THE EFFECTIVENESS OF PROBLEM-BASED LEARNING (PBL) ONLINE ON STUDENTS' CREATIVE AND CRITICAL THINKING IN PHYSICS AT TERTIARY LEVEL IN MALAYSIA

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By

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DEDICATED

to

Allahyarhamah Bahariah Larang

My beloved mother whom I loss during my struggle to complete this thesis.

AL-FATIHAH

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ABSTRACT

The purpose of this study was to investigate whether student performance in creative thinking could be enhanced through Problem Based Learning delivered online (referred to as PBL online) and critical thinking. Students' perceptions and adoptions of PBL learning and online learning also were studied. The PBL online model was adopted from the McMaster's Model, and comprised three major steps: (i) problem posing; (ii) information searching; and (iii) discussion and application of knowledge in solving problems. PBL is operationally defined here as an instructional strategy which focuses on problem solving. Students are faced with real issues which they have to solve through information searching and group discussion online. In this study, students were given physics problems to solve as part of their Modern Physics course. The phases involved were (i) overview of the topic of the lesson; (ii) problem encounter; (iii) problem definition; (iv) exploration; (v) solution; and (vi) reflection. All of these phases were done through the University's Learning Management System (LMS), which thus acts as the online delivery tool.

This study employed a quasi-experimental design based on mixed between-within-subjects repeated measures. The independent variable was the instruction method, either PBL online (experimental) or Traditional method online (control), and the dependent variables were performance in creative and critical thinking. The Torrance Test of Creative Thinking (TTCT) and the Watson Glaser Critical Thinking (WGCT) were used to measure the respective dependent variables. In the TTCT, there are four criteria used to evaluate creative thinking: (i) *fluency*; (ii) *flexibility*; (iii) *originality*; and (v) *elaboration*. For the critical thinking, five criteria were used: (i) *making an inference*; (ii) *making an assumption*; (iii) *deduction*; (iv) *making an interpretation*; and also (v) *evaluation argument*. Additionally, students' perceptions and adoptions of PBL, as well as online learning, were captured through this study. A total of 102 students from the School of Science and Technology (SST) and the School of Education and Social Development were the subjects of the study. The SST students were science physics students (N = 61), and the SESD students were pre-service science teachers (N = 41).

Results of the Mann-Whitney U test and also Independent Sample t-Test showed that there was significant difference in creative thinking in overall for both SST and SESD cohorts in favour of the PBL group. In addition, when the analysis was focussed on the two cohorts (i.e., SST and SESD), there were statistically significant differences observed for *flexibility, originality* and *elaboration* also in favour of the PBL group. However, results from the same analyses showed there was, in general, no significance difference for critical thinking for both cohorts. Further analysis identified statistically significant differences for *making an inference* (in favour of the PBL group) and *assumption* (in favour of the Traditional group). For the SST students, there were statistically significant differences in *making an inference* and *evaluation argument* criteria, in favour of the PBL group. Nevertheless, there were statistically significant differences for *assumption*, in favour of the Traditional group. No statistically significant differences were noted in any criterion for the SESD group.

Students' perceptions of PBL and willingness to adopt it were positive, even though they reported feeling confused at the beginning of the learning process. PBL was also reported as taking more time and requiring more effort. Nevertheless, students reported managing to build their capacity for self-directed learning and improving soft skills (i.e., communication, managing their learning timetable, finding relevant and valuable knowledge online, etc.). In the case of online learning, the students felt that they had learned how to get much more information online, and how to critique such information. Students' readiness to use online learning was encouraging, and it provided at least basic experience on courses delivered through online learning. However, the Internet access needs to be adequate to ensure that online learning operates satisfactorily.

Important findings were derived from this study. First, the results from this study suggest that PBL online enhances of Malaysian tertiary students' creative thinking for both science physics students and pre-service science teachers. Second, PBL online also is capable of having a positive impact on students' critical thinking for certain criteria, but this would be fostered by a whole programme approach rather than delivery via a single course. Third, students' acceptance and perceptions of PBL and online learning were positive and encouraging, this despite encountering some issues technical during the intervention.

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CHAPTER 1: INTRODUCTION

1.0 CONTEXT AND ORIGINS OF THE STUDY

The origins of this study are found in a worrying trend of unemployment for Malaysian science and physics graduates. Undergraduate science education in Malaysia has been subject to much recent criticism, and the unemployment rate for Malaysian science graduates is tenaciously high. The main criticism is that Malaysian science graduates lack creativity, are weak in critical thinking, and in problem-solving (Malaysian, 2008). Hence, one goal of this thesis is to seek an approach to teaching and learning - specifically in the domain of undergraduate physics - that might improve students' creative and critical thinking. Given Malaysia's current emphasis on online learning, online learning provides the vehicle for the intervention. In 1996, no fewer than five new Acts of Parliament considered to either revise old educational rules or initiate new rules were introduced (Puteh & Hussin, 2007). It is this latter set of initiatives that comprise the most significant attempt to address the needs of tertiary education in Malaysia - especially in online learning. The question, therefore, is what did these legislative changes seek to accomplish? Is the main point to make online learning more successful and helpful compared to the face-to-face approach? If online learning can make the teaching and learning process easier and more effective, does it also have the capacity to improve students' other skills such as creative thinking, especially at the tertiary level?

One reason why the Malaysian government seeks to drive the development of learning via online learning in higher education is that international literature suggests it may enhance students' knowledge and academic performance (Beadle & Santy, 2008). It is also considered to be effective in developing higher-order thinking skills, including defining problems, judging information, solving problems, and drawing appropriate conclusions and solutions (Rice & Wilson, 1999). Additionally, and arguably of equal importance, is that online learning because it is networked, systematic, and easy to access, allows for the storage, retrieval and sharing of information and learning material without boundaries (Beadle & Santy, 2008; Rosernberg, 2001). Students can then access an almost boundless amount of information, and potentially apply it in a variety of ways

(Kauffman, 2004). Thus, online learning has the potential to provide for a more sophisticated and flexible learning approach, one that allows greater access to higher education, and this is a key driver in the Malaysian government's thinking. Therefore, this study seeks to identify the potential of learning via online learning in improving undergraduate creative thinking. Besides creative thinking, there are other important elements of learning that might be investigated by integrating a particular pedagogy with online learning; for example, problem-solving skills, science process skills, along with affective variables such as anxiety, attitude, and self esteem. However, in the case of this work, the Malaysian government is also keen to seek new ways to enhance critical thinking. Hence, this thesis also seeks to understand the impact of this learning approach on students' critical thinking for undergraduate science and pre-service science teachers.

In Malaysia, the teaching of physics as a subject begins at the upper secondary level of the school system (Year 10, known as Form 4 in Malaysia). Prior to that, physics is taught as part of science as a general subject. The level of physics taught at upper secondary level (i.e., Forms 4 & 5) is equivalent to that of the British O-level. Throughout the mid-1970s, the medium of instruction in Malaysia was English, and the textbooks used were those used in the British Commonwealth such as *Physics* by Abbot. At the advanced level, the A-level, the standard text was *Physics* by Nelkon and Parker. Before that, students explored only science when in primary school, up until about 11 or 12 years of age. The science curriculum continues when students enter secondary school at 13 to 15 years of age. After taking the Middle of Lower Certificate of Education (LCE) or Lower Secondary Evaluation (Penilaian Menengah Rendah, PMR) at age 16 years, they split into three major groups; *science*, *economics* and *art*. In their science classes, students learn and study three main science subjects separately, *physics*, *chemistry* and *biology*. After finishing the Malaysian Certificate of Education (MCE) (the MCE was based on the old British 'School Certificate' examination before it became General Certificate of Education O Levels examination, which in turn became the General Certificate of Secondary Education - GCSE) examination (*Sijil Pelajaran Malaysia*, SPM) at about 17 years of age, students either take the Matriculation Certificate, pursue the Malaysian Higher School Certificate examination (its British equivalent is the General Certificate of Education A Levels examination or internationally, the

Higher School Certificate, *Sijil Tinggi Persekolahan Malaysia*, STPM), or go into polytechnics and private colleges. The STPM is considered more difficult than the GCE A levels, covering a broader and deeper scope in syllabus. Although it is generally taken by those desiring to attend public universities in Malaysia, it is internationally recognised and may also be used, though rarely required, to enter private local universities for undergraduate courses. Additionally, all students may apply for admission to matriculation, which is a one or two-year programme run by the Ministry of Education. Previously, it was a one-year programme, but beginning 2006, 30 percent of all matriculation students were offered two-year programmes. After completing either Matriculation or STPM in Form 6 (Form 6 consists of two years of study which is known as Lower 6 - *Tingkatan Enam Rendah* and Upper 6 - *Tingkatan Enam Atas*), only then do they continue to the university undergraduate level, when they are around 19 - 20 years old. Tertiary education in the public universities is heavily subsidised by the government. Applicants to public universities must have completed the Malaysia matriculation programme or have an STPM grade, or at least have the same recognized qualification.

Malaysian universities offer physics courses in either pure or applied physics. Work by Koh (1992) suggests that many students feel it is of little value to study physics, and they cannot see the relevance of physics courses for real life situations and applications compared with other courses such as medicine, engineering, and architecture. Poor career prospects also are often cited as the main reason for the dwindling number of physics majors in Malaysia (Koh, 1992). It seems, then, that many students fail to realize the importance of physics for the study of other disciplines such as those cited above. Such a situation is likely to contribute to a lack of student interest, and may result in a lack of problem-solving skills, creative and critical thinking which are seen as a core part of effective physics learning (Bowers-Brown & Harvey, 2004). Thus, the researcher also seeks to understand if problem-based learning (PBL) - a constructivist-based educational instruction and learning strategy, may positively influence students' interest in studying in physics.

In Universiti Malaysia Sabah there are two groups of undergraduate students who undertake undergraduate physics study. The first group does the Physics with Electronics Programme and is located in the School of Science and Technology

(SST). The second group is the Science with Education Programme pre-service teachers whose doing a major or minor in physics in the School of Education and Social Development (SESD). This research involved both cohorts of students.

1.1 PROBLEM-BASED LEARNING

Problem-based learning (PBL) is a pedagogical approach to science education that focuses on helping students develop self-directed learning skills (Barrows & Tamblyn, 1980; Boud & Felleti, 1991). It was originally developed in a medical school in 1969 at McMaster University (Rideout & Carpio, 2001), but has since spread to other subjects. It derives from the idea that education, knowledge and learning is a process in which the learner actively constructs new knowledge on the basis of current knowledge. Unlike traditional teaching practices in higher education, where the emphasis is on the transmission of factual knowledge, the courses consist of a set of problems that are carefully sequenced to ensure the students are taken through the curriculum. The students encounter these problem-solving situations in small groups guided by a tutor who facilitates the learning process by asking questions and monitoring the problem-solving process. The ability to solve problems is more than just accumulating knowledge and rules; it is the development of flexible, cognitive strategies that help analyse unanticipated, ill-structured situations to produce meaningful solutions. Even though many of today's complex issues are within the dominion of student understanding, the skills needed to tackle these problems are often missing from our pedagogical approaches.

Research at the School of Physics at the Dublin Institute of Technology in September 2001 pointed to positive feedback from the students engaged in PBL: having fun learning, learning from each other; not falling behind as everyone is constantly learning; more effective learning as it enables students to remember better; students having to interact; and real-life problems seen as more interesting and challenging. PBL is not just about problem solving, and it is important to distinguish between PBL and learning via problem-solving learning. In physics, the use of problem-solving learning is well established, and in this method the students are first presented with the material, in the form of a lecture, and are then given problems to solve. These problems are typically narrow in focus, test a restricted set of learning outcomes, and usually do not assess other key skills. When learning in this way, students do not get the opportunity to evaluate their knowledge or understanding, to explore different approaches, or to link their learning with their own needs as learners. They have limited control over the pace or style of learning and this method tends to promote surface learning (Woods, 1994). Surface learners concentrate on rote memorisation (Araz & Sungur, 2007); this often arises from the use of didactic 'spoon-feeding', which does not encourage students to adopt a deep approach learning (Kember, 2000; Kit Fong, O'Toole, & Keppell, 2007). Deep learners, in contrast, use their own terminology to attach meaning to new knowledge (Rideout & Carpio, 2001). In PBL, the students determine their learning issues, and develop their own unique approach to solving the problem. The members of the group learn to structure their efforts and delegate tasks. Peer teaching and organisational skills are critical components of the process. Students learn to analyse their own and their fellow group members' learning processes and, unlike problem-solving learning, must engage with the complexity and ambiguities of real life problems. PBL is thus well suited to the development of key skills, such as the ability to work in a group, problem-solving, critiquing, improving personal learning, self-directed learning, and communication.

There has been reluctance to introduce PBL into physics courses due to a view that students require a sound body of knowledge and mathematical skills before they are equipped to engage with this type of approach (McDermott & Redish, 1999). It has been revealed that first year students tend to rely more on lecture notes than students in later years, and that first year students tend to be assessment driven (Dublin Institute of Technology, 2005). However, it has been reported in the School of Physics in Ireland that PBL can be introduced successfully into first year, if it is facilitated correctly and the tutors are aware that the students are only in the early stages of developing as self-directed learners (Dublin Institute of Technology, 2005).

There are many features of learning in PBL and PBL appears, to at least in part, address concerns about other educational methods noted in the literature, such as how to enhance creative and critical thinking (Ward & Lee, 2002). According to Meier, Hovde, and Meier (1996), students taught within a teacher-dominated, lecture-based system typically are not able to solve problems that require them to make connections and use relationships between concepts and content. Only emerging scientists who are trained and taught to think creatively and critically are likely to be able to solve the real life problems. The literature thus suggests if we want our future scientists to be capable of solving problems facing our society, then we need to find ways to develop creativity and critical thinking skills. The research reported in this thesis seeks to investigate the effectiveness of PBL in enhancing students' creativity skills in Malaysia, and at the same time the researcher also is interested to see whether or not there is any positive impact on students' critical thinking.

1.2 RESEARCH QUESTIONS

The context of this work is a desire for Malaysia to enhance creative and critical thinking in science undergraduates and pre-service science teachers. Online learning provides the vehicle for the intervention - integrated with a PBL approach. Therefore, the research questions for this thesis are:

1. Does PBL online improve undergraduate physic students' and pre-service science teachers' creative thinking?
2. Does PBL online improve undergraduate physic students' and pre-service science teachers' critical thinking?
3. What are Malaysian undergraduate science physics students' and pre-service science teachers' perceptions about learning via PBL?
4. What are Malaysian undergraduate science physics students' and pre-service science teachers' perceptions about online learning?

This thesis reports on research done at the Universiti Malaysia Sabah, where the researcher taught several physics courses including, Mechanic Physics (SP1013), Physics III (SP1043), Physics Electric and Magnet (SP2013) and Physics Method for Experiment and Measurement (SP2083), from December 2004 until March 2008. For SP1013 and SP1043, three contact hours per week were involved, consisting of lectures and tutorials. For SP2083 and SP 2013, the courses also involved three contact hours per week, consisting of lectures, tutorials and laboratory classes.

1.3 RATIONALE OF THE STUDY

This study seeks to address concerns expressed about higher education in Malaysia. In 2006, for example, almost 70 percent of Malaysian graduates were unable to secure employment (Ram, 2006), and in the Budget speech by the Prime Minister, the number of unemployed graduates in 2007 was reported to number about 31,000 (Shakir, 2009). The latest report revealed about 32,000 graduate students failed to get any job in any sector (Utusan Malaysia, 2010), something attributed to a lack of creativity, critical thinking and problem-solving skills. Hence, this study seeks to develop a teaching and learning approach based on problem-based learning (PBL) to help Malaysian higher education teachers develop creativity and critical skills in their students.

Consistent with the Tenth Malaysian Plan that will be implemented from 2011 until 2015, one of its major contents is revamping and implementing new curriculum in education which includes the higher learning institutions needing to significantly raise students' outcomes and one of its features is to promote creativity and innovation particularly in the Information Communciation and Technology (ICT) millennia:

> During the Plan period, to further reinforce this philosophy, emphasis will be placed on the participation in sports and co-curricular activities in schools to contribute towards character building of students. The education system will reinforce the importance of values and ethics as these represent critical building blocks on the journey to Vision 2020. The use of information and communications technology (ICT) in schools will be given greater emphasis to nurture creativity and innovation among students, in order to equip them with new skills and capabilities to meet the demands of a high-income economy. (Economic Planning Unit, 2010, p. 196)

The findings of this study are intended to provide science educators generally, and physics educators particularly, with fresh ideas for teaching and learning in undergraduate science and pre-service teachers courses that might inform the educational practice for physics graduates and go some way towards contributing to future proofing the physics workforce in times of rapid movement in technology and scientific knowledge.

This study also may help educators and researcher in higher education to better utilise online learning as an instructional tool. The intent here is not to generalise to all online learning courses, but to examine this one case in depth in order to understand the possibilities of integrating problem-based learning principles with online learning. This study thus may contribute to existing literature on online learning courses, and potentially impact on the practice of online learning.

1.4 JUSTIFICATION AND CONTEXT FOR THE STUDY

In selecting this particular field of research, the researcher also has been influenced by her own learning and teaching experiences in Malaysia, as an undergraduate student, and as a lecturer in physics at Universiti Sains Malaysia and in the Universiti Malaysia Sabah. One issue noted in an academic audit of the teaching and learning for science undergraduate courses in the University Malaysia Sabah, was that particular focus needed to be placed on improving creativity and critical thinking. As a result of these experiences, the researcher came to hold the view that the teaching and learning of undergraduate science in physics is not satisfactory across Malaysia. The science education research literature indicates that teaching undergraduate physics is problematic all over the world (see e.g., McDermott & Redish, 1999; Yerushalmi, Henderson, Heller, Heller, & Kuo, 2007), and there is much debate about what are the best teaching approaches (McDermott & Redish, 1999), and about the nature of the content or level of content to be taught (Ishak, 2007). The science education literature consistently suggests that students learn better when engaged in active learning, rather than passive learning, but details of how to achieve effective active learning in the classroom are open to debate (Tobin & Tippins, 1993). Thus there appears to be a gap in the literature relating to the teaching of undergraduate physics, and in particular the ability of physics graduates to adapt to the outside world upon graduation in terms of their level of thinking and scientific process skills.

The context for this study is in the Malaysian higher education system. As noted above, the government of Malaysia encourages the use of information and communication technologies, in particular the Internet, to promote a learning society (Bajunid, 2001). The Malaysian National Information Technology Council (NITC) on Electronic Learning recommends that learning in Malaysia, in the new millennium, should make extensive use of the Web and Internet and other information and communication technologies to create and maintain meaningful learning. According to the government, the learning process should enable Malaysians to become knowledge builders and not just consumers of knowledge (Bajunid, 2001). There also is an emphasis on lifelong learning, a knowledge-based society and the provision of flexible learning without the constraint of time and space.

Debate over the quality of Malaysian higher education science graduates is typified by criticism provided by influential local commentators. For example, Historian Professor Emeritus Tan Sri Khoo Kay Khim said the exam-oriented education system was the problem. He argued that lecturers and educators should not be telling students what is coming out in examinations or how they should answer questions; students themselves have to figure that out for themselves (New Straits Times, 2008). Khoo asserts that even in universities, students ask lecturers what topic to study, and then ask what are the possible questions, and how to answer them: “The younger lecturers fall into this trap and tell students what they want to know, partly in their attempt to be popular … My students come up to me as well, and I say I don’t know, just study everything.” He said that even in school, there were teachers who refused to teach the whole syllabus so that students would attend their tuition classes outside school, and at these extra classes, they offer examination tips.

A review of the literature published in the year 2009 at five major universities in Malaysia with established education faculties using Malaysian Thesis Online (MYTO) databases (i.e., Universiti Sains Malaysia, Universiti Malaya, Universiti Kebangsaan Malaysia, Universiti Putra Malaysia, and Universiti Teknologi Malaysia), revealed not less than 30 PhD research outputs related to teaching and learning using technology (e.g., Web; Internet; courseware; Multimedia; Hypermedia; and computer assisted interactive/learning (CAI/CAL)) in various higher learning courses (e.g., in Mathematics, Islamic studies, English, Chemistry and Physics). However, these studies were based on criteria for its effective design and development, and did not provide a specific pedagogical framework. On the other hand, three doctoral dissertations and two master’s thesis reported on investigation of the effectiveness of PBL in various ways. The doctoral dissertations involving PBL include work by Mohammed (2002) who investigated matriculation students' knowledge achievement, reasoning achievement and dynamism in chemistry, and Juremi (2003) who studied secondary school students' critical thinking, creative thinking, science process and achievement in biology. Finally, Ahmad (2008) investigated students' attitude, values and motivations for pre-service teachers of environmental education. An important difference between these prior studies and the present work is that the former studies all involved students learning via a face-to-face modality.

Hence, despite recommendations and enthusiasm of the Government of Malaysia, claims about the benefits of integrating technology into teaching and learning in Malaysia, appear to lack direction and a sound research evidence base. Any research reported so far seems to be more concerned with the combination of technology, especially the Internet, and lacks grounding in any learning theory. In summary, Malaysian-based literature on using the Web/Internet/LMS/CAI/Courseware as an educational strategy is scarce, and more to do with application than theory (see e.g., Ahmad, 2005; Balasubramaniam, 2008; Kong, 2006). Educators in Malaysia still tend to depend on recommendations and results from international research in blending particular instructional methods of educational processes with technology, and these fail to take into account important contextual issues that exist in Malaysia.

1.5 DEFINITION OF TERMS

A number of terms are used throughout this thesis; they are used as defined below.

Achievement:

Achievement is the "performance by a student in a course: quality and quantity of a student's work during a given period" (Gove, 1986, p. 16). In this study, achievement refers to the students' grades in a basic concept test of physics prior to the intervention.

Asynchronous Communication:

Online communication that is not dependent on time. That is, participants can read responses and reply time-independent of others with whom they are in communication.

Creative Thinking:

Creative thinking is a mental process or mental activity involving the generation of new concepts or theories, or new associations between existing concepts or theory. The product of creative ideas and opinion, from a scientific point of view (sometimes referred to divergent thought) are usually considered to have both originality and appropriateness (Cowley, 2005; Harris, 1998b). In this study, creative thinking refers to the individual's ability to give ideas, characterised by fluency, flexibility, originality and to elaborate any ideas identified (Torrance, 1996).

Critical Thinking:

Critical thinking consists of thinking activities that are reasonable and reflective and focussed on what to believe or do (Bullen, 1998). In this study, critical thinking refers to the cognitive presence responses of the integration and resolution phases (Garrison, Anderson, & Archer, 2000, 2001), and consists of making inferences, recognising assumptions, making deductions, making interpretations and evaluating arguments (Watson & Glaser, 1980).

Internet:

A worldwide network of computers linked together (a network of networks, actually) over phone system, satellites, broadband, and some cable systems.

Learning Management System (LMS):

Learning management system (LMS) in this thesis is defined as a course management system designed to help facilitators to create an online learning management. This system is based on Moodle, open source software protected under the GNU Public Licence. This system provides functions such as register course online, course cataloguing, bulletin system, information searching, online quizzes, chat room, forum and so on. Users are able to upload or download course materials (notes, assignment, projects, etc.); announce new coursework via registered e-mail or announcement functions; engage in discussions in open chat rooms with friends and facilitator/lecturers/peers; submit completed coursework, and so on.

Online Learning:

In this thesis, online learning is defined as the delivery of training, education activities, and learning by electronic means. Online learning involves the use of a computer or electronic device (e.g., a mobile phone, camcorder, camera, etc.) in some way to afford teaching, educational activity or learning material (Stockley, 2006). Online learning can engage a multiplicity of tools for online training or education; as the name implies, 'online' involves using the Internet or an Intranet.

Students' Perceptions of PBL:

Students' perception of PBL and specifically of learning outcomes such as knowledge, skills and the application of knowledge and skills, communication, independent learning; students' reflections on problem-based learning (PBL) approach; and also their open feedback about the PBL approach.

Students' Perceptions of Online Learning:

Students' perceptions of online learning were based on students' learning in a Modern Physics course which happens to involve online learning; student's perceptions of satisfaction; student's perception of interaction; students' perceptions of individual features (content available on the web course; online learning as a communication tool; assignment; and online student assessment), and their open feedback on the direction of this online learning matter.

Problem-based learning (PBL):

Learning that results from the process of working towards the understanding or resolution of a problem. The problem is encountered first in the learning process and serves as the focus for application of problem-solving or reasoning skills, as well as the search for or study of information or knowledge needed to understand the mechanism responsible for the problem and how it might be resolved (Barrows, 1986).

Physics Basic Achievement:

In this thesis, physics basic achievement is defined as the students' overall performance on selected questions of basic physics concept test prior to the intervention.

Web or the *World Wide Web:*

The Web, also referred to as the WWW, is an Internet-based network that uses hypermedia technology. Users at their computers have 'browsers' (e.g., Netscape, Internet Explorer), which are 'graphical interfaces' that make utilising the vast information found in the network connected via the Internet much easier. The idea is to make navigation easier for users, by having the browser include embedded 'programming language' in the various 'tools' on the browser page. This makes it seamless for the user, as opposed to having a list of 'commands' in programming language. Before 1994, this language was necessary to navigate, communicate, and do research on the Internet.

1.6 THE STRUCTURE OF THE THESIS

This thesis is organized into eight chapters. Each chapter begins with a chapter overview, in order to help readers understand the flow of ideas presented. A brief outline of each chapter follows.

Chapter 1: Introduction to the Thesis. Presents the context and origins of the study – setting out the reason why this study is currently the focus of the researcher's attention and interest.

Chapter 2: Literature Review. The literature review is contained in Chapter 2, and consists of a review of relevant literature of theories of learning, PBL, problem-solving, creative thinking and critical thinking.

Chapter 3: Integrating PBL with Online Learning. This chapter presents a literature review on the possibilities of blending the PBL with online learning.

Chapter 4: Theoretical Underpinning for the Thesis. This chapter presents the learning dimension, which is students' learning process in physics. The PBL dimension - PBL models from previous research that were used in this thesis; the thinking models; and also the conceptual frameworks are presented here. This chapter also describes the developing of the particular PBL model used in the thesis.

Chapter 5: Research Methodologies. Presents the methodologies used in the inquiry including a description of the characteristics of educational research, research design, and research activities. This chapter also describes the development of all instruments (questionnaire, test questions, and interview) used in this inquiry, followed by a description of the data collection strategies employed. The data analysis procedures are presented along with a discussion of the measures taken to maintain the trustworthiness of the inquiry. This chapter concludes with consideration of the ethical issues relevant to the inquiry.

Chapter 6: *Research Findings.* Presents the results of the data collection based on the questionnaires, tests, and interviews.

Chapter 7: Discussions. Presents a discussion and elaboration of the findings from the previous chapter.

Chapter 8: Implications, Suggestions and Conclusions. This chapter considers the implications of the study for teaching and learning and makes some suggestions for further study. The chapter ends with overall conclusions for the thesis.

1.7 CHAPTER SUMMARY

This chapter presented an introduction, context and origins, rationale for the thesis, and some justification for the study. In summary, the researcher proposes that there is a need to consider a new approach of teaching and learning, especially in physics. The particular instructional method that has been suggested in this research is the problem-based learning (PBL) approach delivered via online learning in an attempt to enhance students' creative and critical thinking. The next chapter presents a review of literature about of theories of learning, PBL, problem-solving, creative and critical thinking.

CHAPTER 2: LITERATURE REVIEW

2 CHAPTER OVERVIEW

This chapter is divided into eight main sections. It begins with a section that describing the conduct of the literature review, followed by a description of theories of learning. Next it discusses problem-based learning (PBL) in detail, which includes literature about the successful implementation of PBL in practice. The subsequent two sections provide a description of the literature on creativity and creative thinking, and critical thinking. Afterward this, the chapter focuses on a discussion of thinking skills, particularly in relation to creativity and critical thinking. This section also presents literature on the relationship between thinking skills and problem-solving. The last two sections provide a review of issues about the learning process and problem solving, and end with the chapter summary.

2.1 CONDUCTING THE LITERATURE REVIEW

The literature review first examined key texts to obtain an overview of the research topic for designing a problem-based learning environment and integrating technology into this learning. Texts involved were Barrows (1986, 1996, 1997, 2002), Barrows and Tamblyn (1980), Savery and Duffy (1995; 1996), Hmelo-Silver (1998; 2004), Savery (2006), Gallagher (1997), Lee, Wong, and Mok (2003), Colliver (1993), Finucane, Johnson, and Prideaux (1998), Ahlfeldt, Mehta, and Sellnow (2005), and Engle (2005). Other texts by Boud and Feletti (1991) and Wilkerson and Gisjelaers (1996) provided background on implementing PBL across various disciplines in higher education. The online *American Journal Physics,* provided relevant readings on the issues and problems in physics education, and details about PBL online learning were found in Candela et al. (2009), Savin-Baden (2000), Cheaney and Ingebritsen (2005), and Savin-Baden and Wilkie (2006). Whilst Cowley (2005), Torrance (1966, 1996), Bergstorm (1991), Boden (2004), and Cropley (2001) provided key texts on creative thinking and Lipman (1988, 1995), McPeck (1981), Watson and Glaser (1980), and Brookfield (1987; 1995) provided terms on critical thinking.

A search of the libraries of five major universities in Malaysia conducted through MYTO gave general ideas of the extent of research conducted on PBL and the use of online learning for educational purposes in Malaysia, as noted in Chapter 1. This search focused on unpublished doctoral dissertations and master's thesis. Recent articles from a number of online journals also were canvassed - *Technological Horizons in Education*, *Journal of Asynchronous Learning Networks*, *Journal of Distance Education*, *Australian Journal of Educational Technology*, *Educational Technology and Society*, *Journal of Technology and Teacher Education, International Review of Research in Open and Distance Learning*, *Journal of Computer Mediated Communication*, *Academic Medical Journal, Medical Journal of Australia, Journal of Research on Technology in Education* (formerly the *Journal of Research on Computing in Education*), *Higher Education Research & Development, American Journal Physics* and *British Journal of Education Technology*. The researcher also looked through various conference sites related to the use of the Web/online learning in education such as Australian World Wide Web Conference, and the International World Wide Web Conference Committee.

After finishing these readings, the research topic and research questions were refined, and a list of key terms related to the research questions was compiled. This step involved identifying the most important terms in the research questions and locating other closely related terms. These terms were used in the search criteria for searching library databases and the Internet. This was deemed necessary since there are such a variety of terms used in the literature about the issues investigated in this thesis. Some of the key terms were: online learning, e-learning, Web-based learning, Web-based instruction. Other related terms searched were: physics achievement, problem-based learning, creative thinking, critical thinking, problem-solving skills, and students' perceptions of PBL learning and online learning. The search criteria were linked with logical Boolean search combinations.

Databases available at the University of Waikato's library covered fields such as Arts and Humanities, Social Sciences, Computing and Mathematical Sciences, Education, and Science and Engineering. The researcher also searched the Informit database, Academic OneFile database, ScienceDirect database, ProQuest database, EBSCO HOST database, and the ERIC database. Searches for digital dissertations were made through the Australian Digital Theses program and also from the University of Waikato Research Commons.

Once the key readings and journal articles were located, additional readings were obtained either by going back or forward in time. By reading the references in the reference list of the key readings and journal articles, the researcher went back in time, to better understand the background of the points raised in the key readings. The researcher then went forward in time by using citation indexes. For example, the researcher decided that the article by Barrows (1997) was an important paper on PBL and so accessed the Web of Science citation indexes for this paper for education and social sciences available online through the library. Conducting a search using key words "Barrows HS" and "1997" produced a list of several journal articles citing this article ranging from 1990 to 2010, some were relevant to the present study and helped to fill in gaps about points raised by the Barrows (1997) article. The researcher then went back in time by using the reference list for other relevant articles.

