, 1997). This action aims to improve students' metacognitive strategies. Metacognitive skills improve with development (Kail and Ferrer, 2007), therefore, metacognitive understanding expands between the ages of 5 to 10 (Siegler, 1991).

Therefore, problems should gradually get more difficult towards far transfer knowledge in order to develop reasoning skills among students, and should also consider the development of students' reasoning abilities. One possibility in longer PBL implementation is that reasoning ability would be statistically noticeable if PBL moves gradually from near transfer to far transfer situations over time.

Some researchers believe that providing appropriate scaffolding to students must gradually fade out for developing students' transformation abilities (Hung, 2013). This could be more effective for older students. Nevertheless, the scaffolding should gradually fade out and problems should gradually become more complex towards far transfer knowledge. This can possibly lead to an improvement in students' reasoning over time. The relationship between scaffolding and the complexity of the problem seems positive; as the problem becomes more complex students need more scaffolding. Therefore, as students improve their reasoning skills, problems should be more complex to meet their possible higher standards. This needs more investigation in future research to study the relationship between scaffolding and complexity of problems, and how teachers should make the balance between the level of problem complexity and their scaffolding.

7.2.1.4 The effectiveness of PD on students' achievement

The quantitative result of this study showed that, apart from the results for primary school students in the applying domain, there was no significant effect in the achievements of primary and intermediate students' who received training using PBL implementation in knowing, applying, and reasoning (see Table 5.4, Table 5.7, Table 5.11, Table 6.4, Table 6.6, Table 6.8and Table 7.1). In other words, this study indicates that no significant difference was found between the effects of implementing PBL by the teachers who had received face-to-face training and the teachers who had undertaken self-directed learning on both the intermediate and primary school students' mathematics achievement in the knowing, applying, and reasoning domains although a difference was noted with the primary school students outcomes in knowledge application. However, the qualitative findings suggest that the trained teachers show abilities in meta-cognitive teaching skills which contrast those shown by the self-directed learning teachers who did not demonstrate such skills in the PBL lessons.

It is important to point out that, as far as the author is aware, there has been no single study conducted which carried out these comparisons. In addition, in the majority of studies there is a lack of detailed descriptions about any training which has taken place. Indeed, some studies did not even mention whether the participating teachers had undertaken any training courses or not. Many studies needed to identify which, if any, training courses or skills were deemed necessary and which skills were considered as sufficient for the self-directed development of teachers. Thus, the current research may provide an insight into how to reduce the cost of PD in the world, as well as saving time and energy.

For 'knowing ability', although training tutors is consensually agreed as critical, by PBL theorists such as Barrows, 1996, Hmelo-Silver and Barrows, (2006), the result of this study does not suggest a significant difference between groups whether with the trained or untrained teachers. This is perhaps because the role of the teacher in PBL is to focus on facilitating learning processes through posing meta-cognitive questions (Brown, 2003; Hmelo-Silver and Barrows, 2006; Hmelo-Silver and Barrows, 2008; Leary et al., 2013) which target only the higher order thinking skills such as problem solving and self-directed learning (Barrows 1998). In other words, PBL is interested in meaningful processes instead of memorisation. The role of teachers, however, is to coach students' meta-cognitive learning strategies by using meta-cognitive teaching skills such as meta-cognitive questions. Teachers are more interested in '*stimulating reflective critiques of the nature of knowledge'* and less concerned with content (Graffam, 2007, p.39). On other hand, with traditional teaching methods, the role of the teacher is to transfer his or her knowledge to his or her students. Teachers are the facilitators of PBL instead of content experts (Brown 2003). Therefore, training teachers face-to-face may not necessarily produce a positive impact on students' knowledge acquisition. In both international and Saudi contexts there is a need for more research studies to investigate the impact that trained teachers have on students' knowledge retention, as discussed previously.

In respect of 'applying ability', this study reveals that training teachers in PBL implementation is an effective factor on primary students' results in applying achievement (see Table 6.6, and 7.1), but not on intermediate school students' results. With PBL, teachers are expected to improve students' awareness about their thinking strategies which is also expected to reflect an improvement in their knowledge application abilities (Barrows, 1998; Zimmerman and Kitsantas, 2005). Therefore, appropriate training should help teachers to help their students to improve their knowledge application and undertaking self-directed learning only may be insufficient.

These primary schools' findings were supported by the results of the meta-analysis conducted by Leary, Walker et al. (2013) which show a significant relationship between tutor training and student achievement. The study also suggests that untrained teachers have similar student outcomes to teachers who use traditional teaching methods which also supported the current study. This study also supported the study of Maxwell, Mergendoller et al. (2005) who suggested that PBL instruction can improve learning more than conventional methods with teachers who were well trained in using PBL strategy (Maxwell et al., 2005).

The role of tutor in PBL is to facilitate learning processes (Hmelo-Silver and Barrows 2006; Hmelo-Silver and Barrows, 2008). This shift to PBL requires new roles and skills such as facilitation skills (Wilkerson and Hundert, 1997). Teachers can facilitate problem-based learning (PBL) processes by using meta-cognitive teaching skills such as thinking aloud with students and modelling behaviours (Delisle, 1997). Training teachers in these facilitation skills could improve the ability to increase achievement in students' applying skills.

In both experiments in this study the trained teachers show reasonable performance in PBL implementation by posing meta-cognitive question to facilitate students' learning processes, while the untrained teachers led students and provided explanations for them. For example, if students got stuck and did not know what they should do, the trained teachers ask them metacognitive questions such, as 'what you have done so far?', 'what next?', 'why did you stop?' and 'have you considered this?. The untrained teachers would provide suggestions such as, 'you should not do this', or lead them by offering suggestions such as, 'choose this way' and 'leave this way out'. In addition, the untrained teachers found difficulty in intervention; they did not know when and how to intervene in tutorial groups. For example, the untrained teachers did not know when or how they should intervene in order to keep students' discussions flowing (see Table 7.2). Van Mook, De Grave et al. (2007) placed emphasis on the importance of training tutors in how and why the assessment of professional behaviour is important and also to encourage tutors to confront students and provide them with appropriate feedback.

This result supported the study of Spronken-Smith and Harland (2009) in suggesting that some teachers found difficulties in knowing when and how they should intervene (Spronken-Smith and Harland, 2009). Intervention strategies such as making decision on what, when and how intervention should occur to enhance cooperation and production in tutorial groups (Bosse et al., 2010). From the current study it was clear that intervention strategies were absent with the untrained teachers during PBL classroom sessions, while these techniques were present with the trained teachers. It would seem that training teachers to implement PBL and in how intervene in groups to enhance cooperation and production, could be beneficial.

Regarding students' 'reasoning' ability, the quantitative results show that training teachers to implement PBL effectively is not a contributory factor to students' 'reasoning' achievement scores. However, some improvement in students' reasoning was reported, particularly for students who were taught using PBL with the trained teachers (see Table 7.1 and 7.2). As discussed above, a statistically significant improvement in students' reasoning ability, for far transfer knowledge application, may have occurred over time with PBL curricular planning. This is likely to be done only with teachers who are able to coach their students' reasoning through posing meta-cognitive questions.

This study suggests that self-directed learning teachers could not be able to effectively intervene in students' learning processes, while trained teachers were able. Therefore, the teachers who have undertaken self-directed learning may also need additional training in interventional strategies and both trained and untrained teachers may also need training in how to gradually improve students' reasoning skills from near transfer knowledge to far transfer knowledge. This needs further investigation; it would require an experimental study to measure reasoning skills relating to the variation in level of transformation knowledge over time to see the effect of planning to reach the far transfer knowledge application levels, on students' reasoning ability.

7.2.1.5 Attainment ability levels with PBL and students' achievement

Figures 5.1, 5.2 and 5.3 show that the overall trend of results in intermediate schools increased for low level achievers and decreased in the 'knowing', 'applying' and reasoning domains for high level achievers. The difference between the levels of overall achievement was significant in each domain (knowing, applying and reasoning) with a large effect size (see Table 5.4, Table 5.7 and Table 5.11). This shows that overall, intermediate low level achievers improved more than the high achievers in knowing, applying and reasoning domains. This improvement did not significantly interact with types of treatments. On other hand the trend of the results improved for primary school low and high achievers (see Figures 6.1, 6.2 and 6.3). The results show that there was no significant interaction between the different levels of students (high and low achievers) and the types of treatments (see Table 6.4, Table 6.6 and Table 6.8). However, the teachers paid more attentions to less able students than the more capable ones (see Table 7.1). Therefore, this may explain the difference in the changes in the achievement levels experienced by the intermediate school's low and high achievers, and the lack of differences in the achievements of the primary school's low and high achieving students, particularly if the high achievers were expected to improve more than the low achievers (Elshafei, 1998; Simons and Klein, 2007).

Hung, (2013) has argued that all students should be ready to learn new knowledge; they should already possess the necessary prior knowledge and skills before transferring to the PBL teaching strategy. However, during the course of this study, the teachers' discussions in interview, and the researcher's observation, indicated that the less able students were suffering from a lack of prerequisite knowledge and skills (see Tables 7.1 and 7.2). As a result, the teachers felt professional obligation to spend a significant amount of time helping those students, in order that they were able to keep up with others. The researcher observed, and he did not intervene in the teachers' practices, because he believed that the low achieving students really needed such amounts of support. Therefore, with this scenario, the low achieving students were expected to learn more than the high achievers, because they needed to learn prerequisite knowledge as well as some new knowledge. Meanwhile, the high achievers' learning was restricted by the low achievers, who were given more attention and time by the teachers. Irrespective of whichever teaching model is used, the learning of high achievers should not be restricted by the failings of the low achieving students or their lack of prerequisite knowledge and skills. It is prudent to point out that this outcome would not have been evidenced so clearly in any study which did not use the repeated measures ANOVA model, which, importantly, takes into account the prior knowledge of students.

The result of this study indicates that using the PBL teaching strategy, whether with trained or untrained teachers compared to conventional methods, could not give any priority for high or low achievers in learning mathematics. This is an unexpected trend, particularly for high achievers. Although very few researches have investigated the interaction between achievement levels and the PBL strategy, the available results show superior achievement levels with PBL and high achievers (Elshafei, 1998; Simons and Klein, 2007) although this is not supported by the results of the current study. However, the results of the study carried out in the primary school are study supported by an earlier study undertaken by Al-Khateeb and Ababneh, (2011) which found no interaction between the mathematical thinking scores and students' achievement levels for high, medium and low achievers for male seventh grade students in Jordan.

The suggestions to tackle these difficulties were to identify the students who lack prerequisite knowledge and teach them the necessary knowledge outside of the classroom before joining the groups. This approach could help them cope as well as the others with the new learning style and would also limit any restriction of instruction in classrooms. The lack of prerequisite knowledge and/or skills is supported by TIMSS 2011 outcomes which indicate that prerequisite knowledge and/or skills cause a limitation of instruction and leads to a limitation of learning (Mullis et al., 2012).

Further research is needed to investigate the relationship between teachers' attention and different attainment levels of students on students' achievement in mathematics. This needs further research to investigate the implications of the restrictions of less able students when compared to the more able students' achievement in mathematics.

It can be concluded that the more able students may obtain similar achievement levels having less coaching from their teachers as the less able students who receive more coaching from the teachers. Therefore, the comparison may be invalid unless the same level of treatment was applied in both cases. This could be possible if all students in the classroom are ready to learn mathematics. Readiness to learn mathematics will be discussed later in this chapter.

7.2.2 The effectiveness of PBL on students' 'attitudes towards mathematics'

This section will discuss the effectiveness of PBL on students' attitudes towards mathematics: their liking of learning mathematics, placing value on mathematics, and their confidence to learn mathematics. It will also address the effects of PD types (training and self-directed learning teachers in PBL) on students' attitudes, along with how this affects the different levels of students.

7.2.2.1 Like learning mathematics

The results suggest that there was no significant difference between the groups of intermediate school students over time in their 'Like Learning Mathematics' scores (see Table 5.16 and Table7.1). This indicates that using the PBL teaching strategy, whether with trained or untrained teachers, is likely to produce similar results as the conventional teaching methods in its impact on eighth grade students 'Like Learning Mathematics'. The qualitative results supported the quantitative results in that the teachers felt that their students liked learning with both methods similarly (see Tables 7.1 and 7.2).

With PBL, students are supposed to be motivated by the real-life problems they have previously encountered. These kinds of problems are expected to drive students' curiosity and capture their interest which results in them engage more effectively in self-directed learning in order to solve the problems (Schmidt et al., 2009). However, not all real-life problems are curiosity or interest-driven and this needs to be investigated in future research. Additionally, problem design has emerged from the qualitative findings as a potential factor which may or may not encourage students to like PBL more than traditional teaching methods.

The teachers believe that if the problems could have been easier, clearer and shorter, students would like the PBL strategy more (see Table 7.2). Exposing students to problems which are too difficult will negatively affect their motivation and confidence (Westwood, 2011). However, the problems provided were not too difficult, as discussed earlier, but perhaps because the students had been accustomed to receiving knowledge from their teachers and were suddenly expected to construct their knowledge by themselves, this made them feel frustrated in the beginning. It is therefore possible that if the problems were easier, clearer and shorter at least in the beginning, their attitudes would be positively significantly raised. It seems that problem designers should consider the previous instructional methods that students have been taught with.

In the primary school situation, problems are designed to consider length and clarity levels, (see chapter 4 for more details). In primary school contexts, Table 6.10 and Table 7.1, show a significant difference between the groups over time in favour of PBL. In addition, there was significant difference overall in the ‘Like Learning Mathematics’ scores over time. This indicates that using the PBL teaching strategy, whether with trained or untrained teachers, is likely to be better than using conventional teaching methods for improving the positive attitudes towards mathematics for third grade school students. The supporting qualitative measures were compatible with this quantitative result (see Tables 7.1 and 7.2). Both trained and untrained teachers noticed that almost all students liked the PBL strategy much more than the traditional methods; however, their explanations about the reason behind this were different. The trained teacher believes that the problem is a key motivation for students and he stated that once students had understood the problem, their motivation suddenly rose. Students became intrinsically motivated when they worked on tasks which were motivated by their own interests, sense of satisfaction or challenges (Hmelo-Silver, 2004).

The primary school trained teacher noticed that when the teacher’s explanations were reduced, this motivated students and increased their willingness to learn. He also noticed that the students’ levels of concentration became increased with PBL because they were responsible for learning by themselves. It would seem that students engage in problem-solving processes through self-directed learning for longer than with traditional methods. This may be due to their motivation to solve problems. Ronis, (2008) reported that one of the principles of PBL is that motivation is explicitly the key to self-directed learning through problem-solving, because students will be responsible for their own development and progressing their learning and skills (Ronis, 2008).

The untrained teacher believes that working with groups is the key point and this view supports the views of Goodnough and Cashion (2006). The untrained teacher stated that students like this strategy because it encourages active learning, supports working in groups and it also provides students with a variety of learning approaches and methods. This perspective is supported by Goodnough and Cashion (2006).

Both opinions seem to be right; it was noticed that students with the untrained teacher had been given a shorter amount of time for understanding problems than those who were with trained teacher. The reason for this was because the trained teacher did not allow students to carry on solving the problem until they had completely understood the problem and demonstrated their passion to solve it. It was noticed that students became extremely motivated to solve the problem once they had understood it. However, when the untrained teacher asked students whether they understood the problem or not he often proceeded after hearing anyone shout “yes”. Thus it was noticed that some students did not understand the problem, but because the less able students received more attention by the untrained teacher, they eventually did understand it, but this approach did not appear to increase the motivation of the students which was seen with the trained teacher’s group. The primary school results supported Alshahrany, (2010) who found that male sixth grade Saudi students’ attitudes towards mathematics significantly improved when taught with PBL more than those taught via traditional methods (Hinyard, 2013).

7.2.2.2 Value on mathematics scores

Table 5.21 and Table 7.1, illustrate that there was no significant difference between the groups over time with the intermediate school students’ ‘value mathematics’ scores. This indicates that the PBL teaching strategy, whether with trained or untrained teachers, is likely to be similar to conventional teaching methods in respect of its impact on ‘placing value on mathematics’ for eighth grade students. Real-life problems in PBL are considered to be the key to showing the function of mathematics in real world. Real-life problems, ‘at an age-appropriate level’, could be of interest and also show students the value of the mathematics function (Westwood, 2011). It supposes that students could appreciate mathematics and place more value on it if they are exposed to problems that show them the function of mathematics in a real world context. However, although PBL students were presented with real-life problems (see Appendix4.A.2); their feelings on mathematics value were still similar to students who were taught using traditional methods. The probable reason for this is that the students were already aware of the value of mathematics before being exposed to the study. Another possible reason is that the students could not see the mathematics function being useful in real life situations because of the less appropriate problem design characteristics discussed above (i.e. they were not designed to fit into one session). The current research is limited to eighth grade students because the third grade students seemed too young to realize and express the importance of mathematics in real life. Further research is therefore required to see what could have hidden the importance of the mathematics function in real life from students' feelings within PBL settings.

7.2.2.3 Confidence to learn mathematics scores

In respect of the intermediate school students, it can be seen in Table 5.24 and Table 7.1, that there was no significant difference between the groups on students' 'confidence' scores over time. This indicates that the results of the PBL teaching strategy, whether with trained or untrained teachers, are likely to be similar to conventional teaching methods in respect of its impact on confidence to learn mathematics for intermediate school students. The measure assesses how much students feel confident to learn mathematics quickly compared to learning other subjects and compared with their classmates.

With PBL, students take responsibility for their own learning and this is expected to improve their confidence to learn more than when students rely on their teachers in order to learn. However, a shift in responsibility from the teachers to the students and the difficulty of problems, as discussed above, can have an effect on the outcomes. Exposing students to problems which are too difficult will negatively affect students' motivation and confidence (Westwood 2011). The students were provided with 'not too difficult' problems (see Appendix4.A.2). The shift from teacher-centred to student-centred learning may add more difficulty to the situation, as previously discussed. This could be addressed if problems were easier, particularly at the outset of the implementation of the new strategy. In addition, students might benefit form training in PBL group processes before the PBL strategy is implemented.

Achilles and Hoover (1996) suggest that students are required to train in PBL group processes before working in PBL instruction (Achilles and Hoover, 1996). The students who took part in this study received training in PBL instruction before embarking on the study, however, this was only for a short period of time over two sessions. They received two short interesting problems relating to travelling for holiday, and poverty. The students worked within groups to prepare for the PBL sessions. They were encouraged to ask open questions, listen to others and think critically. On reflection, however, the training did not seem to be adequate for students who have been accustomed to traditional teaching methods for a long time. Taking this transformation into consideration could increase students' confidence to learn. The transformation challenge and design of problems had been considered prior to the next experiment involving primary school students, where the problems were designed to be easier, shorter, and clearer, and students were already accustomed to active learning for longer.

It can be seen from Table 6.12, and 7.1, that there was a significant difference between the groups over time in favour of PBL. In addition, there was no significant difference overall in the ‘confidence to learn mathematics’ scores over time. This may be due to the decrease in the scores of the traditional group; group B’ scores decreased possibly because they were exposed to traditional teaching methods and they were used to learning by active learning, such as cooperative learning. This indicates that using the PBL teaching strategy, whether with trained or untrained teachers, is likely to lead to improved results for third grade students’ in their confidence to learn mathematics, more than the students taught using traditional teaching methods. This result supported Ertmer et al. (2014) who stated that their findings showed significant gains in confidence in both implementation of PBL and science teaching efficacy for 6–12 grade science and mathematics classrooms (Ertmer et al., 2014).