2.2 THEORIES OF LEARNING

Remarkably there is sometimes a lack of attention paid to student learning amongst educational policymakers and practitioners. As an example, in Britain and Northern Ireland, theories of learning do not strongly figure in professional education programs for teachers or those within related fields such as informal education. It is almost as if learning is seen as essentially unproblematic, and this leads one to postulate that the underlying view is that if the instructional administration is right, then learning (as measured by tests and other assessment) will naturally follow. Such a stance is consistent with traditional thinking about learning, in which learning is seen as the acquisition of knowledge, skills and values, something the literature nowadays suggests belies the complexity of learning processes (Cepni & Keles, 2006; Nuy & Moust, 1990). Modern theories of learning consider that learning happens through a variety of experiences and produces relatively permanent changes in our understanding and ultimately, in our actions and behaviours (Van Gyn & Grove-White, 2005). Whilst humans are capable of learning on their own, learning theorists believe that learning can be enhanced, accelerated, and purposefully directed by exploiting our understanding of learning processes, and by taking into account both the situation of learners and the contexts in which learning takes place (Gurrie, 2003; Van Gyn & Grove-White, 2005). Working with students to enhance their learning is the essence of every modern educational system, but what theories are applied and how they function is based on many circumstances such as social, cultural, economic, and political factor in which the learning is situated (Van Gyn & Grove-White, 2005). In the following sections, the researcher discusses theories of learning under two main themes, which represent the key approaches or theoretical orientations to learning.

2.2.1 Approaches to Learning

In the psychology and education literature, a learning theory is presented as an attempt to describe how people (and animals) learn, thereby helping us understand the inherently complex process of learning. In the 1960s and 1970s, learning was seen in terms of a change in behaviour. In other words, learning was approached as a result - the end product of some process that can be recognized or seen. This approach or view of learning has the virtue of highlighting a crucial aspect of learning, that is, it involves change. As an example, Merriam and Caffarella (1991) ask questions such as; Does a person need to perform in order for learning to have occurred? Are there other factors that may cause behaviour to change? and, Can the change involved include the potential for change? However, not all changes in behaviour resulting from experience involve, or are associated with, learning. For example, conditioning may result in a change in behaviour, but the change may not have involved drawing upon experience to generate new knowledge or skills. If we are to say that learning has taken place, experience and knowledge should have been used in some way (Smith, 1999b). Not surprisingly, many theorists have been less concerned with noticeable behaviour, but with changes in the ways in which people understand, experience, or conceptualize the world around them (Ramsden, 1992). The focus is, then, on *gaining* knowledge, skill or ability through the use of experience.

The nature of the learning changes for students is likely to be dissimilar. As an example, adult students' feedback on what they conceptualize as learning can be categorized in five ways (Ramsden, 1992):

i. Learning as a quantitative increase in knowledge - learning is acquiring information or ‘knowing a lot’;
ii. Learning as memorizing - storing information that can be reproduced;
iii. Learning as acquiring facts, skills, and methods that can be retained and used as necessary;
iv. Learning as making sense or abstracting meaning - learning involves relating parts of the subject matter to each other, and to the real world; and
v. Learning as interpreting and understanding reality in a different way – learning involves comprehending the world by reinterpreting knowledge.

Ramsden (1992) observes that we can see immediately that conceptions (iv) and (v) are qualitatively different from the first three. Statements (i) to (iii) suggest a less complex view of learning. Learning here is seen as something ‘external’ or independent of the learner. It might even be something that just occurs or is done to you by teachers (as in statement (i)). In a way, gaining experience becomes a bit like shopping. People go out and ‘buy’ knowledge - it becomes theirs. The last two statements look to the ‘internal’ or personal aspect of learning. Gaining knowledge here is seen as something that you do in order to understand the real world. The difference here involves what Ryle (1949) has termed ‘knowing that’, and ‘knowing how’. The first two categories mostly involve ‘knowing that’, and as we move to the third we see that alongside ‘knowing that’ there is growing emphasis on ‘knowing how’. This system of categories is in order - each higher statement or conception involves all the rest underneath it. In other words, learners who conceive of learning as understanding reality, are also be able to see it as increasing their knowledge (Ramsden, 1992).

2.2.2 Learning and Theoretical Orientations

Merriam and Caffarella (1991) provide a framework of learning and theoretical orientations and consider how we might classify learning theories (Table 1). This section focuses on four different learning orientations in this framework: the behaviourist orientation to learning; the cognitive/constructivist orientation to learning; the humanistic orientation to learning; and the social or situational orientation to learning.

Table 1
Framework for learning theories (after Merriam & Caffarella, 1991)

Aspect	Behaviourist	Cognitivist/Constructivist	Humanist	Social and Situational
Learning theorists	Thorndike, Pavlov, Watson, Guthrie, Hull, Tolman, Skinner	Koffka, Kohler, Lewin, Piaget, Ausubel, Bruner, Gagne	Maslow, Rogers	Bandura, Lave and Wenger, Salomon
View of the learning process	Change in behaviour	Internal mental process	A personal act to fulfil potential.	Interaction /observation in social contexts. Movement from the periphery to the centre of a community of practice
Locus of learning	Stimuli in external environment	Internal cognitive structuring	Affective and cognitive needs	Learning is in relationship between people and environment
Purpose in education	Produce behavioural change in desired direction	Develop capacity and skills to learn better	Become self-actualized, autonomous	Full participation in communities of practice and utilization of resources
Educator's role	Arranges environment to elicit desired response	Structures content of learning activity	Facilitates development of the whole person	Works to establish communities of practice in which conversation and participation can occur
Manifestations in adult learning	Behavioural objectives Skill development and training	Cognitive development Learning how to learn	Andragogy Self-directed learning	Socialization Social participation Associationalism Conversation

Behaviourist Learning

The behaviourist view of learning was introduced by theorists such as Thorndike, Pavlov, Watson, Guthrie, and Hull. Behaviourism is a worldview that operates on the principle of 'stimulus-response'. All behaviour has its origins in external stimuli, and all behaviour can be explained without the need to consider internal mental states or consciousness. From this view of the learning process, educators and teachers aim to change human behaviour. The locus of the learning is to condition students to respond to stimuli from the external environment, so that learners learn to adapt to any environment. The main purpose in this view is to produce learners that can change their behaviour in desirable ways. The educator must then manipulate the surrounding environment to elicit the desired response.

The learner, it is argued, will develop skills as a result of such training and gain in competence, based on their education. Examples of educational practice based on a behaviourist approach to learning are things such as rote-learning; direct instruction (e.g., lectures); prescriptive feedback; competency-based education; and design of learning outcomes. There are some keywords used in the literature to label learning activities in this domain: classical conditioning (Pavlov, 1930); operant conditioning (Skinner, 2002); stimulus-response (S-R); sensorimotor; preoperational; concrete; formal; accommodation; assimilation (Gallagher & Reid, 2002).

Cognitive/Constructivist Learning

A cognitivist approach to learning essentially argues that the 'black box' of the mind should be opened and understood, with the learner viewed as an information processor (like a computer). Koffka, Kohler, Lewin, Piaget, Ausebel, and Gagne are the main proponents of this approach to learning. Other important contributors include Merrill – with component display theory (CDT); Reigeluth – with elaboration theory; Briggs, Wager, Bruner – with constructivism; Schank – with scripts; and Scandura – with structural learning. Cognitivism sometimes overlaps with constructivism in the literature, but constructivism assumes that learning is an active process of mental construction in the learners' mind, and that the learner is an information constructor or creator (Wilson, 1995, 1996). According to constructivism then, people actively construct or create their own subjective representations of objective reality. New information acquired is linked to prior knowledge, thus mental representations are subjective and personal.

In a cognitive/constructivist approach to learning, the learning process is viewed as an internal mental process involving insight, information processing, memory, perception. The locus of learning is internal cognitive structuring, which is concentrated only on thinking. To develop capacity and skills to learn better in the future is the main objective for this approach. The educator has to structure content and the curriculum for each learning activity. The manifestation of learning is to build cognitive development such as intelligence; learning and memory as function of age, and ultimately for the learner to 'learn' how to learn. Key terms or ideas used to describe learning in this approach are schemata; information processing; symbol manipulation; information mapping; and mental models. Educational practices in this approach include problem-based learning; inquiry-based learning; cooperative learning; collaborative learning; active participatory learning; activity and dialogical process; anchored instruction; cognitive apprenticeship (scaffolding); and inquiry and discovery learning.

Humanist Learning

Humanist learning was proposed by Maslow and Rogers (DeCarvalho, 1991; Huitt, 2001), and here the learning process is seen as a personal act employed to fulfil a learners' potential. Humanism is a paradigm, philosophy, and pedagogical method that believes learning is best viewed as a personal and particular act, to fulfil one's potential. The main objective, according to humanists, is to help the learner to become self-actualized, autonomous and independent in everything they have learned. The teacher facilitates learner improvement and development as a whole person. This approach involves self-directed learning.

Social and Situational Learning

Bandura, Lave, Wenger and Salomon are the main proponents of social and situational learning. Bandura's social learning theory, for example, posits that people learn from one another, via observation, imitation, and modelling. This theory has often been seen as a bridge between behaviourist and cognitive learning theories, because it encompasses attention, memory, and motivation. The learning process here is seen as interaction and observation in a particular social context. The locus of learning is to engage the 'relationship' between people and environment, and the purpose of learning is to help students engage in full participation in particular 'communities of practice'. The main task for educators or teachers is then to work to establish communities of practice, in which conversation and full participation can happen. Learning can be seen as the result of socialization, social participation, association, and conversation with other people.

As with any framework of this sort, the divisions are somewhat arbitrary, and there are sub-divisions to the scheme and a number of ways in which the orientations or approaches overlap and draw upon each other. However, as can be seen from Table 1, these views involve contrasting ideas as to the purpose and process of learning and education - and as a consequence the role that educators may take.

The next section elaborates further on constructivist theory and practice. As noted above, problem-based learning (PBL) is 'located' in the cognitive or constructivist perspective of learning. The researcher thus now elaborates on how the literature suggests we support learning, and the potential of PBL to enhance learning.

2.3 PROBLEM-BASED LEARNING

Jonassen (1991a) noted, there are many ways to implement a constructivist view of learning: anchored instruction, situated cognition, flexibility theory, and cognitive apprenticeship. For example, situated cognition, argues that instruction should include genuine and related tasks that focus on everyday situation cognition. Savery and Duffy (1996) and Gallagher (1997) mantain that problem-based learning is one of the best examples of situated cognition, because it promotes students' understanding, integration, and retention of concepts, facts, and skills. Boud and Felleti (1997) argue that PBL is the most significant innovation in education for many years, and that it is based on a set of assumptions about learning from experience (Boud & Felleti, 1991), and can be taught in three different modes (Saarinen-Rahiika & Binkley, 1998): a fully integrated PBL curriculum (such as in many medical and health science programmes); a translational curriculum which begins with a more traditional (lecture-based) approach to the education and then a gradual introduction to PBL, and; as isolated courses in a traditional curriculum. Oliver and Omari (2001) note that PBL can be implemented in a variety of ways, including a Web-based course. Jonassen (1991b, pp. 35-37) argues that "the most effective learning contexts are those which are problem- or case-based and activity oriented, that immerse the student in the situation requiring him or her to acquire skills or knowledge in order to solve the problem or manipulate the solution." Of note is that Lee et al. (2003) insist that the PBL process does not aim to teach learners how to solve a problem, rather it seeks to expose learners to methods and techniques of how to solve problems across the learner's lifetime.

PBL is then a student-centred instructional approach in which students collaboratively solve problems, and reflect on their experience and practical knowledge. It was pioneered and used extensively at McMaster University in Canada. Characteristics of PBL are that learning is driven by challenging, open-ended problems. Students work in small collaborative groups, and lecturers or teachers take on the role as 'facilitators' of learning. Accordingly, students are encouraged to take responsibility for their group and organize and direct the learning process with support from a tutor or instructor (Albanese & Mitchell, 1993; Colliver, 1993; Finucane et al., 1998; Gallagher, 1997; Lim, 2005). PBL approaches involve confronting situations where students are uncertain about information and solutions, and mastering the art of the instinctive leap in the process of resolving these situations (Boud & Felleti, 1991). Learning thus occurs through the application of knowledge and skills to the solution of authentic problems, often in the context of real practice (Bligh, 1995). PBL is a form of situated learning, and learning occurs through goal-directed activity situated in circumstances that are authentic in terms of intended application of the learnt knowledge. Advocates of PBL claim it can be used to enhance content knowledge and foster the development of communication, problem-solving, and self-directed learning skills. It is also an instructional method of hands-on, active, learning-centred education involving the investigation and resolution of messy, ill, loosely-structured problems, that one can find in real-world situations (Ahlfeldt et al., 2005; Paget, 2004).

Shortly after its introduction, three medical schools — the University of Limburg at Maastricht (Netherlands), the University of Newcastle (Australia), and the University of New Mexico (United States) - adopted the McMaster model of PBL. Various adaptations were made and the model soon found its way to various other disciplines — business, dentistry, health sciences, law, engineering, education, and so on.

There are some defining attributes of PBL:

i. Learning is guided by challenging, open-ended problems with no single ‘right’ answer;
ii. Problems/cases are context specific;
iii. Students work as self-directed, active investigators and problem-solvers in small collaborative groups (typically of about five students);
iv. A key problem is identified and a solution is agreed upon and implemented; and
v. Lecturers/teachers take the role as facilitators of learning, guiding the learning process and promoting an environment of inquiry.

The PBL characteristics defined by Barrows (1997) are:

i. Student-centred

   The student is responsible for his/her standalone learning, and teachers/lecturers only act as facilitators.

ii. Problem-based

   The problems are ill-structured problems such as are found in real world situations. Information given to students is only sufficient to stimulate their thinking processes, and hence they generate a hypothesis involving inductive and horizontal reasoning. Thus, educators must develop the problems carefully so that they trigger inquiry learning among students.

iii. Problem-solving

The intention of the problems is to encourage student development, and the skills of effective and efficient reasoning in students. In the early stages, the teacher models problem-solving, and from here his/her role decreases.

iv. Self directed

Students are able to choose what they want to learn based on their efforts about how to solve problems.

v. Reiterative

After students finish with standalone learning (in order to find information and knowledge to solve problems), they step back from the problems, and apply their new learning to the problems. In executing this activity, they criticize early hypotheses, their understanding, and reasoning.

vi. Collaborative

Students work collaboratively to solve problems and try to recognize learning issues. Collaborative learning happens when students with standalone learning experience form a group to study together and identify learning issues.

vi. Self reflecting

After solving problems, students execute self reflection on their learning. Learning activities such as comparing new problems with old ones, engaging in reflection based on their preparation and facing the same problems in the future, identifying concepts or principles, drawing concepts map to show the relationships between each element in the problems and the logical relationships between these are engaged in.

vii. Self monitoring

Students monitor their own achievement and evaluate their own progress. This self achievement can come from combining feedback from the teacher/lecturer, group members and others' evaluations.

viii. Authentic

All of the behaviours embraced in PBL are steps acquired by students as they evaluate real world problems in the future.

A synthesis of studies in the literature on PBL produced the following six guidelines for the design of problem-based learning environments.

1. Students challenge their perceptions, principles, thoughts and accumulate knowledge through collaborating with other team members, peers and the facilitator. The fact is that, every individual has different perpectives on each problem and the probability they will observe and examine the world in exactly the similar way in the genuine world and have a single correct answer is very rare. Conversation and debate with group members through collaborative learning is vital in PBL (Koschmann, Myers, Feltovich, & Barrows, 1994). In PBL, collaboration is fostered instead of competition with colleagues (Engle, 1997), the learning process involves social consultation and cooperation from group members. Students are capable of challenging their thinking, beliefs, perceptions and their own knowledge by cooperating with fellow members - this can encourage them to expand their cognitive development (Boud & Felleti, 1991; Camp, 1996; Savery & Duffy, 1995). Students should eloquently present their newly obtained knowledge with team members, including both content and process elements. This requires that they review, summarise and present their findings in ways which foster understanding by their fellow students (Engle, 1997). The outcomes of independent learning are shared in order to expand their collective understanding. PBL is consistent with constructivist principles (Savery & Duffy, 1995).

2. PBL problems must represent both the breadth (reflected in the range of problems but within the context of living) and the depth (reflected in the number of dissimilar and diverse issues which show the application of the same knowledge) of actual situation. Knowledge can be developed and it is best achieved through varied applications of the concept. Honebein, Duffy, and Fishman (1993, p. 97) comment that “long standing prescription for instruction that numerous examples of a concept should be provided for study and

practice." Koschmann et al. (1994) likewise argue that "aspects of richness in concepts and cases will be missed with single representations, and the resultant simplification may prove misleading" (p. 233).

3. PBL engages students by placing them in important roles as they work with ill-defined real-world problems (Ahlfeldt et al., 2005; Constantino, 2002; Paget, 2004). PBL is more than an isolated activity, PBL is both a curricular organizer and an instructional method that develops students' higher order thinking skills (Constantino, 2002). Students are responsible for their own learning, and should be active participants in PBL. Rather than being told what to do or how to solve a problem, students within a PBL environment generate their own learning issues (Corrent-Agostinho, Hedberg, & Lefoe, 1998). "Learning is an active process requiring mental construction on the part of the student; instruction should foster cognitive initiative and effort after meaning" (Koschmann et al., 1994, p. 233). Savery and Duffy (1995), Boud and Felleti (1991) and Camp (1996) state active and engaged learning processes where anchored instruction and situated learning are two learning concepts behind this principle. Learning is about active engagement with a task, whether working individually or collaboratively with others. The emphasis is on students posing their own questions, and seeking answers.

4. Students' prior learning experience plays an important role in the learning process. In PBL, students construct their own knowledge (Savery & Duffy, 1996) by linking recent issues and experience with past learning, and creating connections amongst ideas and concepts through contrasting individual understanding of the knowledge with others' in a collaborative atmosphere (Camp, 1996). Engle (1997) emphasizes that in PBL, learning is cumulative, and what is most important is to improve familiarity. Simulation of existing knowledge facilitates anchoring of the new knowledge. Students function in a metacognitive way with learning focused towards thinking skills. Students generate their own problems, and seek to solve them strategically (Boud & Felleti, 1991; Camp, 1996; Savery & Duffy, 1995).

5. Support of reflection is provided in the PBL environment. Just having knowledge does not necessarily mean that learning has taken place. The vital aspect that can turn new knowledge into learning is the process of reflection. Reflection on recent knowledge and experiences is an effective method of learning (Engle, 1997). Critical and creative reflection helps students to increase understanding of their own thinking and includes self-questioning activities such as: How are we going to start with this problem?; What is the learning issue in this situation?; How did we go about our independent learning?; Are there other actions we should have taken? and Against what standards or expectations did we measure our success? (Brookfield, 1987). Skilled participators of these metacognitive functions are able to arrange activities, evaluate the success or failure of their own performance, and adjust behaviour in accordance with the activity (Roger, Cisero, & Carlo, 1993). The facilitator assumes a crucial role in encouraging reflection, and in so doing is provided with opportunities to monitor the quality of the students' understanding of concepts and issues (Engle, 1997). Hence, the facilitator is also a 'guide' or a 'coach', probing students' thinking, monitoring their thinking and keeping the process moving (Boud & Felleti, 1991; Camp, 1996; Savery & Duffy, 1995). Continuous challenge, used in a encouraging way, of the level of metacognitive awareness, combined with integrated application of knowledge, skills and attitudes to professional situations, has the capacity to support deep learning (Ramsden, 1992). The learning process involves social interaction, and so PBL needs teamwork from group members. Students are able to challenge each others' thoughts, ideas, beliefs, perceptions, attitude and their own knowledge by assisting group members, and this can encourage them to develop their cognitive growth.

6. PBL is a group-based teaching technique. Groups or cooperative groups vary in size and may consist of 5 to 8 members (Ahlfeldt et al., 2005); 8 to 10 members (Savin-Baden & Wilkie, 2006); or 10 to 12 members (Segers, Dochy, & De Corte, 1999). Cooperative groups work through the problems together, while using a trained facilitator to guide the learners without teaching them in a traditional manner (Baker, 2000; Biley, 1999). Having someone act as facilitator for the groups leads to a richer, more holistic level of learning

(Dahlgren, 2000). Hitchcock (2000) suggests that skilled and experienced facilitators and instructors are vital for PBL. Through the process of working together, learning takes place. The group members interact to solve the problem and this discourse eventually leads to a solution. The discourse within the group consists of an active series of conversational interactions as group members collaborate to extend alternative forms of an issue in resolving a diagnostic dilemma (Frederiksen, 1999).

Barrows (1986) describes five categories or types of PBL: case-based lectures, case method, modified case-based, problem-based, and closed-loop problem-based. These are now described briefly in turn.

i. Case-based lectures involve students receiving background information on a case to study prior to the lecture.

ii. In the case method, students receive complete details on a case to study and research before coming to class. The instructor, acting as a tutor, facilitates class discussion in analyzing the case.

iii. For modified case-based PBL, students receive partial details on a case and, after class discussion, choose from a limited number of inquiry actions or decisions. The list of inquiry actions and decisions may be generated by the class or provided by the instructor. Students then receive additional information on the case and further discussion ensues.

iv. In problem-based cases, students are presented with say a simulated patient. The students evaluate the patient’s signs and symptoms, generate hypotheses, and decide what additional information is needed. The instructor facilitates the class exploration of the problem.

v. Closed-loop problem-based cases involve students completing a problem-based case and undertaking self-directed study. They return to the problem as it was initially presented and evaluate their prior reasoning and knowledge and the information sources used.

Some of these methods are probably not practical for an isolated course, if it is not part of a curriculum based entirely on PBL, because of the time needed for research related to the cases and for self-directed learning. However, the case-based lectures, case method, modified case-based, and problem-based methods all could be modified and used in a traditional curriculum (Boyle, 1999; Knapp & Miller, 1987). Moreover, PBL does not include methods that use problems simply as an example of what has been learned, such as in the lecture-based cases method (Barrows, 1996). In this approach, the facilitator lectures on a course of action and then tries to make the action significant by applying it to the analysis of an actual or artificial data set. The background information provided for these cases are usually shortened, often no more than several points containing the essential information needed to perform the tasks. In this case, students do not practice using the experience the way they will have to use it in their research, even though they are encouraged to some extent.

The literature also reports a series of phases of learning activities involved in PBL (e.g., Adelskold, Aleklett, Axelsson, & Blomgren, 1999; Albanese, 2000; Albanese & Mitchell, 1993; Pastirik, 2006; Walton & Matthews, 1989; Wilkerson & Gisjelaers, 1996). Normally there are five phases of learning in PBL: problem analysing, information gathering, synthesising, abstracting and reflecting.

1. Phase of analysing the problem - Students, separated into groups (normally 4 - 8) with a facilitator, are presented with a complex problem without any instruction being given. They generate knowledge about possible solutions to the problem, based on their prior knowledge. Next, they identify the key learning issues and plan actions to tackle the problem.

2. Phase of gathering information - A period of independent learning takes place. Students are in charge of searching for significant and relevant information individually. A number of sources may be available for tracking information. Students in this phase are engaged in learning as they are searching for information when their need to 'know' is greatest.

3. Phase of synthesising - Students reassemble after a particular period and re-examine the problem-based on their newly acquired knowledge. They do not

simply tell what they have learned. Rather, they use that learning to re-examine the problem (Savery & Duffy, 1996). Therefore, students develop knowledge by anchoring their new experience on their existing knowledge on their existing knowledge base. The second and third phases may be repeated if new learning issues are identified.

4. Phase of abstracting - Once the students feel that the problem task has been successfully concluded, they examine the problem in relation to similar and dissimilar problems in order to form generalizations.

5. Phase of reflecting - The students re-examine the problem-solving procedure. Students experience self- and peer evaluation. This phase helps students' metacognitive capability as they discuss the procedure and reflect on their newly acquired knowledge.

Savery and Duffy (1996) stress that these phases can be applied in a different ways and over various time-spans. Similarly, Boud and Felletti (1997) state:

> PBL is an approach to structuring the curriculum which involves confronting students with problems from practice which provide a stimulus for learning. However, theare many possible forms that a curriculum and process for teaching and learning might take and still be compatible with this definition. (p. 15)

Ramsden (1992) says that PBL involves 'deep learning', where learning goes away from memorization of facts, and instead is focused on a deeper understanding of the situation under study. PBL engages students in the learning process through using real problems. Thus, the way of presenting problem to students also plays an important role in learning process.

2.3.1 Presenting Problems to Learners

As mentioned above, the literature suggests that PBL is normally organized in small groups of students, along with guidance from a facilitator or instructor. Throughout this process, a complete series of problems, usually such as are encountered in everyday life, are supplied to students with guidance provided early in the PBL process. Guidance is reduced as learners gain in expertise and confidence (Merill, 2002). Merrill suggests the learning begin with less difficult or complex problems, and as the process of learning progresses, problems should be changed by adding more complex components to make them more realistic, exciting, and adventurous. Therefore, it is important to start with simplified versions of real world problems, and to progressively add components. This advancement stimulates and inspires learners as they slowly acquire expertise and take ownership for their learning.

During PBL, students should debate and talk over their problems, define what they know, generate some hypotheses, derive learning goals and organize extra work. Results may later be presented to large groups, under guidance from an instructor or facilitator. A PBL cycle should conclude with students reflecting on the learning that has taken place. From a constructivist perspective, in PBL the role of the instructor is then to guide and lead the learning process, rather than provide knowledge (Hmelo-Silver & Barrows, 2006; Merill, 2002).

2.3.2 PBL and Cognitive Load

Researchers such Sweller and co-workers have studied PBL for many years, and recommend teachers consider the cognitive load, and engage in what is described as the guidance-fading effect (Sweller, 2006). Sweller, Van Merrienboer, and Paas (1998), for example, conducted several classroom-based studies with students studying algebra problems (Sweller, 1988). These studies suggest that active problem-solving early in the learning process is a less effective instructional design than studying worked examples (Cooper & Sweller, 1987; Sweller & Cooper, 1985). Active problem-solving is more practical as students become more competent, skilful, and better able to deal with their working memory limitations. Even though in the early stages students find it difficult to process a large amount of information and detail, once they gain expertise and prowess, the scaffolding inherent in PBL helps students address these issues.

Sweller (1988) suggests that cognitive theory can explain how novices or beginners react to problem-solving during the early phase of PBL. Sweller et al.

(1998) say teachers should provide a worked example early on, and then provide a gradual introduction of problems to be solved. Other options early in the learning process include goal free problems, later replaced by complete problems, with an eventual goal of students solving problems on their own. Tudoreanu and Kraemer (2008) suggest that learning activities that involve effective animations also improve learners cognitive load; whilst Rouet (2009) suggests that, at first, the facilitator or instructor should manage three important elements in order to manage cognitive load in students, reducing irrelevant sources while optimizing useful sources of load. The elements are individual, task and also environment. In PBL, many forms of scaffolding have been used to reduce the cognitive load of students, but they share the notion of slowly transiting from studying examples to solving problems more independently (Sweller et al., 1998).

2.3.3 Enhancement of Learning via PBL

The literature thus suggests that PBL can be an effective means of enhancing student learning, and there has been a substantial amount of research that seeks to provide evidence to support this. Hmelo-Silver, Duncan, and Chinn (2007), for example, comment that PBL is a good way of using constructivist problem-based learning and inquiry-learning methods. There is evidence that PBL sustains the expansion of reasoning skills (e.g., Hmelo-Silver, 1998), problem-solving skills (e.g., CTGV, 1992; Gallagher, Stepien, & Rosenthal, 1992), and self directed learning skills (e.g., Hmelo-Silver & Lin, 2000). As an example Horwitz, Neumann and Schwartz (1996) developed a project named GenScope, an inquiry-based science software. Students using GenScope software showed significant advances in sophisticated domain reasoning (effect-to-cause).

Knowledge in this millennium is increasingly characterized by creative integration of information and learning from diverse disciplines. For these disciplines, PBL is probably the most extensively used tool (Ward & Lee, 2002), and many educational institutions worldwide have used PBL in educational reform and curricular innovation (Tan, 2004). Various studies using PBL in many disciplines, including in science, chemistry, biology, marine, and management, suggest that PBL works especially well for complex, multi-disciplinary subjects like medicine. Koh, Khoo, Wong, and Koh (2008), for example, reported that trainee doctors who learnt via PBL in a medical school showed enhanced social and cognitive competencies, such as coping with uncertainty and enhanced communication skills. Colliver (1993) likewise reports gains in clinical skills (see also Blake, Hosakawa, & Riley, 2000, for more work on medical school).

A key feature of PBL is the way it can help students to take charge of what they learn (Spronken-Smith, 2005). This involves students taking responsibility for their own learning, learning to build their own prior knowledge, focusing on the process of knowledge acquisition (rather than on the products of such processes), movement towards self-and-peer assessment, and a focus on communication and interpersonal skills (Boud, 1985). As an example, work by Sulaiman (2004) indicated that undergraduate physics students enjoyed the PBL delivered online, and it helped them to communicate their science ideas better (see also Duch, 1996).

Reasons have been proposed as to why PBL may enhance learning, and it seems that increased success of students involved in PBL is based on the ability of PBL to activate prior knowledge more effectively (Jones, 1996). It does this by virtue of the fact that the increased elaboration of information promotes mental processing, greater understanding, and recall, the latter supported by the notion that learning occurs in a context that resembles real-world situations (Finucane et al., 1998).

2.3.4 Students' Perception of PBL

Research about PBL also has focused on how easily students adapt to what, to many, is a very different learning approach. The results vary with some studies suggesting PBL is acceptable to students, and others indicating that although a PBL-based curriculum is initially perceived positively, there are limitations and restrictions and ways that PBL can be improved. Studies that report positive findings are presented first, followed by those that were positive about how well PBL was received by students.

The nature of students' motivation in PBL may depend on their academic or professional discipline of study (Dahlgren & Dahlgren, 2002). For example, PBL students in medical school report being satisfied with their learning, and more confident in their understanding than those taught traditionally (Albanese & Mitchell, 1993; Vernon & Blake, 1993). PBL also is popular with younger learners (see e.g., Albion & Gibson, 2000; Gordon, Rogers, & Comfort, 2001; Stepien & Gallagher, 1993), because young students feel the PBL approach, with its active learning and teamwork, makes learning relevant and enjoyable. In addition, teachers report that younger students' behaviour improved when PBL was utilized (Albion & Gibson, 2000).

The literature suggests that PBL works well with complex abstract subjects like physics. Kampen, Banahan, Kelly and McLoughlin (2003), for example, report that students studying thermal physics found the topic significantly more interesting and relevant. Such a positive perception of PBL may be because it inspires greater motivation and provides satisfaction, because it provides demonstrable and tangible outcomes (Earthman & Nieves, 2000; Gackowski, 2003; Sulaiman, 2004). Students also report PBL as an effective means of learning their course material (Sulaiman, 2004). Typically, such students emphasized the 'realistic', 'hands-on', and/or 'big' picture' qualities PBL provides. Moreover, students report they accrue teamwork skills, and becoming a more resourceful learner. Positive comments also typically mention that PBL improved students' learning process, communication skills, and ability to solve real-world problems (Gackowski, 2003).

At least some part of these positive perceptions of PBL may be due the differences in assessment of learning in PBL approaches. Bowe (2005) reports that, in PBL, the assessment strategy is seen by the students as supportive and helpful in terms of their development as a member of learning group – in other words, the formative nature of the assessment was appealing. Other factors are the supportive nature of the PBL learning environment, with Sulaiman (2004) reporting that students find their skills in the discussion room improve when they can talk on any particular matter about their study without anxiety or being rejected by their friends (see also Bowe, 2005). Motivating factors also come from the realism that experiential learning brings into the process (Gackowski, 2003). Such features of the learning environment enhance students' affective, attitudinal, ethical and behavioural dimensions of learning (Gackowski, 2003). Students also report that PBL helps them to address real-life challenging problems though engaging with their own learning processes, meaning they had to become self-directed learners and to collaborate with and rely on peers as well as confronting the challenges of group dynamics (Spronken-Smith, 2005).

Recent research suggests that students think greater engagement with real-life problems/tasks created in PBL scenarios encourages them to think about the diagnostic processes involved in problem-solving (Gossman, Stewart, Jaspers, & Chapman, 2007). For example, PBL provides motivation and encourages discussion about searching for information, and students say this makes them more capable, and increases their ability to solve problems more appropriately in physics (Kampen et al., 2003; Sulaiman, 2004). Students thus are generally enthusiastic about PBL, and welcome the approach, finding it a refreshing and enjoyable change from traditional teaching (Spronken-Smith, 2005). There also appears to be evidence that students take more responsibility for their learning and are able to apply the skills acquired in subsequent lectures and laboratories (Kampen et al., 2003), with many students keen to see PBL used for other topics and courses (Sulaiman, 2004).

Students' perceptions of PBL fall into four main categories (Spronken-Smith, 2005): students' understanding of PBL; initial struggles with PBL instruction; the domination of PBL in study; and skills gained in PBL. Some students see PBL as something of a burden because the format of the course is so unlike a traditional class or lecture (William, Macdermid, & Wessel, 2003). Nevertheless, Spronken-Smith (2005) says that whilst PBL is not favoured by all students, the majority value PBL because although it is challenging, students feel empowered as learners. This view resonates with the views of Harland (2002) and Silen (2004) who report that PBL students developed a new awareness of learning and metacognition – consistent with the beliefs of Biggs (2003) and Ramsden (2003) that in a PBL course, students are more likely to take a deep approach to learning.

Hmelo-Silver (2004) claims that there is little research that bears directly on the issue regarding students' motivation, rather than their satisfaction and confidence.

He insists that enhancing student motivation is purported to be a major advantage of PBL, because learning issues arise from the problem (in response to students' need to know), meaning that intrinsic motivation is enhanced. However, some students resist changing their way of learning, and do not like working collaboratively. Derry, Levin, Osana, Jones, and Peterson (2000) argue that such views may be as a result of the amount of time taken up by PBL or that the topic is not appropriate to PBL, since students need time to understand the nature of PBL (see also, Kampen et al., 2003; Sulaiman, 2004). The literature suggests there are a number of 'worst case scenarios' for implementing PBL: the problem itself can create confusion and frustration among learners; the instructors' role may result in ineffective facilitation and superficial discussion; and the learner can experience helplessness with little sense of learning, resulting in a failure to learn either content or process skills (Tan, 2004).

2.3.5 Summary of Literature on PBL

In summary, the literature suggests that students in general are fairly positive about PBL instruction, and that there are useful gains in terms of student learning and skill development. Educators and curriculum developers, however, need to ensure good preparation of students; design good problems; and carefully construct dynamic PBL curricula. PBL effectiveness is a result of the successful interplay of forces pertaining to the problem, the instructor and the learner.

Students' experiences point to a need to prepare mindsets and ensure good design of problems and PBL curriculum. Schmidt (1993) proposes the structuring of knowledge in PBL in the following way: initial analysis of the problem/s and activation of prior knowledge through small-group discussion; elaboration on prior knowledge and active processing of new information; restructuring of knowledge, construction of a semantic network; social knowledge construction; learning in context; and stimulation of curiosity related to presentation of a relevant problem. The literature suggests that PBL is likely to be successful when we develop students' confidence in independent learning, and scaffold them towards learning that is closer to the real world. Hence, for effective PBL implementation, there is a requirement for staff to be competent in terms of process skills (i.e., handling group dynamics, energy, questioning skills, facilitating meta-cognition, etc.), and to be able to identify, articulate and assess these skills.

2.4 CREATIVITY AND CREATIVE THINKING

Creativity or creativeness is a mental process or mental activity involving the generation of new concepts or theories, or new associations between existing concepts or theory. The product of creativity, ideas and opinion, from a scientific point of view (sometimes referred to divergent thought) is usually considered to have both originality and appropriateness (Cowley, 2005; Harris, 1998b). An alternative, more everyday conception of creativity is that it is simply the act of creating something new, that was not there before (Awang & Ramly, 2008). A full literature definition of creativity is explored later; first the importance of creativity in the Malaysian context is discussed.

2.4.1 Creativity in the Malaysian Context

As noted in Chapter 1, the fact of almost 70 percent of the graduates from public universities in Malaysia being unable to secure employment is a cause of considerable anxiety, and local commentators consider that many Malaysian university graduates remain unemployed because they lack creativity and soft skills (Nain, 2010). The President of Malaysian Association of Creativity & Innovation (MACRI), Datuk Ghazi Sheikh Ramli, claims that the creativity of Malaysians is suppressed by the education system, and a perceived need to follow societal norms. He adds that Malaysian society generally puts many barriers and constraints on children's learning, arguing that children need space to grow, and when this space is not given, it slowly kills their natural inborn creativity. Ghazi claims that in more open societies, students are not subjected to such mental blocks, and can freely challenge the opinions of their lecturers and elders.

In the formal Malaysian education system, education about thinking emphasizes skills such as of analysis, teaching students how to understand claims, follow or create a logical argument, figure out the answer, eliminate incorrect paths and focus on the correct answer. However, Harris (1998b) suggests there is another kind of thinking we should foster, one that focuses on exploring ideas, generating possibilities, looking for many right answers rather than just one. Both of these kinds of thinking are vital to a successful working life, yet the latter tends to be ignored until after college in Malaysia.

In Malaysia, efforts are being now made to encourage creativity through curricular and co-curricular activities (Utusan Malaysia, 2008; Yong, 1986; Yong, 1993). As stressed by the Deputy Prime Minister of Malaysia recently, Tan Sri Muhyiddina Yassin (who also acts as the Minister of Education) said that the Malaysian education needs to be transformed urgently to enhance economic development based on creativity and innovation (Zakaria, 2010). Thus, teachers are encouraged to use pedagogies to promote creativity, and students are likewise encouraged to be innovative and come up with new ideas. Students are encouraged to participate in creative activities by allowing them to become conscious of the ways in which they think and learn. The way of thinking will also attempt to involve students in the teaching-learning process through evaluations of what is taking place during learning, and can provide a window into the student's creativity.

2.4.2 Definitions of Creativity and Creative Thinking

As noted above, most people probably think of creativity in fairly simplistic terms, but it is actually quite a complex notion. Creativity has been studied from the point of view of behavioural psychology (e.g., Fink, Graif, Neubauer, 2009), social psychology (e.g., Reckhenrich, Kupp, & Anderson, 2009), drama (e.g., Karakelle, 2009), psychometrics (e.g., Keri, 2009), cognitive science (e.g., Gale, 2009), architecture (e.g., Styhre & Gluch, 2009), engineering (e.g., Awang & Ramly, 2008), instructional strategy (e.g., Hall, 2009), accounting (e.g., Omurgonulsen & Omurgonulsen, 2009), economics and management studies (e.g., Bergstorm, 1991; Cunningham & Higgs, 2009) and many more. In addition, there is variation in terminology used in the literature: creative, creative thinking and creativity all are used interchangeably.

In general terms, to be creative is viewed as the *ability to create* (e.g., to be imaginative, innovative, or artistic). What is created is characterized as being original and new or formed by a new process (Awang & Ramly, 2008; Bergstorm, 1991; Weisberg, 1986). Similarly, creative thinking is the *specific thought processes* which improve the ability to be creative. It is also considered as a series of mental actions which produce changes and development of thought, and the process of exploring multiple avenues of action or thought. While creativity may be defined as the ability to produce work that is both novel (e.g., original, unexpected) and appropriate (e.g., useful, adaptive concerning task constraints) (Lubart, 1994; Ochse, 1990; Sternberg, 1988b; Sternberg & Lubart, 1991; 1995; 1996), the ideas must be of high quality. Hence, a creative response to a problem is new, good, and relevant (Kaufman & Sternberg, 2007).

Creativity has been credited to a variety of sources: to divine intervention, cognitive processes, the social environment, personality traits, and chance events such as ‘accident’ and ‘serendipity’. It has been linked with genius, mental illness and also humour. Some also say it is a habit or characteristic we are born with; others say it can be taught with the implementation of simple techniques such as ordinary cognitive processes (Weisberg, 1999). Although well known and often associated with art and literature, creativity is also an essential part of innovation, invention and discoveries, and is important in careers such as business, economics, architecture, industrial design, architecture, and engineering (Facaoaru, 1985; McKinnon, 1983). In spite of, or perhaps because of, the ambiguity and multi-dimensional nature of creativity, entire industries have been spawned from the pursuit of creative ideas and the development of creativity techniques. This mysterious occurrence, though undeniably important and continuously perceptible, seems to lie tantalizingly beyond the grasp of scientific study.

Gardner (1983, 1999) proposed a theory of multiple intelligences which he applied to creativity, in which eight distinct intelligences function somewhat independently, but interact to produce intelligent behaviour. Sternberg (2005), on the other hand, suggests that there are at least three different forms of multiple creativities: processes, domains, and styles. Multiple creativities occur if creativity is not only multidimensional, but multiple in nature. Taylor (1988) argues that the root of the word in English and the most other European languages, comes from the Latin *creatus* literally ‘to have grown’. He claims that creativity is displayed in the *production* of creative work that is original and useful.

There are more than 60 different definitions of creativity reported in the literature (Taylor, 1988) and it is beyond the scope of this literature review to list them all. However, Harris (1998b) suggests there are three main words which can describe creativity: an ability; an attitude; and also a process. These are described in turn.

i. An ability

A simple definition is that creativity is the ability to imagine or invent something new. Creativity is not the ability to create out of nothing, but the ability to generate *new* ideas by combining, changing, or reapplying existing ideas. Some creative ideas are astonishing and brilliant, while others are just simple, good, practical ideas that no one seems to have thought of yet. Harris believes that everyone has substantial or considerable creative ability. Creativity, he argues, has too often been concealed through education for adults, but it is still there and can be reawakened. Often, all that is needed to be creative is to make a commitment to creativity, and to take the time for it.

ii. An attitude

Creativity is also an attitude: the ability to accept change and newness; a willingness to play with ideas and chances; a flexibility of outlook; the habit of enjoying the good, while looking for ways to improve it. Learners are socialized into accepting only a small number of permitted or normal things, like chocolate-covered strawberries, for example. The creative person realizes that there are other possibilities, like peanut butter and banana sandwiches, or chocolate-covered prunes.

iii. A process

Creative people work hard and continually to improve ideas and solutions, by making gradual alterations and refinements to their work. Hence, we can view creativity as a process of continual improvement. Contrary to common myths surrounding creativity, very few works of creative excellence are produced by the process of a single stroke of brilliance or in a frenzy of rapid activity. Much closer to the real truth are, for example, stories of companies who had to take the invention away from the inventor in order to market it because the inventor would have kept on tweaking it and fiddling with it, always trying to make it a little better. The creative person thus feels that there is always room for improvement. Torrance (1967, p. 74) sees creativity as:

> …the process of becoming sensitive to problems, deficiencies, gaps in knowledge, missing elements, disharmonies, and so on; identifying the difficulty; searching for solution, making guesses, or formulating hypotheses about deficiencies; testing and retesting these hypotheses and possibly modifying and retesting them; and finally communicating the result.

Costa (1985) defines creativity as a process or action that will produce something new and original and authentic.

2.4.3 Characteristics of Creativity

Claxton, Edwards, and Scale-Constantinou (2006) grouped the dispositions or characteristics of creativity into six main themes. Taken together, they form the acronym CREATE, as provided in Table 2. CREATE serves to make general point that 'being creative' is more than being able 'to do' 'mind maps' and indulge in brainstorming.

Table 2
Disposition for characteristics of creativity (adopted and adapted from Claxton et al., 2006)

Acronym	Statement
Curiosity	If something bothers a creative person, they will seem to have an appetite for questioning that sometimes borders on the obsessive, more likely the questioning dispositions manifests most strongly in their particular domain of creative expertise.
Resilience	Genuine creativity is demanding, complicated, not simple and easy and it is certainly not the case that 'anything goes'. Whether the sense of creative satisfaction derives from meeting an external challenge or from inner need to capture and express something through an artwork, creative people have a accented feeling for what is 'right' which often make them always doubt the simple answer. The 'quality' that they sense, and the tolerance for effort and frustration that the commitment to quality entails, is essential to creativity. That capability to allow confusion and frustration, to relish a challenge, and not to give up prematurely, has to be core attribute of creative people.
Experimenting	Creative people like disordering around with ideas, opinions, materials, actions and possibilities. Though their projects are dear to them, they have a playful approach to answer, and are always on the lookout for new angles and views.
Attentiveness	The discoveries of experimenting cannot be gathered and put to good use if they are not noticed. A propensity for intense, effortless concentration, are the kind of dispositions that creative people must have. They are able to let themselves go into their experience (or into their imagined worlds) whole heartedly, and become rapt, engrossed and absorbed.
Thoughtfulness	Their creativity powerfully acts upon how people make use of the private rooms and resources of their own. The attribute such as 'thoughtfulness', pondering over questions and chances, carefully reasoning and methodically, being sensitive to that inner feelings of rightness is another; allowing and enjoying the semi-autonomous play of images and metaphors that happen in states of reverie; having a mental attitude of 'respectful skepticism' towards hunches; knowing when to keep trying to figure something out, and when to give up; and relax-being a skilful orchestrator of their own states of mind and mental modes - is very much a help.
Environment-setting	Creative people seem to know that their physical and social environment can make a big difference. They need different kinds of settings, support (or challenges) at different points. As far as possible, they are consistent with their social world so that it supports the kind of reasoning that they need to do. They also seem to surround themselves with people who are going to support their creativity - whether emotionally, intellectually or practically. They also seem to know how to use the rhythms of time to balance different kinds of thinking. Their daily rhythm allows for both hard work and reverie; they know the worth of breaks and holidays. They know the places and the times of day that seem conducive to the muse.

Rhodes (1961) makes a useful distinction between the characteristics of the creative person, the creative product, the creative process, and the creative 'press' or environment. Boden (2004), however, argues it is important to distinguish between ideas which are psychologically creative (i.e., which are unusual to the individual and particular mind which had the idea), and those which are historically creative (i.e., which are unusual with respect to the whole of human history. Boden, drawing on ideas from artificial intelligence, defines psychological creative ideas as those which cannot be constructed by the same set of generative thought as other, well known, ideas. Consistent with this, Koestler (1964) suggests embedded in the notion of creativity is a concomitant presence of motivation and inspiration, cognitive leaps, or intuitive insight as a part of creative thought and action.

Wiesner (1967) observes that there is an important characteristic of creativity in the contributions in science that is not significantly present in creative contributions in many other fields, namely that these creative acts or outputs are quantitatively definable with a logical relationship to pre-existing scientific present knowledge. Thus, although the emotional and intuitive appeal of a new idea or concept, or its artistic affluence, may make it creative in philosophic or artistic feelings, in science it must also meet the standard of being logically relatable, in quantitative terms to the body of science in order to be considered scientifically ‘productive’. Wiesner (1967) agrees, adding that the new science idea must clearly follow from what is already known, if it is to result in enrichment of available scientific knowledge.

2.4.4 Process of Creativity

As noted above, creativity can be viewed as a process of being creative; in other words, as a series of actions that take place, resulting in new ideas, thoughts, or physical objects. Creativity is then the blending of ideas, theories and opinion, which have not been merged before. This raises the question as to what kind of process take places in order to classify the thought process as creative. One creativity process is brainstorming, which works by merging ideas to create a new idea; and the individual thus uses or builds on others’ ideas to stimulate new ideas (Infinite Innovations, 2009). The creative thinking process provides the method for deliberately combining ideas in ways one would not normally come across or think about; the attitude to accept change; and the process to continue to improve (Harris, 1998a).

Creativity can be used to develop a new idea by using special techniques (Awang & Ramly, 2008). These techniques force the consolidation of a range of ideas to trigger new thoughts and processes. Brainstorming activity is one special technique, but traditionally we start with unoriginal ideas, and if we use a deliberate technique, evolution of products or ideas happens more rapidly than by accidental techniques. People considered as creative are likely to use this deliberate technique, but may not be aware they are doing so because they have not been formally trained in such techniques. Thus, if someone can learn how to use deliberate techniques, for example, when recognizing and defining problems, he or she too may become more creative (Moore, McCann, & McCann, 1985).

Cowley (2005) argues that creativity is a process that involves taking imaginative and innovative approaches to whatever we do – seeing pretty much anything and everything as a chance to shape something that did not exist before, with the aspiration of advancing the sum total of human existence. Cowley goes on to say we can enhance the creativity process via two phases. The first phase is to find and work with an initial idea or impulse, playing around with the thoughts that we produce and sometimes searching for other material to develop our thinking. The second phase is the process of putting order onto those initial ideas, with the hope and intention of producing some kind of end product, although, this will not necessarily be achieved. These two phases overlap, and vary according to the task at hand and the person or people undertaking it. Weisberg (1986, 1988; 1993; 1999) claims that creativity involves essentially ‘ordinary’ cognitive processes yielding extraordinary products. Weisberg (1999) reports that insight depends on subjects using conventional cognitive processes (such as analogical transfer) applied to knowledge already stored in memory.

Torrance and Hall (1980) believe that creativity includes special aspects of the processes outlined by Cropley (2003). Specifically, Torrance and Hall stress processes such as uniting divergent ideas by putting them into a familiar context; being able to imagine, at least as a theoretical possibility, almost anything; enriching one’s own thinking through the application of fantasy; adding spice to one’s thinking through the use of humour. Necka (1986) proposes a similar triad framework for creativity that goes beyond purely cognitive or thinking processes, to encompass motives and skills, although thinking is still very significant in his method. The aspects he stresses include forming associations, recognizing similarities, constructing metaphors, carrying out transformations, selectively directing the focus of attention, and seeing the abstract aspects of the concrete. It is important to realize that creativity processes may show a number of dimensions. According to Johnson (1972) these are sensitivity to problems and difficulties by the creative 'agent'; originality, ingenuity, unusualness, usefulness; appropriateness in connection to the creative outcome; and intellectual leadership on the part of the creative agent.

In science, creativity as a process may include a component or element of chance. Pauling suggests that when one creates scientific theories and hypothesis, one must endeavour to come up with many ideas, and then discard unimportant ideas (as cited in Wapedia, 2007). He describes creativity as 'assumptions breaking processes.' Creative ideas may then be generated when somebody 'tosses out' preconceived conjectures, and decides on a new procedure or method that seems unimaginable to others.

Cropley (2003) suggests that when new information is considered novel it is common to speak of 'creativity', whereas what in fact has happened involves processes of using existing information to construct new or advanced information. These processes include selecting from among the masses of information available at any moment (i.e., perception is not simply a passive acceptance of everything that impinges on the senses or is already stored in mind); relating new information to what is already known; combining elements of new and old information; evaluating newly emerging combinations; selectively retaining successful combinations (i.e., which may then function as new information, returning the process to the phase of relating elements of information); and then communicating the results to others. However, according to Sternberg (2005) creativity should not necessarily be considered as a process, or even multiple processes. Instead, Sternberg (1988) provides a three-facet model of creativity, and differentiates between three components: intellectual, personal and style. He places most emphasis on creativity style, which he claims arises from special cognitive processes, such as adapting successfully to special circumstances, recognizing opportunities, finding order in chaos and building broad categories. Creative people, according to Sternberg, can tackle new problems, recognize possibilities, cross boundaries, or find order in apparent chaos. Sternberg says a creative person also brings forth more ideas more quickly, and expresses them in a more understandable way to others. Mehlhorn and Mehlhorn (1985) agree, and say that highly creative people resemble each in such traits, and less creative people posses fewer such traits.

2.4.5 Importance of Creativity

If creativity is something that is inherent, then should we bother to study creativity or try to enhance creativity? Creativity, some authors argue, is significant for society since it is important for individuals who are more fulfilled when creative, and who do not need to be the next Einstein to manifest creativity (Bergstorm, 1991). Consistent with this, the literature on creativity focuses on the ordinary, rather than the extraordinary. The assumption here then, is that an ordinary person also can be creative (Craft, 2001a, 2001b; National Advisory Committee on Creative and Cultural Education [NACCCE], 1999; Seltzer & Bentley, 1999), and that this is something educational institutions at all levels should seek to enhance. Why is creativity important in education, and especially in higher education? The argument here is that we are constantly dealing with a changing world. From a purely economic viewpoint, globalization and competition have produced new challenges for business. Some corporations have 'discovered' creativity, and according to Munroe (1995) 70 percent of the cost of a product is determined by its design, so that creative design can lead to substantial savings in production. As a result, creativity training for employees is now widespread (Clapman, 1997; Thakray, 1995). Cowley (2005), however, urges caution, saying when an aspect of education becomes trendy - be it learning styles, thinking skills, or creativity - it is all too easy to get pulled into doing it because others say that it is crucial. If our target is to enhance creativity in our students, our schools, and also in society, then we really need to have a clear understanding about why it is really important to do this. We need to believe that it is worthwhile and there are many reasons why it might be important to take a creative approach to what we do. Cowley (2005) provides several reasons as to why creative thinking is important.

The first reason is *it's enjoyable*. Being creative can be fun and enjoyable: putting some music on and letting one's body bend and stretch to the beat; getting some paint out and making a mess as one tries to paint a picture; singing at the top of one's voice in the shower, and so on. In school, letting students have fun is one way we can seek to avoid children's disaffection, and lack of engagement in learning. The second reason is *advancing humanity.* Creativity can develop in all domains of human existence, from the important scientific discoveries, to the aesthetically pleasing paintings of great artists, and absorbing opera. The students we teach might not yet be working at the level of the creative genius, but there are likely to be children sitting in classrooms who will advance humanity during their lifetimes. The third reason is creative thinking can *impact on our world*. In a world that seems to be ever more complex and diverse, we can be left feeling adrift from our community. The ability to be creative gives us at least some feeling that we can impact on, make sense of, or better, the world in which we live - than we can, in some small way, make a contribution. Another reason that we should pay attention is where creativity *is a culture of expression*. Creativity is very much an aspect of an individual's own cultural practical knowledge. People need to reveal themselves in a way that has its origins in the culture from which they come and in doing so they become part of an ongoing tradition. They can also fortify their friendships and connections with the society in which they live, by expressing their own creative spontaneity. In a multicultural society, lifestyles need to be mixed and intermingled, and creativity may enhance positive connections between different cultures in society (Cowley, 2005). A *sense of unity* is another reason why creativity is significant - when learners do produce something in conjunction with others, this promotes a unique bond between them, and some creative endeavours are only made possible through teamwork that occurs during such collaboration. Creativity also has the capacity to *enrich our lives*. Creativity is a crucial part of us as human beings, and it is, for example, hard to conceive of a world without music, art, and books. Our lives would be less rich without the artistic and personal pleasure that the creative impulse can provide. Creativity can give us a sense of *personal fulfilment* with the end product, such as a beautiful watercolour, or by being involved with the creative process. Such a sense of creative fulfilment contrasts with the destructive impulses that can arise when an individual has a low sense of dignity or fulfilment. The notion of *success for our society* is an important aspect of creativity, because a society where expertise is highly valued can result in benefits for society, for example, excellence in the manufacturing of new and exciting products. *Change and adaptations* are of importance since our world keeps changing, meaning we need the ability to adjust to rapidly changing situations - learning to use and adapt new technologies, or adapting to different careers. Creativity helps learners to find ways of adapting, adjusting and reorganizing in changing situations. Creating something beautiful or worthwhile can give people *improved self-esteem* as a result of their accomplishment - the 'I did that!' feeling. The ninth reason is *discovering our own strengths*. Achievement or accomplishment is not just about academic ability; it also is about harnessing an individual's creativity, giving them the chance to discover their own strengths and abilities. For those who find the more academic subjects difficult, discovering an innate sense of creativity can make a real difference in maintaining engagement at school. The final reason why creative thinking is important is *problem-solving*. Creativity is a valuable aspect of problem-solving. With a creative frame of mind, an individual can discover different ways of resolving problems they already face; and searching for those problems which have not yet become apparent.

2.4.6 Creativity in Higher Education

William (1977) argues that higher education is the 'dominant force' in education, and that students in higher education merit special investigation. What a university teaches, plays a major role in the advancement of society as a whole. The Western democracies were shocked by the so-called Sputnik issue and many authors claimed, post-Sputnik, that higher education is indifferent or even hostile to creativity (see e.g., Farquhar, 2010). As an example, a survey by the Australian government in 1999 reported that universities were not providing necessary training in creativity. According to employers in the survey, only three-quarters of all new graduates in Australia, regardless of discipline, were 'suitable' for employment because of 'skill deficiencies' in creativity, problem-solving, and independent and critical thinking (Cropley, 2001).

In order to address such criticism, the connection between change and education has received considerable attention in the literature recently. Neice and Murray (as cited in Cropley, 2003) call for a 'pedagogical ethic,' familiarized to coping with change. The critical concern, they argue, is that people need to be able to adjust to change that is both rapid and sweeping. They need to do this, both for their own well-being, and to foster flexibility, the skill to produce novelty, and the ability to tolerate uncertainty. Mezirow (1990), one of the most prominent writers in recent discussion of post-school education, endorses an earlier call by Botkin, Elmandjra, and Malitza (1979) for higher education that can bring change, renewal and restructuring. The teaching of creativity is, it is argued, necessary for modern students in higher education; the world of tomorrow belongs to the problem finders and solvers of today. Educators thus need to help students become masters of the present, and creators of the future. The notion here is that if one wanted to select the best novelist, artist, entrepreneur, or even chief executive officer, one would most likely want someone who is creative.

However, it is not clear from the literature how we might foster creativity in higher education. Claxton et al. (2006) say there is good evidence for the development of the disposition to make use of imagination in the course of routine learning, but in a critique of this work, Persaud (2007) claims that there is little evidence that children develop a deeper insight into what judgement external critics might pass on the products of their imagination. Claxton et al. claim that, in so far as education has acknowledged creativity at all, it has commonly focused on ‘allowing’ rather than ‘developing’ creativity, on arts-based ‘expression’ rather than broader or deeper kinds of creativity; and on the role of techniques rather than dispositions. Claxton et al. also suggest that there are more generic habits and dispositions of mind that seem to be supportive of creativity. It is then, they argue, necessary to use such terms - rather than the more common ‘skills’- to emphasize that creativity relies not just only the ability to think, attend or reflect in certain ways, but on the inclination to do so, and to take pleasure in doing so.

2.4.7 Teaching Approaches Reported to Enhance Creativity

There are a number of teaching approaches reported to improve creativity and creative thinking in students. These include online courses (Mintu-Wimsatt, Sadler, & Ingram, 2007); a collaborative approach to teaching and learning (Liu, 2006); and open-ended problems (Kwon, Park, & Park, 2006). There is also interest in the role information and communication technologies (ICT) generally can play as cognitive tools, and it seems that creative thinking can be stimulated through the use of ICT integrated into curricular activities (Allegra, Chifari, & Ottaviano, 2001). Awang and Ramly (2008) report that once creative ideas are generated through the PBL approach, there are useful techniques to develop these 'tender' ideas so that they may grow into a productive concept or solution.

Juremi (2003) reports that creativity can be developed through the PBL approach from blended learning activities such as generating ideas, small group discussion, reasoning, finding information individually in individual own ways, selecting appropriate knowledge for problems, and experimenting. The result of her work suggests that students who have been taught through PBL showed significant improvement in flexibility and originality elements of creative thinking compared to their control-group counterparts. Research by Tan (2000) suggests that students' creativity can be enhanced through cognitive functions such as associative thinking, analogy, imagery, taking multiple perspectives, release from unwarranted constraints, flexibility, fluency, originality, desisting from premature conclusions and elaboration. These aspects are vital to building up skills associated to learning to learn and problem-solving. In addition, Dewett and Gruys (2007) claim that creativity type activities implemented in a classroom situation, improve students' creativity when they join organizations. This is because students will be more cooperative, tolerant and understanding of each other when working in an organization. Awang and Ramly (2008) say that by blending learning activities in PBL such as brainstorming to identify problems, generating and implementing plans for finding solutions, creating a product on a small scale to become the solution, then coming together to communicate their findings, solutions and conclusions does really improve students' creativity in all three main elements (fluency, flexibility, and originality). Allegra et al. (2001) suggest that creative thinking can be improved and aroused by using ICT as learning tools, for content delivery medium and, integrated with the curricular activities such as scaffolding, guides students to boost their diverging thinking throughout increasingly complex activities of creative writing, utilization of multimedia systems and online resources, and eventually the design and development of a hypertext. Kwon et al. (2006) report successfully implementing an open-ended approach in teaching students to become more divergent (one important element in creative thinking). By giving open-ended problems to students, they can either identify their own approach and clarify the rationale for their choice, or they can also use high-dimensional thinking skills and employ divergent thinking in the search of their own solutions. These activities encourage diverse thoughts, since an open-ended problem contributes towards boosting divergent thinking. In the course of searching for diverse solutions and various approaches, students can put forward many ideas freely (fluency), and formulate other efforts to create new strategies to engage in the problem where others do not succeed (flexibility), and think up very knowledgeable and unexpected ideas (originality).

2.4.8 Creativity and Critical Thinking

It is widely reported that the development of creativity and critical thinking can be beneficial for both the individual student and society (Sternberg & Lubart, 1995), moreover Moore, et al., (1985) suggest that "the methods of modern science are both creative and critical thinking" (p. 6). The meaning of creativity is frequently intertwined with critical thinking, and a number of authors have written about these different terms at the same time. Creativity, as noted above, is considered to be involved with the creation or generation of new ideas, processes, experiences, or objects. However, critical thinking is concerned with people's ability to engage in evaluation (Klenz, 1987). Can creativity be related to critical thinking? Some authors suggest that creativity and critical thinking are in fact opposed to each other (see e.g., Marrapodi, 2003), but others see them as functioning complementarily (Bleedorn, 1993; Menssen, 1993). It also is argued that it is difficult to distinguish two separate kinds of thinking, and it is suggested that our focus should be on *good* thinking in the context of the rules, methods and criteria of specific domains (Bailin, 1993). For example, a number of researchers say that critical thinking involves not only logical, but also creative (intuitive) aspects (Brookfield, 1987; Garrison, 1991; Meyers, 1986; Paul, 1993).

The Malaysian government has expressed a desire to foster both creativity and critical thinking in students, as has been stressed by the former Prime Minister, Tun Abdullah Ahmad Badawi in responding to the blueprint for education development (2006-2010), "We want the development of *modal insan* [model citizen], students who can think critically and creatively**,** who are able to solve problems and have the ability to adapt themselves to an ever-changing global environment" (Badawi, [speech] January 16, 2007). Therefore, based on this matter, it is important to investigate the relationship between creativity and critical thinking in this thesis. Thus literature on critical thinking is detailed in the next section.

2.5 CRITICAL THINKING

As noted above, the Malaysian government wishes students to become better critical thinkers, but this represents a big challenge to educators and curriculum developers. Careers such as an architect, businessman, scientist, engineer, medical doctor need individuals to think ‘outside the box’, and to critically evaluate their ideas. Based on research in cognitive psychology, some authors believe that schools should focus more on teaching their students critical thinking skills, intellectual standards, and cultivating intellectual traits (such as intellectual humility, intellectual empathy, intellectual integrity, and fair-mindedness), rather than on memorizing facts by rote learning. Bauslaugh (2004), for example, states that the curriculum in colleges and universities is much too focused on academic specialization, and is little concerned with equipping students to lead the lives they would actually lead - as workers, as citizens and as responsible individuals. He adds that more students should acquire some knowledge of the intellectual traditions of the society they live in, they should learn to interact with others in a civil way, they should learn how to critically evaluate evidence and draw reasonable conclusions. In other words, they need to learn become critical thinkers. There are a number of ways critical thinking has been conceptualized in the literature, so the next section considers definitions of critical thinking, along with the characteristics of critical thinking, the process of critical thinking, the role of cognitive development in critical thinking, and the role and value of critical thinking.