Primary school students show positive attitudes towards working within groups; it was also noticed that they like to be more active than intermediate school students. Development has an effect on children’s motivation (Wigfield and Eccles, 2002). Therefore, it can be said that exposing not too difficult, short and clear problems to young students who seem to like working within groups and like to be more active, may lead to an increase in their confidence to learn mathematics. One of the critical factors required for solving problems is that students need to believe that they can solve them (Kirkley, 2003). Young children are highly motivated about what they can do, but this decreases with development (Schunk, 2012). Therefore, any problems students think they cannot solve will be considered as difficult and/or unclear. Achilles and Hoover (1996) found shorter PBL problems could be more effective. They believe that regular timetabling (50-minute periods) required creative designing for the PBL process.

7.2.2.4 The effectiveness of PD on students’ attitude towards mathematics

TIMSS 2011 included scales about three motivational constructs: intrinsic value (interest), utility value and ability beliefs (Mullis et al., 2012). Therefore, in TIMSS, motivation measures contain attitudes, value of the subject and confidence to learn.

In general there was no significant difference between the PBL groups and traditional groups for eighth grades students in their ‘attitudes’, ‘value’ and ‘confidence measures’ scores (see Table 5.16, Table 5.21 and Table 5.24), while the primary school results show a significant difference between the PBL students’ scores and traditional methods students’ scores in ‘like learning mathematics’ and ‘confidence to learn measures’ scores. Primary school students were not exposed to value assessment because they were considered to be too young to assess the importance of mathematics in their daily lives or future career (see Table 6.10 and Table 5.12). This suggests that receiving PD in PBL implementation is not a contributory factor on students’ attitudes towards mathematics.

The difference between the results (in primary and intermediate school contexts) could be due to problem design including difficulty levels, length and clarity of the problems provided, the characteristics of students’ age and/or the different teaching instructional methods they had before conducting this study. As previously discussed, the intermediate school teachers suggested that easier, shorter and clearer problems would help to produce better results. In addition, intermediate school students had been accustomed to traditional teaching methods before the current study was conducted whereas primary school students had been almost switched to active learning before this study was implemented, see Table 7.3. Other possible reasons include difference in students characteristics; primary school students showed enthusiasm to work within groups and partake in active learning, while intermediate school students did not show the same level of motivation in these areas. Therefore, receiving training for teachers in PBL implementation seems to have no discernible impact on students’ attitudes towards mathematics. To the author’s knowledge, no empirical study has been conducted to measure the effects of professional development types (face-to-face training and self-directed learning) on students’ attitudes towards mathematics.

Although there was no study found, as far as the researcher knows, that assessed the interaction effect of different ability students with PBL in attitudes levels, TIMSS research asserted that motivation levels (attitudes towards mathematics) have a strong relationship with academic achievement (Mullis et al., 2012). The current study shows that there is no significant difference in academic achievement for low or high achievers when interacted with the different types of treatment. The same applies to the relationship between academic achievement and attitudes towards mathematics. Therefore, if the high achieving students had not been restricted by the low achieving students who were suffering from a lack of perquisite knowledge and/or skills, as discussed previously, they may have improved more than the low achievers and consequently their attitudes towards mathematics would also be improved.

In Chapter Eight, these findings will be related directly to the research questions, and their significance will be assessed. Furthermore, the implications of this study in the Saudi Arabian context will also be examined.

Chapter Eight: Summary and Conclusions

8.1 Introduction

Previous studies have neglected to research the interaction of different types of professional development in depth (face-to-face training and self-directed learning) with different types of treatment (PBL and traditional teaching methods). In addition, no substantial empirical study conducted in Saudi Arabia, or elsewhere, has considered all of the important factors or looked at the different abilities of students and teachers in PBL settings. Equally, no substantial empirical study conducted in Saudi Arabia, or elsewhere, has assessed the effect of PBL on different aspects of achievement, such as looking at 'knowing', 'applying' and 'reasoning' abilities along with the different aspects of attitudes, such as 'like learning mathematics', 'value mathematics' and 'confidence to learning mathematics', or assessed the teachers' perspectives about implementing PBL. This study has addressed theses gaps.

The study set out to measure the effectiveness of a problem based learning (PBL) teaching strategy on the mathematics achievements of third and eighth grade students, along with their attitudes towards mathematics, when compared with traditional teaching methods in Saudi Arabia. The study has also sought to examine the effects of the interaction of different types of professional development for teachers, specifically, face-to-face training and self-directed learning, on students' outcomes, including mathematics achievement and attitudes towards mathematics. The study also investigated the effects of the interaction of the different ability levels of students, i.e. low and high achieving students, with the different teaching strategies (traditional teaching methods and PBL).

The study was based upon the findings and techniques of international TIMSS benchmarks. The outcomes of TIMSS 2007 and 2011 were reviewed and the contributory factors on students' achievement were considered. These factors included 'readiness to learn mathematics', 'engagement of students in mathematics lessons', 'attitudes towards mathematics' (including 'like learning mathematics', 'placing value on mathematics' and 'confidence in learning mathematics'). This study has taken advantage of these factors by including 'attitudes towards mathematics' (including the above mentioned aspects), and considered 'student engagement and readiness' in the interviews carried out with teachers and in the researcher's diary observations.

TIMSS instruments were also used in the current study, including mathematics tests ('knowing', 'applying' and 'reasoning') and attitudes towards mathematics, including 'like learning mathematics', 'placing value on mathematics' and 'confidence in learning mathematics'. The study's objective was to attempt to answer the following research questions:

1. What are the effects of PBL teaching strategies, using trained and untrained teachers, on students' achievement levels (knowing, applying, and reasoning) when compared with conventional methods?

2. What are the effects of PBL teaching strategies, using trained and untrained teachers on, students' attitudes towards mathematics (like learning mathematics, placing value on mathematics, and confidence to learn mathematics) when compared with conventional methods?

3. Is there any significant interaction between treatment and levels of achievement (high and low achievers) in students' achievement levels in 'knowing', 'applying', and 'reasoning'?

4. Is there any significant interaction between treatments and levels of achievement (high and low achievers) in students' attitudes towards mathematics (like learning mathematics, placing value on mathematics and confidence to learn mathematics)?

5. What is the perspective of the teachers about PBL after the treatments when compared with conventional teaching methods?

The study adopted a mixed method, quantitative approach, where the quasi-experimental study data was collected using mathematics tests and measured attitudes towards mathematics; and a qualitative approach where exploratory-explanatory case study data was collected using semi-structured interviews and field observation notes. Therefore, the design of this study is a two-phase design (Lee, 1999) which embeds a case study design - exploratory-explanatory - within and between a quasi-experimental design (Cohen and Manion, 1994, p. 259). Thus, in this study the quasi- experiment design was conducted as the main quantitative approach with a higher priority, and the qualitative approach was carried out before, during and after the quasi-experiments.

In this chapter the original contribution to knowledge and the general findings of the study will be presented, followed by the implications of the study. Future research and the limitations of the study will then be presented.

8.2 An original contribution to knowledge

This may be summarised as follows, by providing a response to each research question:

Finding for question 1 (the effects of PBL teaching strategies, using trained and untrained teachers, on students' achievement levels (knowing, applying, and reasoning) when compared with conventional methods): no significant difference between PBL and traditional methods was found except for third grade students' knowledge application with the trained teacher's group.

Finding for question 2 (the effects of PBL teaching strategies, using trained and untrained teachers on, students' motivation (attitudes towards mathematics, placing value on mathematics, and confidence to learn mathematics) when compared with conventional methods): no significant difference between PBL and traditional methods, in attitudes, for eighth grade students' scores was found. However, the third grade students' average scores for attitudes towards mathematics (like learning mathematics and confidence to learn mathematics) were significantly improved using PBL teaching strategy compared to the traditional methods.

Finding for question 3 (interaction between treatment and levels of achievement (high and low achievers) in students' achievement levels in 'knowing', 'applying', and 'reasoning'): no significant interaction between high and low achieving students' mathematics achievement scores with PBL was found. However it was found generally that the eighth grade low achievers significantly improved more than the eighth grade high achievers in knowing, applying, and reasoning.

Finding for question 4 (interaction between treatments and levels of achievement (high and low achievers) in students' motivation (attitudes towards mathematics, placing value on mathematics and confidence to learn mathematics) : no significant interaction between high and low achieving students' attitudes towards mathematics' scores with PBL was found. However it was found generally that the eighth grade low achievers significantly improved more than the eighth grade high achievers in attitudes towards mathematics, including like learning mathematics, value mathematics, and confidence to learn mathematics. In the third grade students, generally the high achieving students' confidence to learn mathematics' scores significantly improved, more than the low achievers' scores.

Finding for question 5 (the perspective of the teachers about PBL after the treatments, when compared with conventional teaching methods): the teachers indicated that some students were suffering from a lack of prerequisite knowledge or skills which led to limited instructions in their classrooms, and they paid more attention to them to keep up with other students. In addition, the teachers indicated that face-to-face training is important for improving meta-cognitive teaching skills and intervention strategies. The eighth grade school teachers indicated that students began to like PBL over time. This liking was not instant, but developed during the research. In addition, the eighth grade trained teacher thought that his students' thinking was improved. However, the third grade teachers thought that their students' self-directed learning was improved. In addition, the third grade trained teacher indicated that his students' critical thinking skills improved. The third grade teachers indicated that students like learning mathematics through PBL because they like working in groups and they like active learning. The third grade, trained teacher also indicated that students could like PBL more if they are given time to understand problems better. Next these results will be synthesised in details

8.3 The general findings of the study

- ***Mathematics achievement***

Academic achievement, which included 'knowing', 'applying' and 'reasoning', were measured for both the third and eighth grade students. The results of both the third and eighth grade students showed no significant difference between the effects of using the PBL teaching strategy when compared with conventional methods of teaching for students' 'knowing' and 'reasoning' scores. However, a significant difference occurred between the trained teacher's PBL group and the conventional teaching methods results in 'applying achievement'. This indicates that it was necessary for teachers to receive face-to-face training in intervention teaching strategies in PBL sessions in order to show an impact on third grade students' mathematical knowledge application.

The trained teachers easily switched to using the PBL teaching strategy and began using meta-cognitive questions to coach their students. However, the self-directed development teachers could not completely switch to PBL, thus they used explanations and led their students. The trained teachers posed meta-cognitive questions to their students and noticed an improvement in their critical thinking skills, while the untrained teachers did not use these types of questions but instead they left students to answer what they could and helped them with the difficult parts by giving them explanations and giving them indirect examples. The self-directed development teachers found difficulties in knowing when and how they should intervene in groups to enhance cooperation and production.

However, the effectiveness of PBL on the outcomes of the eighth grade students may be affected by the problem design (longer problems fit into more than one session) as well as the fact that they were accustomed to their previous teaching methods, namely, the teacher-centred approach.

- ***Attitudes towards mathematics***

'Attitudes towards mathematics' involved 'like learning mathematics', 'placing value on mathematics' (for only the eighth grade) and 'confidence to learn mathematics'. The result showed no significant difference between the groups in all aspects of 'attitudes towards mathematics' for the eighth grade students. However, there was a significant difference improvement which occurred between the groups in the third grade taught via PBL, whether with the trained or the self-directed learning teachers. This significant difference could be due to the PBL strategy irrespective of the method of professional development the teachers had undertaken. The third grade students showed that they liked active learning and working within groups. The effects of PBL on the eighth grade students' 'attitudes towards mathematics' may be affected by the problem design and the fact that they were accustomed to learning via the teacher-centred teaching approach, as discussed above.

- ***Different ability levels of students***

The results of the low achieving students in the eighth grade significantly improved more than the high achieving students, regardless of the type of treatment they received, i.e. PBL or traditional teaching methods. However, the third grade students' data showed that there was no difference between the outcomes of the low and high achieving students in 'learning mathematics', regardless the types of treatment.

These results were not expected as, according to the literature review. The more able students were expected to learn more than the less able ones (Elshafei, 1998). The reason behind this is perhaps because they are considered to be more intelligent and/or have a greater degree of prior knowledge and/or skills. It is possible that if all students receive the same amount of attention from the teachers, the more able students' learning would be more improved than the less able students.

The less able students received more attention and input from the teachers than the other students because they had a lack of prerequisite knowledge and skills. This meant that the teachers were forced to pay more attention to them and give them more support than the other students. Thus, the low achieving or less able students learned some prerequisite knowledge as well as some new knowledge. The more able students, who were already furnished with prerequisite knowledge, were ready to learn the new knowledge, however, they did not receive sufficient attention to enable them to utilise their time and skills to obtain the necessary knowledge they needed to fit their abilities.

8.4 Implications of study

The issues that the findings of the study raise for reforming mathematics education in Saudi Arabia include curricula and mathematics teacher education:

- ***Curricula of mathematics***

The results of the study indicate that teachers in this study found designing problems to be challenging (see Table 7.2). Indeed, the teachers suggested that the mathematics textbooks need adapting to incorporate PBL implementation. In addition, they suggested that either the PBL problems should be designed by experts, or that teachers should receive appropriate training in how to design problems. This study supports the proposed ideas and the author also believes that the problems should be designed in such a way as to capture students' motivation and interest and provoke their curiosity. Furthermore, the PBL problems should also be designed to fit into one session which lasts for 45 minutes and structured so that the students are required to use their reasoning ability. The problems should gradually become more complex over time, and in parallel with the students development and growing age, and in line with the improvement of their reasoning abilities. Knowledge application skills from near transfer knowledge to far transfer knowledge should also be developed. With adequate and appropriate planning, this approach, aims at improving students' applying skills over time, and could give insight to the King Abdullah bin Abdulaziz's Education Development Project (Tatweer) which states one of its goals as being "To *develop the curriculum and learning materials to meet current and future skill needs*." (Hakami, 2010, p. 12). This also can give insight to the National Transformation Program 2020 which aims to improve curricula (Saudi Arabia's Vision 2030, 2016).

- ***Mathematics textbooks***

It was noted that teachers were blamed a greater reprimanded when they did not follow the instructions of the textbook. This might explain why more percentage of Saudi fourth and eighth grade students were taught using textbooks as the primary basis than the average internationally. According to TIMSS (2011) outcomes, more than 90% of Saudi fourth and eighth grade students were taught using textbooks as the primary basis comparing to an average of 70% internationally (see Mullis et al., 2012). This may indicate that a higher percentage of students in Saudi Arabia were taught using traditional teaching methods which depend on following textbook instructions. Therefore, the teachers had to follow the instructions of mathematics textbooks. This should be reconsidered to give teachers more chance to implement new and creative teaching methods rather than restricting them to using one textbook and asking them to follow this method of instruction. This idea is consistent with goals of the Tatweer project which are: *'decentralising the educational process administration and giving more authority to educational regions and schools*" (Strategic plan for public education development in the Kingdom of Saudi Arabia, 2011, p. 3).

- ***Assessment PBL learning***

Students should be assessed in accordance with the way they have been taught. For example, with traditional teaching methods, students are expected to recall the learning that they received by transfer from teachers. However, students should not be expected to do the same when they have been taught with PBL instruction; rather, they should be assessed in the same manner in which they were taught. Thus, the assessment should include solving real-life problems within his or her own group. If the method of assessment is not guaranteed to be similar to the method of teaching then this could result in the ineffectiveness of this method of teaching being questioned and distrusted. This idea may help The Public Education Evaluation Commission (PEEC) to achieve one of its objectives which is "*Constructing and implementing standardized national tests for each stage.*" (PEEC, 2016). (See http://www.peec.gov.sa/objectives-of-the-commission?lang=en).

In addition, in future research in Saudi Arabian study contexts in mathematics education, researchers should measure knowing and applying separately to give a more accurate assessment of the effects of PBL.

- ***Mathematics teachers***

Professional development (PD) should include training courses and self-directed development. *The term 'training' is the most prevalent term mentioned when it comes to educational research in Saudi Arabia*" (Mansour et al., 2015, p.10). However, no attention was given to learning activities for teachers.

This study suggests that training Face-to-Face is necessary for intervention teaching strategies, however, self-directed learning for teachers could be sufficient for other skills. In addition, self-directed development training could decrease the need for teachers to be trained in other skills. By undertaking self-directed learning, teachers may be able to identify their own teaching problems and enable them to identify any training courses which they feel they need. This would reduce the professional development costs and may encourage the continued self-development of teachers. This suggestion may be supported by Mansour, et.al (2012) who suggests that professional development leaders need to design meaningful learning experiences for all teachers as a guiding framework that frames all learning activities. In addition, this can also give insight and help to build an effective teachers licensing requirements system which the PEEC aims to apply (PEEC, 2016). (See http://www.peec.gov.sa/objectives-of-the-commission?lang=en. This also can give insight to the National Transformation Program 2020 which aims improve recruitment, training and development of teachers (Saudi Arabia's Vision 2030, 2016).

- ***Students' readiness***

Although teachers are required to teach all students of all ability levels, it may be necessary and reasonable for them to give more attention to the students who are less able than others. However, it is not fair for them to spend significantly more time teaching the less able students as this clearly could hinder the more able students' learning potential. In this study, the gap between the students' with prerequisite knowledge and skills negatively affected the high achieving students' learning outcomes. This gap also forced the teachers to perform unfairly. So, although this practice may help all students to pass from one grade to the next, it might also decrease the number of distinguished students.

Thus, this study recommends that students' prerequisite knowledge and skills should be tested and considered prior to their exposure to the PBL teaching strategy and, where necessary, any students who lack the necessary level of prerequisite knowledge and skills should be taught separately and then join the PBL groups once this level of knowledge has been attained. This process could help to reduce the knowledge gap between students and enable all students to focus on learning the new knowledge only, which may also help teachers when they begin to implement the new PBL teaching strategy. In addition, this recommendation may also help to achieve one of the visions of the Tatweer project for Saudi education which is: "To achieve excellence in learning for all learners, according to their abilities" (Strategic plan for public education development in the Kingdom of Saudi Arabia, 2011, p. 3)

- ***Learning engagement***

Students may effectively engage in PBL when they are exposed to real-life, curiosity-driven, interest-driven and reasoning-appropriate problems and are taught by a teacher who is able to coach their meta-cognitive learning skills. In addition, this can be more effective when the students have the required level of prerequisite knowledge and skills. Therefore, it can be recommended that in order to achieve effective engagement from their students, both the teachers and students need to be adequately prepared to work together to produce better learning outcomes.

8.5 Future research

The researcher recommends that interaction between students' readiness to learn mathematics', and 'teachers' performance in implementing the PBL teaching strategy needs more research. The differentiation between the students' levels of prerequisite knowledge and skills can result in unfair treatment among low and high achieving students. This can also highlight the obstacles that prevent high achievers from progressing at their normal pace because they may receive less attention than other students. Extremely low achievers can possibly be left in a position where they do not progress sufficiently in their learning.

The characteristics of the problems used in PBL seem to play an important role in students' mathematics achievement and their attitudes towards mathematics. This area needs more research to investigate the effects of problem design on students' outcomes. Design problems may cover length, difficulty, curiosity, interest and authenticity of problems. Some work on students' perspectives about problem characteristics could be useful.

The professional development of mathematics teachers needs more research to identify which skills need training courses and which do not. Self-directed development can help in PD to reduce the cost, energy and time needed from both the teachers and trainers and this should be investigated. In addition, intensive research is needed in how develop teacher's self-directed learning skills to reflect improvement in self-directed professional development.

In future PBL research, previous teaching methods for students should be taken into account as an important factor. Additionally, prior knowledge and skills should be considered as an important factor.

Finally, the assessment process of PBL needs more investigation. Assessment of students learning through PBL is a concern to teachers, as although the PBL teaching strategy is taught differently to traditional teaching methods, the assessment methods may still be similar to traditional assessment, focusing primarily on knowledge acquisition and neglecting some of the positive outcomes of PBL.

8.6 The limitations of the study

The selected sample of third and eighth grades students from Hail City was not to any degree representative of the entire population. This was true for two reasons. The first reason was that each student did not have an equal chance of being selected from the population. The second reason was that the schools in Hail City are divided into two categories: public schools and private schools. The public schools are free of charge, while the private schools are not. Students who come from lower socioeconomic backgrounds cannot afford to study at private schools. Therefore, this suggests that the characteristics of private school students may be different in terms of socioeconomic issues. This could be a contributory factor in respect of their mathematics achievement and abilities, because there is large association between lower socioeconomic background of students and poorer development and learning (Bradley and Corwyn, 2002; Mullis et al., 2012). Another possible factor is that private schools may compete with other schools for high quality students, while public schools may not engage in the competition and hence, attract wider range if abilities. To generalise the results of this study would require random and stratified samples of significant site (William, 2005).

The results also cannot be generalised to k-12 because of the student developmental differences. The size of sample for teachers was small with only four teachers; it worked with two teachers only for each grade and as such a very tentative conclusion has been drawn which is based on their views and experiences. Thus, this could not support the generalisation of some of the results of this study, such as training teachers and teachers' perspectives.

In addition, the size of the sample for all studies was relatively small. The reliability of the study would be more robust if the sample size was larger, particularly for the intermediate school data. The research is also limited to mathematics education. The study is also limited to a short-term assessment; therefore, if this study had considered retention of knowledge, it would have also been better able to evaluate the effectiveness of PBL over an extended period.

Furthermore, this study is also limited to male students due to a gender segregation system that is operational in Saudi Arabia. The current study is limited to male students, despite the fact that the difference between males and females in learning styles has been shown to be significant in many studies (Dunn et al., 1993; Park 1997; Slater et al., 2007; Isman and Gundogan 2009; Ramayah et al. 2009; Saadi 2014).

Finally, therefore, generalising the results of this study should be done with caution, taking into account the above contextualising factors.

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Appendixes

Appendix 3.1: The Characteristics of Students in each Benchmark in TIMSS 2007 and 2011

The characteristics of students in each benchmark for the fourth grade:

Students who gained 625 points or more should be able to:

1. Apply their knowledge and understanding in relatively various complex situations and can clarify their reasoning.
2. Solve various multi-step word problems including proportions and whole numbers.
3. Show a growing understanding of fractions and decimals.
4. Apply geometric knowledge to two and three-dimensional shapes in various situations.
5. Come to conclusions from data in a table and justify it.

Students who gained between 550 and 625 points should be able to:

- Apply their understanding and knowledge to solve problems.
- Solve word problems including operations with whole numbers.
- Use division with various problems.
- Use their understanding of place value to solve problems.
- Extend patterns to discover a later identified term.
- Explain their understanding of geometric properties and line symmetry.
- Use and interpret data in graphs and tables to solve problems.
- Use data in pictographs and tally charts to complete bar graphs.

Students who gained between 475 and 550 points should be able to:

1. Apply basic mathematical content knowledge in straightforward situations.
2. Show an understanding of whole numbers and some fractions.
3. Distinguish between two and three-dimensional shapes.
4. Interpret pictographs, bar graphs and tables in order to solve simple problems.

Students who gained 400 and 475 points should be able to:

6. Know some basic mathematical content knowledge.
7. Add and subtract whole numbers.
8. Recognize perpendicular and parallel lines.
9. Be familiar with coordinate maps and geometric shapes.
10. Read and complete simple tables and bar graphs.

The characteristics of students in each benchmark for the eighth grade:

Students who gained 625 points or more should be able to:

1. Organise and come to conclusions from information, make generalisations and solve non-routine problems.
2. Solve a variety of percent, proportion and ratio problems.
3. Apply their knowledge in algebraic and numeric concepts and relationships.
4. Model situations and express algebraically the generalisations.
5. Apply their geometric knowledge in complex problems.
6. Use and derive information from different resources to solve multi-step word problems.

Students who gained between 550 and 625 points should be able to:

1. Apply their knowledge in variety of complex situations.
2. Link and calculate with decimals, fractions and percentages, deal with negative integers and solve word problems which include proportions.
3. Deal with linear equation and algebraic expressions.
4. Apply knowledge of geometric properties including volume, area and angles in order to solve problem.
5. Interpret data in a variety of tables and graphs and also resolve simple problems including probability.

Students who gained between 475 and 550 points should be able to:

1. Apply basic mathematics knowledge in simple situations.
2. Multiply and add in order to solve one-step word problems including decimals and

whole numbers

3. Work with simple fractions.
4. Understand simple algebraic relationships.
5. Understand basic geometric concepts and properties of triangles.
6. Read and interpret data from tables and graphs.
7. Know the basic notions of likelihood.

Students who gained between 400 and 475 points should have: Some knowledge of decimals and whole numbers, basic graphs and operations.

Appendix 3.2: The Results of Saudi and the International Students in both Content and Cognitive Domains, for both Fourth and Eighth Grade Students in TIMSS 2007 and 2011

Domain 1 Content Domain including:

a) Number, b) Algebra, c) Geometry, and d) Data and chance.

Domain 2 Cognitive Domain including:

1. Knowing, b) Applying, and c) Reasoning

Saudi Arabia's results for both domains are shown in Table below:

Country	Average Scores in Content Domain				Average Scores in Cognitive Domain		
	No.	Algebra	Geometry	Data and Chance	Knowing	Applying	Reasoning
Saudi Arabia 2007	309	344	359	348	308	335	___
Saudi Arabia 2011	393	399	364	387	402	375	388
International average	500	500	500	500	500	500	500

The result of Saudi Arabia in both Content Domain and Cognitive Domain for eighth grade students

The results of each domain for fourth grade students

The test of TIMSS 2011 for fourth grade included two domains, namely:

Domain 1 Content Domain including:

a. Number, b) Geometric shapes and measures, and c) Data display
b.

Domain 2 Cognitive Domain including:

1. Knowing, b) Apply, and c) Reasoning

The results for Saudi Arabia for both domains are shown in Table below:

Country	Average score in Content Domain			Average score in Cognitive Domain		
	No.	Geometric Shapes and Measures	Data Display	Knowing	Applying	Reasoning
Saudi Arabia 2011	410	404	403	409	405	412
International Average	500	500	500	500	500	500

The results for Saudi Arabia in both Content Domain and Cognitive Domain for fourth grade students

Appendix 3.3: The Percentage of Eighth and Fourth Grade Students in Saudi Arabia and Internationally who had been taught in all Scales

TIMSS 2011, mathematics topics in intended content at school and how much it had been taught for eighth grade students

	Number of TIMSS 2011 mathematics topics intended to be taught and the average number of students (%) who were taught in the eighth grade											
	All TIMSS mathematics topics (19 topics)				Number (5)				Algebra (5)			
Country	For all or almost all students	Only for the students who are more able	Not included in the mathematics curriculum	Percentage of students who had been taught	For all or almost all students	Only for the students who are more able	Not included in mathematics curriculum	Percentage of students who had been taught	For all or almost all students	Only for the students who are more able	Not included in mathematics curriculum	Percentage of students who had been taught
Saudi Arabia	19	0	0	92	5	0	0	99	5	0	0	85
International average	16	1	2	80	5	0	0	98	4	0	1	75

TIMSS 2011, mathematics topics in intended content at school and how much it had been taught for eighth grade students (continued)

	Number of TIMSS 2011 mathematics topics intended to be taught and the average number of students (%) who were taught in the eighth grade (continued)							
	Geometry (6)				**Data and chance (3)**			
Country	**For all or almost all students**	**Only for the students who are more able**	**Not included in the mathematics curriculum**	**Percentage of students who had been taught**	**For all or almost all students**	**Only for the students who are more able**	**Not included in mathematics curriculum**	**Percentage of students who had been taught**
Saudi Arabia	6	0	0	93	3	0	0	88
International average	5	0	1	75	2	0	0	66

TIMSS 2011, mathematics topics in intended content at school and how much it had been taught for fourth grade students

	Number of TIMSS 2011 mathematics topics intended to be taught and the average percentage of students who were taught them for fourth grade											
	All TIMSS mathematics topics (18 topics)				Number (8)				Geometric shapes and measures (7)			
Country	For all or almost all students	Only for the students who are more able	Not included in mathematics curriculum	Percentage of students who had been taught	For all or almost all students	Only for the students who are more able	Not included in mathematics curriculum	Percentage of students who had been taught	For all or almost all students	Only for the students who are more able	Not included in mathematics curriculum	Percentage of students who had been taught
Saudi Arabia	18	0	0	86	8	0	0	87	7	0	0	87
International average	13	1	4	72	0	2	5	76	0	0	2	65

TIMSS 2011, mathematics topics in intended content at school, and how much it had been taught for fourth grade students (continued)

	Number of TIMSS 2011 mathematics topics intended to be taught and average the percentage of students who were taught them for fourth grade (continued)			
	Data display (3)			
Country	**For all or almost all students**	**Only for the students who are more able**	**Not included in mathematics curriculum**	**Percentage of students who had been taught**
Saudi Arabia	3	0	0	82
International average	2	0	1	76

Sources: TIMSS 2011 report, see http://timss.bc.edu/timss2011/international-results-mathematics.html

Appendix 3.4: Engagement of Fourth and Eighth Grade Students and Internationally in Learning, Reported by Teachers, TIMSS 2011

Country	Most of the lesson		About half of the lesson		Some of the lesson	
	Percent of students	Average achievement	Percent of students	Average achievement	Percent of students	Average achievement
Saudi Arabia 2011 for eighth grade	87	397	12	381	1	------
International average 2011 for eighth grade	80	469	17	459	3	484
Saudi Arabia 2011 for fourth grade	66	418	33	395	1	------
International average 2011 for fourth grade	69	492	30	488	2	- -----

Instruction to engage students in learning TIMSS 2011

TIMSS 2011 for eighth	Linking the lesson to students' daily lives				Bring interesting materials to class			
Country	Every lesson or almost every lesson		About half the lesson or less		Every lesson or almost every lesson		About half the lesson or less	
	Percent of students	Average achievement	Percent of students	Average achievement	Percent of students	Average achievement	Percent of students	Average achievement
Saudi Arabia 2011 for eighth grade	58	397	42	392	20	398	60	394
International average 2011 for eighth grade	39	467	61	568	18	469	82	467

Linking the lesson to daily lives and bringing interesting materials to class

Sources: TIMSS 2011 report, see http://timss.bc.edu/timss2011/international-results-mathematics.html

Appendix 3.5: Engagement of Fourth and Eighth Grade Students and Internationally in Learning, Reported by Students, TIMSS 2011

Country	Engage		Engage to some degree		Do not engage	
	Percent of students	Average achievement	Percent of students	Average achievement	Percent of students	Average achievement
Saudi Arabia 2011 for eighth grade	30	421	56	387	14	369
International average 2011 for eighth grade	25	484	54	468	21	449
Saudi Arabia 2011 for fourth grade	47	431	47	396	6	395
International average 2011 for fourth grade	42	507	49	482	8	464

Sources: TIMSS 2011 report, see http://timss.bc.edu/timss2011/international-results-mathematics.html

Appendix 3.6: Readiness to Learn Mathematics for Fourth and Eighth Grade Students Internationally and in Saudi Arabia, TIMSS 2011

Country	Not at all		Some		A lot	
	Percent of students	Average achievement	Percent of students	Average achievement	Percent of students	Average achievement
Saudi Arabia 2011 for eighth grade	10	405	57	401	33	383
International average 2011 for eighth grade	15	490	57	471	28	443
Saudi Arabia 2011 for fourth grade	17	430	60	410	23	398
International average 2011 for fourth grade	27	506	61	489	12	467

Sources: TIMSS 2011 report, see http://timss.bc.edu/timss2011/international-results-mathematics.html

Appendix 3.7: Mathematics Homework for Eighth and Fourth Grade Students, TIMSS 2007 and 2011

Country	**High level of doing mathematics homework**		**medium level of doing mathematics homework**		**low level of doing mathematics homework**	
	Percentage of students	**Average achievement**	**Percentage of students**	**Average achievement**	**Percentage of students**	**Average achievement**
Saudi Arabia for eighth grade TIMSS 2007	13	316	61	339	26	334
International average for eighth grade TIMSS 2007	27	458	53	457	20	441
Saudi Arabia for eighth grade TIMSS 2011	5	356	18	391	77	398
International average for eighth grade TIMSS 2011	15	464	38	478	48	460

Sources: TIMSS 2011 report, see: **http://timss.bc.edu/timss2011/international-results-mathematics.html. TIMSS 2007 report, see: http://timss.bc.edu/timss2007/intl_reports.html.**

Appendix 3.8: Eighth Students and Teachers' Reports about Five Activities in Mathematics Classes and Information on how long these Activities lasted, TIMSS 2007

Country	Report from both students and teachers about the length of time five mathematics activities lasted (half of the lesson or longer) - percentage for eighth grade students									
	Practice adding, subtracting, multiplying and dividing without using calculator		**Work on fractions and decimals**		**Write equations and functions to represent relationships**		**Solve problems about geometric shapes, lines, and angles**		**Interpret data in tables, charts, or graphs**	
	Students' report	Teachers' report	Students' report	Teachers' report	Students' Report	Teachers' report	Students' report	Teachers' report	Students' report	Teachers' report
Saudi Arabia	57	76	40	27	62	39	62	35	53	27
International average	59	65	51	42	57	34	58	34	45	17

Appendix 3.9: The Teachers and Eighth Students' Reports about Learning Activities in Mathematics Lessons, TIMSS 2007

Country	**Report from both students and teachers about the length of time five mathematics activities lasted (half of the lesson or longer) - percentage for eighth grade students**											
	Memorize formulas and procedures		**Work through problems on their own**		**Explain answers**		**Relate what is being learnt in mathematics to their daily lives**		**Decide procedures for solving complex problems**		**Work on problems for which there is no immediately obvious solution**	
	Students' report	Teachers' report	Students' report	Teachers' report	Students' report	Teachers' report	Students' report	Teachers' report	Students' report	Teachers' report	Students' report	Teachers' report
Saudi Arabia	60	65	58	65	70	70	55	62	55	45	-	32
International average	63	49	64	68	70	78	51	57	50	42	-	22

***The source id TIMSS 2007 report* – sources of appendix 3.8 and 3.9: TIMSS 2007 report, see http://timss.bc.edu/timss2007/intl_reports.html**

Appendix 3.10: Learning Activities in Mathematics Lessons for Fourth Eighth Grade Students, TIMSS 2011

TIMSS 2011 for fourth grade students	Percentage of students doing the following activities every lesson or almost every lesson				
	Work through problems (individually or with peers) with teacher guidance	Work through problems together in the whole class with direct teacher guidance	Work through problems (individually or with peers) while teacher occupied by other tasks	Memorize rules, procedures, and facts	Explain their answers
Saudi Arabia	56	61	21	56	65
International average	55	45	16	37	62

TIMSS 2011 for eighth grade students	Percentage of students doing the following activities every lesson or almost every lesson					
	Work through problems (individually or with peers) while teacher occupied by other tasks	Memorize rules, procedures, and facts	"Work Problems (Individually or with Peers) While Teacher Occupied by Other Tasks"	"Memorize Rules, Procedures, and Facts"	Explain their answers	Apply facts, concepts, and procedures
Saudi Arabia	53	57	16	43	65	54
International average	55	48	14	45	60	49

Sources: TIMSS 2011 report, see http://timss.bc.edu/timss2011/international-results-mathematics.html

Appendix 3.11: Time of Lesson Spent on Variety of Activities, Learning Activities in Mathematics Lessons for Eighth Grade Students, TIMSS 2011

Country	'Reviewing homework'	'Listening to lecture-style presentations'	'Working problems with teacher's guidance'	'Working through problems on their own without teacher's guidance'	'Listening to teacher re-teach and clarify content/procedures'	'Taking tests or quizzes'	'Participating in classroom management tasks not related to the lesson's content / purpose'	'Other student activities'
Saudi Arabia	12%	22%	17%	11%	15%	10%	7%	7%
International average	11%	20%	21%	16%	12%	10%	5%	5%

Sources: TIMSS 2011 report, see http://timss.bc.edu/timss2011/international-results-mathematics.html

1

Appendix 4.A1: Academic School Records for Intermediate School Students

School Records

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
					Lower Bound	Upper Bound		
PBL with trained teacher's group	17	67.7647	9.13461	2.21547	63.0681	72.4613	50.00	82.00
conventional method with trained teacher's group	17	60.4706	9.63793	2.33754	55.5152	65.4260	40.00	80.00
PBL with untrained teacher's group	14	62.5714	9.38669	2.50870	57.1517	67.9911	45.00	78.00
conventional method with untrained teacher's group	16	63.5625	11.52949	2.88237	57.4189	69.7061	50.00	93.00
Total	64	63.6406	10.10794	1.26349	61.1157	66.1655	40.00	93.00

school record - ANOVA

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	476.074	3	158.691	1.597	.199
Within Groups	5960.660	60	99.344		
Total	6436.734	63			

Appendix 4.A.2: Examples of Eighth Grade Students' Problems

Problem A

You have been selected for the role of consultant for your company. Please read the letter below:

Dear consultant,

As you are a new consultant with the company, please could you please give us your opinion as to what you think is an appropriate price for us to sell the smallest of our range of nut keys, taking into account the relevant factors, as detailed below?

1. A nut key that measures is 3/7 inches
2. A nut key that measures 5/7 inches

Notes:

a) The total manufacturing cost for the small nut key is 3/9 SR.

b) Transportation and marketing costs 1/9.

c) Government aid totals 2/9 SR.

d) Profit must be at least 20% and not exceed 50%.

e) All decimal numbers should be rounded to the nearest thousandth.

Yours faithfully

The Management

Problem B

The school administration department has a number of textbooks (1600) which need to be stored appropriately in the school library. Please provide your opinion on what you consider to be the best options for storage, taking into account the information provided.

a) 400 books: the thickness of the book is 1½ cm
b) 300 books: the thickness of the book is 2 cm
c) 500 books: the thickness of the book is 3/5 cm

d) 400 books: the thickness of the book is 1¼ cm

There are a variety of options and a wide range of shelves available, as follows:

a) One shelf is 30 ½ cm in length and costs 100 SR
b) One shelf is 70 3/4 cm in length and costs 210 SR
c) One shelf is 40 1/4 cm in length and costs 110 SR

The school administration hopes that you all will reach the most appropriate and cost effective solution.

Note: all decimal numbers should be rounded to the nearest integer.