2.5.1 Definitions of Critical Thinking

Over the past decade, interpretations of critical thinking have constantly changed (Huitt, 1998). Nevertheless, in summary, the definition of critical thinking basically can be considered and characterized by skilful and responsible thinking in which one studies a problem from all angles and perspective, and engages in investigation to eventually come up with the best judgment, assessment, or opinion, using perspicacity to draw conclusions (Sies, 1998). Schafersman (1991) comments that critical thinking means thinking that is reasonable, reflective, responsible, and skilful - that is focused on deciding what to believe or do. There is overlap between views of critical thinking and creativity, with Persaud (2007) observing that creativity also can be defined as the cognitive operation by which creative products are critically evaluated, selected, altered or dismissed by the creator. A key feature of critical thinking embedded in such definitions is that of higher ordering thinking skills, with critical thinking seen as disciplined self-directed thinking, which is an example of the ideal of thinking advantageous to a particular mode or domain of thinking (Paul, 1990). Lipman (1995, p. 146) suggests that critical thinking must be related to judgement, saying, "critical thinking is skillful, responsible thinking that facilitates good judgments because it: (i) relies upon criteria, (ii) is self-correcting, and (iii) is sensitive to context." Lipman combines the concept of standards (criteria to measure achievement), skills (especially cognitive) and personal judgment (making wise choices). In other words, critical thinking consists of mental processes of discernment, analysis and evaluation. The process of reflecting in order to form a solid judgment that reconciles scientific evidence with common ideas is the essence of critical thinking skills. But in current usage, 'critical' has a certain negative connotation. Some authors argue that the term 'analytical thinking' conveys the idea more accurately, since critical thinking involves synthesis, evaluation, and reconstruction of thinking (Chance, 1986; Hickey, 1990; Huitt, 1998). McPeck (1981) claims that the propensity and expertise to engage in an activity with reflective skepticism is an important part of critical thinking. One can then regard critical thinking as involving two aspects: (i) a set of cognitive skills, intellectual standards, and traits of mind; and (ii) the disposition or intellectual commitment to use those structures to improve thinking and guide behaviour.

Rusbult (2006) says critical thinking thus does not include simply the acquisition and retention of information, or the possession of a skill-set which one does not use regularly. Nor does critical thinking merely exercise skills without acceptance of the results. The essence of critical thinking is, according to Rusbult, logic and logical evaluation — by using reality checks and quality checks — something he sees as a core aspect of scientific method. In support of this view, Watson and

Glaser (1980) see critical thinking as a combination of cognitive and affective dimensions, saying critical thinking is based on affiliation of attitude, knowledge and skills. Based on the views of Dressel and Mayhew (1954), Watson and Glaser propose four skills related to critical thinking:

i. Capability of defining problems;
ii. Capability of choosing relevant information for problem-solving;
iii. Capability to develop and choose between relevant hypotheses; and
iv. Capability to make a legitimate conclusion and evaluate inferences.

To think critically then, an individual must learn general skills in problem-solving, and be able to use knowledge in new settings. The general skills which form critical thinking skills in relation to problem-solving form the Watson-Glaser Critical Thinking Appraisal:

i. Making an inference;
ii. Recognition of assumption;
iii. Deduction;
iv. Interpretation; and
v. Evaluation of argument.

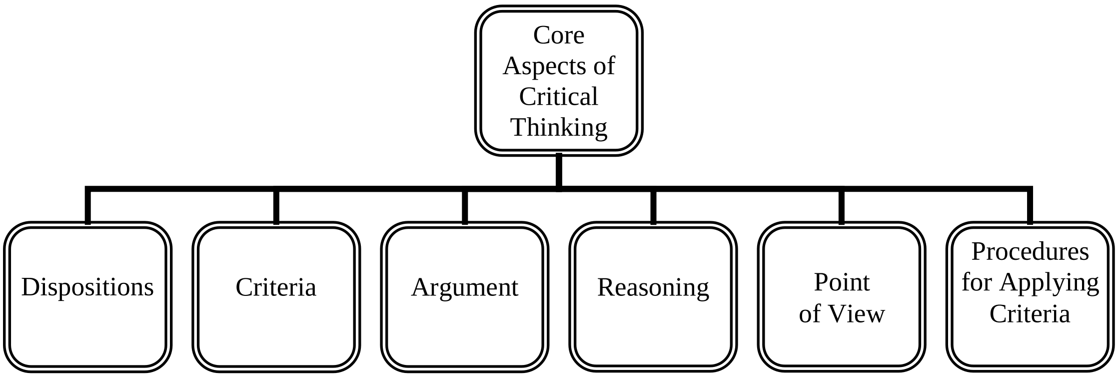
In this research, the researcher will take into account critical thinking as defined by Watson-Glaser (1980).

2.5.2 Characteristics of Critical Thinking

Definitions of critical thinking point to aspects or characteristics of a critical thinker, leading some authors to conceptualize critical thinking in terms of the characteristics of the thinking engaged in. Wade (1995), for example, says there are eight characteristics of critical thinking: asking questions, defining a problem, examining evidence, analyzing assumptions and biases, avoiding emotion, reasoning, avoiding oversimplification and considering other interpretations, and tolerating ambiguity. Strohm and Baukus (1995, p. 56) comment further on dealing with ambiguity, something they see as an essential characteristic of critical thinking: “Ambiguity and doubt serve a critical-thinking function and are a necessary and even a productive part of the process.”

Beyer (1995) elaborates on what he sees as the core characteristics of critical thinking (Figure 1). Each of these characteristics, as conceptualized by Beyer, is then discussed in turn.

Figure 1
Core characteristics as defined by Beyer (1995)



Dispositions

Critical thinkers are sceptical, open-minded, value fair-mindedness, respect evidence and reasoning, respect clarity and precision, look at different points of view, and will change positions when reason leads them to do so.

Criteria

Criteria must be used when we think critically, so we have conditions that must be met for something to be judged as believable. Even though the argument can be made that each issue or area has different criteria and requirements, some standards are relevant to all subjects. A statement of evaluation and resolution has to be based on significant, precise information; based on convincing sources; clear-cut; unprejudiced; free from logical misleading notions; logically reliable; and strongly reasoned (Beyer, 1995).

Argument

Logical evidence must be presented to support a statement or proposition. Critical thinking includes identifying, evaluating, and constructing arguments.

Reasoning

One must have the ability to infer a conclusion from one or multiple premises. Relationships among statements or data require logical examination.

Point of View

The way one views the world, shapes one's construction of meaning and significance. Critical thinkers are required to view phenomena from various points of view, in searching for understanding,

Procedures for Applying Criteria

Other types of thinking use a general procedure to analyze thinking. Critical thinking, in contrast, makes use of many procedures such as asking questions, identifying assumptions, and making judgments.

In thinking critically, we use our command of the elements of thinking to adapt our thinking to be logical. As we come to think critically routinely, we develop special features of the mind: intellectual humility; intellectual courage; intellectual perseverance; intellectual integrity; and confidence in our reasoning (Paul, 1990).
These views of critical thinking and the characteristics of critical thinking, paint a picture of an active learner. Critical thinking requires learners to be proactive, resolute in working through complex problems and open-minded in looking into other ideas and solutions (Murchu & Muirhead, 2005). Critical thinking is thus an 'energetic' learning approach that can be aroused by a variation of formal and informal activities. Critical thinking also is an emotional process, and emotions are always involved when making resolutions or conclusions (Brookfield, 1987). The critical thinking process thus has an inherent emotional element, because people are often occupied in assessing the need to change their values and principles. This characteristic of critical thinking can arouse anxiousness and even

opposition to applying changes that might appear threatening to an individual. Those who cast aside entrenched assumptions may then experience feelings of lack of self-confidence.

2.5.3 Process of Critical Thinking

The literature thus suggests we can conceptualize critical thinking as comprising a series of characterises that define our thinking (Paul, 1992). From the perspective of critical thinking as a process, critical thinking embraces the whole process of identifying and challenging assumptions, and searching other ways of thinking and acting (Brookfield, 1987). Gathering information uses all our senses, verbal and/or written expressions, reflection, observation, experience and reasoning to come up with solutions or products. However, Kurfiss (1988) says that the cognitive process of critical thinking can be divided into five main phases: i. stimulate students' interest by using problems as the organising principle for lessons; ii. facilitate students into when and how to utilize what they are learning (i.e., use coaching, practice, modelling and feedback to teach reasoning skills relevant to the subject of study); iii. demonstrate metacognition and construct metacognitive prompts class exercises and assessments; iv. bring out and discuss beliefs about the nature of what is to be learned and provide experiences to overcome students' naïve conceptions and prior knowledge about any related matter; and v. use social and cognitive approaches to improve purpose and motivation to learn.

Brookfield (1987) suggests it is hard to standardize all the process of critical thinking. Nonetheless, it still can be applied to the context the learning takes place. What is clear is that encouraging critical thinking is an activity as difficult as the process of critical thinking itself (Brookfield, 1987). It entails teachers, trainers, counsellors, and helpers who possess an unusual combination of qualities. Students need to be skilled in a number of systematic instructional methods, but sceptical enough of the value of these to be able to abandon them when it seems appropriate. They need to have a general aim in mind, and a partly developed notion of how this is to be achieved, yet they also need to be open to changing both aim and methods according to participant's personalities, abilities and past experience.

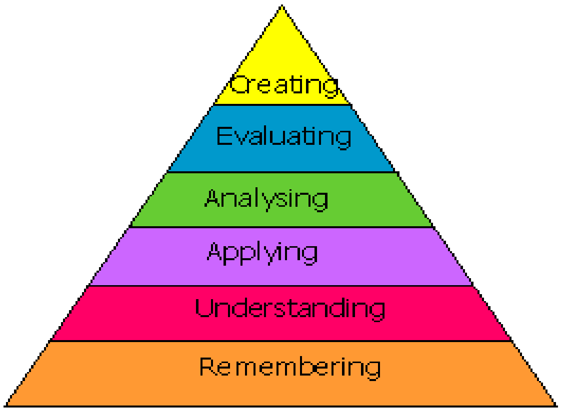
2.5.4 Role of Cognitive Development in Critical Thinking

The role of cognitive development in definitions of critical thinking ranges from simple statements about an individual's ability to create logical conclusions based on reasoning, to more complex definitions which take into consideration a person's emotions, personal feelings, and cultural biases. According to Erwin (2000a), critical thinking is a wider expression describing reasoning as open-ended practice, having no limit in range of solutions. Critical thinking demands learners improve the quality of their thinking by skilfully and masterfully taking charge of its very structures and by imposing intellectual standards upon them (Brookfield, 1987; Paul, 1990; Shurter & Pierce, 1966).

Cognitive development plays a significant role in a person's ability to think critically. Piaget proposed that cognitive development consists of the development of logical competence, and that this development consists of four major stages (Piaget, 1979, 1983, 1981; University of Alberta, 2008), culminating at around age 11 or 12, when a person enters the *formal operational stage*, and becomes capable of advanced logical thought about abstract concepts. This is the ultimate stage of human cognitive development according to Piaget (1979, 1983, 1981), but other theorists argue that Piaget's theories are faulty. Vygotsky, for example, says that an individual's higher mental functions develop more through social interaction, and that humans learn from their interaction and communications with others (Daniels, 1996; Newman & Holzman, 1993). Vygotsky thus assumes intellectual development is continual without an end point (as cited in Erwin, 2000b). Likewise, Riegel (1976) proposes a fifth phase to Piaget's four phases of cognitive development, dialectical reasoning, saying that dialectical reasoning is when a person's mental processes move freely back and forth among all the Piagetian stages. According to Erwin (2000a), biological and cultural developments are interrelated, and do not develop in isolation, cognitive skills like evaluation and development are complicated, and are affected by social and cultural contexts.

Critical thinking involves higher order thinking, and Bloom, Englehart, Furst, Hill, and Krathwohl (1956) have produced one of the most often cited documents in establishing educational outcomes based on higher order thinking: the so-called Taxonomy of the Cognitive Domain. According to this model, erudition and knowledge is composed of six successive levels arranged in a hierarchy: remembering, understanding, applying, analyzing, evaluating and creating (Figure 2).

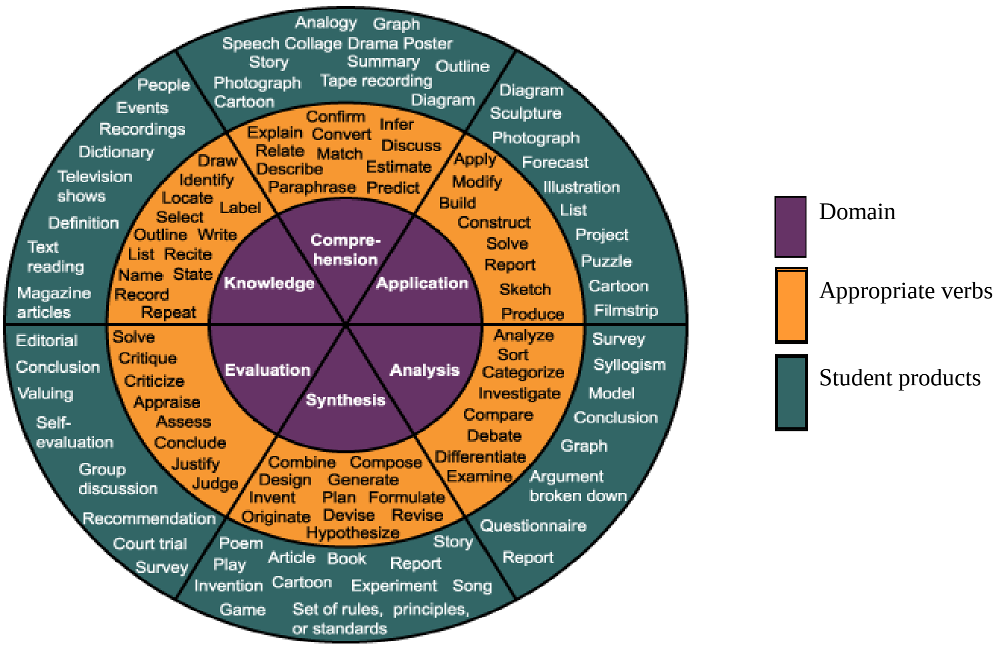
Figure 2
Bloom's Taxonomy (adapted from New South Wales Department of Education and Training, 2005)



Research over the past 40 years or so suggests that the first four levels are indeed a true hierarchy; that is, knowing at the knowledge level is easier than, and subsumed under, the level of comprehension and so forth up to the level of analysis. However, there is some debate as to the relationship of synthesis and evaluation with the other levels; it is possible that these are not set at an appropriate level in the original taxonomy, or they represent two separate, though equally difficult, activities (Seddon, 1978).

Bloom's taxonomy has been presented in a number of different ways after its original proposition, such as the verb-based wheel (Figure 3). Here the inner wheel represents the *domain* and this consists of *knowledge* (draw, identify, locate, select, label, outline, write, record, repeat, etc.); *comprehension* (confirm, convert, match, explain, etc.); *application* (apply, modify, build, construct, solve, report, sketch and produce); *analysis* (analyse, sort, categorized, investigate, compare, debate, differentiate, examine); *synthesis* (combine, design, invent, originate, compose, generate, plan, formulate etc); and *evaluation* (solve, critique, criticize, appraise, assess, conclude, justify, judge). The outer wheel contains the expectations of student products for each domain and appropriate verbs to describe these outputs.

Figure 3
Verb wheel based on Bloom's Taxonomy (adapted from The CalStateTEACH Technology Enhancement Project, 2008)



Examination of this wheel suggests that synthesis and evaluation are two types of thinking that have much in common (cf. the first four levels of Bloom's Taxonomy); however, they are quite different in intention. Evaluation - considered an important part of critical thinking - focuses more on making an assessment or judgment based on analysis of a statement or proposition. Synthesis, on other hand, is more related to creative thinking, and requires an individual to look at parts and relationships and then to put these together in a new and original way.

Huitt (1992) suggests that there is an equivalent-but-different relationship between critical thinking or evaluative thinking, and creative thinking or synthesis thinking, is appropriate. Huitt classified techniques used in problem-solving and decision-making into two groups roughly corresponding to the critical or creative dichotomy. One set of techniques tended to be more linear and serial, more structured more rational and analytical, and more objective-oriented. These techniques are often taught as part of critical thinking. The second set of techniques tends to be more holistic and parallel, more emotional and intuitive, more creative, more visual, and more tactual and kinaesthetic; these techniques are more often taught as part of creative thinking. This dissimilarity as well matches up to what is sometimes referred to as left brain thinking (viewed as analytical, serial, logical, objective) and right brain thinking (viewed as global, parallel, emotional, subjective) (Springer & Deutsch, 1993).

In summary, the literature suggests critical thinking is very important in developing cognition. It allows us to evaluate, explain, analyze, synthesize, and restructure our thinking, decreasing thereby the risk of acting on, or thinking with, a false premise (Ennis, 1987; 1991; 1996). In thinking critically, students use their command of the elements of thinking to adjust their thinking successfully to the logical demands of a type or mode of thinking. As students come to habitually think critically, they develop their special traits of mind; intellectual humility, intellectual courage, intelligent perseverance, intellectual integrity, and confidence in reason (Ayersman & Reed, 1995).

2.5.5 Role and Value of Critical Thinking

Critical thinking skills are considered important by many authors (Browne, Freeman, & Williamson, 2000; Huitt, 1998), and most authors argue that students must learn to become more thoughtful about what they learn in order to develop skills in problem-solving. The main purpose for developing critical thinking skills in students is to prepare them to succeed in the future, and thereby improve their quality of life. Many authors now feel that education must consist of more than an unreasoning accumulation of facts and skills, and to become active participants in a contemporary community requires in students a highly-developed critical awareness to cope with life issues (Huitt, 1998). Most advocates of thinking skills such as critical thinking and creativity highlight the relevance of such thinking skills for everyday living. The argument here is that critical thinking is the art of taking charge of one’s own mind, in which case its value is plain: if we can take charge of our own minds, we can take charge of our own lives. Other authors argue that critical thinking is not an isolated goal unrelated to other important goals in education (Rusbult, 2006). Rather, it is a seminal goal which, done well, simultaneously facilitates a host of other learning outcomes. Rusbult suggests critical thinking is best visualized as a core of education. To illustrate with an example, as students learn to think more critically, they may become more adept at mathematical, historical and scientific thinking. Critical thinking is not normally presented as an intrinsic part of instruction and students are not often exposed to explicit instruction in such skills, with teachers tending to take it for granted that critical thinking is automatic by-product of their teaching. However, Rusbult (2006) argues that without critical thinking being systematically designed into instruction, learning is likely ephemeral, and superficial.

Philosophers also have considered the value of critical thinking with authors such as Paul reminding us that critical thinking is a process of thinking to a standard (Paul, 1990). Simply being involved in the process of critical thinking is not enough; it must done well and should guide the establishment of our beliefs and impact on our behaviour or action. Proficient and critical thinking as an important element of life success to the movement of information age is emphasized by Huitt (1995), who claims that critical thinking needs to be a key focus in schooling. Huitt argues that old standards of simply being able to score well on a standardized test of basic skills cannot be the sole means by which we judge the academic success or failure of our students. Given traditional conceptualizations of the purpose of the education, one might expect that evaluation would focus on higher level thinking such as critical thinking. However, evaluation of general education programs tends to be driven by instrumentation such as national tests, and exams. Research of students' critical thinking skills is rare (Facione, Giancarlo, Facione, & Gainen, 1995), and there are few multi-institutional and longitudinal studies which include sufficient control of variables and appropriate comparison groups (Ewell, 1993; Pascarella & Terenzini, 1991). Empirical research on critical thinking skills is further inhibited by disagreement among theoreticians with regards to the definition of the construct (Ewell, 1993; Jones & Ratcliff, 1993; Kurfiss, 1988). However, recent evaluation of critical thinking skill development suggests that at the college level at least, improvements in critical thinking have occurred (Astin, 1993; Ewell, 1993; Facione, 1990). The next section considers what pedagogies have been helpful in improving critical thinking.

2.5.6 Pedagogies Reported to Enhance Students' Critical Thinking Skills

The literature suggests that higher order thinking skills among students are essential in problem solving, and that critical thinking is an important part of problem-solving (Juremi, 2003). In addition, through explicit teaching of critical thinking, students are exposed to concepts such as inference, deduction, interpretation, judging and argument, all of which encourage them to think critically. There are many teaching approaches reported to improve critical thinking: project-based online learning (Kurubacak, 2006); dialogic-learning (Frijters, Dam, & Rijlaarsdam, 2008); immersion learning (Warren, Memory, & Bolinger, 2004); a collaborative faculty approach (William et al., 2003); problem-solving (Zohar, Weinberger, & Tamir, 1994); evidence-based practice (Profetto-McGrath, 2005); asynchronous discussions (Walker, 2005); problem-solving on the Internet using Web-based authoring tools (Neo & Neo, 2000). For example, Juremi (2003) reports that a PBL approach improved students' critical thinking by teaching them explicit critical thinking learning process skill (i.e., evaluate all the relevant information and knowledge to solve a particular issue; thus by this phase the application of critical thinking subset will occur, making an inference, making an assumption, deduction, interpretation and also evaluation of argument). Other research by Zohar et al. (1994) likewise suggests that activities that expose students to use of critical thinking skills such as discussion in class and in a small group, experimental analysis, data management and problem-solving, are capable of increasing their critical thinking skills.

2.6 THINKING SKILLS

According to the literature, the thinking process comprises three components: mental operations, knowledge, and attitude. Mental operations are carried out by our minds and can be divided into two types - cognitive operations and metacognitive operations. Cognitive operations consist of thinking skills and thinking processes. The thinking processes that are the focus of many researchers and scholars are creative and critical thinking skills, where the objective is to make a decision or solve problems, or both (Brookfield, 1987; de Bono, 1967; Dietsler, 1994; George, 1967; Wallace, Maker, Cave, & Chandler, 2004; Wilks, 1995). Whilst knowledge is a component of metacognition that involves executive control of declarative, procedural, and conditional information relative to a task, it is also a body of information commonly associated with a particular content area or field of study, and attitude, personally held principles or beliefs that govern much of one's behaviour (Kizlik, 2009).

Butts (1981) suggests several appropriate processes of thinking skills can be moulded, especially for those who are studying science. The main point here is to solve problems that can be learned through experience in science education (Butts, 1981). These thinking skills include analyzing, comparing, categorizing and classifying, identifying cause and effect, problem-solving, persuading, empathizing, synthesizing, interpreting, evaluating, communicating, and applying (Zwiers, 2004).

Beyer (1991) summarizes much of the research about thinking skills as follows:

1. Thinking skills cannot be learned as a learning outcome automatically from learning a subject course;
2. Thinking skills cannot be learned in a simple learning from a course or little teaching / a few lessons;
3. It is very rare that the transfer of thinking skills occurs by itself outside the original learning context;
4. To dominate a skill, it is supposed to be over-learned at the earlier stage;
5. At the earlier stage of learning skills, one must be explicitly focused towards learning skills. Some interference from subject, course and others skills must be limited or avoided;
6. Earlier teaching skills must be followed by often guided practice;
7. To make transformation easier, skills must be applied in context linkage and in difference situations with proper teaching;
8. A skill generalization will be produced by executing some tasks that require operation of thinking skills;

9. Learners will be more motivated to study skills when it is assumed that the skills are needed to achieve an objective in an ongoing subject course; and
10. Systematic and explicit observation of cognitive operation are required to understand learning content and produce higher achievement.

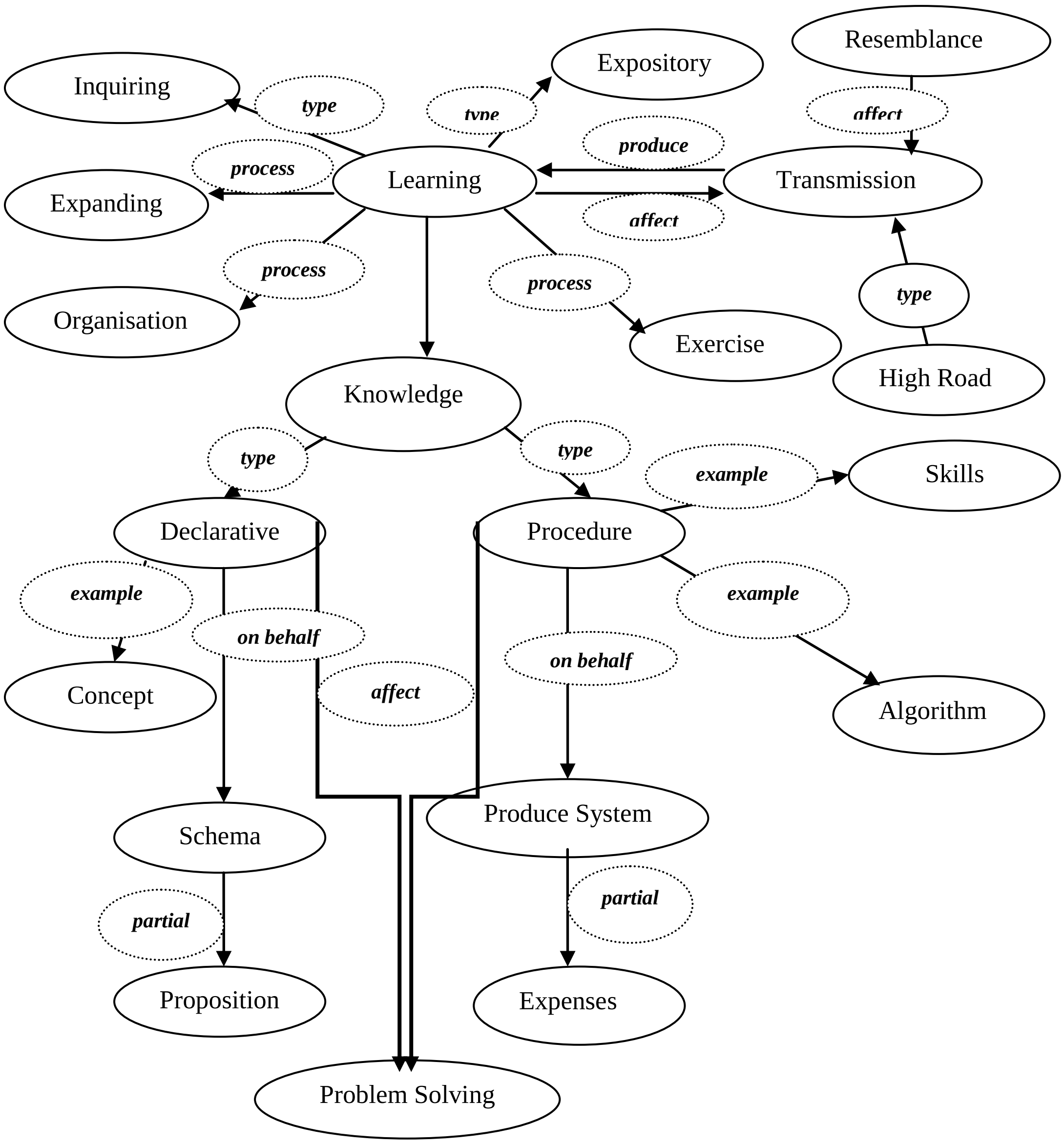
In summary, it seems that some of these thinking skills actually overlap with creativity and critical thinking. Hence, the next section discusses in detail how these thinking skills can be associated in the learning context to solve problems, especially in science education.

2.7 LEARNING PROCESS AND PROBLEM-SOLVING

There is a substantial body of research about the learning process and problem-solving, and here the literature concerning learning stages and how the learning process influences problem-solving is considered. According to Slavin (1994), constructivist teaching approaches which place emphasis on active learning can enhance thinking skills. Constructivist approaches to teaching often involve cooperative learning approaches such as group and whole class discussions. McClure, Sonak, and Suen (1999) say that learning, whether it is inquiry learning or expository learning, means that declarative knowledge and procedure knowledge is achieved. Gaining such declarative and procedure knowledge influences students' ability in problem solving. The links between these concepts are shown in Figure 4, and these suggest that creativity and critical thinking can be seen in terms of both cognitive process and learning outcomes.

Figure 4

Relationship between learning, knowledge and problem solving (after McClure et al., 1999)



Clarke (1990) suggests that all learning consists of problem-solving, and that experience is important and necessary in order to solve problems when learning. However, consistent with a constructivist view of learning, the learning processes used to enhance thinking skills need to focus on the individual learner. There are many factors that influence how an individual thinks, such as how fast they process information, and how they accept or deal with challenges. The issue from a constructivist viewpoint is how it can foster talent in each individual to help them monitor and control their thinking processes and engage in metacognition (Juremi, 2003). Vykotsky (1962) says learning is a social activity and an important factor is to shape and form the learner's thinking model, and to expose and challenge them in their thinking. A constructivist approach thus places emphasis on inquiry and experimentation, and open problem-solving. Open problem-solving has been reported as successful in the learning science in terms of many perspectives (Ahlfeldt et al., 2005; Distlehorst & Robbs, 1998), reading (Duffy & Rochler, 1986), writing (Bereiter & Scarmadalia, 1987), and mathematics (Carpenter, Fenneme, Peterson, Chiang, & Loef, 1989; Kwon et al., 2006).

Many learning models are based on rote-learning or memorization, and higher order thinking process and learning approaches such as scaffolding and problem-solving, do depend on students remembering content. A feature of memory is the recall process, and research in this field suggests we need to emphasize this type of operation or activity. There are three important processes if students are to store knowledge in their long term memory: reiteration; encouragement; and encoding.

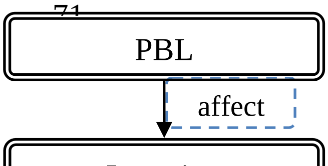
From a cognitive perspective, effective learning involves three states. The first state is the activation of prior knowledge (Anderson, 1977; Bransford, 1979). Structuring is the particular learning domain characteristic, and here 'old knowledge' can be used to learn new knowledge. This can be done by connecting and relating old knowledge to new knowledge (Bransford, 1979). Activation of relevant old knowledge with new is crucial, and the effectiveness of a learning method is often dependent on how it can help to activate learner's prior knowledge (Mayer, 1992). The second state concerns knowledge elaboration, and is related to activation. Elaboration is a process of generating new ideas that are accepted from an outside sources (Gagne, 1990). This involves incremental memorization of declarative information and learning new information (Anderson, 1976). The third state is knowledge organization, the way we structure information kept in our memory. Information that is structured inline can be retained and recalled more easily. Gagne (1990) suggests structuring enables close relations to be formed, and strengthens links to information required to be memorized so that activation occurs in the relevant 'region' and it is not necessary to go to a new or unrelated region. Structuring is then significant in decreasing the burden on short term memory. It does this by providing a step to monitor all information that is structured, without the need to transfer it all back into the short term memory.

Selective attention theories suggest that focus be placed on how we acquire information (Rothkopf, 1970). The activation activities are used to attract the learner’s attention so that they can subsequently use their creativity and critical thinking skills when choosing to recall relevant information for the problems. There are four main components that stimulate thinking in the classroom: i. an environment that stimulates thinking where thinking is seen as a valuable activity; ii. using strategies and techniques for structuring information; iii. stimulating metacognition through a thinking process model demonstration, which helps students to consider the thinking process they have done; and iv. teaching how to think explicitly. A model of teaching problem-solving methods is necessary to support learners to find information, or with the provision of information, so that they can solve problems successfully (Son & VanSickle, 2000). McClure et al. (1999) propose the relationship between learning, knowledge acquisition and problem solving as shown in Figure 5.

From about 1990, the literature suggests that teaching creativity and critical thinking needs to be linked to meta-cognitive reflection about learning (Fogarty & McTighe, 1995). In the research reported in this thesis, it is proposed that PBL will influence the learning of problem-solving, and problem-solving is the main focus of learning, (see Figure 5). The learner will use declarative knowledge or semantic and acquiring skills such as creativity and critical thinking skills to solve problems. This process will iterative and ongoing, meaning it may be retained in the learner’s long term memory, making recall more rapid and automatical.

Figure 5

Relation of problem-based learning, problem-solving learning and skills in this study.



2.8 CHAPTER SUMMARY

Not surprisingly, most studies of how specific pedagogies enhance creativity and critical thinking are based on a face-to-face learning teaching approach. Researchers describe these two distinctly different kinds of thinking, creative and critical thinking, in many ways. The literature also suggests that both kinds of thinking here been thought of in face-to-face methods worldwide. However, Rosernberg (2001) asserts that Internet technologies have changed the education, technological and economic landscape so dramatically that it is now crucial to make use of these technologies in education. Likewise, Hall (2001) reports that e-learning is the fastest-growing area in education. Thus the Malaysian Ministry of Higher Education is being urged by the government to ensure graduate students are supposed to feel comfortable learning in the new era of information and communication technologies and at the same time capable of benefitting from it. Hence, the purpose for the work reported in this thesis is to investigate the effectiveness of PBL in developing problem-solving skills, creative and critical thinking via online learning in physics at the tertiary level. Therefore, in the next chapter, online learning is considered in terms of its definition, pedagogy, the importance of online learning, and the capacity of online learning when blended with PBL to enhance creativity and critical thinking, particularly in the Malaysian context.