Appendix 4.A.3: Lesson Goals for Eighth Grade Students

The objectives of rational number units for eighth grade students

Lesson one:

1. Student should recognise rational numbers.
2. Student should be able to transit common fractions to decimal fractions.
3. Student should be able to transit fractional numbers to decimal fractions.
4. Student should be able to transit decimal fractions to common fractions.
5. Student should be able to transit decimal fractions to fractional numbers.
6. Student should be able to round fractional numbers to the nearest thousandth.
7. Student should be able to make comparisons between rational numbers.

Lesson two:

1. Student should be able to make comparisons between positive rational numbers.
2. Student should be able to make comparisons between decimal fractions.
3. Student should be able to arrange rational numbers in ascending and descending order.
4. Student should be able to make comparisons between negative rational numbers

Lesson three:

1. Student should be able to multiply two common fractions by each other.
2. Student should be able to multiply two fractional numbers by each other.

Lesson four:

1. Student should be able to produce multiplicative inverse for rational numbers.
2. Student should be able to divide two rational numbers by each other.

Lesson five:

1. Student should be able to add rational numbers that have common denominators to each other.

2. Student should be able to subtract rational numbers that have common denominators to each other.

3. Student should be able to add fractional numbers to each other.

Lesson six:

1. Student should be able to add rational numbers that have non-common denominators to each other.
2. Student should be able to subtract rational numbers that have non-common denominators to each other.
3. Student should be able to add decimal numbers to each other.

Appendix4.A.4: Final Version of the Exam for Eighth Grade Students (Combination of Released Exams of TIMMS 2007 in Arabic and in English), and Approval Email from TIMMS

The e-mail I received from TIMSS

From: TIMSS [timss@bc.edu]
Sent: 17 September 2012 16:01
To: Nawaf Alreshidi
Cc: Ina Mullis; Michael Martin; Martin Hooper
Subject: RE: asking for the mathematics itms 2007 for eighth grade arabic version and english one.

Dear Nawaf,

Thank you for your interest in TIMSS. Because TIMSS is a trend study, only a subset of the items used in the TIMSS assessments are released to the public so people can see what TIMSS items are like, and only the international (English) version of these. The rest are kept confidential to be used again in future assessments. Released items from TIMSS are for non-commercial, educational, and research purposes only. Although the items are in the public domain, please print an acknowledgement of the source, including the year and name of the assessment you are using. If you publish any part of the released items from TIMSS 2007, please use the following acknowledgement:

SOURCE: TIMSS 2007 Assessment. Copyright © 2009 International Association for the Evaluation of Educational Achievement (IEA). Publisher: TIMSS andPIRLS International Study Center, Lynch School of Education, Boston College.

Although we do not release all of the TIMSS items themselves, we do release all of the item information, including cognitive and content classifications for each item. For TIMSS 2007, this information is available on our website, here (Click on the link for "Items"):

http://timssandpirls.bc.edu/TIMSS2007/idb_ug.html

I hope this information will be helpful for your research.

Best regards,

Gabrielle

اختبار للصف الثاني متوسط

اسم الطالب: ....

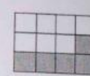
اسم المدرسة: ....

الشعبة: ....

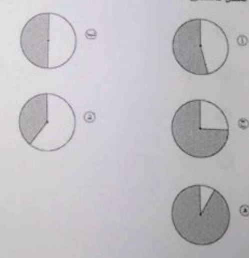
اسم المعلم: ....

أجب عن جميع الاسئلة التالية:

السؤال الاول



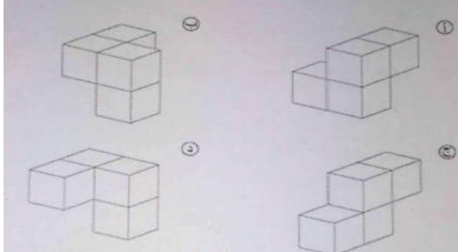
في أي دائرة يكون الجزء المظلل منها يدل على كسر يساوي تقريباً الكسر الذي بالجزء المظلل للمستطيل ؟



السؤال الثاني

عند تدوير هذا الشكل إلى وضع آخر

أي من الأشكال التالية يمكن أن يكون بعد التدوير ؟



السؤال الثالث

$\frac{س}{٣} > ٨$ تكافئ أي من التالية :

أ) س > ٥

ب) س > ٢٤

ج) س > $\frac{٨}{٣}$

د) س < ٥

هـ) س < ٢٤

السؤال الرابع

$\frac{٢}{٥} + \frac{٥}{٤} + \frac{٩}{٨} =$

أ) $\frac{١٦}{١٧}$

ب) $\frac{٤١}{٤٠}$

ج) $\frac{٨١}{٤٠}$

د) $\frac{١١١}{٤٠}$

السؤال الخامس

عدد طلبة صف يساوي ٣٠ . في الصف نسبة عدد المتفوقين إلى الغير متفوقين تعادل ٢ : ٣.

فما عدد المتفوقين في الصف ؟

أ) ٦

ب) ١٢

ج) ١٨

د) ٢٠

السؤال السادس

وضع بائع سيارات في الصحف اليومية الإعلان التالي : « سيارات جديدة وقديمة للبيع، وبأسعار مختلفة، متوسط أسعارها ٥٠٠٠ دينار ». من الإعلان، أي العبارات التالية يجب أن تكون صحيحة ؟

أ) من المحتمل أن معظم السيارات تكلف بين ٤٠٠٠ دينار إلى ٦٠٠٠ دينار.

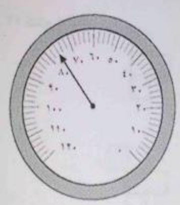
ب) من المحتمل أن نصف السيارات تكلف أقل من ٥٠٠٠ دينار ونصفها يكلف أكثر من ٥٠٠٠ دينار.

ج) من المحتمل أن على الأقل سيارة واحدة تكلف ٥٠٠٠ دينار.

د) من المحتمل أن بعض السيارات تكلف أقل من ٥٠٠٠ دينار.

السؤال السابع

ما قراءة الفولتية المبينة على العداد ؟



أ) ٧٣

ب) ٧٤

ج) ٧٦

د) ٧٨

السؤال الثامن

أي الأعداد التالية هو الأصغر ؟

أ) $\frac{١}{٢}$

ب) $\frac{٥}{٨}$

ج) $\frac{٥}{٦}$

د) $\frac{٥}{١٢}$

السؤال التاسع

أسعار البطاقات لمباراة رياضية : هي إما ١٠ دينار أو ١٥ دينار أو ٣٠ دينار للبطاقة الواحدة، من ال ٩٠٠ بطاقة المباعة، $\frac{١}{٥}$ البطاقات بيع بسعر الواحدة ٣٠ دينار و $\frac{٢}{٣}$ البطاقات بيع بسعر الواحدة ١٥ دينار

ما الكسر الذي يمثل البطاقات التي بيعت بسعر ١٠ دينار للبطاقة الواحدة ؟

الإجابة : ____________

السؤال العاشر

تصنع دانا كعكة أكبر مرة ونصف من حجم الكعكة الموجودة في الوصفة . إذا كانت الكعكة في الوصفة تحتاج $\frac{٣}{٤}$ كوب من السكر، فما عدد أكواب السكر التي تحتاجها دانا لصنع كعكتها ؟

أ $\frac{٣}{٨}$

ب $١\frac{١}{٨}$

ج $١\frac{١}{٤}$

د $١\frac{٣}{٨}$

السؤال الحادي عشر

في رحلة مدرسة كان هناك معلمٌ واحد لكل ١٢ طالباً. إذا ذهب ١٠٨ طالباً في هذه الرحلة، فكم كان عدد المعلمين في الرحلة ؟

أ ٧

ب ٨

ج ٩

د ١٠

السؤال الثاني عشر

ما العدد الذي إذا قسم على ‎-٦ يعطي ١٢ كناتج ؟

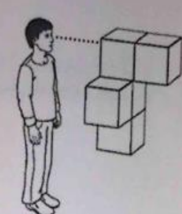
أ ‎-٧٢

ب ‎-٢

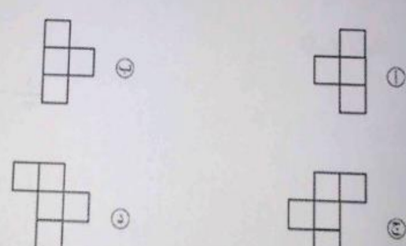
ج ٢

د ٧٢

السؤال الثالث عشر



يتكوّن المجسم أعلاه من ٥ مكعبات صغيرة.
ايّ شكل يراه الشخص المبين في الرسم ؟



السؤال الرابع عشر

الصف	الكبار	الصغار
١	١٢	٩
٢	١٤	١١
٣	١٦	١٢
٤	١٨	١٥

يبين الجدول أعلاه عدد الكبار والصغارفي أربعة صفوف،
أي صفين فيهما نفس نسبة الكبار إلى الصغار؟

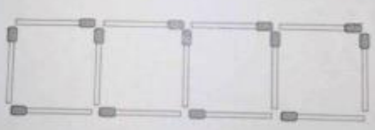
أ ١ و ٢

ب ١ و ٣

ج ٢ و ٣

د ٢ و ٤

السؤال الخامس عشر



في الشكل، ١٣ عود ثقاب استخدمت لعمل ٤ مربعات في صف. ما عدد المربعات التي يمكن عملها بالطريقة نفسها باستخدام ٧٣ عوداً ؟
بيّن الحسابات التي توصلت من خلالها إلى إجابتك ؟

الإجابة : ____________

السؤال السادس عشر

كان عدد الأطفال في إحدى الرحلات أكثر من ٥٥ ، وأقل من ٦٥. وكان من الممكن توزيع الأطفال على مجموعات في كل منها ٧ أطفال، ولكن لا يمكن توزيعهم على مجموعات في كل منها ٨ أطفال.
ما عدد الأطفال في الرحلة؟

الإجابة : ________________

السؤال السابع عشر

أي مما يلي يوضح إجراءاً صحيحاً لإيجاد ناتج $\frac{١}{٥} - \frac{١}{٣}$

أ) $\frac{١}{٥} - \frac{١}{٣} = \frac{١-١}{٥-٣}$

ب) $\frac{١}{٥} - \frac{١}{٣} = \frac{١}{٥-٣}$

ج) $\frac{١}{٥} - \frac{١}{٣} = \frac{٥-٣}{٥\times٣}$

د) $\frac{١}{٥} - \frac{١}{٣} = \frac{٣-٥}{٥\times٣}$

السؤال الثامن عشر

في إحدى المحلات التجارية كان ثمن معطف ١٢٠ دينار، وخلال فترة التنزيلات أصبح ثمن المعطف ٨٤ دينار. ما النسبة المئوية لتخفيض ثمن المعطف ؟

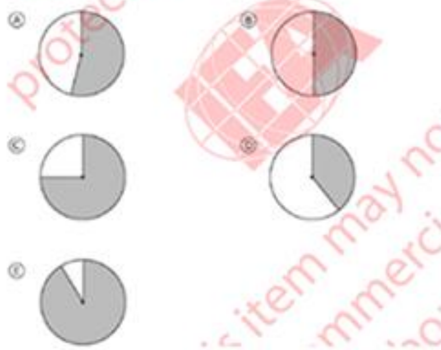
أ) ٢٥
ب) ٣٠
ج) ٣٥
د) ٣٦

انتهت الأسئلة

The Exam for Eighth Grade Students (Combination of Released Exams of TIMSS 2007: in English)

Question 1:

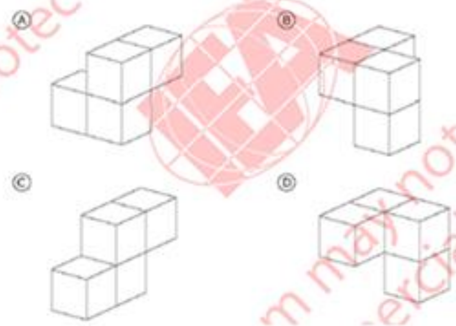
Which circle has approximately the same fraction of its area shaded as the rectangle above?



Question 2

This object will be turned to a different position

Which of these could be the object after being turned?



Question 3

$\frac{x}{3} > 8$ is equivalent to

Ⓐ $x < 5$

Ⓑ $x < 24$

Ⓒ $x > \frac{8}{3}$

Ⓓ $x > 5$

Ⓔ $x > 24$

Question 4

$\frac{2}{5} + \frac{5}{4} + \frac{9}{8} =$

Ⓐ $\frac{16}{17}$

Ⓑ $\frac{41}{40}$

Ⓒ $\frac{81}{40}$

Ⓓ $\frac{111}{40}$

Question 5

There are 30 students in a class. The ratio of boys to girls in the class is 2:3. How many boys are there in the class?

Ⓐ 6

Ⓑ 12

Ⓒ 18

Ⓓ 20

Question 6

A car salesman placed this advertisement in the newspaper: "Old and new cars for sale, different prices, average price 5,000 zeds." From the advertisement, which of the following must be true?

Ⓐ Most of the cars would cost between 4,000 zeds and 6,000 zeds.

Ⓑ Half of the cars would cost less than 5,000 zeds, and half would cost more than 5,000 zeds.

Ⓒ At least one of the cars would cost 5,000 zeds.

Ⓓ Some of the cars would cost less than 5,000 zeds.

Question 7

What is the voltage reading shown on the meter?

Ⓐ 73

Ⓑ 74

Ⓒ 76

Ⓓ 78

Question 8

Which of the following numbers is SMALLEST?

Ⓐ $\frac{1}{2}$

Ⓑ $\frac{5}{8}$

Ⓒ $\frac{5}{6}$

Ⓓ $\frac{5}{12}$

Question 9

Tickets for a concert cost either 10 zeds, 15 zeds, or 30 zeds.

Of the 900 tickets sold, $\frac{1}{5}$ cost 30 zeds each and $\frac{2}{3}$ cost 15 zeds each.

What FRACTION of the tickets sold for 10 zeds each?

Answer: ______________

Question 10

Dana makes a large batch of cranberry bread that is one and a half times the original recipe. If the original recipe requires $\frac{3}{4}$ cup of sugar, how many cups of sugar are required for the bread Dana is making?

Ⓐ $\frac{3}{8}$

Ⓑ $1\frac{1}{8}$

Ⓒ $1\frac{1}{4}$

Ⓓ $1\frac{3}{8}$

Question 11

On a school trip there was 1 teacher for every 12 students. If 108 students went on the trip, how many teachers were on the trip?

Ⓐ 7

Ⓑ 8

Ⓒ 9

Ⓓ 10

Question 12

What number divided by –6 gives 12 as the result?

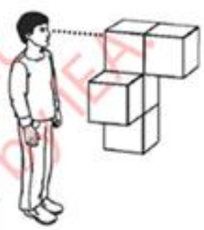
Ⓐ –72

Ⓑ –2

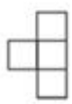
Ⓒ 2

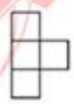
Ⓓ 72

Question 13



The solid is made of 5 small cubes.
Which shape does the person in the diagram see?

Ⓐ 

Ⓑ 

Ⓒ 

Ⓓ 

Question 14

Class	Boys	Girls
1	12	9
2	14	11
3	16	12
4	18	15

The table above shows the numbers of boys and girls in four classes.
Which two classes have the same ratio of boys to girls?

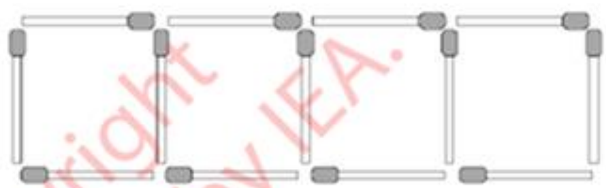
Ⓐ 1 and 2

Ⓑ 1 and 3

Ⓒ 2 and 3

Ⓓ 2 and 4

Question 15



In the figure, 13 matches were used to make 4 squares in a row. What is the number of squares in a row that can be made in this way using 73 matches?
Show the calculations that lead to your answer.

Answer: ______________

Question16

The number of children on a trip was larger than 55, but smaller than 65. The children could be divided into groups of 7, but not groups of 8. How many children were on the trip?

Answer: ______________

Question17

Which shows a correct procedure for finding $\frac{1}{5} - \frac{1}{3}$?

Ⓐ $\frac{1}{5} - \frac{1}{3} = \frac{1-1}{5-3}$

Ⓑ $\frac{1}{5} - \frac{1}{3} = \frac{1}{5-3}$

Ⓒ $\frac{1}{5} - \frac{1}{3} = \frac{5-3}{5\times3}$

Ⓓ $\frac{1}{5} - \frac{1}{3} = \frac{3-5}{5\times3}$

Question 18

In Zedland the original price of a coat was 120 zeds. During a sale the price of the coat was 84 zeds. By what percentage was the price of the coat reduced?

Ⓐ 25

Ⓑ 30

Ⓒ 35

Ⓓ 36

Appendix4.A.5: Attitudes Towards Mathematics Measures for Intermediate Students in Arabic and in English

استبيان قياس الاتجاهات نحو الرياضيات

أسم الطالب ....

الفصل.......................... الشعبة:..........................

ضع اشارة √ في المكان المناسب أمام كل عبارة :

م	العبـــــــــــارة	أوفق بشدة	أوافق الي حد ما	لا أوافق بشدة	لا أوافق الي حد ما
1	أجتهد في الرياضيات عادة				
2	اود دراسة حصص رياضيات أكثر في المدرسة				
3	أجد صعوبة في الرياضيات أكثر من زملائي في الفصل				
4	أجد متعه في تعلم الرياضيات				
5	الرياضيات ليست من المواد التي اتفوق بها				
6	اتعلم الأشياء بسرعة في الرياضيات				
7	الرياضيات مملة				
8	أحب الرياضيات				
9	أعتقد أن تعلم الرياضيات سيساعدني في حياتي اليومية				
10	احتاج الي الرياضيات لتعلم مواد أخرى في المدرسة				
11	يجب ان اجتهد في الرياضيات لأدخل الجامعة التي أرغبها				
12	يجب ان أجتهد في الرياضيات لأحصل على الوظيفة التي أريدها				

المصدر: TIMSS 2007 ترجمة الباحث

How much do you agree with these statements about learning mathematics?

*Fill in **one** circle for each line*

		Agree a lot	Agree a little	Disagree a little	Disagree a lot
a)	I usually do well in mathematics	①	②	③	④
b)	I would like to take more mathematics in school	①	②	③	④
c)	Mathematics is more difficult for me than for many of my classmates	①	②	③	④
d)	I enjoy learning mathematics	①	②	③	④
e)	Mathematics is not one of my strengths	①	②	③	④
f)	I learn things quickly in mathematics	①	②	③	④
g)	Mathematics is boring	①	②	③	④
h)	I like mathematics	①	②	③	④

How much do you agree with these statements about mathematics?

*Fill in **one** circle for each line*

		Agree a lot	Agree a little	Disagree a little	Disagree a lot
a)	I think learning mathematics will help me in my daily life	①	②	③	④
b)	I need mathematics to learn other school subjects	①	②	③	④
c)	I need to do well in mathematics to get into the <university> of my choice	①	②	③	④
d)	I need to do well in mathematics to get the job I want	①	②	③	④

Appendix4. A.6: 'G' School Letter

March 2013

Re Nawaf Alreshidi

It is in order that Nawaf Alreshidi carry out a research project with pupils from [redacted] School in conjunction with The University of Glasgow.

Mary T Fyfe

[redacted]

Head of Mathematics

[redacted]

Senior Depute Rector

Appendix 4. A.7: The Teacher Training Programme

Implementation of PBL

Students are taught two lessons in PBL. At the outset, students are tasked with specific goals and problems, which act as learning tools, are designed for the students to enable them to achieve the specified goals. The goals are divided into educational and PBL goals.

a) Educational goals

After the completion of the task, students are expected to be able to calculate the area of a parallelogram and other irregular shapes by making them into shapes with areas that can be calculated using specific formulas.

b) PBL goals

The following goals are likely to be fixed in every problem which is taught using the PBL process (Hmelo-Silver andBarrows, 2006):

1. to keep all the students active in the learning process;

2. to keep the learning process on track;

3. to make the students' thoughts and their depth of understanding apparent; and

4. to encourage students to become self-reliant for direction and information.

PBL model

A PBL problem can be broken down as follows:

1. Meeting a problem.
2. Understanding the problem.
3. Identifying what students know, what they need to know and what their initial ideas are about how to solve the problem.
4. Defining the problem statement.
5. Gathering and sharing information with groups.
6. Generating possible solutions.
7. Choosing the best solution.
8. Presenting the problem.
9. Debriefing the problem.

Preparing the learners

All students need to be prepared prior to being introduced to the PBL strategy for the first time. The initial training is normally based on their interests, background and the nature of the PBL problem. However, students who have previous experience of PBL are normally not required to undertake any additional preparatory training.

One approach teachers can use in order to prepare students for PBL is called the KWL strategy and is based on three key points, namely 'what do I know?', 'what do I want to know?' and 'what have I learned?' Another approach could be to conduct a small scale, problem-based experience.

FIRST: Meeting the problem

Students meet problems in a variety of forms. Some examples include problems which take the form of a written letter, a video played in class, a number of miscellaneous documents or even a person from outside the classroom which the teacher has enlisted for the students to approach for help in solving a problem.

The role of students in a problem must be clear as stakeholders, such as: engineers or consultants….etc. This is to personalise the learning and to motivate students to solve the problem. This role should achieve effective and deeper understanding for the students.

The following is an example of a problem presented to students in the form of a letter:

Problem 1

You are employed as a landscape architect. You work on the design team and your group has received the following letter:

‘G’ School

1 Secondary School Lane

Landscaping Design

Dear Sir or madam

We would like to create an additional grazing enclosure in the enclosed circular grassland area of our land to house a herd of goats. The radius of this area of grassland is 50 meters and is shown in Figure 1 which is appended to this letter. We would like you to incorporate the following features in your design and ensure that:

1. the enclosure is not smaller than 40% or greater than 70% of the remaining grassland are; and
2. the shape of the area must take a different form than the other buildings seen in Figure 1

We have read your brochure and have enclosed the $200 design fee. We appreciate your guaranteed delivery date of two days for receipt of your design proposal.

Yours faithfully

Sandy

[Sandy’s Farm]

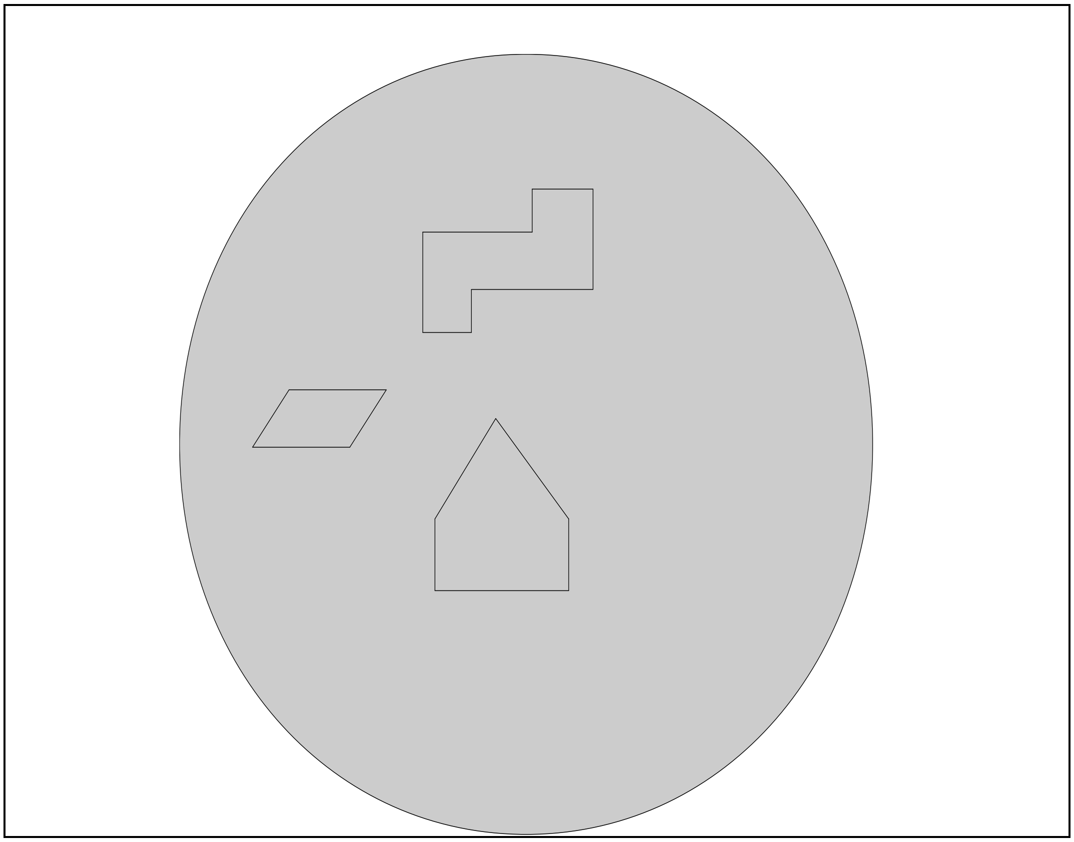


Figure 1

SECOND: Understanding the problem

To explain the step of understanding the problem, the teacher could follow the process detailed below.

A. The teacher or a student reads the problem out to the rest of the class.

B. The teacher gives the students time to digest and understand the problem collectively.

10. The teacher randomly asks students to restate the problem in their own words.

11. The students listen to the responses from the other students and make comments.

12. The teacher asks students about the facts and requirements of the problem, so the process will continue in the same way, randomly asking students as a way of making sure that everything is going very well and all the students understand.

Example questions

1. Could you tell me your understanding of the problem in your own words?

2. What are your thoughts on your classmates' comments? Do you agree with them?

3. Do you think your classmates have covered everything?

4. Is there anything else you would like to add?

The types of questions asked by the teacher enable the students to answer the questions without any input from the teacher.

THIRD: Identifying what we know

Students record what they know about the problem, the facts, the requirements and prior information in the 'Know' column (see Figure 2). This step supports students through developing their awareness in areas which they know. One of goals of this step is to activate prior information about the problem and thus, each student is required to contribute. The role of teacher is to coach students to enquire about the knowledge they have:

Coaching: encouraging students to identify and record what they know which might be related to the problem. Coaching students to explore this knowledge by asking questions such as: 'are you sure of the information that you gave?'

Assessment: listening to students, observing what they have mentioned and what they have not and asking question to prompt or probe.

Prompting questions: asking students to support their claims such as: 'how do you know?'

Probing questions: asking question to go deeper into an idea or concept such as: 'tell me more about it'.

To explain the step of identifying what we know, the teacher could follow these processes:

1. The teachers ask students to record what they already know about the problem.

2. The teacher encourages students to refer to their prior knowledge and relate this to the current problem.

3. The teacher records students' information on the whiteboard.

4. The teacher encourages students to reflect on this and facilitates discussions.

Know	Need to know	Ideas

Figure 2- Model of what know and need to know and ideas to solve problem

Regarding the problem example

Students must have studied and should know the following information:

1. The area of the circle.

2. The area of the rectangular.

3. The area of triangular.

4. The area of square.

5. The ratio (of what??)

Teachers should consider all of the above and then pose some additional questions, such as (for example):

1. Is there anything else which has not been considered? (This question should be asked if the students do not mention all the points relating to the prior information they have been taught).

2. Why do you mention this? (For a deeper understanding).

3. What do you mean by this? (To gain a deeper understanding and further clarification / explanation).

4. Are you sure? (To allow the student to reflect on and refer to their prior knowledge and information).

FOURTH: Identifying what we need to know

Students record what they need to know in order to solve the problem in the column entitled 'Need to know' in Figure 2. The process of establishing this information will be derived through active dialogue with the other students.

Coaching: encouraging learners by asking further questions and by setting learning goals about what the students need to know. Asking questions such as: 'do we need to know more?' and 'why?'

Assessment: listening to students, observing what they have mentioned and what they have not, asking questions or asking students to draw a map to demonstrate their understanding of the problem (refer to Figures 4 and 5). Also asking questions such as, 'have you considered……either about aspects of information or strategies?'

The teacher does the same process as outlined in previous stage.

When approaching the problem students are expected to mention all of following points:

Need to know
1. What do irregular shapes mean? 2. How to find the area of the irregular shapes? 3. What is the [area of the] parallelogram? 4. How to calculate the area of parallelogram

Figure 4- Model of what we need to know

FIFTH: Identifying students' ideas

This step requires students to record their initial thoughts and ideas about how they will go about acquiring any additional information they need and how they might approach solving the problem through active dialogue and group discussions. This process also encourages students to explain their hypotheses and ideas.

Coaching: encouraging students to generate ideas about how to gain information and solve the problem by asking questions such as: 'how can we learn about this?' Students are asked to document their ideas and are encouraged to critically evaluate their own ideas as well as their fellow classmates.

Assessment: listening to students' ideas and asking questions such as: 'what makes you say that?' and 'how does this apply to …...'

The teacher will carry out the same process as outlined in the previous stages.

When approaching the problem, students may consider some of the ideas suggested in Figure 5 below:

Need to know
a) Can we find out more about irregular shapes by searching the Internet (e.g. the teacher could ask 'why?' and 'what else?') b) The irregular shapes are considered as a combination of regular shapes (for example, the teacher could ask students to explain or provide an example of 'the benefit of this idea' or ask 'what made you think of this?'

Figure-5– Model of students' ideas

SIXTH: Defining the problem statement

Students write the problem with its conditions. In other words, they write the problem and how they will control it. Teachers can encourage students to use this form:

How can we {state the issue}

So that {state the conditions}

Coaching: asking students to record the problem statement in clear and simple words. Asking questions such as: 'how will you decide when you know enough and have all the necessary information you need to solve this problem?'

Assessment: listening to the problem statement and deciding whether it is compatible with the learning outcomes or not and then asking questions based on that situation, such as:

1. 'What if ….?'
2. 'Do we have enough facts to suggest…?'
3. 'Why is this important?'

The teacher does the same process as outlined in the previous stages

The problem statement in the problem-1 will be:

How can we {state the issue}

So that {state the conditions}

How can we design an enclosure for the goats, **ensuring that** the shape is irregular, whilst being no smaller than 40% or greater than 70% of the remaining land area?

SEVENTH: dividing the students into groups in class:

The teacher divides students into 3 or 4 groups, depending on the number of students in the class, with each group consisting of between 4 and 8 students. Each member of the group should have a specific role, such as chairperson, recorder, reader or observer. The members of the group should not be homogenous in terms of attainment level. In other words, each group has an equal mix of high level, medium level and low level achievers.

The role of every member of the group is to:

1. go through the processes of PBL;
2. actively participate in discussions and be equally involved in presentations made by the group;
3. listen and respond to each other's comments and suggestions;
4. ask open questions; and
5. research and share information.

The role of chair is to:

1. lead the group through the process of PBL;
2. make sure that every member of the group participates and is equally involved;
3. keep time; and
4. check the work of others and act as a scribe.

Teachers can create new roles for other students, such as a nominating someone to be responsible for making sure that all the other students understands their roles and responsibilities.

EIGHTH: Gathering information

After identifying what students need to know in order to solve the problem, students are allocated with specific tasks and then search for the required information. This process involves gathering important, evidence based information and assessing its validity in order to support their situation and their decisions.

Coaching and assessment: encouraging students to question everything and ask questions such as:

a) 'How reliable is….?'

b) 'How valid is...?'

c) 'Where does this fit?'

d) 'What still needs to be done?'

e) 'Where can we start?'

f) 'Who will do this and by when?'

g) 'How does that relate to our problem statement?'

h) 'What obstacles do you see?'

Meta-cognitive questions such as: 'what did not work?', 'what do you need to do next?', 'what is your strategy?' and 'what have you accomplished?' should also be asked.

To explain the steps for gathering information, the teacher could follow these processes:

1. The teacher asks students to gather in small groups and discuss how they gather the information needed. They might find it on the Internet, in textbooks or from other sources.

2. The students divide the work between them. For example, each member of the group, either individually or in pairs, is responsible for obtaining a particular piece of the required information.

3. The students begin to gather the information they need and could continue to do the rest of this stage in their home.

This suggests that:

a) students should set specific goals related to what they need to know;

b) these goals are broken down and allocated to different members of the group; and

c) the information gathering process should be documented, as shown in Figure 6.

Goal	**Strategy**	**Justifying the strategy**	**Assessment of strategy or the resource**	**Assessment of achieving the goal**	**Assessment of understanding the information gathered**	**Reword the information gathered to explain it for classmates**

Figure 6 - Model of the information gathering process

To explain the model above, students should fill in columns 1, 2 and 3 before they embark on information gathering, assess the strategy or the resource and then complete the remaining columns.

In the process of solving the problem it is expected that individuals or pairs within each group are tasked with researching and ascertaining specific information and facts about what they need to know, such as:

1. What do irregular shapes mean?

2. How to find the area of the irregular shapes?

3. What is the parallelogram?

4. How to calculate the area of parallelogram?

Once established, this information is then documented, as demonstrated in Figure 7 below:

Figure 7 – Example model of how to record the information gathering process

Goal	What are our initial thoughts about it?	Strategy or source	Justifying the strategy or source	Assessment of the strategy or the resource	Assessment of how likely it is for the goal to be achieved	Assessment and understanding the information gathered	Rewording the information gathered to explain it to classmates
What do irregular shapes mean?	Are any rules applied to mixed shapes? If so, what are these rules?	Carry out research by searching the Internet and referring to relevant texts.	Does this information provide any relevant examples?				

NINTH: Sharing information

Students re-group to share the obtained information. Interpersonal communication and collaborative learning will have a positive impact on solving the problem effectively. Sharing information with others and being involved in active dialogue to analyse the information gathered is an important aspect of this process.

Coaching: encouraging active dialogue, debate and discussion, asking questions such as: 'how can we fit this together with…?', 'what conclusions have you drawn?' and 'have you reached your goal?'

Assessment: listening to students and observing their discussions. Each student could be asked in assessment form, questions such as: 'do you think that your participation in the group was appropriate and helpful?'

To explain the step of sharing information, the teacher could follow these processes:

a) The students regroup with new information and share this with others in small groups.

b) The teacher encourages students to question the new information and assesses their understanding of it.

c) The teacher could assign one students in each group to make sure that each member of the group understands the new information.

In this step, teachers have to make sure all students within groups have understood the learning issues.

TENTH: Generating possible solutions

Students have written the conditions of solving the problem in the problem statement and they have gathered information in light of it; students return to the problem statement again and generate all possible solutions.

Students' role: generating possible solutions based on the information gathered and checking if this matches the problem statement or not.

Coaching and assessment: encouraging students to consider all possible solutions which must match the problem statement. This can be done through written assignment or by asking meta-cognitive questions such as: 'how does that match our problem statement?' and 'have you considered -----?'

To explain the step of generating possible solutions, the teacher could follow these processes:

1. The students start generating all possible solutions.

2. The teacher questions their work and takes into consideration whether the solution matches the problem statement or not and embeds an assessment.

Eleventh: Determining the solution

After generating all possible solutions for problem, students assess the advantages and disadvantages of each possible solution in light of the conditions of the problem statement. Students can use a decision-making matrix (see Figure 8) to choose the best fit solution for the problem. This step is the step of critical thinking.

Strategy / Possible Solution	**Advantages**	**Disadvantages**	**Consequences**
Strategy1/ Possible Solution 1			
Strategy2/ Possible Solution 2			
Strategy3/ Possible Solution 3			

Figure 8 - Decision-making matrix

Twelfth: Presenting the solution

Students present their work explaining the information they have obtained and how they have obtained this information. They also detail why this information is important and how they intend to use it. For this step, teachers often arrange for an expert in the field to be present in order that they can assess the students' hypotheses and recommendations. Students are assessed by a detailed rubric about context and presentation skills and work in teams to find an appropriate solution (see Figures 9 and 10).

Criteria	**Result**	**Comments**
Understanding		
Communication		
Self-assessment		
Presentation		
Making a decision or hypotheses		
Researching		
Debriefing the problem		

Figure 9 - Portfolio evaluation rubric

Criteria	**Result**	**Comments**
Content		
Cooperation		
Organisation		
Presentation		

Figure 10 - Group presentation rubric

Thirteenth: Debriefing the problem

Students discuss the efficacy of their strategies and the issues that were not answered or needed further inquiry and information. In doing so, self-directed learning will be developed as students consider what they might do differently when approaching other problems. Teachers can ask students to write a report about what they have learned from the problem and give them feedback.

Facilitating learning processes

1. **Summarising**

Students are asked to summarise their case in order for the teacher to check their understanding and also to give the less vocal members of the group an opportunity to be more involved in the discourse. Teachers may also follow this by asking other members of group if they agree with what the student has said and keep the discussion flowing or they may refer to the hypothesis and assess their work so far. In cases where students suggest that changes need to be made the teacher may also ask them why they are going to make these changes. This presents another opportunity for the student to show what they have learned and more in depth discussion will take a place, thus allowing them to reconstruct and structure new knowledge that they have learned (Hmelo-Silver andBarrows, 2006). This could be done by asking such questions such as: 'could you summarise what your group has done so far?' The teacher would then ask the rest of students if they agree with what he or she said.

2. **Generating hypotheses**

Engaging students in inquiry knowledge and making them aware of their knowledge limitations is vital for developing self-directed learning and effective reasoning. 'Encouraging students to generate hypotheses' (Hmelo-Silver andBarrows, 2006) is a key factor in enabling students to effectively summarise their learning processes,

3. **Re-voicing**

Re-voicing what students have said is a practice that can help to facilitate learning processes. For example, sometimes students mention concepts in their own words which the teacher could then relay back to the students using academic words.

Be aware

a) When teachers penalise students for mistakes or reward them for their successes, this can cause students to be cautious or make them feel anxious which adversely affects their willingness to fully participate at both emotional and intellectual levels.

b) Teachers should avoid offering answers or explanations and encourage students to do this themselves.

Conclusion

One of the responsibilities of teachers is to monitor students' engagement in the group and, where necessary, intervene and encourage students who do not participate. One good idea to solve this problem is to use 'talking chips' as this will make all members of the group contribute to the discussion for an equal period of time and will also resolve the problem of domination by one or more students in the discussion.

Teachers can ask students individually to write reports about what they have learned from the problem as home work and give them feedback.