CHAPTER 3: INTEGRATING PBL AND ONLINE LEARNING

3 CHAPTER OVERVIEW

This chapter considers online learning and highlights some of the recent issues of integrating PBL with technology. The introduction of this chapter is followed by details on issues and reported advantages of PBL online. The next section discusses facilitation, dialogic learning and online teams in this particular field. This chapter also synthesizes the PBL online experience, activities and practices in higher education system, emphasizing pedagogical considerations in delivering online learning. The last two sections discuss learner and technology issues in Problem-Based Learning (PBL) online, and ends with the chapter summary.

3.1 INTRODUCTION

There is now a substantial literature on how PBL and online learning might be merged (see e.g., Candela et al., 2009; Cheaney & Ingebritsen, 2005; Jennings, 2006; Lee, 2006; Lim, 2005; Savin-Baden & Gibbon, 2006; Savin-Baden & Wilkie, 2006), a combination that is sometimes called PBL online (see below, where this notion is expanded). The argument in favour of this combination is that PBL online is capable of promoting both the development of problem-solving, and student ability to use information technology; emphasizing the advantages of PBL as a promoter of process, as opposed to content, objectives (Watson, 2002). At first, technology was only used by teachers for administrative purposes, or for information dissemination (Lim, 2005), but as teachers became more familiar with such technologies, they sought to explore the potential of ICT in delivering collaborative inquiry through online forums (Lim, 2005). Some authors report integrating constructivist-based education of practical work such as PBL with online learning (Lim, 2005).

Integrating PBL with online learning basically means merging the pedagogy (which in this case is PBL) and delivering the content partly, or entirely, online via the Web. A key feature of PBL online is the online collaboration that occurs as part of the learning activities (Savin-Baden & Wilkie, 2006), and this focuses on team-oriented knowledge-building discourse, and reduced teacher-centred learning (Savin-Baden, 2006b). Savin-Baden also notes that PBL online involves students working collaboratively in real time, or asynchronously, and collaboration tools such as shared whiteboards, video conferencing, group browsing, e-mail, and forum rooms are vital for the effective use of PBL online. Students can learn through the use of Web-based materials such as text, simulations, videos, demonstrations and related resources (Savin-Baden & Gibbon, 2006). In some cases, no print materials are provided, and students only can access materials directly from the course website (see e.g., Yong, Jen, & Liang, 2003). In other cases (e.g., Savin-Baden & Gibbon, 2006) there is a focus around a particular site, through which students are guided by the use of strategy problems, online material and specific links to core material, rather than wholly online delivery of PBL. In both cases, use of web sites is mostly student led, and the materials provided support the learning they undertake in face-to-face PBL groups. An example of such a site is that for the SONIC (student online of nursing integrated curricula) project (Savin-Baden & Gibbon, 2006), which implemented PBL in an interactive environment using FlashPlayer-based physiology resources in order to improve students expertise in nursing. Savin-Baden and Gibbon in an investigation of the interrelationship of PBL and interactive media, report that the assessment of combined PBL and interactive media to date have not extrapolated the difficulties of combining these two approaches. Further information on PBL online is detailed in the next section.

3.2 ISSUES AND REPORTED ADVANTAGES OF PBL ONLINE

Savin-Baden and Wilkie (2006) describe how PBL can be implemented successfully in an online learning environment, noting that it must be integrated with the right pedagogy, and must be handled by an experienced practitioner, especially when it comes to tutoring or facilitating learning (see also Barrows, 2002). Hong (2002) reports that PBL implemented in a Web-course in Malaysia at the university level led to enhanced student attitude and academic performance, mostly as a result of implementing a conversation discussion room online, so that students could engage in online discussion asynchronously. Lim (2005) likewise supports the benefits of asynchronous online forums to support discussion within learner groups to improve the current use of online forums in the PBL approach, and Sulaiman (2004) integrated PBL with online learning, using simulation, pictures, chat rooms and other learning aids. In a variation of PBL online, Lim (2005) incorporated an online forum and PBL in Law so learners could discuss facts and interview their clients electronically. Gosmann, Stewart, Jaspers, and Chapman (2007) sum up much research about PBL online, saying PBL can be integrated into a Web-course delivery and that such PBL online is at least as effective as a traditional PBL curriculum version, and that students enjoy learning via such a PBL approach.

It is reported that PBL online has many of the trademarks of traditional PBL models developed in 1960s by McMaster University, Canada, and delivered through face-to-face pedagogy. PBL online, like traditional PBL, is more than a linear approach to problem solving, where problem scenarios are used as key learning or key issues in online learning environments. However, Savin-Baden and Wilkie (2006) say that many practitioners, educators and researchers hold concerns about whether PBL online might adversely affect the existence of face-to-face PBL, because PBL online may be seen as being more cost effective. One concern here is practitioner anxiety that PBL online may conflict with intentions of PBL generally, since some forms of PBL online tend to put more emphasis on solving closely defined or outlined problems, meaning PBL online may be less successful in encouraging students to become independent inquirers who own their learning. A second concern is that learning in groups online may inhibit students' capacity to work through team difficulties and conflicts in the way face-to-face PBL occurs (Savin-Baden & Wilkie, 2006). Nevertheless, PBL online is an approach that stresses complementing, constructing and improving what is already in existence, rather than trying to replace face-to-face learning pedagogy activities (Gossman et al., 2007; Savin-Baden & Wilkie, 2006), and it is reported that PBL online promotes good cognitive engagement among students (Gossman et al., 2007).

PBL online also aims to enhance students' ability to form structured approaches to deal with PBL exercises. When undertaking a PBL exercise, students are required to analyse and assess the given situation, make choices as to how they might tackle it, and provide recommendations for future action. They can, for example, make observations, seek further information from various sources and undertake common diagnostic tests. The use of PBL online to deliver PBL can, therefore, integrate the theory and the practice of the topic being studied. A PBL online approach allows students to be presented with a previously unseen problem (Gossman et al., 2007), and the literature suggests that it also can support student learning by reducing cognitive load because of the supportive learning environment (Gossman et al., 2007). What is important is that students have access to the objectives of the module, and the ability to negotiate their own learning needs in the context of the given outcomes (Savin-Baden & Wilkie, 2006). Facilitation of learning in PBL online requires teachers or tutors to have access to the ongoing discussions without necessarily participating fully, giving the groups minimal guidance, and ensuring the group discussion is maintained (Boud & Felleti, 1991; Camp, 1996; Savery & Duffy, 1995). It is important to realise, however, that different forms of environments utilized, whether created specifically for PBL, or adapted to be used with it, all seem to have a strong management genre in terms of the forms of authorship used. In other words, the design and management of the digital space is always strongly influenced by the teacher/tutor and their pedagogical inclinations or philosophies (Savin-Baden & Wilkie, 2003). The design of such digital spaces could be seen as being authored; both in the sense of authorial design behind the Web and the authors of the written text who make up components of the web site(s). While the authoring of text (whether traditional or virtual) and the authoring of design can be seen as very different functions, it seems that both have the capacity to “impede the free circulation, the free manipulation, the free composition, decomposition, and free composition of fiction” (Foucault, 1988, p. 209). This would seem to introduce questions about the extent to which, for example, constructivist-based approaches to learning can be authored and managed in PBL online. Hence, as Ravenscroft (2004, p. 139) argues, “We need to investigate, examine and where possible, design appropriate learning communities if we want to support effective e-learning discourse.”

The literature thus suggests that group learning is the norm in PBL whether face-to-face or online, and group characteristics must be taken into account when establishing an effective collaborative learning group. To compose a small effective group, whether cooperative, collaborative, or mixed, a number of factors must be taken into account: students’ academic ability, gender and ethnicity

(Aronson, 1978; DeVaries & Slavin, 1978; Slavin, 1978a; Slavin, 1978b; Springer, Stanne, & Donovan, 1999). Slavin (1980) says we must also include mutual concern among students. Some authors suggest we should maximize heterogeneity of ability levels (Aronson, 1978; DeVaries & Slavin, 1978; Slavin, 1978a; Slavin, 1978b). There are some outcomes that have also been measured or seen in cooperative learning; such as liking school, self-esteem, time on-task, ability to take the perspective of another person, and various measures of cooperativeness and competitiveness (Slavin, 1980). From a Malaysian perspective, work by Neo and Neo (2009) suggests that to compose a positive, effectively collaborative group, students should be randomly assigned, come from different backgrounds or faculties, and work with someone they do not know.

3.3 FACILITATION, DIALOGIC LEARNING AND ONLINE TEAMS

There has been increasing debate about whether facilitation is just one form of good teaching or whether, in fact, it is an entirely different approach to teaching (Savin-Baden, 2006a). The literature suggests that facilitating face-to-face PBL is a complex activity, which requires tutors to be trained to become facilitators (see e.g., Juremi, 2003; Savin-Baden & Wilkie, 2006). Key to this is a hands-off role, and Barrows and Tamblyn (1980) claim that the job of the teacher or tutor in a PBL tutorial group, rather than being to convey knowledge, should be to pave the way for student learning. For tutors engaged in PBL, this transition from lecturer to facilitator, requires them to revise their assumptions about what it means to be a teacher (Savin-Baden & Wilkie, 2006). Thus, in this environment, the position of the teacher demands new techniques and skills for the teaching faculty so that they are able to empower students to take an active role in their own learning, and in teaching one another (Barrows & Tamblyn, 1980). Becoming a facilitator can then be intimidating for some teachers or tutors (since they lose power and dominance), because even though they may have taught students through workshops and small group sessions, their role as a facilitator in PBL requires more facilitating and guiding than other forms of teaching (Neville, 1999). For many teachers, this involves 'letting go' of decisions about what students should learn, trusting students to acquire knowledge for themselves, and accepting that students will learn even if they are not supplied with a lecture or handout by their tutor (Savin-Baden & Wilkie, 2006). The conflict for many tutors is in allowing students freedom to manage knowledge, where students determine their learning objectives, rather than keeping their previous roles and relationships with students as the controllers and patrollers of knowledge (Neville, 1999). There are suggestions in the literature that an early module part of the PBL course should seek to equip students with an understanding of the objectives so they become more knowledgeable about PBL (Neami & Powis, 1981). As students' skills and knowledge about PBL increase, the tutor's role or style also should change (Neville, 1999). Whether in face-to-face PBL or PBL online, there appears to be an assumption that there are specific roles, attributes and ways of being that characterise some facilitators as being good or better than others, and somehow they must be catalyst, clarifying and amplifying without prescribing (Collier, 1980). PBL online does require that tutors are support on how they handle and manage their students (Lycke, Strømsø, & Grøttum, 2006). An electronic moderator is someone who "presides over an electronic online meeting or conference" (Salmon, 2000, p. 3).

What is the different between *facilitating* and e-moderating? As noted above, it seems most likely that PBL online requires more of a silent presence by the facilitator, along with appropriate guiding and hinting, but not telling students in direct ways that seems to be evident in much e-moderating (Savin-Baden & Wilkie, 2006). However, the skills in facilitating face-to-face PBL are similar to those required for facilitating PBL online (Savin-Baden & Wilkie, 2006). It seems that what is effective practice for face-to-face facilitators does not necessarily translate into effective practice in an online setting. The main reason for this may be the absence of non-verbal cues in PBL online (Savin-Baden & Wilkie, 2006). It is reported, for example, that non-verbal cues influence activities such as requesting help and information, getting commitment, and recognising the attempts and efforts of other group members (Rosenberg & Sillince, 2000). Hence, learning via information communication technology (ICT) may make such collaboration hard to achieve. However, Wegerif and Mercer (1996) claim that rich conversations can occur in collaborative forms of online learning, if problems that are more likely to require 'exploratory dialogue' are used, that is, problems that involve explaining, defining, elucidating, clarifying, challenging and justifying. In summary, facilitation is a specific kind of task and tutors need to develop a strategy to prevent themselves from becoming too concerned about passing on knowledge to students (Barrows & Tamblyn, 1980).

Although there is now a substantial research base covering what occurs in face-to-face PBL (e.g., Ahmad, 2008; Barrett, 2007; Mohammed, 2002) there are fewer of studies that have considered students' activity when they go online. There are reports of tutors' and students' involvement in engaging with certain online environments (Bayne, 2005; Donnelly, 2004; Salmon, 2000), and in discussions about tutor participation. So far, there is little evidence in the literature about what goes on in the minds of tutors and students who participate in PBL online. How and what learners learn in groups is not clear in the context of online or face-to-face PBL (Savin-Baden, 2006b), although Ravenscroft (2003; 2004) identifies a number of issues in online communities. Similarly, Pearson (2006) evaluated PBL that used ICT based on four criteria: the extent to which PBL facilitated academic discourse; the extent of 'new' knowledge about ICT that had been created; the role of the tutor; and the online learning environment provided. The result confirmed that PBL offered a convenient method of investigating ICT in online learning environments, most important to knowledge of challenges linked with the implementation and use of new technologies in various educational settings.

Facilitators and students in PBL online can influence one another's views about what is knowledge, the interplay of content and process and the ways they handle engagement in the group (Savin-Baden & Wilkie, 2006). Disagreement may occur due to a group member feeling a peer is not participating, or alternatively, if the online facilitator is interrupting rather than interacting. The way conversations occur in PBL online affects the nature and process of the learning that takes place. For example, asynchronous conversations are likely to produce a reflective learning space, in which the learner is able to respond in a way that is both a reply and a reflection. Such written commentary in learning support seldom happens in face-to-face PBL, where discourse flow is typically characterised by fast exchanges of short sentences. In asynchronous PBL online, students often seem to be in the process of sense making as they converse. Such sense making affects the quality of the dialogic learning in the group, and results in more meta-commenting than occurs in face-to-face PBL. Dialogic learning, that is, learning that happens when insights and comprehension occur, comes through dialogue in a learning setting (following Mezirow, 1981). Learning occurs when students describe concepts and ideas when they are presented with problems, and then use that experience to make sense for themselves, and to explore further ideas. This kind of learning, learning with and through others, can motivate students to critique and challenge ideas, whether virtual or face-to-face. Learning through dialogue like this brings to the fore, for students and tutors, the value of prior experience to learning and thus can engage students in explorations of and (re)constructions of their identity.

Many of the questions and queries raised by authors concerned about using PBL online seem to relate to wider considerations about the relationship between the technology and the pedagogies of PBL. For example, Barrows asks:

> Can a communication technology be developed that will mediate PBL yet avoid distorting the PBL process as it is used in face-to-face small group work? It would have to be able to present an ill-structured problem verbally, visually and auditorially as appropriate. It should allow for both synchronous and asynchronous discussion. There should be a whiteboard, operated by a member of the group, to facilitate and record the group's progress, recording ideas generated, data acquired, and learning issues to be pursued. I am waiting with baited breath. (2002, p. 122)

Perhaps Barrows has missed the point of PBL online, since PBL online has different requirements to face-to-face PBL at all levels: the nature and type of dialogue has changed, the means of giving and receiving information is largely through hyperlinks, and facilitation is often about indicating presence and using hinting and prompting exploration, rather than some kind of embodied notion of presence. Nonetheless, there are still doubts about the way in which problem scenarios are designed for PBL online, and the extent to which digital settings can be learner-centred and learner-driven. Possibly too, we need to be asking whether students are allowed to recreate the problems wiki style. If they do, how might this then influence the perceived authenticity and authorship of the problem? So far, regardless of the worries and concerns in relation to the notions of a bodiless personality identified by both facilitators and students, in a number of studies, PBL online does seem to provide a new learning space for identity (re)construction and formation, with technology that can sustain new forms of interactive learning (Savin-Baden & Wilkie, 2006).

There is now a substantial literature on effective small group learning generally. Apparently there are few differences between cooperative, collaborative or mixed forms of small-group learning in terms of student achievement (Springer, Stanne, & Donovan, 1999). Indeed, it seems out-of-class meetings such as study sessions have greater impact on students' achievement than in-class collaboration, and in-class collaboration has more favourable effects on student attitudes than out-of-class meetings (Springer et al., 1999). Various procedures used for assigning students to groups also do not seem to have much effect on student achievement. Slavin (1995) says that what matters is a combination of four major theoretical perspective on cooperative learning and its achievement: motivational perspectives (e.g., rewarding groups based on group performance); social cohesion perspectives (e.g., groups will help one another learn as they care about one another and want one another to succeed); empirical support for the social cohesion perspectives (e.g., experiment, group investigation, and hands-on learning); and cognitive perspectives (e.g., communication within groups will improve student achievement for reasons which have to do with mental and intellectual processing of information). However, in the Malaysian context, students are often reluctant to answer questions posed by their teacher/tutor face-to-face, and oftentimes they avoid activities in academic discussion (Seng & Mohamad, 2002).

A number of Malaysian-based studies about co-operative learning have been reported (see e.g., Neo, 2004). This work has considered the makeup of groups, and, for example, investigated whether students in a class are divided into several groups of students randomly (Neo, 2004), or given the opportunity to take charge - dividing themselves into groups of 4-5 members and selecting a leader for each group (Neo & Neo, 2009). In either case, positive feedback was received about students' attitude towards doing such projects, and working in teams throughout the respective phases of learning (i.e., problem identification, project conceptualization, project authoring, presentation, and reflection) (Seng & Mohamad, 2002).

3.4 PBL ONLINE EXPERIENCE, ACTIVITIES, AND PRACTICES

This section describes the experiences and activities of tutors and learners using PBL online. Issues addressed include the blending of technology and pedagogy in PBL online, and literature on the design of curricula for PBL online; the skills needed for the approach and those acquired through the engagement with PBL online; and the technology's relationship with the pedagogy; the actual technology used (e.g., the virtual learning environment (VLE), Flash Player, etc.) and elements of the pedagogy itself (e.g., online, flexible, blended learning).

Cousin (2005) recommends consideration of whether pedagogy makes use of existing technology, or if the technology effects the pedagogy, saying that teaching and learning strategies have always been related to the technology available at the time, be it chiselling in stone or palm-held wireless computers! She argues that the technology contributes to or, in some cases (e.g., brainstorming & flipcharts), drives the teaching strategy. This argument is supported by Candy (2000) who contends the Internet deserves to be considered a pedagogy in its own right. According to Savin-Baden and Wilkie (2006), current pedagogy that helps people's learning via online is ill-defined, but the current online pedagogies are mostly based on teacher-centred education. Savin-Baden and Wilkie argue that learning will only be improved by the use of technology if the chosen technology is matched to a planned educational strategy (Dupuis, 2003). Without this well thought-out arrangement, there is little likelihood that learning will be successful; the computer should not just simply be an addition to pedagogy of online learning but the technology should be *incorporated* into the teaching methodology. Cousin (2005) suggests that neither the pedagogical method nor the media by which it is conveyed drives the other, but that both components are an inextricably knitting together of all essential elements. PBL online has grown as the pedagogy has exploited developing technology related to the learning context (student: facilitator/teacher ratios; geographical remoteness; accommodation limitations, etc.) (Savin-Baden, 2006a).

3.5 PEDAGOGICAL CONSIDERATIONS IN DELIVERING ONLINE LEARNING

The literature suggests that it is important that teachers/tutors become familiar with technology and the appropriate pedagogies if they are to use PBL online effectively. Jennings (2006), for example, reports that teachers skilled both in using virtual learning environment (VLE) and in PBL, ran PBL online without anxiety. Similarly, Savin-Baden and Gibbon (2006) likewise report learner groups with some knowledge of PBL and VLEs engaged more effectively with PBL online (see also Cook & Dupras, 2004; Lee, 2006 for research about PBL online medical education).

It seems that learning preference influence student capability of engaging successfully with PBL online (Clarke, 2005). For example, some students find being presented with a lesson and/or learning plan that relies on visual material, helpful and others do not (Clarke, 2005). There are ways of using the technology to provide students with learning experiences that rely on more than visual capabilities. For instance, as mentioned above, the SONIC project reported by Savin-Baden and Gibbon (2006) involved a spoken element, and non-verbal communication was supported by social activities that positively enhanced problem solving (Rosenberg & Sillince, 2000). Hence, whilst the loss of non-verbal cues may disadvantage some students, there are ways of employing ICT to address this - at least in part. Wood (2001), for instance, describes computer programs that integrate a non-human voice in response to student postings. The programmed responses can be drawn from observation of human facilitative responses.

3.6 LEARNER AND TECHNOLOGY ISSUES IN PBL ONLINE

The literature identifies a number of issues concerning the learner and technology. In PBL online, students are given the chance to develop a *persona* which differs from their real self, known to friends and family. Whilst some students find this exciting and novel, others speak of worries associated with this created self, such as loss of control and of making postings that they later regret (Bayne, 2005). Other issues are that some students report feelings of shyness and reluctance to expose themselves in the permanent setting of online conversation groups. Their contributions are there for peers to see, scrutinize and respond to over time. In contrast, the spoken words in traditional PBL are seen as temporary, and related to the idiosyncrasies of human memory, and thus somehow less concerning. Students reluctant to post ideas online and share their opinions and results with others seem to have few difficulties in online café type surroundings. This suggests there is then a blurring of social and learning environments online, with concepts such as infotainment (Ritzer, 1996), Bayne's 'playful experiment' (Bayne, 2005), game-based science online learning (Fatah, Tanalol, & Tahir, 2005), or ADDIE methodology (Analysis. Design, Develop, Implement, and Evaluate) as the instructional design model for game based learning (Omar & Abd. Aziz, 2005) meaning the boundaries between work and play are becoming indistinct. This may make it harder for students to remember, arrange and recognize what is work, and what is play. One result of this may be the sort of situation reported by Bayne (2005), where an online persona is generated for online learning in a way similar to computer games such as Tomb Raider or Max Pyne where the player assumes the character of Lara Croft and Max Pyne. The net result may be inability to decide what should be posted in virtual cafés, and what should be contributed to online discussion strings in PBL online (Savin-Baden & Wilkie, 2006).

The level of interactivity with the resource as well as the amount of discussion generated depends not only on students' cognitive abilities and readiness to give and provide, but also on their capability to navigate sites and their way around the virtual learning environment (VLE). Given the literature on infotainment (Ritzer, 1996) and the growth of the Internet, there is, perhaps, an assumption that today's students will arrive on the virtual campus fully equipped with all the technological skills required for online learning. This is a questionable assumption, especially given the diverse nature of the student body. Students who choose online courses may do so from a convenience and access perspective by preference, and this does not mean online learning corresponds with their preferred learning style. In support of this view, the literature indicates that in the early stages of learning online, much of the students' time is spent learning technical skills, such as posting to discussion boards, sending email, and conducting web searches, rather than engaging with course content (Atack, 2003). The learning of these skills in some cases can take up to half the time dedicated to the module. Some online learners say that having 'one's own room' to work in is an advantage of online learning (Atack, 2003), but others say that the study space should be flexible, amalgamating with family and working life rather than being separate from it, working online at home or during breaks or quiet periods on work placements (Savin-Baden & Gibbon, 2006). A number of students' difficulties in online learning are associated with technical issues such as complaints that the server system is sometimes down, the fact that no broadband is available in the setting along with technical difficulties in course registration (Mohamad, 2005). The rapid development of technology and the rising number of software packages available often means that students are required to download programs in order to access materials (Deepwell, 2005; Syson, 2005). Though these plugins are free, extra navigation is necessary and may put students off, specifically those who do not have (or cannot afford access to) fast broadband access in their home setting. Dennis (2003), comparing face-to-face PBL with PBL online, emphasizes the need for training sessions to handle and administer the software, and Donnelly (2004) likewise reports that lecturers often lack the basic knowledge of technology or specific software packages. Rather than getting instruction or guidance from the software itself, teachers and learners prefer to be trained by more capable tutors (Atack, 2003). Other difficulties are associated with the way teaching staff interacts with students, such as the quality of notes posted by the teachers, and that in some cases the notes only repeat lectures. Mohamad (2005) thus suggests that students also need to understand the benefits of using online learning, and that online learning should be seen by them as a process of learning rather than convenient technology.

Technology has grown and developed rapidly in the past decade (Deepwell, 2005; Syson, 2005). Applications of technology to problem-based learning with respect to student interactions were discussed. From an educational perspective the use of technology is still regarded as being new, with many experienced teachers lacking the skills to capitalise fully on the benefits of these virtual learning environments. The current situation may be another example of a theory-practice gap, where the learning theories required to explain how students learn online and ways in which that process may best be supported, have yet to develop with the opportunities offered by the technology.

Overall the literature indicated that PBL and online learning are the way for the future and this is consistent with the notion made by the government that wants to revise graduate students especially at tertiary level using more efficient technique of online learning. That is leaves and emphasises in this thesis, is online learning and PBL worth doing and does it capable to improve students' creative and critical thinking.

3.7 CHAPTER SUMMARY

In conclusion, the literature suggests there are many online learning web-pages that have been developed, but most are teacher-centred. This literature review points to the importance of developing student-centred online learning embedded in a constructivist view of learning and involving activities such as collaborative learning and co-operative group learning. Thus PBL online is potentially an important practice to accompany the development of face-to-face PBL. PBL online at the tertiary level thus has the capacity to help students, including mature students, learn knowledge and skills, and gain in expertise in the use of ICT at the same time. This is consistent with the stated desires of the Malaysian government who want students to become familiar with computers and ICT generally, and to develop as creative and critical thinkers.

The next chapter will focus more on the theoretical underpinning of this thesis, discussing both the learning dimension and the PBL dimension.

CHAPTER 4: THEORETICAL UNDERPINNINGS FOR THE THESIS

4 CHAPTER OVERVIEW

The description of the literature on problem-based learning (PBL) in science education presented in the previous chapter is based on the research questions set out in Chapter 1. The present chapter seeks to draw together dimensions that form the theoretical underpinnings for the thesis presented in Figure 6. The first dimension is the *learning dimension*, and considers students' learning process - particularly in physics. The topics emphasized here are how students learn in physics, and suitable teaching approaches in physics. The second dimension is the *PBL model dimension*, and this consists of PBL models defined by Barrows, Torp and Sage; theories of cognition and metacognition; thinking models and problem-solving models. The present chapter also refines the conceptual framework for the thesis, along with a description of the development of the PBL model. Some clarification about the research scope at the end of the chapter is included. The third dimension is the *research dimension*, which is detailed in Chapter 5. This chapter is divided into eight main sections. This present chapter is presented under nine subheadings of learning in physics; problem-based learning model used in this thesis; cognition and metacognition learning theories; thinking models; problem-solving models; conceptual frameworks for the thesis; developing the problem-based learning modules used in this thesis; research scope; and the chapter summary.

Figure 6
Theoretical underpinning for this thesis

Theoretical underpinning in this thesis

Learning Dimensions (Chapter 4)
Students' Learning Process in Physics
i. How students learn in Physic
ii. What is the suitable alternative of teaching approach in physic?

Research Dimensions (Chapter 5)
i. Research Paradigm
ii. Research methodology
iii. Qualitative and Quantitative research methods
iv. Research methods used in the thesis

PBL Dimension (Chapter 4)
i. PBL models
ii. Theories of Cognition and Learning Metacognition
iii. Thinking Models
iv. Problem-Solving Models

4.1 LEARNING IN PHYSICS

4.1.1 How Students Learn Physics

How students learn has been the subject of much research in science education. However, Latuor (1987) observes that a large number of studies of science 'learning' in fact deal mostly with what he describes as 'ready-made science' (i.e. students not really engaged with the process of learning, instead learning consisting of memorizing a concept or complex algorithms in order to answer exams and exercise questions). Roth (1998) summarizes much research in this area across several domains of physics. He observes that much of this research is qualitative in nature, and concerns the learning processes of a small number of students in different content areas of physics: mechanics (e.g., McDermott, Rosenquist, & van Zee, 1987; Trowbridge & McDermott, 1980), relativity (e.g., Hewson, 1982; Saltiel & Malgrange, 1980), electricity (e.g., Dupin & Joshua, 1987; Fredette & Lochhead, 1980; Gutwill, Frederiksen, & Ranney, 1986), light and optics (e.g., Bendall, Galili, & Goldberg, 1993; La Rosa, Mayer, Patrizi, & Vicentini-Missoni, 1984), waves and sound (e.g., Linder & Erickson, 1989; Maurines, 1992), thermodynamics (e.g., Hewson & Hamlyn, 1984; Nachmias, Stavy, & Avrams, 1990). There are similarities and differences regarding the theoretical bases and analytical frameworks used for such studies. These studies investigated the learning processes using rich data gathered during instruction that was designed according to the authors' theoretical frameworks. Some findings show examples of students' learning process leading to understandings that were neither intended nor noticed by the teacher during instruction. These learning process studies describe in detail interrelations various aspects of the instructional setting (e.g. social configuration, artifacts, materials, discursive resources), and cognitive processes during teaching-learning situations.

In recent years, physics educators have begun to look more closely at what their students understand about physics concepts (see e.g., Chen & Whitehead, 2009; Kruhlak & Vanholsbeeck, 2008). Students' patterns of response to questions about circuits' phenomena, for example, often are in conflict with those accepted by the physics community. The term misconceptions – also known as the students' incorrect pattern of response (Englehardt & Beichner, 2003) - is seen by some authors as a pattern or part of a coherent naïve theory of some physical phenomena. In other cases, it is seen as a more fragmented and primitive response produced on the spot as a result of the question posed during teaching or perhaps research.

McDermott and Redish (1999) question why physics students, even those who are considered smart and hardworking, often study in ways considered unproductive and fruitless by physicists and physics teachers. It seems that despite the repeated pleas of their instructors, many students memorize and remember formulas and problem-solving skills algorithms, rather than trying to develop a deeper meaningful conceptual understanding. To be fair, this may be because such learning processes have proven successful in past learning experiences. But McDermott claims it also may be because rote-based study habits stem from naïve epistemological beliefs – beliefs about the nature of physics knowledge and learning (see also Eylon & Reif, 1984; Schommer, 1990). For instance, Hammer (1994) says some epistemologically naïve students think that physics knowledge consists of weakly-connected pieces of information. Such students may believe that remembering formulas, knowing facts and algorithms is tantamount to achieving a full understanding of their course material. Furio and Guisasola (1998) suggest that students' difficulties in understanding new concepts are likely to originate from difficulties of an ontological and epistemological type, rather than from the existence of preconceptions about them. Elby (1999), however, suggests that although epistemological beliefs explain many aspects of students' behaviour, they still do provide the full picture. Elby investigated differences in how physics students study and how they would advise a hypothetical student to study if they were trying to learn physics, with no grade pressure. Interestingly, his findings suggest most students perceive learning physics deeply to be a significantly different activity from trying to do well in the course.

Hence, it seems that students engage in learning processes that are 'successful', at least in terms of how secondary schools often reward their work; rote learning works for many students because they pass exams or tests by doing so (Schoenfeld, 1989). Deliberately, or unconsciously, such messages are reinforced by many teachers. Research suggests that even though more sophisticated learning models like a cognitive-apprenticeship instructional approach achieves higher level learning goals (e.g., problem-solving, see Cumming, Marx, Thornton, & Kuhl, 1999; Heller & Hollabaugh, 1992), according to Yerushalmi et al. (2007), few teachers who acknowledge this actually implement such approaches in their classrooms. As a consequence of school learning experiences, many college and high school physics students enter their advanced level classrooms with deeply-entrenched views, supported by years of experience, that rote learning will be rewarded. It would then be strange for these students to abandon these long-held beliefs solely because instructor tells them to! Furthermore, the first few graded assignments that physics students typically encounter often consist of homework problems selected from their textbook, for the purpose of revision of school learning. A student can approach such problems by (i) struggling to obtain a real understanding, *or* (ii) scanning the textbook for relevant formulas and problem-solving algorithms. Since the two approaches often lead to similar grades for their homework, students who use the second approach reinforce their beliefs that rote memorization study habits also will be rewarded at university. If a student's prior and current experiences point towards the effectiveness of rote learning, he or she is perfectly rational to disbelieve a teacher's claim that only deep understanding will be rewarded.