Bibliographies:

Hmelo-Silver, C.E. and Barrows, H. S., 2006. Goals and Strategies of a Problem-Based Learning Facilitator. *Interdisciplinary Journal of Problem-Based Learning*, *1*(1), P.4.

Torp, L. and Sage, S., 2002. *Problems As Possibilities: Problem-Based Learning for K-12 Education*. 2nd ed. Alexandria, VA: Association for Supervision and Curriculum Development.

Appendix4. A.8: Approval Letter for the Implementation of Study in Saudi Arabia

بسم الله الرحمن الرحيم

المملكة العربية السعودية
وزارة التربية والتعليم
وكالة الوزارة للتخطيط والتطوير
الإدارة العامة للبحوث

وزارة التربية والتعليم
MINISTRY OF EDUCATION

الرقم: ٣٤١٦١٨٥٧٩
التاريخ: ٢٠/٩/١٤٣٤هـ
المشفوعات: ١

الموضوع : بحث الطالب/ نواف بن عوض الرشيدي

سعادة مدير عام التربية والتعليم بمنطقة حائل وفقه الله

السلام عليكم ورحمة الله وبركاته

تجدون سعادتكم برفقه الطلب المقدم من الطالب/ نواف بن عوض الرشيدي، أحد طلاب الدراسات العليا لمرحلة الدكتوراه بجامعة "جلاسكو" في بريطانيا بشأن بحثه حول "فعالية التعلم القائم على مشكلة في تعليم الرياضيات" .

آمل من سعادتكم التكرم بالتوجيه بتسهيل مهمته .

والسلام عليكم ورحمة الله وبركاته

مدير عام البحوث

عبدالرحمن بن عبدالله الغنام

ص. للإدارة .
ص. لخدمات البحث .
ص. للباحث
(٢٨٠)

هاتف : ٤٠٤٢٨٨٨ - ٤٠٤٦٦٦٦ - فاكس : ٤٠٣٧٢٢٩ - ٤٠١٢٣٦٥ - العنوان البريدي : الرياض - وزارة التربية والتعليم ١١١٤٨

Appendix4.A.9: Sample of consent Form and Plain Language Statement taken from ethical approval (university of Glasgow)

University of Glasgow | College of Social Sciences

Plain Language Statement for children

1. Study title and researcher details

I am Nawaf Alreshidi and I am studying a PhD in Education at The University of Glasgow. I am carrying out a project to research the effect of using problem-based learning (PBL) and teaching strategies on developing mathematics cognitive domains and attitude towards learning mathematics among middle school and lower primary school students in Saudi Arabia. This research is supervised by Professor Victor Lally (Interdisciplinary Science Education, Technologies and Learning (ISETL) Group Director at The University Glasgow; contact details: email: victor.lally@Glasgow.ac.uk, telephone: 0141 3303424; and Andrew Gallacher, email: .Gallacher@glasgow.ac.uk, telephone: 0141 3303422.

2. Invitation paragraph

You are being invited to take part in this research study. Before you decide whether you would like to take part it is important for you to understand why the research is being done and what it will involve. Please take the time to read the following information carefully and discuss it with me if you wish. Please feel free to ask questions about anything you are unclear about or if you would like to have more information. Please take the time to consider whether or not you wish to take part.

3. What is the purpose of the study?

The purpose of the study is to measure the effectiveness of using problem-based learning (PBL) teaching strategies on mathematics cognitive domains of middle school and lower primary school students in mathematics and their attitudes towards learning mathematics in Scotland. The study will take approximately 6-8 weeks.

4. Why have I been selected?

The school has been selected based on the expression of assistance and cooperation received from teachers and administration of the school. In addition, the study is focusing the middle school and lower primary school students to evaluate the effectiveness of PBL strategies in achieving desired goals in mathematics and making the discipline more meaningful and enjoyable for students. The sample selected for the study consists of 4 groups of participants and 2 teachers.

5. Do I have to take part?

It is up to you to decide whether or not to you wish to take part. If you decide to take part you are still free to withdraw at any time and do not need to provide a reason. Please also be aware that if you decide not to participate, this will not affect your school marks in any way or have any other detrimental effect in respect of your relationship with others in the school.

6. What will happen to me if I take part?

You will be given a questionnaire and pre-tests in two areas (a measure of your attitude towards learning mathematics and a short examination in mathematics to assess your level of achievement). After approximately two to three weeks you will be given two post-tests (a measure of your attitude towards learning mathematics and a short examination in mathematics to assess your level of achievement). This process will be repeated in the second stage of study. You will be taught by the PBL teaching strategies for two to three weeks in either the first or second stage of the study.

7. Will my taking part in this study be kept confidential?

All information which is collected about you during the course of the research will be kept strictly confidential. You will be identified by an ID number and any information about you will have your name and address removed so that you are unable to be identified.

8. What will happen to the results of the research study?

If requested, you can receive a copy of the results of this study and the research findings. You may also receive a copy of my thesis if you so request this.

9. Who will review the study?

This study will be reviewed by the College of Social Sciences Research Ethics Committee.

10. Contact for Further Information

For further information, please contact Professor Victor Lally on: victor.lally@glasgow.co.uk telephone: 0141 3303424 or Andrew Gallacher on: Gallacher@glasgow.ac.uk, telephone: 0141 3303422. In addition, if you have any concerns regarding the conduct of the research project then you can contact Professor John McKernan, the Ethics Officer, at the College of Social Sciences Research Ethics Committee at: john.mckenan@glasgow.ac.uk.

University of Glasgow | College of Social Sciences

Consent Form for children

Title of Project: The effect of using problem-based learning (PBL) teaching strategy on developing cognitive domains and attitude towards learning mathematics in middle school and primary school students in Saudi Arabia.

Name of Researcher: Nawaf Alreshidi

1. I confirm that I have read and understand the Plain Language Statement for the above study and have had the opportunity to ask questions.

3. I understand that my participation is voluntary and that I am free to withdraw at any time, without giving any reason.

4. I hereby consent to being assessed by carrying out tests and completing questionnaires.

6. I agree / do not agree / (delete as applicable) to take part in the above study.

______________________	________	________________
Name of participant	Date	Signature

______________________	________	________________
Researcher: Nawaf Alreshidi	Date	Signature

Appendix4. B.1: School Records for Primary School Students

school record

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
					Lower Bound	Upper Bound		
1	52	26.1923	13.24733	1.83707	22.5042	29.8804	7.00	50.00
2	39	24.4359	12.07606	1.93372	20.5213	28.3505	6.00	50.00
3	36	24.0833	15.81749	2.63625	18.7315	29.4352	7.00	50.00
Total	127	25.0551	13.61739	1.20835	22.6638	27.4464	6.00	50.00

School record

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	116.198	2	58.099	.310	.734
Within Groups	23248.417	124	187.487		
Total	23364.614	126			

Appendix4.B.2: Lesson Goals for Third Grade Students

The objectives of data display unit for third grade students

Lesson objectives

Lesson one:

1. Student should be able to represent data by codes.

Lesson two:

1. Student should be able to read representation through codes.
2. Student should be able to interpret data within codes.

Lesson three:

1. Student should be able to represent data by columns.
2. Student should be able to read data within columns.

Lesson four:

1. Student should be able to read data that is representing by columns.

2. Student should be able to interpret data that is representing by columns.

Appendix 4.B.3: Examples of Problems for Third Grade Students

Problem A

As a consultant of the school, please work with your group and present the results of some of the students' favourite games from your classroom in codes in such a way as to make it easy for others to understand.

Problem B

The principal of the school has requested a list of all the resorts that were visited by the third grade students in the school. In your role as consultants for the school, please could you describe how you search for this information and present it in codes?

Appendix 4.B.4: The Final Exam for Third Grade Students and Combination of Released Exam of TIMSS in Arabic and English

اختبار للصف الثالث ابتدائي

اسم الطالب:..

اسم المدرسة:..

الشعبة:..

اسم المعلم:..

أجب عن جميع الاسئلة التالية:

السؤال الأول :-

الشارع	عدد البيوت
المحبة	
العز	
النصر	
السلام	

يضع أحمد جدولاً لإظهار عدد البيوت الموجودة في بعض الشوارع .

كل يمثل 5 بيوت هناك 20 بيتاً في شارع السلام .

كم على أحمد رسمها في الجدول إلى جانب شارع السلام ؟

① 4
② 5
③ 15
④ 20

السؤال الثاني : يشير الرسم في الجدول التالي إلى عدد التفاحات التي يقطفها جمال كل يوم .

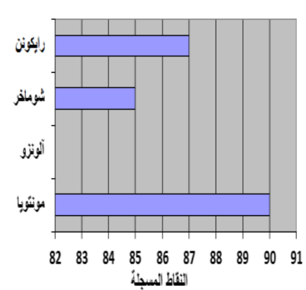
تمثل 10 تفاحات

الشارع	عدد البيوت
الاثنين	
الثلاثاء	
الأربعاء	
الخميس	

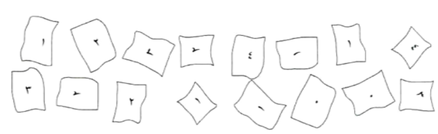
في أي يوم قطف جمال 5 تفاحات ؟

① الاثنين
② الثلاثاء
③ الأربعاء
④ الخميس

السؤال الثالث : يشير الرسم البياني التالي إلى النقاط التي سجلها 4 سائقين في بطولة سباق السيارات . يحتل مونتويا المرتبة الأولى ويحتل آلونزو المرتبة الثالثة . أرسم خطاً عريضاً على الرسم التالي للإشارة إلى عدد النقاط التي سجلها آلونزو .



السؤال الرابع :



طلبت ياسمين من زميلات صفها أن يكتبوا عدد إخوتهم, ثم جمعت وعبرت عنها بعلامات في الجدول, عبرت ياسمين عن الإجابة صفر بعلامتين .

أكمل العلامات التي وضعتها ياسمين في الجدول :

عدد الأخوة والأخوات	العلامات
0	//
1	
2	
3	
4	

السؤال الخامس :

نوع الشجرة	عدد الأشجار
الصنوبر	200
البيسية	100
البلوط	50
البتولا	50

يشير الجدول أعلاه إلى إعداد أربعة أنواع من أشجار مزروعة في حديقة, أي الرسوم البيانية التالية يعرض على أفضل وجه المعلومات الواردة في الجدول ؟

1)


2)

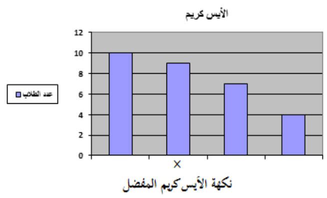

3)


4)


السؤال السادس :

الأيس كريم المفضل	عدد الطلاب
ليمون	|||
شوكولاتة	卌 卌
فراولة	卌 ||||
فانيلا	卌 ||

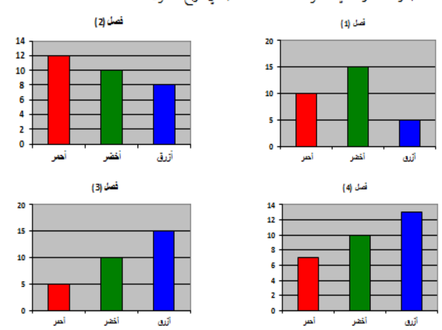
سأل المعلم 29 طالب في الفصل عن الأيس كريم المفضل لديهم, والجدول السابق يوضح تسجيل المعلم لإستجابات طلابه . أي من الأيس كريم المفضل يمثل العلامة (×) في الرسم البياني :-



① ليمون
② شوكولاتة
③ فراولة
④ فانيلا

السؤال السابع :

قام أحمد بدراسة لمعرفة أي الألوان المفضلة للطلاب في أربع فصول :



في أي فصل من الفصول السابقة أختار أقل عدد من الطلاب اللون الأزرق

① فصل (1)
② فصل (2)
③ فصل (3)
④ فصل (4)

السؤال الثامن :

صاحب محل قرر أن يعرف كم عدد الأقلام والمراسم والمساحات والمساطر التي يبعث في أول يوم من أيام المدرسة, ثم عمل جدول البيانات التالي :-

أقلام	مراسم	مساحات	مساطر
卌 卌 卌 卌 ||	卌 卌 卌 | 卌 卌	卌 卌 ||	卌 卌 卌 卌 ||||

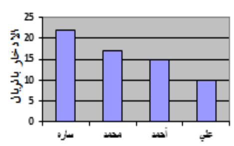
كم يزيد عدد المراسم التي يبعث عن المساطر ؟

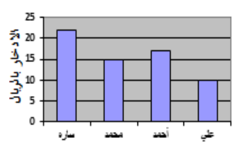
الإجابة : (   )

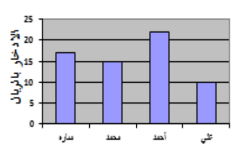
السؤال التاسع :

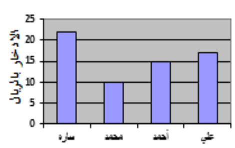
المبلغ	الاسم
ساره	22 ريال
محمد	15 ريال
أحمد	17 ريال
علي	10 ريال

أي من الرسوم البيانية التالية يعرض بيانات الجدول السابق بشكل صحيح :

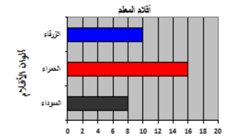
Ⓐ


Ⓑ


Ⓒ


Ⓓ


السؤال العاشر :

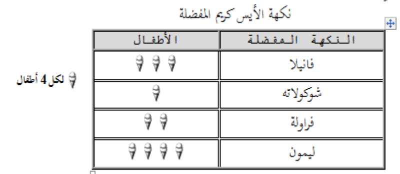


الرسم البياني يوضح عدد الأقلام الزرقاء , الحمراء , السوداء التي على طاولة المعلم كم تزيد الأقلام الحمراء عن السوداء ؟

① قلمان
② 4 أقلام
③ 6 أقلام
④ 8 أقلام

السؤال الحادي عشر :

نكهة الأيس كريم المفضلة



كم عدد الأطفال اللذين اختاروا الفانيلا كانكهة مفضلة ؟

الإجابة : (   )

السؤال الثاني عشر :

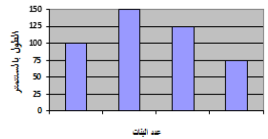
الرسم البياني يوضح عدد الطلاب في كل صف في مدرسة النجاح

في مدرسة النجاح هنالك غرفه دراسية لكل صف تسع 30 طالب .

كم عدد الطلاب الذين تستطيع المدرسة أن تقبل ليكتمل العدد في كل صف : (   )

السؤال الثالث عشر :

يوضح الرسم البياني الطول لأربع بنات



الأسماء مفقوده من الرسم البياني نورة الأطول , هند الأقصر , ريم أطول من ساره .

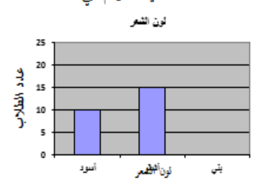
كم طول سارة

① 75 سم
② 100 سم
③ 125 سم
④ 150 سم

السؤال الرابع عشر :

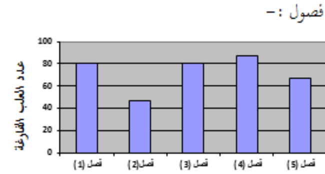
في فصل يتكون من 30 طالب, 10 طلاب لون شعرهم أسود, 15 طالب لون شعرهم أشقر, والبقية لون شعرهم بني .

أكمل الرسم البياني التالي لتبين عدد الطلاب الذي شعرهم بني .



السؤال الخامس عشر :

طلب مدير المدرسة من الطلاب أن يحضروا إلى المدرسة علب فارغة ثم عمل المدير رسم بياني لعدد العلب الفارغة من خمس فصول :-



أي فصل جمع 45 علبه فارغة :-

① فصل (1)
② فصل (2)
③ فصل (3)
④ فصل (5)

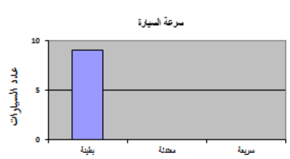
السؤال السادس عشر :

قام العديد من التلامذة بجمع المعلومات حول معدل سرعة السيارات التي تمر بالقرب من مدرستهم يشير الجدول أدناه إلى نتائج 20 سيارة .

السيارة	بطيئة	معتدلة	سريعة
1		×	
2	×		
3	×		
4			×
5			×
6	×		
7		×	
8		×	
9	×		
10	×		
11	×		
12		×	
13	×		
14			×
15			×
16	×		
17		×	
18	×		
19		×	
20			×

بهدف تبسيط قراءة النتائج شرع التلامذة بتمثيل المعلومات في الرسم البياني التالي .

أكمل الرسم البياني :



انتهت الأسئلة

Exam for Third Grade Students and Combination of Released Exam of TIMSS in English

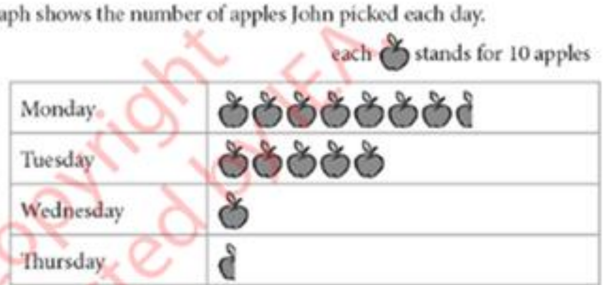
Question 1

Mary is making a chart to show the number of houses on some streets.
Every stands for 5 houses. There are 20 houses on Hill Street.
How many should Mary put in the chart beside Hill Street?

Ⓐ 4
Ⓑ 5
Ⓒ 15
Ⓓ 20

Question 2

The graph shows the number of apples John picked each day.

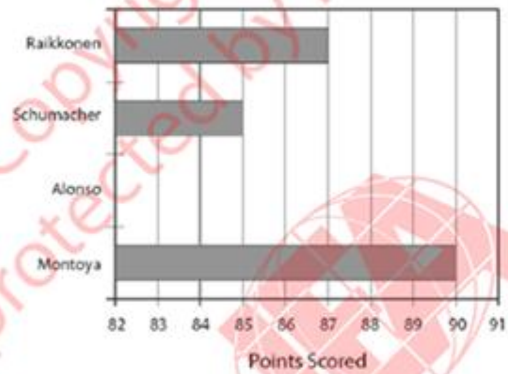


On which day did John pick 5 apples?

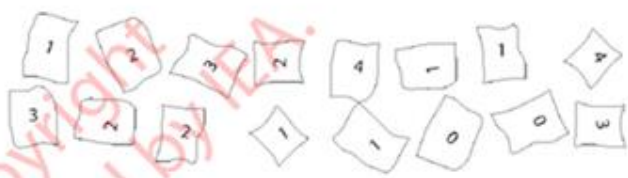
Ⓐ Monday
Ⓑ Tuesday
Ⓒ Wednesday
Ⓓ Thursday

Question 3

This graph shows the points obtained by 4 drivers in the car racing championship. Montoya is in first place. Alonso is in third place. Draw a bar which shows how many points Alonso has scored.



Question4



Jasmin asked her classmates to write down how many brothers and sisters they had. She collected their answers and started to make a tally chart. She put in the two marks for the zeroes.

Complete Jasmin's tally chart.

Number of brothers and sisters	Tally
0	//
1	
2	
3	
4	

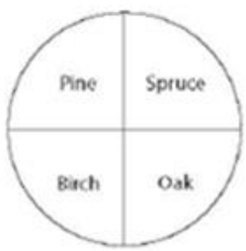
Question 5

Type of Tree	Number of Trees
Pine	200
Spruce	100
Oak	50
Birch	50

The table above shows the numbers of four types of trees growing in a park. Which of the following pie charts correctly displays the information shown in the table?

Ⓐ


Ⓑ


Ⓒ


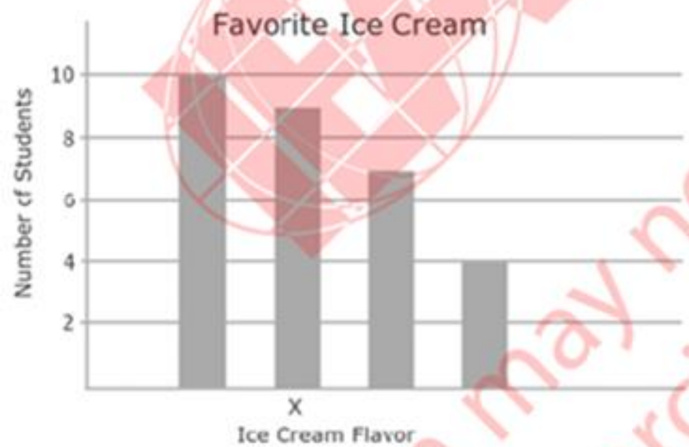
Ⓓ


Question 6

Favorite Ice Cream	Number of Students
Butterscotch	IIII
Chocolate	𝍸 𝍸
Strawberry	𝍸 IIII
Vanilla	𝍸 II

A teacher asked 30 students in her class the flavor of their favorite ice cream. The table above shows how the teacher recorded the students' responses.

In the bar graph below, which ice cream flavor corresponds to the bar that is labeled X?



Ⓐ butterscotch

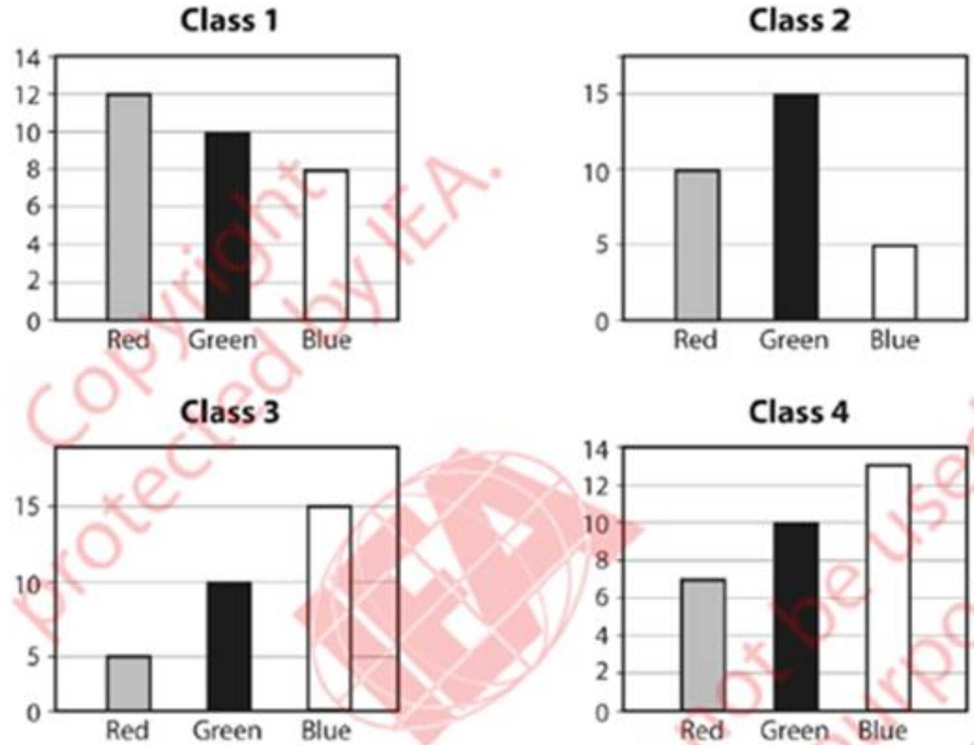
Ⓑ chocolate

Ⓒ strawberry

Ⓓ vanilla

Question7

Ahmed made a survey of the favorite color of the students in 4 classes.



In which class do the fewest students choose blue?

Ⓐ Class 1

Ⓑ Class 2

Ⓒ Class 3

Ⓓ Class 4

Question 8

A store owner decided to check how many pens, pencils, erasers, and rulers were sold on the day school opened. He made the tally chart below.

Pens	Pencils	Erasers	Rulers
卌 卌 卌 卌 ||	卌 卌 卌 卌 卌 |	卌 卌 ||	卌 卌 卌 卌 ||||

How many more pencils than rulers were sold?

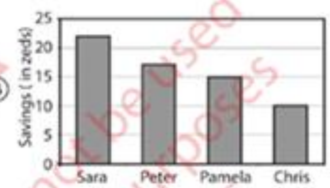
Answer: ______________

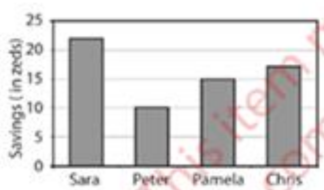
Question 9

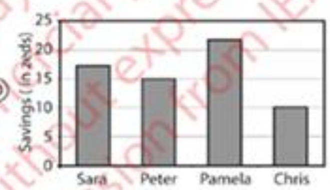
John was given the following table by his teacher and was asked to identify the graph that correctly displays the data. Which graph below should he choose?

Name	Savings
Sara	22 zeds
Peter	15 zeds
Pamela	17 zeds
Chris	10 zeds

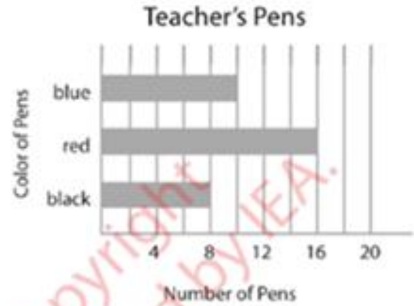
Ⓐ


Ⓑ


Ⓒ


Ⓓ


Question 10



The graph shows the number of blue, red, and black pens the teacher has in his desk. How many more red pens are there than black pens?

Ⓐ 2 more
Ⓑ 4 more
Ⓒ 6 more
Ⓓ 8 more

Question 11

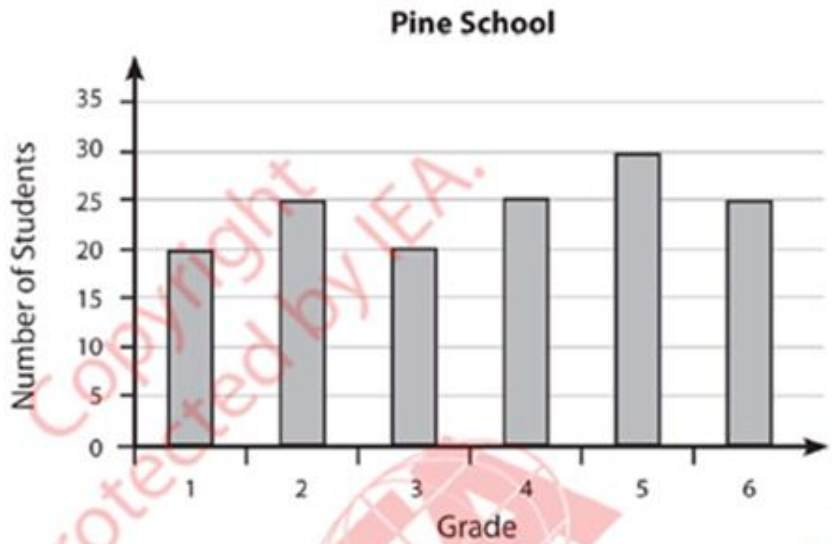
Favorite Ice Cream Flavors

How many children chose vanilla as their favorite flavor?

Answer: ______________

Question 12

The graph shows the number of students at each grade in the Pine School.



In the Pine School there is room in each grade for 30 students.
How many more students could be in the school?

Ⓐ 20

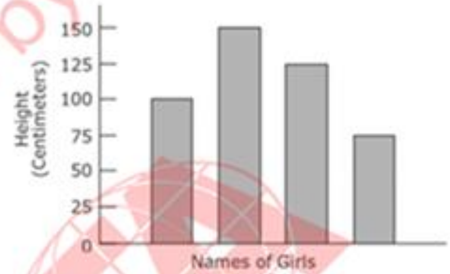
Ⓑ 25

Ⓒ 30

Ⓓ 35

Question 13

The graph shows the heights of four girls.



The names are missing from the graph. Debbie is the tallest. Amy is the shortest. Dawn is taller than Sarah. How tall is Sarah?

Ⓐ 75 cm

Ⓑ 100 cm

Ⓒ 125 cm

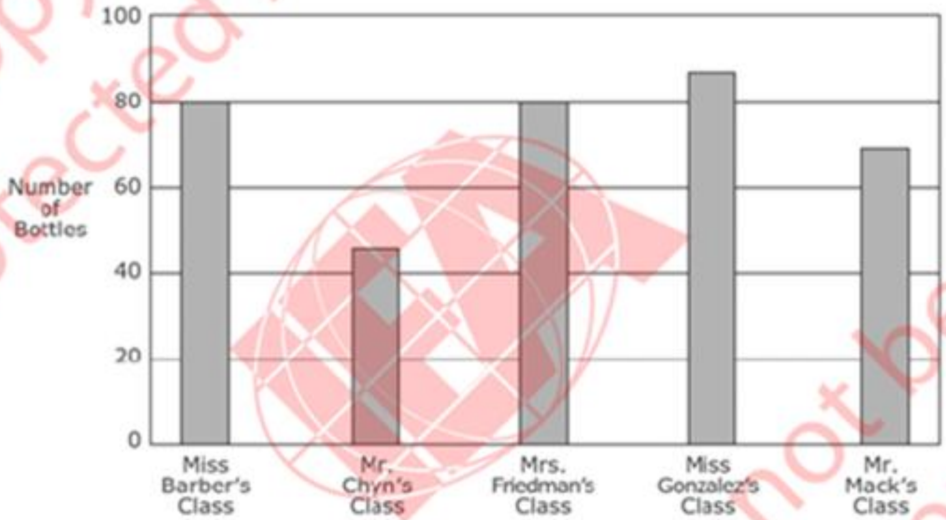
Ⓓ 150 cm

Question 14

In a class of 30 students, 10 have black hair, 15 have blonde hair, and the rest have brown hair. Complete the graph below to show the number of students with brown hair.

Question 15

Central School had a bottle collection. Children in each class brought empty bottles to school. The principal made a bar graph of the number of bottles from five classes.



Which class collected 45 bottles?

(A) Miss Barber's class

(B) Mr. Chyn's class

(C) Mrs. Friedman's class

(D) Mr. Mack's class

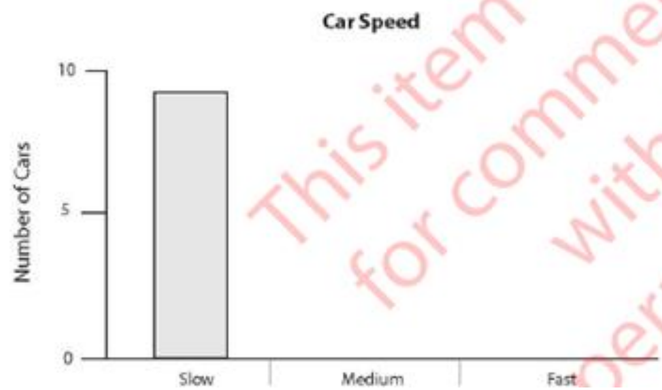
Question 16

Several students were collecting information about how fast cars were driving by their school. The table below shows the results for 20 cars.

Car	Slow	Medium	Fast
1		X	
2	X		
3	X		
4			X
5			X
6	X		
7		X	
8		X	
9	X		
10	X		
11	X		
12		X	
13	X		
14			X
15			X
16	X		
17		X	
18	X		
19		X	
20			X

To make the results easier to read, the students started to put the information into the bar graph.

Complete the bar graph.



Appendix4.B.5: Attitudes Towards Mathematics Measures for Primary Students

استبيـان قياس الاتجاهات نحو الرياضيات

أسم الطالب ....

الفصل.......................... الشعبة:..........................

ضع اشارة √ في المكان المناسب أمام كل عبارة :

م	العبـــــــــارة	أوفق بشدة	أوافق الي حد ما	لا أوافق بشدة	لا أوافق الي حد ما
1	أجتهد في الرياضيات عادة				
2	اود دراسة حصص رياضيات أكثر في المدرسة				
3	أجد صعوبة في الرياضيات أكثر من زملائي في الفصل				
4	أجد متعه في تعلم الرياضيات				
5	الرياضيات ليست من المواد التي اتفوق بها				
6	اتعلم الأشياء بسرعة في الرياضيات				
7	الرياضيات مملة				
8	أحب الرياضيات				

المصدر: TIMSS 2007and 2011 ترجمة الباحث

How much do you agree with these statements about learning mathematics?

*Fill in **one** circle for each line*

	Agree a lot	Agree a little	Disagree a little	Disagree a lot
a) I usually do well in mathematics	①	②	③	④
b) I would like to do more mathematics in school	①	②	③	④
c) Mathematics is harder for me than for many of my classmates	①	②	③	④
d) I enjoy learning mathematics	①	②	③	④
e) I am just not good at mathematics	①	②	③	④
f) I learn things quickly in mathematics	①	②	③	④
g) Mathematics is boring	①	②	③	④
h) I like mathematics	①	②	③	④

Appendix 5.1: Pre-Test results for Total Achievement, Knowing, Applying and Reasoning Ability Between Groups for Intermediate Students

ANOVA

		Sum of Squares	df	Mean Square	F	Sig.
pre_total	Between Groups	9.370	3	3.123	.421	.738
	Within Groups	444.739	60	7.412		
	Total	454.109	63			
pre_know	Between Groups	1.715	3	.572	.540	.657
	Within Groups	63.519	60	1.059		
	Total	65.234	63			
pre_apply	Between Groups	3.374	3	1.125	1.211	.314
	Within Groups	55.736	60	.929		
	Total	59.109	63			
pre_reason	Between Groups	1.377	3	.459	.541	.656
	Within Groups	50.858	60	.848		
	Total	52.234	63			

Appendix 5.2: Pre-Measure Tests for Like Learning Mathematics, Placing Value on Mathematics and Confidence to Learn Mathematics Between Groups

ANOVA

		Sum of Squares	df	Mean Square	F	Sig.
pre_attitudes	Between Groups	21.521	3	7.174	.570	.637
	Within Groups	754.916	60	12.582		
	Total	776.438	63			
pre_value	Between Groups	2.731	3	.910	.135	.939
	Within Groups	405.206	60	6.753		
	Total	407.938	63			
pre_conf	Between Groups	10.330	3	3.443	.549	.651
	Within Groups	376.107	60	6.268		
	Total	386.438	63			

Appendix 5.3: Transcripts of Interviews with Intermediate Teacher

The trained teacher A (Ahmed)

How did you implement PBL in your class?

Ahmed stated: I present a problem to the students; they and then discuss it and after this, one of them reads out the problem to the rest of the students who then explain it in their own words. The students then give their feedback on their understanding of the problem, determine the problem statement then ascertain what they know and what they need to know in order to solve the problem while I record their notes on the blackboard. The students then join their groups and make a plan of how to gather the information they need by allocating specific tasks to each member of the group. The students will then collect the required information and exchange their findings with one another. Collectively they then select the best and most suitable ideas and generate all the possible solutions to the problem. Finally, each group presents their work to the rest of their classmates who will then provide them with their feedback. My role here is to help them learn by asking meta-cognitive questions.

What is your opinion of the experiment?

Ahmed said: In the beginning the students found PBL weird because they were accustomed to conventional methods, but after three lessons they were able to learn by themselves without relying on the teacher as they had previously. I remember that after the first session, one of my students told me that he did not like it; however, after he had been given the chance to participate in group sessions and present in front of the other students, he changed his mind and said that he liked it.

In the beginning students stated that they liked conventional teaching methods more than PBL but at the end of the experiment they had changed their view stating that they liked both methods of teaching instructions. Students need time to become accustomed to using the PBL strategy

I believe that this was a great achievement which would help students in the future when they begin studying at university because the PBL strategy, like the university system, improves learning based on cooperation and each student has a specific role. I think that

PBL improves students' thinking skills to solve problems. This is extremely important to improve students thinking skills.

On other hand unfortunately, we have encountered some obstructions; firstly, with the existing mathematics textbooks as they do not support the PBL strategy very well and because of this the school administration department and supervision team opted against implementing the strategy. Secondly, in order for PBL practices to be effective, the assessment of mathematics should be changed to contain problems which students are asked to solve collectively (in groups).

One important issue it give students time to get familiar with the strategy very well. I think is to combine 2 sessions and have two 90-minute sessions and one 45-mintue session, rather than having 5 sessions lasting 45-minutes each, would be more suitable for teaching with the PBL strategy. I also think that teachers need to be convinced to implement PBL. Also, if we are to effectively implement the PBL strategy in mathematics classrooms, mathematics textbooks must be adapted and include designed problems and adequate training could even be made available to teachers to enable them to design problems for PBL. The strategy leaned students how to think and this is important. Using PBL meant the classroom was noisy and chaos, this would be a problem for those teachers who were accustomed to using conventional teaching methods, while this is ok for me as long as the noise is beneficial for students.

Are you comfortable with the PBL teaching strategy?

Whilst I felt that I learned something new, this strategy [PBL] has one major problem for teachers in knowing how to adequately design problems. I have no problem with introducing it in my class and I am interested in this idea but I cannot guarantee the results because I have been a bit afraid about this and the possibility of having to teach the students again. This is not a concern when teaching with traditional teaching methods as this enables me to give students' exercises the following day and I can therefore assess their learning level. With PBL, however, I do not know how to assess their level of learning.

If you continue teaching with the PBL strategy, do you think would you become more comfortable with it over time?

The student is the most important and this means that any strategy that is suitable for the student is also the most important strategy for the teacher. I believe that PBL could become more comfortable when the students are more familiar with it. I suggest that if this strategy were to be implemented at the beginning of the intermediate school level for students who have just come from primary school, students would adapt to it more easily and also accept it because they might think this is the system of the level of intermediate school and they wouldn't know any different.

What was the reaction and response of the students after they had been taught with PBL?

I think their responses would have been better if we had implemented it at the beginning of the intermediate school level for the students who had just come from primary school as they would probably have been less likely to compare it with the traditional teaching methods that they had been accustomed to and, as it is teacher-centered learning, may be more attractive for some of the students who they tend to be lazy. The problem is that some Saudi students were uninterested in learning in general because they thought that being good in education would not have an effect on their future

What are your suggestions for improving the PBL strategy?

Designing short and clear problems at the beginning of lessons could lead to better outcomes because difficult and longer problems may result in the teacher having to teach too much and also, when students need to search for information it can be difficult for them to find it. In addition, difficult problems may cause the teacher to have to clarify them and this is against the principles of PBL. Another problem which could restrict the implementation of PBL is the administration of education in Saudi as they restrict us by insisting that we have to follow the instructions of the standard textbooks.