Phillips (2000) suggests students need to learn much more than just what is in their text books. During learning, students also are practicing communication skills, sharpening their analytical skills, improving their justification in making decisions, being good observers (Haghanikar, 2003) and being exposed to other people's value systems. While students have always learned such things in the classroom, it is only recently that educators have come to appreciate this layered nature of classroom learning, and altered classroom practice in an attempt to enhance such student learning (see e.g., Park, Jang, & Kim, 2009; Sulaiman, 2004; Tanahoung, Chitaree, Soankwan, Sharma, & Johnston, 2009). In order to do so, learning goals must be established before lessons. Attention must be paid to every detail, from the selection of material down to hand gestures, since all will have an impact on the students. For instance, non-verbal behaviour may help to express an instructor's excitement about the material being studied. There is little likelihood students will get excited about physics unless they see that the instructor is visibly animated. If done well, every action and activity can be used to teach. It is only when teaching is approached with a holistic view that students will be able to learn all they can (Phillips, 2000). Students generally are willing to participate more as long as the expectations are made clear at the beginning of the course (Phillips, 2000).

In Malaysian tertiary level such UMS, the traditional approaches to teaching physics are normally divided into three learning activities (i.e., lectures, tutorials, and laboratory classes) (S. A. K Omang, personal communication, March 13, 2007). The physics programme at UMS is highly exam oriented. A student's mark in a course is 60-70 percent deterimed from the final exam, with 20 percent from tutoriasl and a mid-term test, and the rest from laboratory classes or assignments (S. A. K. Omang, personal communication, March 13, 2007). This assessment regime clearly indicates that the teaching and learning atmosphere a the tertiary level in Malaysia is focused on and rewarded by rote learning and memorisation, since it si dominated by the exam and tests. In lectures for example, the student is typically a passive listener sitting in a chair listening to the lecturer's. They remember every fact or formula and attempt to present in their exam or test the exact details or facts. In laboratory, similarly students focus purely on conducting experiments and seldom know how to relate theory and practice (P. Iynam, personal communication, March 29, 2009).

The situation in Malaysia is that rote learning is widely practiced in schools across the country (Shakir, 2009). A rote learning style is widely employed by Malaysian school children because they are pressured by their parents, peers, and school teacher to do well academically - as measured by an examination-oriented education system (Ahmad, 1998). Although Malaysian students achieve high test scores in national examinations (Shakir, 2009), they rank near the bottom on international tests such as the Trends in International Mathematical and Science Study (TIMSS) (Baran, 2008; Economic Planning Unit, 2010; Patrinos, Macdonald, & Ho, 2009). Moreover, the education system is highly centralized and highly controlled (Nor, 1999). A Confucian style of learning where drill, attention to content, and not the learning process, is employed, and this places great emphasis on examinations, practical questions and proofs, rather than applications. Learning by memorization is thus a common feature of the Malaysian student learning process (Lim & Chan, 1993). Nevertheless, a new approach of teaching and learning concepts emphasizing student-centred learning, active knowledge construction, as well as critical and creative thinking is being promoted across the country (Yen, Bakar, Roslan, Luan, & Rahman, 2005). The intention is to move away from the conventional pedagogies and learning processes described above, which focus on teacher-centred learning, acquisition of facts, and memory-oriented learning (Zakaria & Iksan, 2007). The underlying reason given for this shift in approach in the Malaysian education system is a perception that conventional teaching and learning processes lack the capacity to produce self-regulated learners (Economic Planning Unit, 2010; Mustapha, 1998).

4.1.2 Alternative Teaching Approach in Physics

Duit and co-workers regularly compile large bibliographies of studies on student understanding of science, including physics. These studies suggest that traditional physics instruction, mainly based on lectures and manipulation of formulae described above, has not been as effective as we might hope, with many students holding alternative conceptions for science concepts (Duit, 1996, 2007, 2009; McDermott & Shaffer, 1992; Pfundt & Duit, 1994). During the past five decades, much work in physics education was devoted to these issues. This has led to the widespread adoption of student-centred pedagogies which are based on findings of alternative conceptions studies. Recent research in physics education is distinguished by a strong interaction between physics education research, curriculum development and teacher education, and innovative pedagogies such as the use of analogy and the like (Brown & Clement, 1991; Driver, Squires, Rushworth, & Wood-Robinson, 1994; Hewson & Thorley, 1989). These new approaches, as well as being student-centred in nature, are more active and generally try to engage the student in active, not passive, learning. Welzel's (1997) investigation of individual learning processes during student-centred instruction suggests that students and teachers enjoy such lessons, and learn physics more effectively (Sulaiman, 2004). Welzel suggests that student-centred instruction offers opportunities for students to go through a process of engaging with difficult topics according to their own aptitudes, proficiencies and experiences. Welzel says then that such learning comprises individual processes of growth cognition, and that these processes are shaped internally on the basis of experience, according to the opportunities a student has in the particular learning environment or situation. Hence, students build up and develop this 'situated cognition' on the basis of their own learning experiences. This suggests students need to be provided with a variety of active learning experiences, in which they encounter new content and new context, and begin with a lower level of complexity, and gradually advance in difficulty of topic.

Student-centred learning thus involves students as active learners, and not passive recipients of knowledge. A number of active learning approaches have been developed based on constructivism and similar theories of learning. Activities such peer instruction and small group work help students to work together and not just with their teacher. This gives students opportunities to practice a variety of interpersonal and communication skills (Phillips, 2000). This collaborative approach also gives students some feeling of control over the learning process. However, in order for students to work well in such a situation, the instructor needs to take on more of a facilitator role. The teacher as the instructor here may not be the focus. However, teachers cannot completely divorce themselves from the learning process; they need to be available to help and intervene as necessary. All of the above might well apply to almost any topic, science or otherwise. Nevertheless, a key distinguishing feature of physics learning is a need to acquire expertise in problem solving (Xu & Pihlaja, 2009). Problem solving in physics means developing more than the ability to memorize content and to plug numbers into an equation. Many other skills are needed, including questioning evidence, reducing complex situations to simpler ones, and searching for additional information (Moore et al., 1985). Even if all the equations are forgotten once the semester is over, students who have learned to 'think like a scientist' will have a valuable skill set, helpful for the rest of their lives. A key aspect of helping students advance their problem-solving skills is for the instructor to model this skill. This not only means explaining the logic of an argument, but also placing the problem in context, and clarifying the questions involved (Shurter & Pierce, 1966).

Elby (1999) suggests many questions posed in introductory physics exams can be solved by rote application of a problem-solving algorithm; although he notes a deep understanding physics also works. Nevertheless, as noted above, many students take home the lesson that rote understanding works well enough even at the university level. To avoid students resorting to rote learning, Elby says we need to pose more challenging problems in exams, problems that are harder than those encountered in the usual homework assignments. Only when students encounter such challenging questions might they recognize the inadequacy of rote learning. This might prove demoralizing in the short term, with students thinking that the test was unfair or too difficult, or that they are not good at university level physics (Seymour & Hewitt, 1997). Teachers might try assigning more conceptual, less rote-able homework problems, or give mini-quizzes very early on in the course that exemplify the kind of conceptual understanding needed to succeed; and writing medium-difficulty test questions that cannot be solved by rote, but which, nonetheless, strike students as achievable, had they studied differently (Phillips, 2000). Further research is needed to identify whether such techniques do indeed lead to changes in students' study habits. Instead of blaming students or teachers, Elby (1999) says that teachers and curriculum developers must take into account this interaction between the habits and beliefs students bring to their introductory university physics classes, and their initial experience in those classes. Redish and Steinberg (1999) suggest that this work has implications for teachers and researchers; that there is a need to investigate students' epistemological beliefs about learning, and to develop an understanding of students expectations about how to do well.

4.2 PROBLEM BASED LEARNING (PBL) MODEL USED IN THIS THESIS

As noted in earlier chapters, there are many PBL models reported by researchers and educators, each developed to suit particular objectives (see e.g., Buckler, 2009; Juremi, 2003; Pastirik, 2006). In this study, the researcher employed a model based on a combination of three models; that used by McMaster University (Barrows & Tamblyn, 1980); the Torp and Sage Model (Illinois Mathematics & Science Academy [IMSA] 1998) and the model used by Pastirik (2006). The main purpose of choosing a hybrid model was to ensure students explored their own learning, especially in terms of sharpening their analytical skills, improving their critical justification in making decisions, being creative observers, and practicing their communication skills. All of these characteristics can be sharpened through these established learning models. Thus, these PBL models were modified to suit undergraduate students.

Key features of these models are briefly summarized below.

(a) McMaster University PBL Model:

i. Recognize information and knowledge in the problem given;

ii. Generate ideas/hypothesis about the real problem; and

iii. Recognize the information needed in the learning process to test the hypothesis.

Engel (1997) subsequently modified this three phase model, expanding it to five phases:

i. Information analysis phase;

ii. Information collecting phase;

iii. Synthesis phase;

iv. Abstraction phase; and

v. Reflection phase.

(b) Torp and Sage IMSA Model:

i. Student getting prepared;

ii. Encountering problem;

iii. Recognising information;

iv. Identifying learning issue/s;

v. Collecting and sharing information;

vi. Generating problem solving;

vii. Presenting their solution of problem; and

viii. Debriefing problem once again.

As for Pastirik (2006), there are five main stages that comprise PBL:

i. Problem presented; ill-structured and complex situation;

ii. Student recognizes learning issues and potential sources of knowledge and information;

iii. Engages in independent study by gathering and analyzing essential scenario information;

iv. The student then meets with the small group, they critically discuss the practical application of the information to the scenario; and

v. The student then critically reflects on both the content learned and the process.

These theories are important in this study to maintain the key features of PBL and which, at the same time, can be applied to undergraduate level physics students in Malaysia. This is because the learning process that is embraced in these PBL models also needs to be acceptable in Malaysia, and to promote the soft skills that are deemed important in Malaysian institutes of higher education. Hence, the researcher integrated these models in order to create new PBL model to address the research questions for this study.

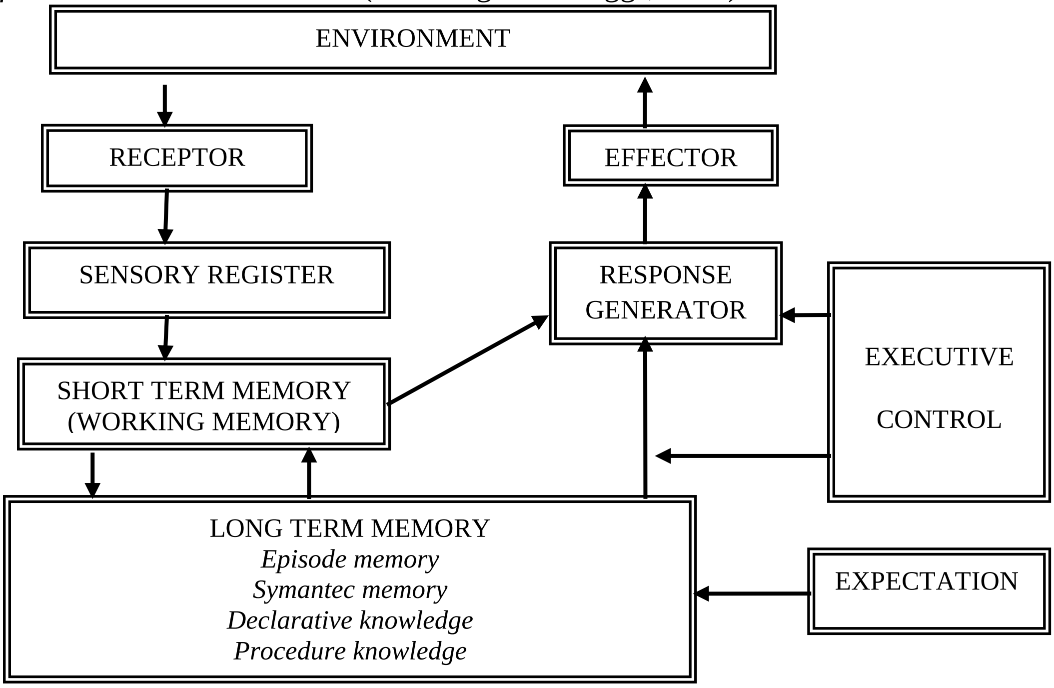
4.3 COGNITION AND METACOGNITION LEARNING THEORIES

The research in this thesis is concerned with improving student learning of physics, and this involves, among other things, helping students to develop as metacognitive learners. Here, the researcher describes key theories of cognition and metacognition, and presents the theories used in this study.

4.3.1 Information Processor Model for Cognition and Metacognition

One of the earliest models for teaching and learning for metacognition is that reported by Gagne and Driscoll (1988) - *an information processor model* for teaching and learning (see Figure 7). Key features of this model are the concepts of *short term memory* or *working memory*, *long term memory*, *executive control* and *hope*. Short term memory or working memory is the location where all the mental work is done, in other words, it can be thought of as a ‘thinking-holding’ site; that piece of the brain where incoming information is placed in the short term (Hindal, Reid, & Badgaish, 2009). This is where thoughts, interpreting, evaluating, synthesizing, understanding and problem-solving take place. It has a limited or fixed capability and, therefore, controls learning (Johnstone, 1997). Input to the short term memory comes from either outside (through the senses) or from inside (from the long term memory), or both. When a new concept is to be learned, knowledge goes to the short term memory, where it can be repeated or easily remembered, and can be stored. This new knowledge can create a number of mental activities, and effect a meaningful relationship between available concepts (Reid, 2009; St Clair-Thompson & Botton, 2009).

Figure 7
Information Processor Model (after Gagne & Briggs, 1974)



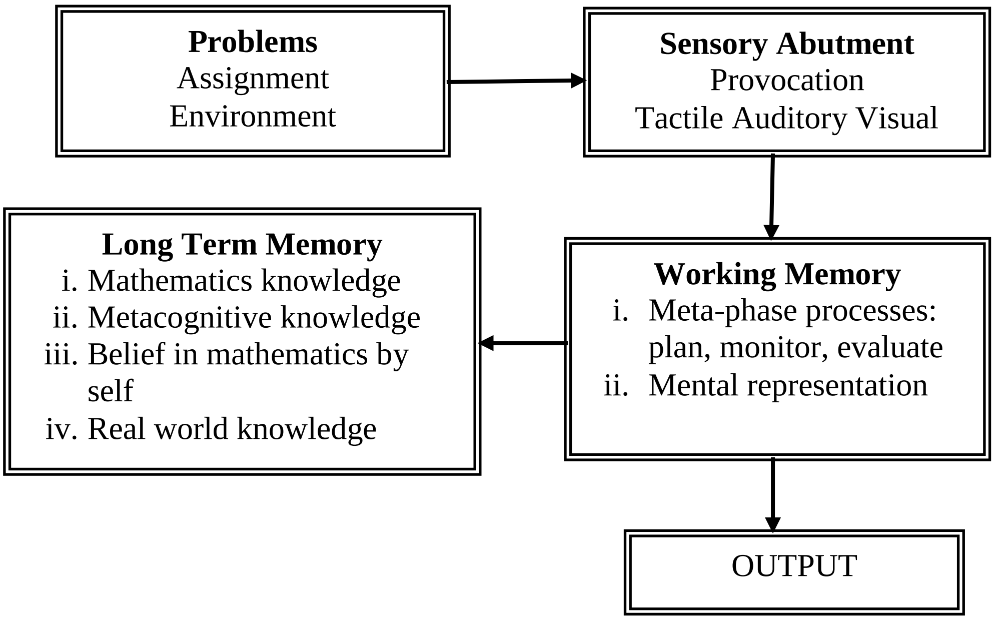
According to the information processor theory, the cognitive process involves intellectual actions that function as an information changer. The cognitive process here consists of attention, perception, rehearsal, encoding and information retrieval. Cognition is then solicited knowledge via reasoning, involving operations to guide learners in order to find meaning, especially planning operations, monitoring and evaluating their thinking. This is best illustrated with an example. Newell and Simon (1972) used the information processor theory to describe the problem-solving process. According to the information processor theory, in the cognitive process the learner acts as a selective monitor who then codes and keeps the new information in their mind in the short term memory; the movement of knowledge is then explained in the form of information transformation from input to output in much the same way control data or information is controlled in a computer.

Schoenfeld constructed a problem-solving model based on information processor theory, which can be used for all domains (Gredler, 1997). His model is based on problem-solving used in mathematics (Figure 8), and has two main components:

i. Basic individual knowledge, including informal information and intuitive domain content knowledge, metacognitive knowledge, along with beliefs about mathematics, and self as a learner.

ii. Steps on how to get information, which involves metacognitive skills based on monitoring, planning, evaluating the effort needed to solve a problem and the capacity of the working memory.

Figure 8
Memory structure and Schoenfeld's problem solving (after Gredler, 1997, p. 186)



4.3.2 Social Constructivist Model of Cognition

Social constructivism posits that knowledge is an outcome based on the interaction between an individual and society. Erudition expands through negotiation and the outcome is affected by social, cultural and environment factors. Cognitive development focuses on social skills, learning and strategies which facilitate social interaction, such as hands-on-projects that give students opportunities to learn using cognitive tools based in their discipline of study. Social constructivism is based on expanding ideas in a particular discipline, and the ability of students to open their minds and their scope of understanding through social interaction (Ernest, 1998). Group discussion, for example, gives students the opportunity to create ideas that can be used in the real world, and they can contribute to new knowledge generated in their group. Based on Piaget’s work, learning activities like this using interaction between peers can result in cognitive conflict or confusion (Wood, Cobb, & Yackel, 1991).

4.3.3 Situated Cognition, Cognitive Apprenticeship and Cognitive Leadership

Situated cognition is a theory of learning which suggests that when learning, students naturally engage with authentic activities, context and culture (Browns, Collins, & Duguid, 1989). Learning here is seen as a sociocultural phenomenon. Students gain knowledge and skill in a particular context or social situation by means of a *cognitive apprenticeship* (Oliver, 1999). This cognitive apprenticeship involves learning from an expert who provides cognitive leadership - a guidance process through discussion, planning, observation, reflection and discussion (Bredo, 1994). There are a numbers of assumptions that underpin such a cognitive model. First, the student and environment cannot be separated while learning occurs. Second, the environment is part of the student's cognitive and thinking system, based on the individual's interaction with the environment. Third, changing the social task will never separate the connection between social interactions, since learning is part of the social generative practice.

According to McLellan (1996), there are several key components that guide the learning situation: apprenticeship, collaboration, reflection, coaching, multiple practices, and articulation of learning skills, realistic representations and technology. In a situated learning approach, learners collaborate with each other and their cognitive leaders (i.e. their teachers) in an attempt to obtain a shared understanding. Educators who subscribe to this theory, believe that a learning culture can be nurtured, and that learners can process the concepts and information more deeply when the ideas, perspectives or beliefs of all members in the learning situation are taken into account. Watola (2000) suggests that cognitive apprenticeship is combination of formal schooling and traditional apprenticeship. In traditional apprenticeship, learning steps consist of modelling, coaching, scaffolding, and fading. This is employed as the master craftsman models real world activities in a sequence geared to fit the apprentice's level of skill. The master models expert behaviour by demonstrating how to do a task while explaining what is being done and why it is being done that way. The apprentice observes the master, and then copies his or her actions in a similar task, with the master coaching the apprentice through the task by providing hints and corrective feedback. As the apprentice becomes more skilled in the task, the master gives more and more authority to the apprentice by fading into the background (Johnson, 1992). The main objective then is to help students to build self understanding for the topics being learned, with non-active knowledge being changed to active knowledge. According to Loring (1998), situated learning is a context-based learning, which involves using experience in a meaningful way. In other words, it is an active form of student-centred learning. Learning is thus a social activity, shaped using special teaching and learning tools relevant to a particular situation, based on experience and not just on theory. It is learning by doing.

These situated learning models are of relevance in this thesis because the work here involved putting students in real-life situations, which may stimulate the learning process, making the learning more realistic and meaningful.

4.3.4 Adult Learning Theory

As detailed in Chapter 2, PBL is an approach often used for more advanced level learners, such as senior high school or undergraduate students. Undergraduate university students who are typically aged around 19-23 years may be considered adult learners. Engle (1993) identifies facets of learning involving a PBL approach which result an effective adult learning: active learning, and cumulative learning (where one accumulates knowledge and abilities that serve as building blocks for subsequent development). Such layered or sequential learning appears to be an essential mechanism, both in acquiring useful abstractions that serve intelligent behaviour, and in producing essential new foundations for further development; learning for understanding - where understanding develops as a person uses what s/he already recognizes (i.e., prior knowledge) to build meaning out of new information (Cerbin, 2000); comprehensive and deep learning - learning in a holistic way and in a deep learning which is defined as continuum series from the stage of *surface learning*, where the learner simply memorizes new ideas, to *deep learning*, where the learner actively combines new knowledge into his or her cognitive structure through learning via social negotiation (Ke & Hie, 2009). Adult learners tend to be self-directed, to have life experiences that are rich resources that they draw upon in their learning, to have readiness to learn, and to want information that is immediately applicable to their circumstances (King, 2008). They also are independent learners - adults that are supposed to take more control of their learning, thus and tend to be self-directed (King, 2008). Effective principles for adult learning such as experienced learning, objective learning, self-regulated learning, problem-centred learning, critical reflection and also learning how to learn also are embedded in a PBL approach (Brookfield, 1995; Lieb, 2000). The students that formed the sample of this study were aged 19 years old and above, and can be considered as adult learners. Therefore a PBL approach that fits well with adult learners is appropriate for undergraduate university students in Malaysia.

In this thesis, it is proposed that the features of adult learning identified above may influence the effectiveness of undergraduate students' learning. Drawing on these principles may encourage students to be creative and engage in critical thinking and develop their problem-solving skills. It is anticipated that, through a cognitive apprenticeship, learners will be motivated to learn, and this may lead to great engagement with learning and thus achievement in their studies. The principles of the cognition theories detailed above were incorporated into the PBL approach used here and Table 3 shows the characteristics of PBL as employed here, and their relationship to the cognition theories.

Table 3
PBL Characteristics

Characteristics	Practice	Theory
1. Learner-centred. Experience learning	Choose a relevant authentic problem and meaningful to the learner interest. Learner is responsible in their study to find and evaluate knowledge resources in the field or in the learning theme	Relevance is a main factor which encourages learner to become a self-regulated learner
2. Inductive learning	Introduce contents of learning through problem-solving process rather than problem-solving after the learning contents are delivered	Deeper learning occurs when information introduced in a meaningful context
3. Built based on challenging previous learning	If the scenario has any problems in its relevance to learners, they need to recall their prior knowledge. They have to focus on that prior knowledge, test their assumption, learning strategies before this, and all facts	Learning occurs when a cognitive conflict exists between new learning and old learning
4. Context specific	Choose real problems or problems that been developed wisely for the purpose of the learning, learning contents being introduced are based on challenge that is embedded in a real life situation	All information in special contexts will be learned more deeply and the learner will remember it longer
5. Problem is complex and ambiguous, need metacognition	Choose examples in real life situations regarding their course. This will use learners' metacognitive ability to analyse strategies to solve problems	Need to use their ability to use higher order thinking skills like analysis, synthesis, evaluate, and create new knowledge
6. Embody cognitive conflict	Choose scenarios that have information which makes an easy solution become harder to use. It may be part of problem solution to the other. It also maybe will trigger another problem more challenging than the previous one	Learning occurs when there is cognitive conflict between new and older learning
7. Collaborative and interdependent	Learners work in a small group	With teamwork, learners can see many of problem-solving skills that they may have and use. They will form a discussion group and be more responsible for their own learning and for each other

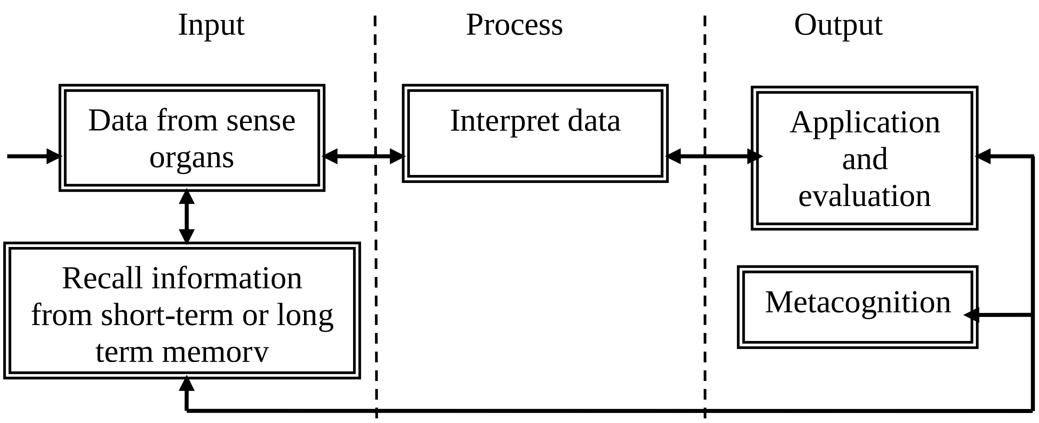
4.4 THINKING MODELS

Examination of the PBL approach to learning suggests that the thinking process is a key aspect of this approach to learning. Here the researcher uses the term ‘thinking models’ instead of ‘cognitive models’ or ‘metacognition models’ since it refers to the particular thinking models of each scholar. Consequently, here theories and models of thinking are considered.

4.4.1 Intellectual Functioning Model (Costa Thinking Model, 1991)

Costa (1991) proposed a model of thinking, and subsequent teaching strategy and teaching behaviour, based on the information processes theory. He says that thinking can be divided into four features: i. Input; ii. Processor; iii. Output; and iv. Metacognition. According to this model, the thinking process starts when a learner is exposed to some external stimuli through the sensory organs, and this is followed by *internal processing*. If the learner wishes to keep this new information, the brain will merge, differentiate, and categorize the knowledge through a pattern-seeking process, and it will be stored in long or short term memory. This process will be applied consciously or unconsciously, and as noted above, knowledge that is considered relevant and meaningful based on past experiences is more likely to be integrated and assimilated into the program store or schemata. Figure 9 below shows the process

Figure 9
Model of Intellectual Functioning (after Costa, 1991)

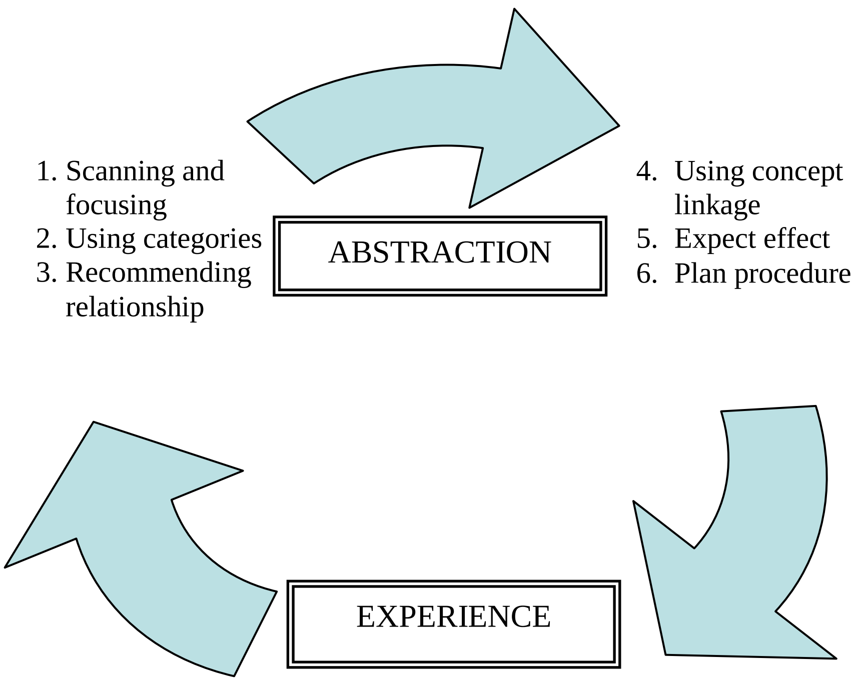


Complex thinking occurs when there is outside 'provocation' that challenges the brain, resulting in one of several outcomes: i. removal of all data or bulk structures from the information store (i.e., in long-term memory); ii. expansion of the structure that already exists in the mind; or iii. development of a new structure. Costa (1991) sees a problem posed during PBL as this type of provocation or challenge, where a suitable response or the answer is not immediately clear. If the information received is not a problem (i.e., not difficult or related to current knowledge), it is easier to assimilate. However, if the new information is 'a problem', accommodation occurs if the knowledge can be integrated with the current knowledge. If the new information is strongly differentiated from existing knowledge, or used in a problem-solving process, then the new information will be stored in the long-term memory.

4.4.2 Clarke Thinking Model (1990)

Clarke (1990) conceptualized thinking as a circular process consisting of six components (Figure 10).

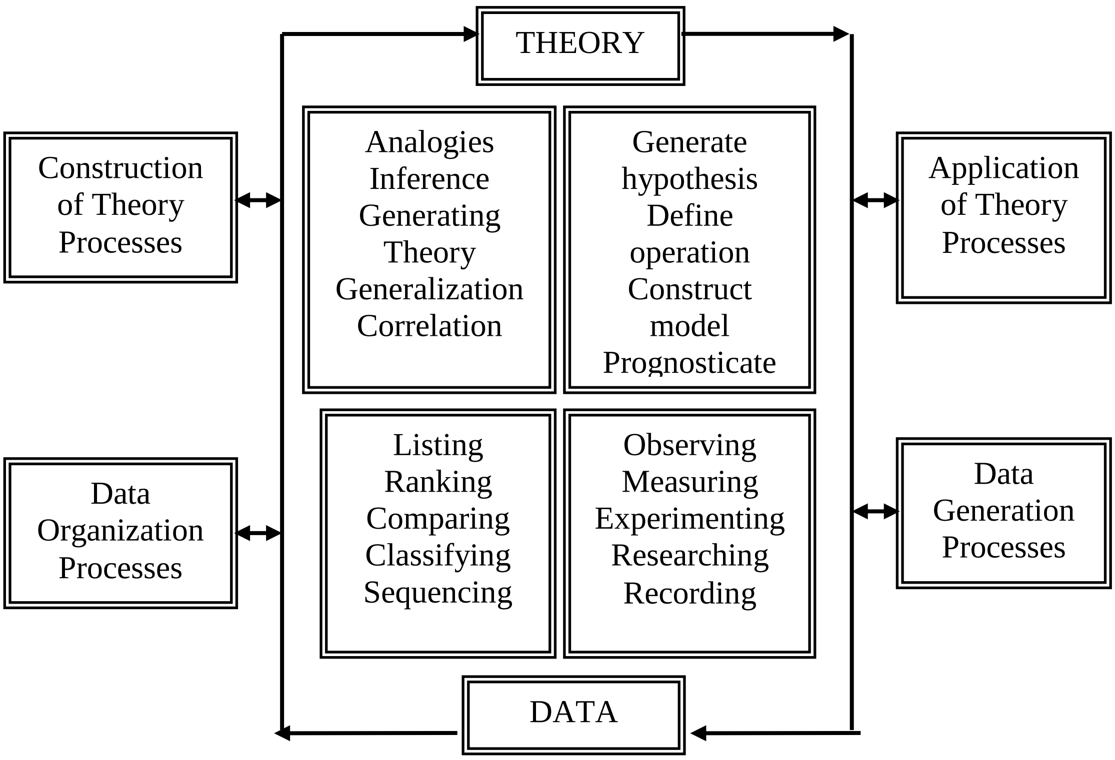
Figure 10
Six Thinking Aspects (after Clarke, 1990)



Clarke (1990) proposed a connection between teaching and thinking as follows:

i. Thinking involves changing concrete experience to generate more abstract ideas;
ii. Teaching involves changing more abstract ideas to a more concrete experience;
iii. Teaching can cause changing of thinking through experience formation; and
iv. Thinking can cause teaching to change through idea formation.

Figure 11
Inquiry Process Cycle (after Clarke, 1990)

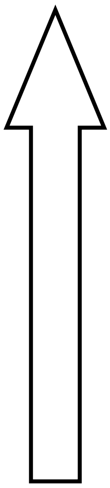


Clarke (1990) adapted the thinking model proposed by Costa (1985) to take into account inquiry-learning (Figure 11), with a focus on problem-solving and critical thinking. According to Clarke's model, data consists of information that enters through sense organs, which is then made abstract and becomes theories. When the data comes through sense organs, this suggests that the information presents as a problem, and the mind will start either processing and organizing data, or developing theory. A theory that is so constructed is then applied in new situations, and subsequently confirmed through a data generating process - these processes consist of a repeating cycle of events.