Did you feel comfortable with the experiment?

Yes, I felt comfortable with it but I would prefer it we could overcome the obstacles that I mentioned earlier.

To what extent did the students who lacked the required level of prior knowledge affect your teaching in class?

Working in groups caused some of the less able students to rely on the more able students and this may affect my performance as a teacher, as well as having a negative effect on all the other students.

How do you assess how well students' engage in the learning processes?

The more able students and those with more prerequisite knowledge or skills were more engaged than others. I think that when a problem is clearer, shorter and considers students' prior knowledge then the engagement level would be raised.

The untrained teacher (self-directed learning teacher: Nasser) intermediate school.

How did you implement the PBL teaching strategy in your classes?

I present the problem to the students, they read and understand it, then they identify what they already know and what is required while I record their comments on the whiteboard. I then ask them to learn from the mathematics textbook and we then discuss what they have learnt. I will answer any questions and explain anything they have found difficult to understand. They then carry out exercises around what they have learnt.

What were the advantages of implementing PBL in your class?

The advantage of using PBL is the interaction students have with each other, this started from identifying the problem, extracting data from the problem, identifying the requirements and then solving the problem.

What were the disadvantages of implementing PBL in your class?

Textbooks should be adapted to incorporate PBL teaching styles. Also, teachers should receive training in how to design problems for PBL. The excessive noise and chaos in the classroom is one of the disadvantages of PBL; some students who are uninterested in the learning work against interested students in a noisy and chaos environment. Some Saudi students are uninterested in education and they are forced to go to the school

Coaching students' thinking in order to improve their self-directed learning skills through PBL learning processes is quite difficult and teachers should be trained to overcome this problem.

How did you find teaching using the PBL strategy?

It was not difficult for me to implement, the difficult part was knowing how to make the students learn by themselves and also how to let students move from one process to another. I like it because it adopted a student-centred approach which I think is better for the students.

Did you receive face to face training in the implementation of PBL?

If the mathematics textbooks were adapted to support the PBL teaching strategy and the teachers received training I think it would be better than using traditional teaching methods.

What were your students' reactions to PBL?

The majority of students were happy with PBL because they liked working in groups.

What are your suggestions for improving PBL?

It could be through developing and adapting the mathematics textbooks adapt it and showing its importance in the first instance and also, every student should have the opportunity to work individually as well as working within groups as this would give better outcomes. Also, designing shorter and clearer problems could reflect a better outcome.

When do you think that PBL would be more successful?

It would be more successful if the students felt the value of science as some students were forced to come to school. Teachers also need time to adapt to using the PBL strategy. I think that PBL should be introduced to primary schools right through to university level.

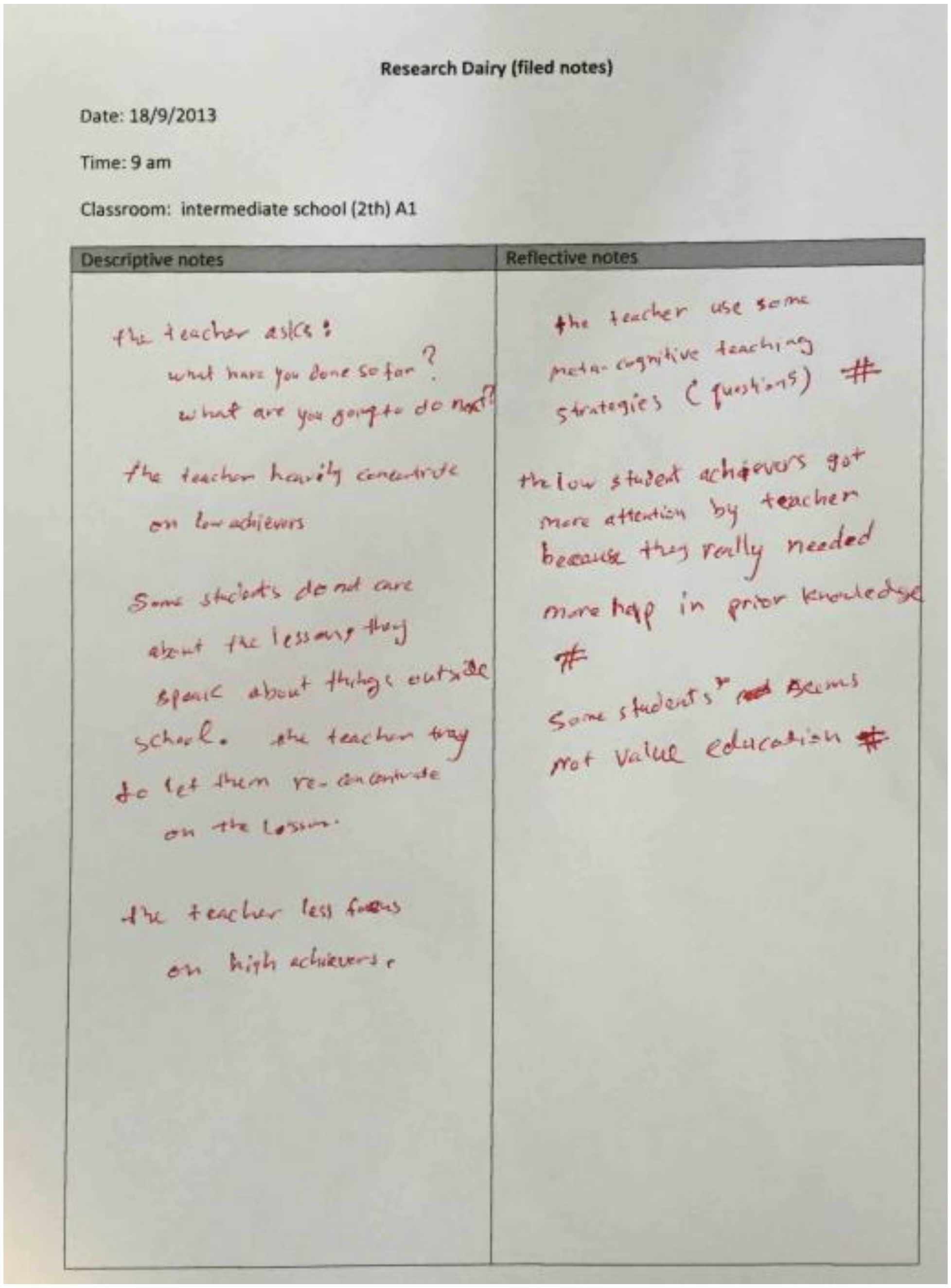
To what extent did the students with a lack of prior knowledge affect your performance as a teacher?

I spent a substantial part of the lesson dealing with the students who had no prerequisite knowledge or skills. Working with groups would hide those students and their problems would never be solved. I think is good to let students work individually within groups. Also, small classroom sizes would produce better outcomes as a reduced number of students in class create more opportunities for teachers to be able to make sure every group is doing very well.

How did the students engage in PBL lessons?

Some students do not feel education is important and they would not engage in learning. In addition, the students who had a limited amount of prior knowledge negatively affected some of the others students.

Appendix 5.4: Example of Hand Written Diary Entry from the Researcher's Research Dairy: Intermediate School



Research Dairy (filed notes)

Date: 18/9/2013

Time: 9 am

Classroom: intermediate school (2th) A1

Descriptive notes	Reflective notes
the teacher asks: what have you done so far? what are you going to do next?	the teacher use some meta-cognitive teaching strategies (questions) #
the teacher heavily concentrate on low achievers	the low student achievers got more attention by teacher because they really needed more help in prior knowledge #
Some students do not care about the lessons they speak about things outside school. the teacher try to let them re-concentrate on the lesson.	Some students ~~not~~ seems not value education #
the teacher less focus on high achievers.	

Appendix 6.1: Pre-Test Results for Total Achievement: Knowing, Applying and Reasoning Ability Between Groups for Primary School Students

ANOVA

		Sum of Squares	df	Mean Square	F	Sig.
pre_know	Between Groups	4.752	2	2.376	2.592	.079
	Within Groups	113.673	124	.917		
	Total	118.425	126			
pre_apply	Between Groups	.919	2	.459	.463	.631
	Within Groups	123.081	124	.993		
	Total	124.000	126			
pre_reason	Between Groups	.777	2	.388	.524	.593
	Within Groups	91.838	124	.741		
	Total	92.614	126			
pre_tot	Between Groups	15.679	2	7.840	1.810	.168
	Within Groups	536.998	124	4.331		
	Total	552.677	126			

Appendix 6.2: ANOVA Tables (Multiple Comparisons) for Applying Achievement for Primary School Students

Tukey HSD - Applying – Multiple Comparisons

(I) group	(J) group	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
PBL with trained teacher's group	conventional method teacher's group	.55*	.185	.009	.12	.99
	PBL with untrained teacher's group	.38	.189	.121	-.07	.82
conventional method teacher's group	PBL with trained teacher's group	-.55*	.185	.009	-.99	-.12
	PBL with untrained teacher's group	-.18	.202	.647	-.66	.30
PBL with untrained teacher's group	PBL with trained teacher's group	-.38	.189	.121	-.82	.07
	conventional method teacher's group	.18	.202	.647	-.30	.66

Based on observed means.

The error term is Mean Square(Error) = .760.

*. The mean difference is significant at the .05 level.

Appendix6.3: Pre-Measure Tests for Like Learning Mathematics and Confidence to Learn Mathematics Between Groups for Primary School Students

ANOVA

		Sum of Squares	df	Mean Square	F	Sig.
pre_attitudes	Between Groups	3.534	2	1.767	.490	.614
	Within Groups	447.222	124	3.607		
	Total	450.756	126			
pre_confid	Between Groups	3.684	2	1.842	.553	.577
	Within Groups	413.340	124	3.333		
	Total	417.024	126			

Appendix6.4: ANOVA Tables (Multiple Comparisons) and T-Tests for Like Learning Mathematics for Primary School Students

Paired Samples Statistics

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	pre_like learning math	10.15	39	1.927	.309
	post_like learning math	8.74	39	3.041	.487

Paired Samples Test

		Paired Differences					t	df	Sig. (2-tailed)
					95% Confidence Interval of the Difference				
		Mean	Std. Deviation	Std. Error Mean	Lower	Upper			
Pair 1	pre_like learning math - post_like learning math	1.410	2.712	.434	.531	2.289	3.248	38	.002

Tukey HSD - **Multiple Comparisons** - Like learning mathematics

(I) group	(J) group	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
PBL with trained teacher's group	conventional method teacher's group	1.49*	.374	.000	.61	2.38
	PBL with untrained teacher's group	.25	.382	.794	-.66	1.16
conventional method teacher's group	PBL with trained teacher's group	-1.49*	.374	.000	-2.38	-.61
	PBL with untrained teacher's group	-1.25*	.408	.008	-2.21	-.28
PBL with untrained teacher's group	PBL with trained teacher's group	-.25	.382	.794	-1.16	.66
	conventional method teacher's group	1.25*	.408	.008	.28	2.21

Based on observed means.- *. The mean difference is significant at the .05 level- The error term is Mean Square(Error) = 3.112.

Appendix6.5: ANOVA Tables (Multiple Comparisons) and T-Tests for Confidence to Learn Mathematics for Primary School Students

Paired Samples Statistics

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	pre_confid	14.10	39	1.903	.305
	post_confid	12.87	39	2.885	.462

Paired Samples Test

	Paired Differences					t	df	Sig. (2-tailed)
				95% Confidence Interval of the Difference				
	Mean	Std. Deviation	Std. Error Mean	Lower	Upper			
Pair 1 pre_confid - post_confid	1.231	2.680	.429	.362	2.100	2.868	38	.007

Tukey HSD- **Multiple Comparisons-** Confidence

(I) group	(J) group	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
PBL with trained teacher's group	conventional method teacher's group	1.44*	.354	.000	.60	2.28
	PBL with untrained teacher's group	.26	.363	.760	-.60	1.12
conventional method teacher's group	PBL with trained teacher's group	-1.44*	.354	.000	-2.28	-.60
	PBL with untrained teacher's group	-1.18*	.386	.008	-2.10	-.26
PBL with untrained teacher's group	PBL with trained teacher's group	-.26	.363	.760	-1.12	.60
	conventional method teacher's group	1.18*	.386	.008	.26	2.10

Based on observed means.

The error term is Mean Square(Error) = 2.796.

*. The mean difference is significant at the .05 level.

Appendix 6.6: Transcripts of Interviews with Primary School Teachers

The trained teacher (Ali)

How did you implement PBL teaching strategy in your classrooms?

I presented the problem to the entire class and asked the students to discuss and understand it. Once the students had understood the problem, their interest in learning mathematics immediately increased and they had a great desire to solve the problem. They [the students] work within groups to solve the problem and I monitor them and coach their thinking with meta-cognitive questions.

What are the advantages of implementing PBL?

PBL remarkably increased how much the students liked learning mathematics; they enjoyed learning using PBL. The lesson became more enjoyable with PBL and students began to look forward to mathematics lessons. Many students ranked mathematics as their second most favourite subject after sports lessons. The mathematics lessons became really exciting.

What was the source of students' motivating in PBL lessons?

The motivation stems from presenting the lesson as a set of problems. When students encountered the problems they tried to solve them and this increased how much they liked learning mathematics. If students could not solve the problem then they became motivated to find the solution; if they were able to resolve it then the solution became a prize for them.

Are there any other advantages in using PBL?

Yes, the atmosphere of learning is positive and PBL can be implemented for a large number of students.

How many students do you think that you can teach with PBL?

It could be implemented on large class sizes of up to 40 students; however, the classroom area must be large enough to allow teachers to easily access all groups.

You mentioned that PBL improves students' motivation – can you elaborate on this?

Yes, of course, it distinguishes it from other active teaching strategies.

You have compared PBL with active learning strategies. What is your view of how PBL compares with traditional teaching methods?

In my experience of implementing traditional teaching methods the concentration of students is rarely longer than 15 minutes for high the achievers, 10 minutes for medium achievers and 5 minutes for low achievers. However, with PBL, students' concentration lasted for more than 40 minutes and this resulted in the students learning more.

My students' levels of concentration became increased when learning via the PBL strategy. The reason is because when the students learn with PBL they study by themselves and this makes them focus for a longer period of time. When the students learn by themselves over a longer period of time they also have a greater level of retention of the knowledge learned. PBL strategies can expand the time students spend because they take over the responsibility of learning

Do you have any suggestions for improving how PBL is implemented?

It could possibly be improved by letting students do exercises after they have learnt the PBL strategy. This could be done through firstly letting them work in groups then splitting the groups into pairs of 2 students and eventually everyone working alone. This could help to eliminate the problem of some students relying on others.

How do you think student outcomes would be affected if they were taught using PBL over a long period of time?

PBL is difficult for teachers in the beginning because the teachers believe that applying more effort could raise their students' motivation. I used to think that, as I made more effort in the classroom, students would be more motivated, but after I had experienced PBL I found the correct relationship between the effort required from teachers to explain everything for students and students' liking learning mathematics is negatively linked. In fact, I feel that with PBL I am not teaching mathematics but improving students' skills.

What were the things you noticed in respect of how your students' performance improved?

To rely on their own thought processes and learn from different resources; this is very important because I am not giving them information directly and they need to conduct self-directed learning and assess that information.

Do you mean that you taught your students how to assess themselves?

Yes, as well as teaching mathematics I also taught critical thinking skills. The students had started to practise self-assessment skills and had begun to assess the ideas of others. Eventually they assessed me. There were some occasions where I purposefully gave students an incorrect answer to see how they responded. I was pleased to see that they did not automatically accept my answer without first carrying out their own assessments; they would then agree or disagree with my answer based on their own level of understanding following their own assessment of the problem. Also, students' critical thinking skills improved over time and they began to critically analyse their own ideas and their answers.

How do you think teachers feel about implementing PBL?

Inexperienced or new teachers may not believe that giving students more responsibility and control of their learning would have a positive effect and increase their ability to learn. Once they had realised and mastered this new way of teaching they would then become more comfortable with this strategy.

What about the disadvantages of using PBL?

It takes more time than using traditional teaching methods; with traditional methods the time is controlled by the teacher, whereas with PBL teaching strategies the time is controlled by the students. It would be more beneficial if lesson times were extended from 45 to 60 minutes, or lessons should be split over two classes of 45 minutes with one class being allocated to learning how to use PBL and another to recap and assess what has been learned. With PBL, students need more time to practice their thinking skills and search for missing information, which is not the case for traditional teaching methods.

What are your suggestions for improving the PBL strategy?

It would be good to implement this strategy in all the schools in Saudi Arabia but student's mathematics textbooks need to be adapted to incorporate the PBL settings. This is because teachers would face difficultly in designing the required materials for PBL. This strategy is not particularly appropriate for the weak and extremely low achieving students. Some of these students were depending on the high achievers to solve problems which meant that they did not learn.

So, how do you suggest dealing with the weaker students?

If the weaker students were given more support outside of classrooms and joined the groups once they had an appropriate level of knowledge and understanding then this would be better. I think that these students should be taught the necessary skills needed separately and prior to joining the groups and this would solve the problem of students having insufficient prior knowledge or skills and negatively affecting the other students or needing more time from the teacher.

How well did the students' engage in PBL processes?

I found that some students relied on each other, particularly those who had a lack of prerequisite knowledge. I think that students should be given exercises and assessed individually as once the students had a clear understanding and when the problems were easy, they were highly engaged in learning processes.

The untrained teacher (Khalid)

How did you implement PBL in your class?

I presented the problem to students and then gave them time to discuss the problem within groups. Then they worked with their groups to solve the problem and I helped them to solve the problem by indirectly explaining any difficulties, for example, by giving them some examples. PBL is the best way to improve students' self-directed learning skills because the students encountered the problem and were able to answer 20% of the problem without any help from me, after this they then needed help to solve the problem. Students were able to learn by themselves, even if only a little, I also paid more attention to students individually, particularly the less able ones, to make sure they were learning.

What do you think are the advantages of using PBL?

The strategy is easy to implement; the students understand the lessons and learn by themselves. Students liked participating and cooperating with each other within groups and this was clear in the PBL settings. Students generally like working in groups and they like competition. The PBL strategy could be implemented on large class sizes of up to 40 students.

What are the disadvantages of using PBL?

The weak students did not participate very much in the groups but I think if PBL is implemented very well then this problem could be solved. Some low achieving students were depending on high achievers to solve the problems and some students with weaker reading abilities could be negatively affected as their ability to read the problem created a problem. This issue could be counteracted by asking the students with better reading skills to read the problem to the rest of the group. More care should be taken of the low achievers and teachers should keep asking them questions. If the strategy could be implemented more efficiently, this would help to counteract the problems encountered by the low achievers

The Saudi mathematics textbooks were inappropriate and I would recommend that they should be adapted to include guidelines for implementing the PBL teaching strategy.

Do you think that you need training in implementing PBL?

PBL is easy and I did not need any training. I will continue to implement PBL with my students in the future.

What are the differences between the PBL strategy and traditional teaching methods?

With traditional teaching methods I can give examples to the students as well as providing more input and explanations as well as giving them exercises. With PBL the students have to learn by themselves.

What about students, do you think they like the strategy?

In general, the young students like working in groups, active learning and competitions.

What about the student engagement in the learning processes of PBL?

I think the students engaged well but if PBL is implemented more effectively then this would increase the levels of engagement.