4.4.3 Three Phases of Thinking (Bellanca & Fogarty, 1991)

Bellanca and Forgaty (1991) say thinking skills involve three phases: thinking skills acquisition; creative skills and critical thinking skill execution; and thinking usage (Figure 12). According to Fogarty and McTighe (1995), in the first thinking phase – we gather all the necessary information and gain skills. In the second phase − we process information and give meaning to this information. In the third phase − we apply information and translate it through our behaviour.

Figure 12
Three Thinking Phases of Models (after Bellanca & Fogarty, 1991)



Phase	Explanations	Example
Third	Applying Data Applying skills and processing into multiple situations	Evaluate Expect Estimation
Second	Data Processing Processing skills through articulations an visualizations	Differentiate Scaffold Categorize Solve Analyse
First	Data Collection Collect information and gain skills	Count Choose Detail Elaborate

4.4.4 Swartz and Parks Thinking Skills Models (1994)

Swartz and Parks (1994) classified thinking skills into three main categories: thinking for explaining and understanding something; creative thinking; and critical thinking. These are now summarized in turn.

1. Thinking to explain and understand something.

The main objective is to gain understanding, and to remember. This involves explaining ideas and requires the explainer to:

a. Analyze ideas

i. Compare and differentiate;

ii. Classify and construct;

iii. See relations of parts/overall;

iv. Compile and arrange;

b. Analyze arguments

i. Finding cause/conclusions;

ii. Finding assumptions.

2. Creative thinking

The main objective of the creative phase is to generate ideas and skills, and has two main parts.

a. Generating possible alternatives:

i. Lots of ideas;

ii. Multiple ideas;

iii. New ideas;

iv. Specific ideas;

b. Combining ideas:

Analogy / Metaphor.

3. Critical thinking

The main objective of critical thinking is critical evaluation, and this involves evaluating suitable ideas in several ways.

a. Evaluate basic information:

Sharpness of view / source reliability

b. Evaluate inference – Use of evidence:

i. Explain cause of effect / prediction

ii. Scaffold through analogy

iii. Make generalizations

c. Evaluate inference – Deduction

Scaffold by category

All of these categories are related to one another and can be used to make a decision or solve problems

1. Make a decision

   The main objective here is to make the best decision and the strategy is to generate choices, consider the effects of a particular choice, and choose the best solution. The skills incorporated here are generating, explaining and evaluating the appropriateness of ideas.

2. Solve problems

   The main objective here is to get better solutions, and the strategy involves generating multiple possible solutions, considering the effects of choices, and choosing the best solution. The skills involved are generating, explaining and evaluating ideas.

Clarke's (1990) model is the model most learners use in order to solve problems (see Juremi, 2003). However, Bellanca and Fogarty's model has some basic features that are similar to how students try to solve problems which are collecting data, processing data, and applying data. Similarly, the models proposed by Swartz and Parks (1994) detail common thinking process used when solving problems. All of these models have some features that are consistent with the skills needed in a PBL approach (see Chapter 2). Therefore, a combination of these three models was employed in this work in order to develop higher order thinking (HOT) skills.

As noted in Chapter 1, the strengthening of creative and critical thinking skills of undergraduate physics students is the main focus of this study. Thus, in the next section will elaborate on problem-solving models and their relationship to thinking models.

4.5 PROBLEM-SOLVING MODELS

As detailed in Chapter 2, there are a number of problem-solving models reported in the literature. There were two problem-solving models chosen for the thesis. The models are first briefly described, and this is followed by a justification for the choice of models.

(a) The *Search, Solve, Create, and Share Problem-Solving* Model (Pizzini & Shepardson, 1992).

In this model, the problem is solved using a series of steps: Search, Solve, Create, and Share (SSCS).

i. Search

In big groups, students will search for problems.

ii. Solve

In small groups, students identify suitable potential solutions, and implement an action plan in order to develop research questions/problems.

iii. Create

In a small group, students gather data and information and present this to the rest of the class.

iv. Share

In a whole class setting group, students share the findings, data and information that been have gathered about the problem-solving exercise. They share all kinds of information through inscription, discussion and consultation.

(b) Hypthetico-Deductive Problem-Solving Model (Lawson, McElrath, Burton, & James, 1991)

According to Lawson, McElrath, Burton and James (1991), the hypothetico-deductive problem-solving model is the main approach used in science. This method consists of questioning and generating a hypothesis through inductive scaffolding. The deductive scaffold is used to make predictions based on the hypothesis, and to test the validity of the prediction.

In this model there are several steps: observation, questioning, hypothesising, prediction, experimenting and deduction.

i. Observation:

Example: Cooking using the microwave oven seems to be more effective than cooking by gas stove.

ii. Questioning:

Example: What makes cooking by microwave oven more effective and faster than using a gas stove?

iii. Hypothesising:

Example: 1. Microwave radiation cooks food better than gas heat

2. Microwave radiation cooks thin food more effectively than a gas stove.

iv. Prediction

Example: 1. To heat a cup of coffee only takes two minutes in a microwave

2. To heat a cup of coffee will take more time when using a gas stove

v. Experimenting

Example: Compare the times needed to heat a cup of coffee using a microwave oven and a gas stove.

vi. Deduction

Example: A microwave oven, or a microwave, is a kitchen appliance that cooks or heats food by dielectric heating. This is

> accomplished by using microwave radiation to heat water and other polarized molecules within the food. This excitation is fairly uniform, leading to food being adequately heated throughout (except in thick objects), a feature not seen in any other heating techniques.

Both of these problem-solving models are deemed appropriate for this study, since they are related to the science learning approach, and have science characteristics such as explaining natural things which involves scientific methods such as observing natural or experimental phenomena; constructing hypotheses; making predictions from hypotheses; collecting data to test hypotheses; hypotheses that survive testing gain the status of a theory; and making conclusions. Thus the use of these models provides opportunities for learners to strengthen their comprehension of the science process - recognizing variables, defining the operationalization of variables, generating hypotheses, experimenting, interpreting data, and graphing or presenting data. From this, the researcher is seeking to establish links between creative thinking, critical thinking, and problem-solving skills in order to understand the content of learning based on the theories of learning detailed above. This is because each of these variables are related, either explicitly or implicitly, as students work through the problem-solving process in the PBL model. Table 4 illustrates this link.

Table 4
Link between solving problems process, creative thinking usage and critical thinking usage in this thesis

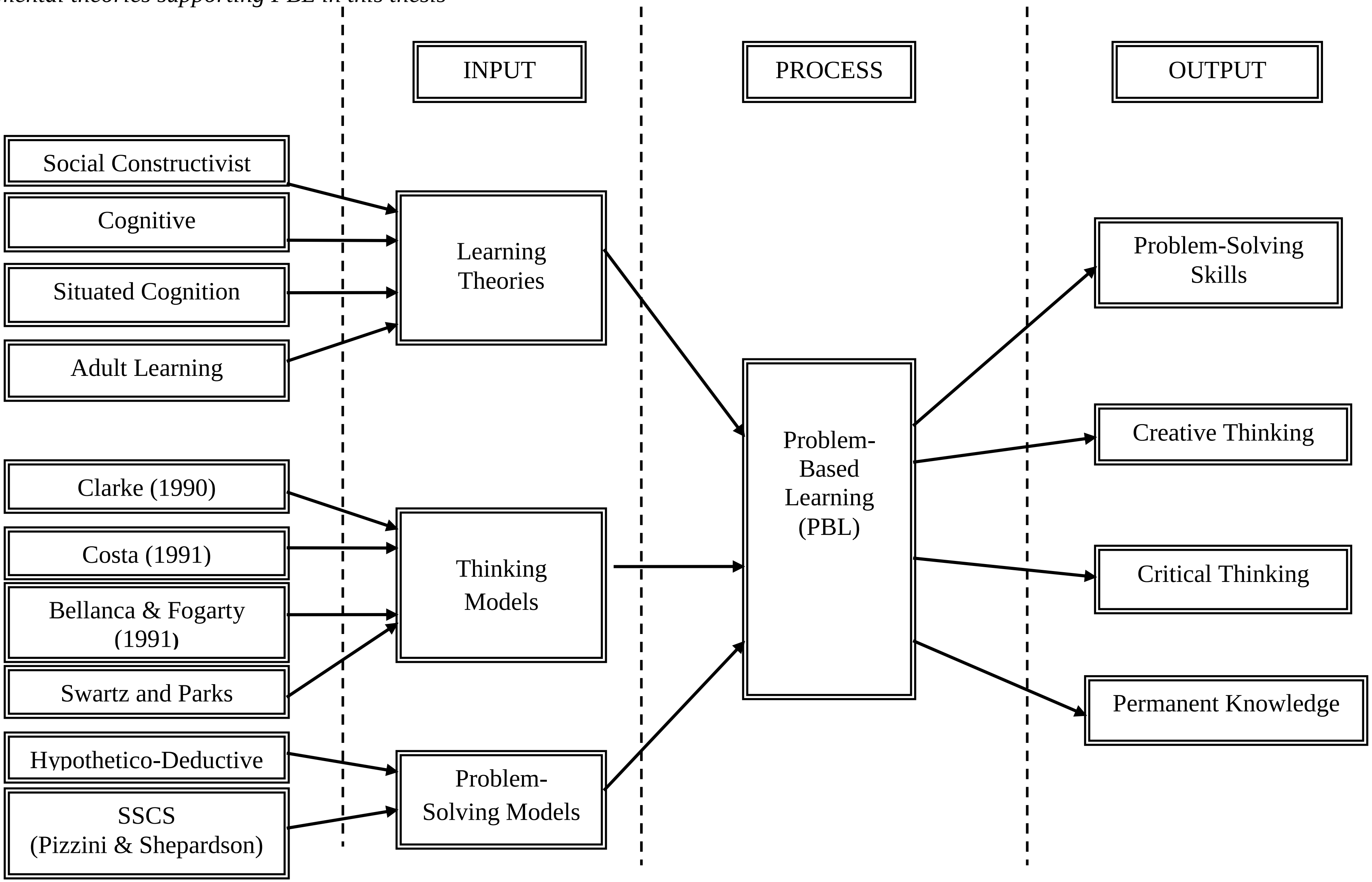
Problem-Solving Steps (in this study)	Student Activity	Creative and Critical Thinking	Science Process Skills	Cognitive and Metacognitive Activity	Learning Theories
1. Survey /Overview	1. Construct a map concepts	Creative and Critical		Activation of prior knowledge	Attention Retrieval
2. Define Problems (group process)	2. Read the problem scenario	Critical	-Variable recognition -Data/graph Interpretations		Social Constructivist
	3.Brainstorming (learning issues and hypotheses)	Creative	-Variable definition operation -Generating operation		Distributed Cognition
	4. Recognise learning issue and hypothesis	Critical	Recognizing	Selective encoding Metacognition	Scaffolding Cognitive Apprenticeship Cognitive Coaching
	5.Discussion and consultations	Critical		Metacognition	
	6. Job distribution				
3.Self-Discovery Learning	7.Find required information	Creative and Critical	Data collection	Elaboration	Adult Learning – Self directed learning
4. Group Process Problem Solving.	8. New Knowledge Application on the Problem	Creative and Critical	Implementing experiment	Elaboration	Distributed Cognition
	9. Discussion and Consultation	Critical		Selective encoding	Distibuted Cognition
5. Reflection	10. Evaluation	Critical		Metacognition	

Figure 13 summarizes the learning theories, thinking models and problem-solving models used in this thesis. It is anticipated that through this process some aspect or principle of these theories and models will strengthen students' problem-solving skills, creative and critical thinking.

Figure 13

Fundamental theories supporting PBL in this thesis

Fundamental



4.6 CONCEPTUAL FRAMEWORK FOR THE THESIS

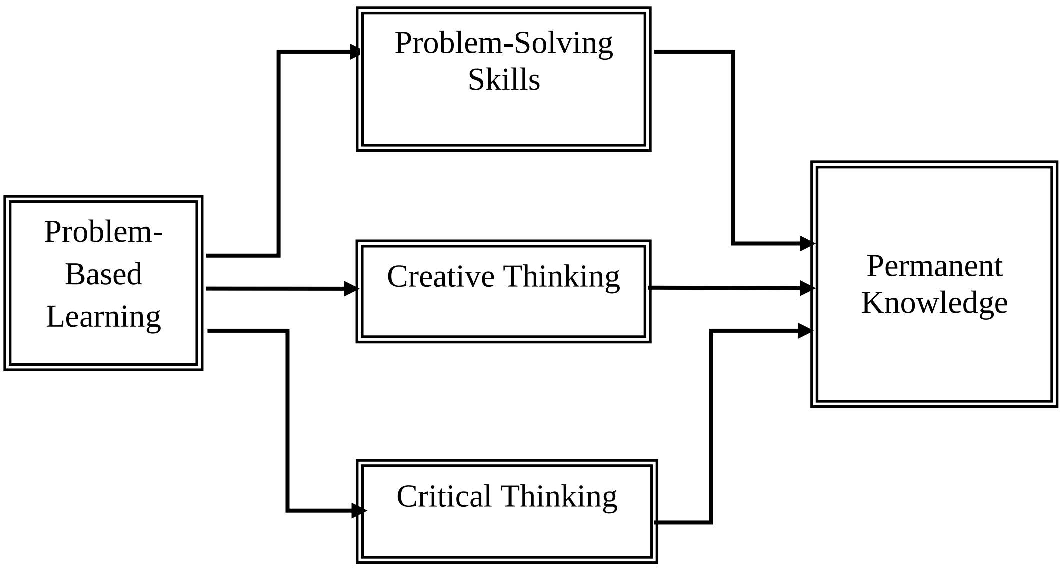
Theories of learning, the literature on creativity, critical thinking and problem-solving (Chapter 2) all were combined with models of scientific thinking/process (this chapter) to develop the conceptual framework for this thesis, which is presented in Figure 14. This framework focuses on the use of problem-solving tasks in order to strengthen learning of content, thinking skills and problem-solving skill for undergraduate physics students. This problem-solving learning developed here is now referred to as problem-based learning. The following assumptions underpin the conceptual framework:

i. Effective problem-solving processes in physics learning involves using problem solving skills, creativity, critical thinking, and physics declarative knowledge;

ii. Problem-solving processes in physics involves student learning activities where their knowledge is applied to new learning situations; and

iii. The more experience students gain in problem solving, the more likely they are to improve their problem solving skills, creativity, critical thinking.

Figure 14
Basic conceptual framework of this thesis



4.7 DEVELOPING THE PROBLEM-BASED LEARNING MODEL USED IN THIS THESIS

Learning theories suggest that for a particular domain in any science course different teaching approaches may be required. Different learning approaches also necessitate specific pedagogies or teaching methods. Likewise, a combination of models and approaches such as those described above require researchers to develop a teaching and learning strategy. The main objective in any such strategy is to achieve successful implementation of the intended curriculum. Hence, drawing upon the conceptual framework and models and theories of learning described above, a problem-based learning model for this thesis was constructed.

The literature presented in Chapter 2 linking PBL with problem-solving skills, creative and critical thinking, inspired the researcher to use a PBL approach to develop problem-solving skills, creative and critical thinking in undergraduate physics students and pre-service science teachers. The researcher also sought to generate a holistic method of learning, in which students gain not only knowledge, but thinking skills and learning skills, as part of their PBL experiences.

The PBL model presented in Table 5 and the PBL model asseement book (Appendix XVI) in this study were developed based on an inductive approach, and desirable thinking skills as detailed by Ministry of Higher Learning of Malaysia (MOHE) (Table 6). Students were recruited and guided in the use of the model to help solve problems using the flow-chart shown in Figure 15.

Table 5
PBL model used in this thesis

PBL Model The Combination of Floating Facilitator Model and Peer Tutor Model	Steps in PBL
1. Overview Lecture gives introduction via online	Construct a concept map
2. Tutorial I (group process). Lecturer acts as facilitator - monitors student's progress for each group and provides cognitive guidance to students in discussion room. Tutor /Instructor monitors the discussion progress in each group.	1. 'Meet' the problems. 1.1 recognize the problem's scenario 2. Define the Problem. 2.1 Brainstorm learning objectives and hypothesis. 2.2 Recognize the learning objective and hypothesis/es. 2.3 Discussion and consultation 2.4 Distribute tasks within group.
3. Self learning Every student will find resources of information needed from multiple resources.	3. Discovery Locate appropriate information
4. Tutorial II (group process) Lecturer acts as facilitator - monitors student's progress for each group and provides cognitive guidance to students in discussion room. Tutor /Instructor monitors the discussion progress in each group.	4. Solutions 4.1 Apply new knowledge to the problems 4.2 Discussion and solutions
5.	5. Reflection Evaluation

Table 6
PBL approach and for development of problem-solving skills, creative, critical thinking and knowledge

PBL Approach	Task Example (Assignment)	Process and Learning Outcomes
1. Problem example	As a scientist, how might you solve the problems of nuclear weapon usage among first world countries?	Students find information and discuss. Work in groups. Physics knowledge regarding nuclear weapons and any related issues used.
2. Define problems	• What are nuclear weapons? • What are the features of nuclear weapons? • What are the functions of nuclear weapons?	i. Critical thinking is used to choose new relevant information. ii. Problem-solving skills are used to consider suitable problem-

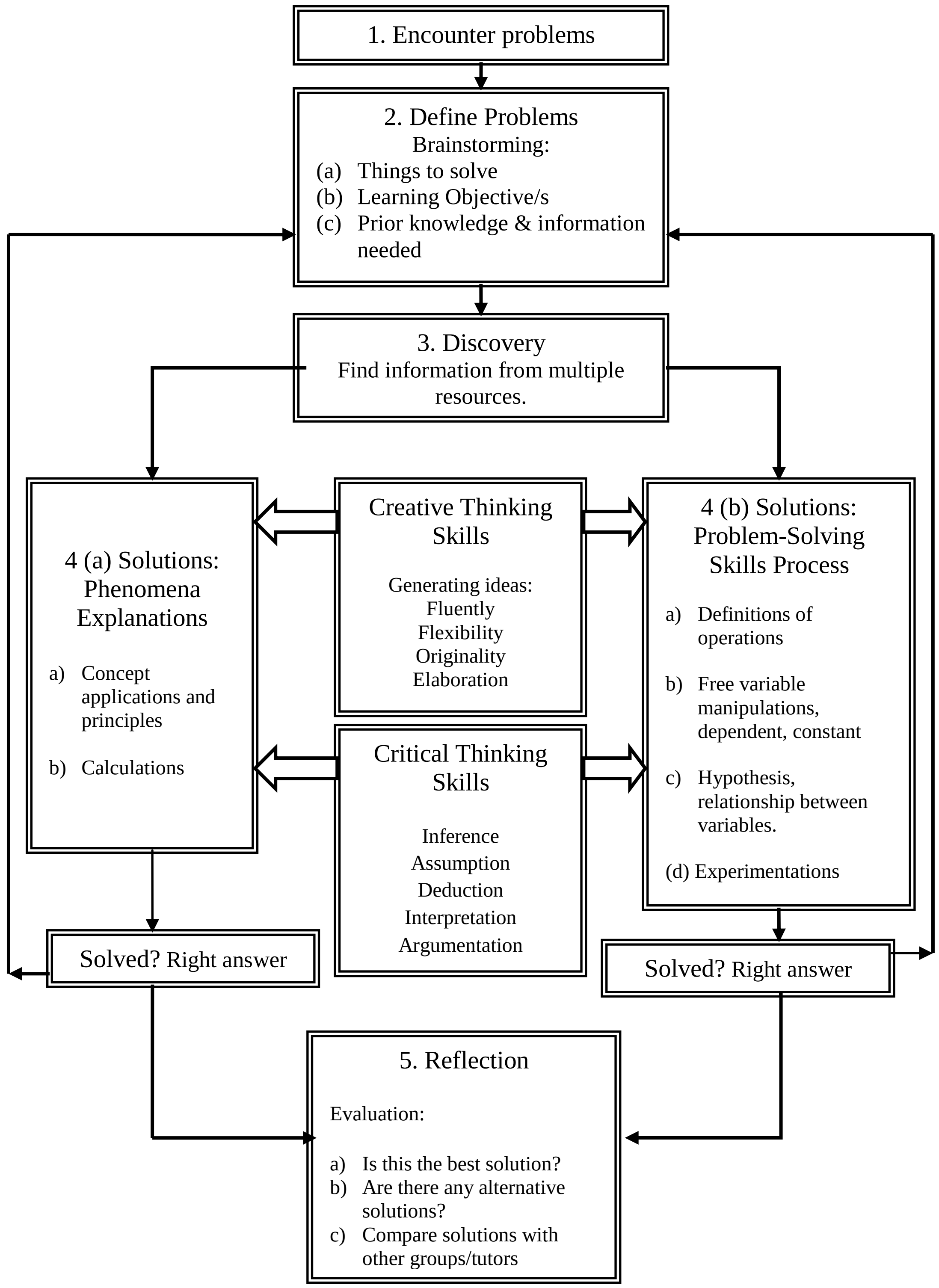
	• What are the advantages of nuclear weapons? • How might nuclear weapons work without being misused?	solving approaches to solve the problems. Recognize variables, and generate hypothesis/es. iii. Creative thinking and critical thinking are used to recognize the variables and generate hypotheses. iv. Problem-solving skills are used to solve problems.
3. Discovery	Find information from a variety of information sourced and evaluate the information.	
4. Problem-Solving	Synthesize and try to provide suggestions in order to solve problems.	
5. Reflections	Evaluate either solution and decide the best way to solve the problems. Are there any other alternatives?	Learning metacognition occurs: Students reflect and evaluate

The problems constructed for this work were based on topics in modern physics and associated with daily life, and that was part of the higher learning curriculum in Malaysia.

This PBL model thus uses problems designed to be authentic, real life problems but consistent with the physics syllabus for Malaysian undergraduate physics students. Questioning techniques, small group discussion, cooperative learning, inquiry, explanations, experimenting, and brainstorming are the main learning activities in the PBL models. A key aim for this PBL model is for students to gain problem-solving skills, creative and critical thinking simultaneously. Students were told of these learning objectives in earlier lectures. The researcher employed the ‘post-hole’ method, where this model was integrated into an existing learning and teaching method (Savery & Duffy, 1995). A pilot study was conducted and the PBL model exercises trailed as detailed in Chapter 5.

Figure 15

Flow-chart of problem-solving process used in the PBL model in this thesis



4.8 RESEARCH SCOPE

The intention of the research was to investigate ways to enhance the learning process. The main focus was to investigate the cognitive effect of using the PBL online method atmosphere. The cognitive effect referred to here consists of problem-solving skills, creative and critical thinking in the domain of modern physics. The general objective of this research is to evaluate the effectiveness of PBL in improving creative and critical thinking delivered online.

The literature suggested that creative thinking is characterized by students' use of divergent thinking (Torrance, 1990). This divergent thinking consists of fluency, flexibility, originality and elaboration when generating new ideas, and is evaluated in this thesis using the Torrance Test of Creative Thinking (TTCT) (Torrance, 1990). Whilst critical thinking for the students is to do with the capability of students to make any inferences, to check assumptions, make deductions, interpret and evaluate arguments, this is evaluated using the test of Watson Glaser Critical Thinking Appraisal (WGCTA) (Watson & Glaser, 1980).

The notion of teaching and learning problem-solving has existed for many years; however, a number of factors have restricted its widespread adoption (Juremi, 2003). As with many innovative pedagogies, it needs time, and it is perhaps less useful when the academic ability of students varies substantially in a given class (Juremi, 2003). Therefore, it is hoped that the research reported in this thesis improves the implementation of PBL for undergraduate physics students and enhances their creative and critical thinking skills.

4.9 CHAPTER SUMMARY

A number of theories about learning are described here. At the start of this chapter, student learning processes, and how students learn in physics were described briefly, with a particular focus on the learning of undergraduate physics. Core theories of cognition, metacognition, thinking models and problem-solving models were described. The PBL model employed in this thesis is based on three PBL models, that of McMaster University model, the IMSA PBL model and the model introduced by Pastirik. The notion in this work is that learning physics, especially in modern physics, using a purpose-designed PBL model involves the application of problem-solving skills. In addition, it is considered that creative and critical thinking may be enhanced in the use of PBL. Other assumptions are that students learn actively through problem-based learning processes, and that prior knowledge may be applied to new problem-solving situations. It is proposed that if students gain more experience in problem-solving in modern physics, they may increase their capability to solve problems skillfully, creatively, and critically. This will, in turn, enhance their performance in terms of physics understanding and content knowledge.

In Chapter 5 which follows, the methodology used in this research is detailed.

CHAPTER 5: RESEARCH METHODOLOGY

5 CHAPTER OVERVIEW

The main focus of the research in this thesis is the development of innovative teaching and learning methods for tertiary level physics. In particular, the researcher seeks to strengthen the creativity and critical thinking for students via problem-based learning (PBL) activities, which focus on 'ill-structured', and authentic problem-solving. In addition, the researcher also seeks to develop an understanding of students' perceptions and acceptance of PBL, and online learning. This chapter presents the methodology and research design used in this thesis. This research is influenced by contemporary research methodologies for investigating aspects of improving learning in physics. The researcher sought to develop a research methodology under an appropriate paradigm to provide data relevant to the context in which the research was conducted. Specifically, the research design included a combination of quantitative and qualitative data collection methods. The research design is based on the theoretical underpinnings presented in Chapter 4. This chapter is presented under nine subheadings: the research design; the research variables; sampling; ascertaining the internal validity; the instrument; the PBL procedure; the research intervention; data analysis; and the chapter summary.

5.1 RESEARCH DESIGN USED IN THIS THESIS

As noted in Chapter 4, the literature suggests that the research methods chosen by researchers should follow directly from the questions asked (Patton, 1990). As this study involved an intervention of nearly four months' duration, an interpretative-based approach using a quantitative and qualitative methodology was regarded as best means of data collection (Juremi, 2003). Given the interventionist nature of this research, it may be considered as a form of experimental research. However, in a complex social situation like a university, it is very hard to arrange a truly experimental method since it is problematic to achieve, for example, random sampling or blind intervention techniques. Tytler (2009) and Adey (2005) suggested that in any intervention study a control group for comparison with the intervention group is needed as learning can be expected to change in uncontrolled ways. Such issues are common to educational research, and not unique to this work. Hence, this research is more properly described as quasi-experimental in design, where the control and treatment group are chosen purposively, and based on performance in pre-test scores and other characteristics are deemed to be reasonably equivalent (Campbell & Stanley, 1963; Fraenkel & Wallen, 1996).

This research follows the fundamental approach of mixed-methods research. Johnson and Christensen (2008) noted that "mixing methods and approaches is an excellent way to conduct high-quality research, you should mix methods in a way that provides complementary strengths and non-overlapping weaknesses" (p. 201). Thus, two dependent variables were being measured simultaneously for both experiment and control groups at two different times. This study used a research design termed 'mixed between-within-subjects repeated measure design' (Tabachnick & Fidell, 2001). The variables were Watson Glaser Critical Thinking Appraisal (WGCTA) Test, and Torrance Test of Creative Thinking (TTCT). Therefore, the research design has both *between* and *within subject factors* and so is called *mixed*. The *between subject factor* is an independent variable, referring to either the PBL method or traditional method, whereas *within subjects' repeated measures factor* refers to the collection of pre-test and post-test data for every dependent variable namely, creative and critical thinking. This research comprised 16 weeks of intervention implemented as follows:

1. Pre-test administered one week before the intervention;
2. Intervention for 13 weeks; and
3. Post-test, administered one-week after the intervention.

The research design, consisting of the intervention and mixed between-within-subjects repeated measures is illustrated in Figure 16 and Figure 17.

Figure 16
Research design used in this thesis

Group	Intervention		
Experiment	Test1	PBL Method	Test2
Control	Test1	Traditional Method	Test2

Figure 17
Mixed between-within-subjects repeated measures used in this research

Group	Time	
	Week Before Intervention	Week After Intervention
Experiment (PBL)	1. Pre-test of Creative Thinking 2. Pre-test of Critical Thinking 3. Physics Basic Achievement	1. Post-test of Creative Thinking 2. Post-test of Critical Thinking.
Control (Traditional)	1. Pre-test of Creative Thinking 2. Pre-test of Critical Thinking 3. Physics Basic Achievement	1. Post-test 1 of Creative Thinking 2. Post-test 1 of Critical Thinking.

5.2 RESEARCH VARIABLES

As detailed in the conceptual framework described in Chapter 4, the independent variables in this research are the teaching methods (i.e., PBL & traditional), and the dependent variables are student scores in the creative thinking test, critical thinking test, and surveys of students' perceptions of PBL and online learning approach.

5.2.1 Independent Variables

An independent variable is a variable that is supposed to cause a transformation in another variable (Johnson & Christensen, 2008). There are two such variables manipulated in this research - the teaching method and the medium of content delivery which is online learning. The teaching method consists of two different teaching approaches, PBL and traditional. The PBL method as described in Chapter 4 Section 4.2 is a teaching approach where students are presented with a problem to work out rather than a lecture to understand (Rogal & Snider, 2008). In the other perspective, the traditional method, the teaching and learning activities have been decided or planned earlier, and are fully controlled by teacher or lecturer.

5.2.2 Dependent Variables

Dependent variables are the variables that are influenced by one or more independent variables (Johnson & Christensen, 2008). There were two dependent variables in this research:

i. The Creativity score, based on the *Torrance Test of Creative Thinking* (TTCT, Torrance, 1990); and

ii. The Critical thinking score, based on the *Watson Glaser Critical Thinking Appraisal* (WGCTA, Watson & Glaser, 1980)

Both tests were conducted as pre-test and post-tests either side of the intervention.

5.3 THE LEARNING ENVIRONMENT FOR THE RESEARCH STUDY

This study was conducted in Univeristi Sabah Malaysia (UMS). There were two university schools of study involved, the School of Science and Technology (SST) and the School of Education and Social Development (SESD). Both schools are located in the main campus of UMS about 11 kilometres from the city centre of Kota Kinabalu, Sabah, Malaysia. The researcher visited the computer lab and facilities at both schools; this revealed that both schools have their own computer lab with Internet access at 100Mbps. In addition, the students have free Internet access at the University's library at a so-called 'Mega Lab'. Some 500 computers are provided at the Mega Lab, and these are available for all students daily from 8am to 10 pm. The Educational Technology and Multimedia Unit (ETMU) also provide UMS with wireless connection, which students can use to access the Internet in certain areas inside the University campus. Almost all schools in the main campus and certain colleges are covered with the wireless connection. The speed of the Internet connection is crucial since it can influence students' interest in and perceptions of online learning activities.

To deliver the course material for both groups, the researcher needed a computer lab with access a suitable Internet browser such as Internet Explorer (IE) or Firefox, so that the students could connect to the Learning Management System (LMS) established by ETMU of UMS. Students also needed to be able to access the PBL or traditional materials of learning from their own rooms, the library, and places with access to the Internet connection at any time. They have to log into the LMS during scheduled lecture times as a compulsory part of the course. Their attendance is recorded automatically whenever they log into the LMS.

The LMS itself uses Moodle and all the learning activities were Moodle-based activities, such as the use of a chat room, forum, uploading and downloading files, quizzes, filling in questionnaires, sending mail, calendar planning, and so on. Thus, the researcher had to make sure both groups of students from both schools of study had the same accessibility to infrastructure and computing facilities.

Before the researcher proceeded with data collection, the research proposal was reviewed by The University of Waikato Human Research Ethics Committee, and approved. A key ethical issue was to ensure that neither the PBL online nor the traditional group were not disadvantaged by the intervention. As described below (see Tables 26 & 27) studenst from both groups were provided with lecture notes via Moodle and sat the same exam and other assessment items.

5.4 SAMPLING

The population for this research consists of all undergraduate students taking physics in universities across the province of Sabah. Two characteristics were used to determine suitable subjects for this research. First, the participants must never have been taught courses involving PBL for the topic of Modern Physics. This was intended to help ensure that the participants were at the same level of understanding of the topic and had comparable backgrounds in the PBL teaching approach. Second, participants in the experimental and the control groups were chosen randomly, and their ability investigated using pre-tests (see below). The pre-tests were conducted for all undergraduate first year physics students in the Physics with Electronics Program at the School of Science and Technology (SST), and second year pre-service teachers at the School of Education and Social Development (SESD) who were doing physics as a major or minor. All of these participants studied Modern Physics during the same semester. Both schools of study are located in the Universiti Malaysia Sabah (UMS) main campus in Kota Kinabalu, Sabah.

The findings for all three pre-tests (i.e., for creative thinking, critical thinking and physics basic concept) revealed that both groups of students, whether in PBL or in traditional group, are similar (i.e., no statistically significant differences were found between the groups - $p>0.05$). The SST and SESD classes were then divided into two groups, the PBL and traditional group, as shown in Table 7. Student numbers for both groups remained constant throughout the study since attendance is compulsory for each class, learning activities and all students sat all of the pre- and post-tests.

Table 7
Sample distribution for experimental and control group

Group	SST	SESD
PBL (Experimental)	SST 1 = 30 students	SESD 1 = 20 students
Traditional (Control)	SST 2 = 31 Students	SESD 2 = 21 students

5.4.1 Student Sample Background (Computer Access and Utility among Students)

A number of characteristics of the students' background were collected in the surveys. This included things such as whether or not they had personal computer and Internet access, and their basic knowledge of PBL, creative thinking and critical thinking. Descriptive statistics for each statement and each group are shown in Table 8. From the table, it seems that both groups (PBL and traditional) have almost the same level of access to computers and the Internet, and perception of PBL, creative and critical thinking. Hence, the researcher assumes here that both groups are similar in the background relevant to the intervention.

Table 8

Access to computer and utility amongst SST and SESD Students

Gender		Have Personal Computer at Home		Have Internet Connection at home		Heard of PBL before		Heard of Creative Thinking before		Heard of Critical Thinking before	
		SST	SESD	SST	SESD	SST	SESD	SST	SESD	SST	SESD
		PBL (Traditional)		PBL (Traditional)		PBL (Traditional)		PBL (Traditional)		PBL (Traditional)	
Male	Yes	12 (10)	6 (3)	6 (4)	5 (1)	3 (6)	5 (1)	15 (10)	6 (3)	13 (10)	6 (3)
	No	3 (2)	- (-)	9 (8)	1 (2)	12 (6)	1 (2)	- (2)	- (-)	2 (2)	- (-)
	Total	15 (12)	6 (3)	15 (12)	6 (3)	15 (12)	6 (3)	15 (12)	6 (3)	15 (12)	6 (3)
Female	Yes	14 (15)	14 (18)	9 (10)	10 (10)	4 (7)	11 (14)	16 (17)	14 (18)	16 (18)	14 (18)
	No	2 (3)	- (-)	7 (8)	4 (8)	12 (11)	3 (4)	- (1)	- (-)	0 (0)	- (-)
	Total	16 (18)	14 (18)	16 (18)	14 (18)	16 (18)	14 (18)	16 (18)	14 (18)	16 (18)	14 (18)
Total	Yes	26 (25)	20 (21)	15 (14)	15 (11)	7 (13)	16 (15)	31 (27)	20 (21)	29 (28)	20 (21)
	No	5 (5)	- (-)	16 (16)	5 (10)	24 (17)	4 (6)	- (3)	- (-)	2 (2)	- (-)
	Total	31 (31)	20 (21)	31 (30)	20 (21)	31 (30)	20 (21)	31 (30)	20 (21)	31 (30)	20 (21)

5.4.2 Student Sample Background (Pointer Mean from previous semester)

A brief survey was distributed to students one week before the intervention to obtain demographic data. The analysis is presented separately for the SST and SESD students since the intervention was done independently for each group. There were several characteristics that were taken into consideration: whether or not they were familiar with problem-based learning, creative and critical thinking (Table 8), and grade (based on highest grade in physics).

Table 9

Pointer mean and test statistics between groups for SST

Group	Pointer Mean (SD)	Independent Samples t-Test Test Statistics (a) for Equality of Means	
		t (df = 59) {Sig (2-tailed)}	z {Asymp.Sig.(2-tailed)}
Traditional (N=31)	4.53 (3.00)	0.58 {0.56}	-0.63 {0.53}
PBL (N=30)	4.09 (2.87)		
Total (N=61)	4.32 (2.92)		

Note. (a) Grouping Variable: Type of Approach

For the SST students, the data in Table 9 shows there are no statistically significant differences for the PBL and traditional group. These data suggests that the samples are similar in terms of their physics grades in the previous semester.

Table 10

Pointer mean and test statistics between groups for SESD

Group	Pointer Mean (SD)	Independent Samples t-Test Test Statistics (a) for Equality of Means	
		t (df = 39) {Sig (2-tailed)}	z {Asymp.Sig.(2-tailed)}
Traditional (N=21)	2.78 (1.38)	-0.47 {0.65}	-0.29 {0.77}
PBL (N=20)	3.00 (1.62)		
Total (N=21)	2.89 (1.49)		

Note. (a) Grouping Variable: Type of Approach

Similarly, for the SESD students, data in Table 10 indicates no statistically significant differences between the groups.

5.4.3 Students' Prior Concepts of Modern Physics Comprehensions

5.4.3.1 Science Physics Students (SST)

Referring to Chapter 5, under the data analyses, the researcher used to analyse the survey data as described in Section 5.9. Thus, only the results will be mentioned in this subchapter.

Table 11

SST students' prior concepts of modern physics report mean (traditional and PBL group) and the Independent Sample t-Test and Mann-Whitney U Test

			Group		Total	t	z
			Traditional Mean (SD)	PBL Mean (SD)	Mean (SD)	(df=59) (Sig 2 tailed.)	Asymp. Sig. (2-tailed)
Chapter 1	1.A	Review of Classical Physics	3.31 (0.69)	3.43 (0.82)	3.37 (0.75)	-0.64 (0.53)	-0.52 (0.60)
	1.B	Unit and dimensions	3.79 (0.83)	3.70 (0.75)	3.75 (0.79)	0.46 (0.65)	-0.53 (0.60)
	1.C	Significant Figures	3.66 (0.70)	3.69 (0.79)	3.67 (0.74)	-0.18 (0.86)	-0.03 (0.98)
	1.D	Theory, Experiment, Law	3.34 (0.74)	3.57 (0.82)	3.45 (0.78)	-1.11 (0.27)	-1.06 (0.29)
Chapter 2	2.A	Postulates of Relativity	2.23 (0.88)	2.59 (0.67)	2.41 (0.80)	-1.76 (0.09)	-1.72 (0.09)
	2.B	Einstein's postulates	2.37 (0.84)	2.83 (0.70)	2.60 (0.80)	-2.36 (0.02*)	-2.26 (0.02*)
	2.C	Simultaneity and Ideal Observers	2.33 (1.08)	2.47 (0.94)	2.40 (1.00)	-0.52 (0.61)	-0.80 (0.43)
	2.D	Time dilation	2.37	2.63	2.50	-1.13	-0.85

			(1.08)	(0.73)	(0.92)	(0.26)	(0.39)
	2.E	Length contraction	2.33 (1.04)	2.63 (0.93)	2.48 (0.99)	-1.19 (0.24)	-1.04 (0.30)
	2.F	Velocities in different reference frames	2.53 (1.02)	2.83 (0.95)	2.61 (0.99)	-1.19 (0.24)	-1.12 (0.26)
	2.G	Relativistic momentum	2.41 (0.98)	2.83 (0.99)	2.62 (1.00)	-1.67 (0.10)	-1.58 (0.12)
	2.H	Mass and energy	2.77 (1.17)	3.23 (0.82)	3.00 (1.03)	-1.80 (0.08)	-1.65 (0.10)
	2.I	Relativistic kinetic energy	2.66 (1.07)	2.87 (0.90)	2.76 (0.99)	-0.83 (0.41)	-0.76 (0.45)
Chapter 3	3.A	The wave-particle duality	2.93 (1.09)	3.23 (0.97)	3.08 (1.04)	-1.13 (0.26)	-0.93 (0.35)
	3.B	Matter waves	3.00 (0.77)	2.93 (0.94)	2.97 (0.86)	0.30 (0.76)	-0.34 (0.73)
	3.C	Electron microscopes	2.57 (0.92)	2.87 (1.04)	2.71 (0.98)	-1.19 (0.24)	-1.28 (0.20)
	3.D	The Uncertainty Principle	2.45 (0.95)	2.80 (0.92)	2.62 (0.95)	-1.46 (0.15)	-1.39 (0.16)
	3.E	Wave functions for a confined particle	2.47 (0.76)	2.67 (0.88)	2.57 (0.82)	-0.95 (0.35)	-0.97 (0.33)
	3.F	The hydrogen atom: Wave functions and quantum numbers	2.47 (0.85)	2.90 (0.92)	2.68 (0.90)	-1.91 (0.06)	-2.03 (0.04*)
	3.G	The exclusion principle	2.17 (0.73)	2.63 (1.00)	2.40 (0.90)	-2.08 (0.04*)	-2.02 (0.04*)
	3.H	electron configurations for atoms other than hydrogen	2.57 (0.99)	3.03 (0.96)	2.80 (1.00)	-1.86 (0.07)	-1.78 (0.08)
	3.I	Understanding the periodic table	3.64 (0.77)	3.57 (0.76)	3.61 (0.76)	0.35 (0.73)	-0.77 (0.44)
Chapter 4	4.A	Nuclear structure	3.04 (0.84)	3.07 (0.87)	3.05 (0.85)	-0.15 (0.88)	-0.14 (0.89)
	4.B	Binding energy	3.31 (0.67)	3.18 (0.79)	3.24 (0.73)	0.69 (0.49)	-0.92 (0.36)
	4.C	Radioactivity	3.35 (0.63)	3.25 (0.77)	3.30 (0.70)	0.54 (0.59)	-0.53 (0.60)
	4.D	Radioactive decay rates and half-lives	3.19 (0.78)	3.43 (0.72)	3.31 (0.75)	-1.24 (0.22)	-1.07 (0.28)
Chapter 5	5.A	Fundamental particles	2.81 (0.68)	2.79 (0.92)	2.80 (0.80)	0.11 (0.92)	-0.02 (0.99)
	5.B	the weak nuclear force	2.88 (0.83)	2.79 (0.71)	2.84 (0.77)	0.50 (0.62)	-0.20 (0.84)
	5.C	the electromagnetic force	3.32 (0.67)	3.19 (0.83)	3.25 (0.75)	0.73 (0.47)	-1.05 (0.29)
	5.D	the strong nuclear force	2.96 (0.75)	2.79 (0.71)	2.87 (0.73)	0.94 (0.35)	-0.37 (0.71)
	5.E	Strong Interaction	3.04 (0.60)	2.71 (0.98)	2.88 (0.82)	1.57 (0.12)	-2.36 (0.02*)
	5.F	Weak Interaction	2.88 (0.70)	2.64 (0.92)	2.77 (0.82)	1.16 (0.25)	-0.87 (0.39)
	5.G	Weak forces and electromagnetic	3.00 (0.73)	2.93 (0.74)	2.96 (0.73)	0.39 (0.70)	-0.82 (0.41)
	5.H	Strong force with the electroweak force	2.92 (0.73)	2.78 (0.92)	2.85 (0.83)	0.68 (0.50)	-0.35 (0.73)
	5.I	The *quarks, lepton, muon* particle	2.31 (0.81)	2.15 (1.01)	2.23 (0.91)	0.69 (0.50)	-0.90 (0.37)

The table above also shows that all the data output of Independent Samples t-Test and Mann-Whitney U test is not significant, except for statement 2B: Einstein's postulates and statement 3G: The exclusion principle scored t = -2.36, p =0.02<0.05*; z = -2.26, Sig. Asymp (2-tailed) = 0.02<0.05* and t = -2.08, p =0.04<0.05*; z = -2.02, Sig. Asymp (2-tailed) = 0.04<0.05* respectively. PBL groups noted higher means for these statements compared to their counter parts. Two statements showing significant differences only in Mann-Whitney U test analyses which are 3F: The hydrogen atom, Wave functions and quantum numbers; and 5E: Strong Interaction scored z = -2.03, Sig. Asymp (2-tailed) = 0.04<0.05* and z = -2.36, Sig. Asymp (2-tailed) = 0.02<0.05* respectively.

Thus, the result indicates generally, no substantly differences in student prior concept of modern physics comprehension aspects exist between PBL and traditional group.

5.4.3.2 Pre-Service Teachers (SESD)

Referring to Chapter 5, under the data analyses, the researcher used to analyse the survey data as described in Section 5.9. Thus, only the results will be mentioned in this subchapter.

Table 12
SESD students' prior concept of modern physic report means (traditional and PBL group) and the Independent Sample t-Test and Mann-Whitney U Test

			Group		Total	t	z
			Traditional Mean (SD)	PBL Mean SD	Mean	(df=39) (Sig 2 tailed.)	Asymp. Sig. (2-tailed)
Chapter 1	1.A	Review of Classical Physics	3.00 (0.95)	3.65 (0.91)	3.32 (0.98)	-2.22 (0.03*)	-1.90 (0.06)
	1.B	Unit and dimensions	3.95 (0.97)	4.06 (0.76)	4.00 (0.87)	-0.40 (0.69)	-0.76 (0.45)
	1.C	Significant Figures	3.90 (1.09)	4.24 (0.61)	4.06 (0.89)	-1.21 (0.23)	-1.08 (0.28)
	1.D	Theory, Experiment, Law	3.35 (0.91)	3.71 (0.63)	3.52 (0.80)	-1.45 (0.15)	-0.85 (0.39)
Chapter 2	2.A	Postulates of Relativity	2.40 (0.92)	2.47 (0.98)	2.43 (0.94)	-0.24 (0.81)	-0.11 (0.91)
	2.B	Einstein's postulates	2.30 (0.84)	2.59 (1.03)	2.44 (0.94)	-0.98 (0.33)	-0.74 (0.46)
	2.C	Simultaneity and Ideal Observers	2.30 (0.95)	2.29 (0.96)	2.30 (0.95)	0.02 (0.98)	-0.12 (0.90)
	2.D	Time dilation	2.60 (0.86)	2.53 (0.92)	2.57 (0.88)	0.25 (0.80)	-0.46 (0.65)
	2.E	Length contraction	2.75	2.76	2.76	-0.05	-0.16

			(0.94)	(0.95)	(0.93)	(0.96)	(0.87)
	2.F	Velocities in different reference frames	2.75 (1.04)	2.76 (1.05)	2.76 (1.03)	-0.04 (0.97)	-0.14 (0.89)
	2.G	Relativistic momentum	2.80 (0.98)	3.00 (0.86)	2.90 (0.92)	-0.69 (0.49)	-0.74 (0.46)
	2.H	Mass and energy	3.60 (0.97)	3.47 (0.92)	3.54 (0.94)	0.44 (0.66)	-0.87 (0.38)
	2.I	Relativistic kinetic energy	3.15 (1.15)	3.24 (1.05)	3.19 (1.09)	-0.25 (0.81)	-0.20 (0.84)
Chapter 3	3.A	The wave-particle duality	2.70 (0.84)	3.00 (0.97)	2.85 (0.92)	-1.06 (0.30)	-1.07 (0.29)
	3.B	Matter waves	2.65 (0.79)	3.18 (0.87)	2.91 (0.86)	-2.03 (0.05)	-2.09 (0.04*)
	3.C	Electron microscopes	2.65 (0.73)	2.82 (0.99)	2.73 (0.86)	-0.64 (0.53)	-0.41 (0.68)
	3.D	The Uncertainty Principle	2.30 (1.00)	2.47 (0.73)	2.38 (0.88)	-0.62 (0.54)	-1.00 (0.32)
	3.E	Wave functions for a confined particle	2.30 (0.95)	2.59 (0.86)	2.44 (0.91)	-1.01 (0.32)	-1.00 (0.32)
	3.F	The hydrogen atom: Wave functions and quantum numbers	2.30 (0.84)	2.65 (0.97)	2.47 (0.91)	-1.23 (0.23)	-1.11 (0.27)
	3.G	The exclusion principle	1.90 (0.83)	2.47 (0.87)	2.18 (0.89)	-2.15 (0.04*)	-2.28 (0.02*)
	3.H	electron configurations for atoms other than hydrogen	2.65 (1.11)	2.53 (1.03)	2.59 (1.06)	0.36 (0.72)	-0.35 (0.73)
	3.I	Understanding the periodic table	3.37 (1.06)	4.06 (0.51)	3.71 (0.90)	-2.65 (0.01*)	-2.71 (0.01*)
Chapter 4	4.A	Nuclear structure	2.85 (0.96)	3.50 (0.65)	3.17 (0.88)	-2.52 (0.02*)	-2.32 (0.02*)
	4.B	Binding energy	2.90 (0.94)	3.44 (0.79)	3.16 (0.90)	-1.97 (0.06)	-1.83 (0.07)
	4.C	Radioactivity	3.10 (1.09)	3.31 (0.84)	3.20 (0.97)	-0.69 (0.49)	-0.55 (0.28)
	4.D	Radioactive decay rates and half-lives	2.95 (0.97)	3.25 (0.89)	3.10 (0.93)	-1.03 (0.31)	-1.37 (0.17)
Chapter 5	5.A	Fundamental particles	2.85 (0.91)	3.25 (0.83)	3.05 (0.88)	-1.47 (0.15)	-1.61 (0.11)
	5.B	the weak nuclear force	2.55 (1.02)	3.06 (0.69)	2.80 (0.90)	-1.87 (0.07)	-1.98 (0.05)
	5.C	the electromagnetic force	3.15 (1.06)	3.50 (0.73)	3.32 (0.93)	-1.23 (0.23)	-0.91 (0.36)
	5.D	the strong nuclear force	2.89 (1.04)	3.25 (0.69)	3.07 (0.90)	-1.28 (0.21)	-1.30 (0.19)
	5.E	Strong Interaction	2.90 (1.09)	3.25 (0.83)	3.07 (0.98)	-1.15 (0.26)	-1.23 (0.22)
	5.F	Weak Interaction	2.95 (1.07)	3.25 (0.83)	3.10 (0.96)	-1.00 (0.32)	-1.11 (0.27)
	5.G	Weak forces and electromagnetic	3.00 (1.10)	3.56 (0.72)	3.27 (0.96)	-1.93 (0.06)	-1.63 (0.10)
	5.H	Strong force with the electroweak force	2.55 (0.80)	3.00 (0.73)	2.71 (0.79)	-1.88 (0.07)	-2.02 (0.04*)
	5.I	The *quarks, lepton, muon* particle	1.60 (0.65)	2.56 (0.97)	2.09 (0.94)	-3.54 (0.00)	-3.25 (0.00*)

Table 12 showed only one statement recorded differences at a significant level after analysis using Independent sample t-test. The statement is 1A: Review of Classical Physics [t = -2.22, p = 0.03<0.05*]. After analysis using Mann-Whitney

U test there are three statements showing significant differences which are 3B : Matter waves; 5H: Strong force with the electroweak force; 5I: The quarks, lepton, muon particle [z =-2.09, Sig. Asymp (2-tailed) = 0.04<0.05*; z = -2.02, Sig. Asypm. (2-tailed) = 0.04<0.05*; z= -3.25, Sig. Asypm. (2-tailed) = 0.04 <0.05*]. And another three statements showing significant differences in both analyses which are 3G: The exclusion principle; 3I: Understanding the periodic table; 4A: Nuclear structure [t = -2.15, p =0.04<0.05*, z = -2.28, sig. asymp (2-tailed) = 0.02<0.05*; t = -2.65, p =0.01<0.05*, z = -2.71, sig. asymp (2-tailed) = 0.01<0.05*; t = -2.52, t =0.02<0.05*, z = -2.32, sig. asymp (2-tailed) = 0.02<0.05*].

All of these statements indicate that the PBL group has a higher mean when compared to its counterparts, whilst the rest shows no significant difference. Thus, in general, the result indicates no substantially differences in SESD students' prior concept of modern physics comprehension aspects exist between PBL and traditional group.

5.4.4 Students' Readiness for Online Learning and Student's Competencies and Skills in using a Personal Computer

5.4.4.1 Science Physics Students (SST)

The researcher analysed the surveys according to subchapter 5.9 (Data Analyses). Thus, only the result will be mentioned in this section.

Table 13
Part A: SST students' skills and readiness for learning through the use of a computer or to work with online learning

Statement	Traditional (N = 31)	PBL (N = 30)	Total (N=61)	t (df=59)	z [Asymp.
COMPUTER SKILLS	Mean (SD)	Mean (SD)	Mean (SD)	[Sig. (2-tailed)]	Sig.(2-tailed)]
1.1 I have easy access to a PC	3.68 (0.95)	3.57 (1.10)	3.62 (4.16)	0.42 (0.68)	-0.42 (0.68)
1.2 I am comfortable about using a PC	3.94 (0.73)	3.80 (0.93)	3.87 (4.26)	0.64 (0.53)	-0.46 (0.65)
1.3 I am very skilful in handling basic PC use	3.42 (0.81)	3.27 (1.08)	3.34 (3.58)	0.63 (0.53)	-0.78 (0.44)
INTERNET SKILLS					
2.1 I have easy access to the Internet	3.29 (1.10)	3.33 (1.06)	3.31 (1.07)	-0.16 (0.88)	-0.11 (0.91)
2.2 I am competent in usage of the Internet	3.29 (0.97)	3.43 (0.82)	3.36 (0.90)	-0.62 (0.54)	-0.46 (0.65)
2.3 My Internet skills are sufficient for taking a web-based course	3.00 (0.97)	3.27 (0.87)	3.13 (0.92)	-1.13 (0.26)	-1.17 (0.24)

STUDENTS' READINESS					
3.1 I feel comfortable learning via a PC and in online learning	3.16 (0.86)	3.63 (0.81)	3.39 (0.86)	-2.21 (0.03*)	-2.16 (0.03*)
3.2 I feel comfortable working with a PC *(e.g. doing assignments, assessment, etc.)*	3.58 (0.72)	3.70 (0.70)	3.64 (0.71)	-0.66 (0.52)	-0.58 (0.56)
3.3 I feel comfortable communicating with other classmates online	3.13 (0.85)	3.37 (0.93)	3.25 (0.89)	-1.05 (0.30)	-0.91 (0.36)
3.4 I feel comfortable communicating with my instructor online	2.97 (0.80)	3.37 (0.81)	3.16 (0.82)	-1.94 (0.06)	-1.72 (0.09)
3.5 I feel comfortable searching for information online	3.87 (0.81)	4.03 (0.67)	3.95 (0.74)	-0.86 (0.40)	-0.67 (0.52)
3.6 I feel comfortable sharing my knowledge with friends and facilitator online	2.90 (0.79)	3.60 (0.77)	3.25 (0.85)	-3.49 (0.00*)	-3.20 (0.00*)
3.7 I am comfortable changing my source of learning with friends via online	2.90 (0.79)	3.40 (0.97)	3.15 (0.91)	-2.20 (0.03*)	-2.19 (0.03*)
3.8 I know how to use a standard word processor, such as Microsoft Word, Microsoft Works, or Word Perfect	3.45 (0.85)	3.73 (1.02)	3.59 (0.94)	-1.18 (0.24)	-1.33 (0.18)
3.9 I feel capable of determining main ideas and concepts when reading notes, text books or other knowledge sources online	3.19 (0.75)	3.63 (0.72)	3.41 (0.76)	-2.34 (0.02*)	-2.22 (0.03*)
3.10 I feel I am a self-motivated, independent learner, when it comes to learning online	2.81 (0.65)	3.57 (0.77)	3.18 (0.81)	-4.15 (0.00*)	-3.65 (0.00*)
3.11 I am comfortable with file management on a PC, such as moving files around different directories and drives, saving files, or deleting files.	3.81 (0.87)	3.83 (0.79)	3.82 (0.83)	-0.13 (0.90)	-0.07 (0.95)
STUDENT PERSONALITIES					
4.1 I have very strong motivation towards learning online learning	2.77 (0.67)	3.41 (0.56)	3.09 (0.69)	-4.05 (0.00*)	-3.66 (0.00*)
4.2 I can improve my problem-solving skill ability via online learning	2.94 (0.81)	3.55 (0.77)	3.24 (0.85)	-3.04 (0.04*)	-3.16 (0.00*)
4.3 I can improve my ability to work independently	3.32 (0.83)	3.83 (0.59)	3.57 (0.76)	-2.73 (0.01*)	-2.47 (0.01*)
4.4 I can improve myself in terms of my task management and organization	3.29 (0.64)	3.76 (0.77)	3.52 (0.74)	-2.58 (0.01*)	-2.47 (0.01*)
CULTURAL FACTORS					
5.1 I find face-to-face learning more convenient than online learning	3.55 (0.96)	3.66 (0.76)	3.60 (0.86)	-0.48 (0.63)	-0.13 (0.90)
5.2 I believe that my cultural beliefs about online learning are acceptable	3.26 (0.68)	3.45 (0.67)	3.35 (0.68)	-1.10 (0.28)	-1.06 (0.29)
5.3 I believe that my culture is consistent with learning via online learning	3.16 (0.69)	3.17 (0.59)	3.17 (0.64)	-0.07 (0.95)	-0.56 (0.58)
5.4 My family support my learning through online learning	3.06 (0.89)	3.52 (0.82)	3.29 (0.88)	-2.07 (0.04)	-1.67 (0.20)
LEARNING STYLE					
6.1 I feel that online learning is important in classroom discussion	3.39 (0.72)	3.59 (0.85)	3.49 (0.79)	-0.99 (0.33)	-0.94 (0.35)
6.2 I think that online learning has improved my reading comprehension	3.35 (0.80)	3.52 (0.68)	3.44 (0.74)	-0.86 (0.40)	-0.44 (0.66)
6.3 I think that online learning has improved my written expression	3.13 (0.72)	3.31 (0.65)	3.22 (0.69)	-1.03 (0.31)	-0.90 (0.37)
6.4 I think that online learning has improved my communication skills	3.06 (0.68)	3.21 (0.71)	3.14 (0.69)	-0.80 (0.43)	-0.86 (0.39)
ANXIETY/ TRUST					
7.1 I am very uncomfortable about disclosing personal information online	3.23 (0.85)	3.14 (0.90)	3.18 (0.87)	0.39 (0.70)	-0.17 (0.87)
7.2 I belief that I can trust Internet security	2.68 (0.98)	2.62 (0.96)	2.65 (0.96)	0.23 (0.82)	-0.17 (0.87)
7.3 I am not anxious or nervous about working in an online environment	3.32 (0.65)	3.31 (0.84)	3.32 (0.74)	0.06 (0.95)	-0.12 (0.92)
7.4 I think the quality of information posted online can be trusted	3.03 (0.84)	2.83 (0.79)	2.93 (0.81)	0.98 (0.33)	-0.95 (0.34)

Table 14
Part B: SST competencies when using a personal computer (PC)

Statement	Trad (N = 31)	PBL (N = 30)	Total (N = 61)	t (df=59)	z [Asymp.
LEVEL OF SOFTWARE KNOWLEDGE	Mean (SD)	Mean (SD)	Mean (SD)	[Sig. (2-tailed)]	Sig.(2-tailed)]
B1.1 Word processor software usage *(e.g. MS word, Ampiro/Word pro, Word Perfect etc.)*	3.10 (0.83)	3.28 (0.78)	3.18 (0.81)	-0.87 (0.39)	-0.94 (0.35)
B1.2 Electronic motherboard usage *(e.g. MS Excel, Lotus 123 etc.)*	2.58 (0.72)	2.66 (0.88)	2.62 (0.80)	-0.36 (0.72)	-0.45 (0.66)
B1.3 Software presentation usage *(e.g. MS Power Point, Freelance etc.)*	3.29 (0.82)	3.07 (0.83)	3.18 (0.83)	1.05 (0.30)	-0.92 (0.36)
B1.4 Database usage *(e.g. MS Access, Dbase etc.)*	2.45 (0.93)	2.45 (0.77)	2.45 (0.85)	0.02 (0.99)	-0.15 (0.88)
B1.5 Graphic software usage *(e.g. Corel Draw, Autocard, Harvard Graphics etc.)*	2.29 (1.01)	2.11 (0.99)	2.20 (1.00)	0.71 (0.48)	-0.46 (0.65)
B1.6 Statistic software usage *(e.g. SAS, SPSS etc.)*	1.90 (0.94)	1.93 (0.91)	1.92 (0.92)	-0.13 (0.90)	-0.19 (0.85)
B1.7.1 Operation system using DOS	2.07 (1.21)	1.86 (0.82)	1.97 (1.03)	0.78 (0.44)	-0.46 (0.64)
B1.7.2 Operation system using Windows	2.94 (1.24)	3.28 (0.98)	3.10 (1.12)	-1.19 (0.24)	-0.94 (0.35)
B1.7.3 Operation system using MAC OS	1.79 (0.87)	1.83 (0.83)	1.81 (0.85)	-0.16 (0.87)	-0.28 (0.78)
B1.7.4 Operation system using UNIX	1.66 (0.74)	1.72 (0.83)	1.69 (0.78)	-0.34 (0.73)	-0.23 (0.82)
B.1.7.5 Operation system using NT/MS2000	1.55 (0.80)	1.83 (0.91)	1.69 (0.86)	-1.26 (0.21)	-1.22 (0.22)
B1.7.6 Operation system using Novell	1.83 (1.07)	1.72 (0.78)	1.78 (0.93)	0.43 (0.67)	-0.05 (0.96)
B1.8 Utility software usage *(e.g. Norton Anti-Virus, Norton Utilities etc.)*	2.71 (1.01)	2.85 (0.78)	2.78 (0.90)	-0.62 (0.54)	-0.05 (0.96)
B1.9 Multimedia package usage *(e.g. MM Director, MM Authorware etc.)*	2.39 (1.05)	2.14 (1.04)	2.26 (1.05)	0.93 (0.36)	-0.85 (0.39)
B1.10 Programming *(e.g. C/C++, Java etc.)*	2.00 (1.10)	1.86 (0.86)	1.93 (0.98)	0.55 (0.59)	-0.29 (0.77)
B1.11 Perisian matematik *(e.g. Matlab, etc)*	1.68 (0.98)	1.86 (0.94)	1.77 (0.96)	-0.75 (0.46)	-1.00 (0.32)
B1.12 Desktop publishing software *(e.g. Publisher, pagemaker, etc.)*	1.84 (1.16)	1.93 (0.98)	1.88 (1.07)	-0.34 (0.74)	-0.66 (0.51)
LEVEL OF COMPUTER HARDWARE SKILL					
B2.1 Upgrading a computer component *(e.g. memory, floppy disk, motherboard)*	2.39 (1.05)	2.62 (1.19)	2.50 (1.12)	-0.81 (0.42)	-1.32 (0.19)
B2.2 I understand specifications needed to make a good decision about buying a computer	3.20 (1.11)	2.90 (1.06)	3.05 (1.09)	1.09 (0.28)	-1.73 (0.08)
B2.3 I know how to install/using every piece of equipment for each unit of computer. *(e.g. monitor, CPU, mouse, CD ROM, key board, etc.)*	3.33 (0.97)	3.03 (0.85)	3.19 (0.92)	1.28 (0.21)	-0.79 (0.43)
B2.4 I know every type of card that is connected to the PC mother board and the function for each card *(e.g. display card, sound card, modem etc.)*	2.44 (0.98)	2.66 (1.09)	2.55 (1.03)	-0.80 (0.43)	-0.01 (0.99)
B2.5 I am using scanner	2.96 (1.05)	2.86 (0.97)	2.91 (1.01)	0.39 (0.70)	-0.01 (0.99)
B2.6 Using printer and plotter	3.23 (1.04)	3.35 (1.09)	3.29 (1.06)	-0.42 (0.68)	-0.64 (0.52)
B2.7 Using CD-RW	3.33 (1.10)	3.59 (0.85)	3.46 (0.98)	-1.01 (0.32)	-0.68 (0.50)
LEVEL OF SKILL OF PERSONAL COMPUTER MAINTENANCE					

B3.1 Computer hardware/equipment maintenance *(e.g. computer, maintenance, printer, scanner etc)*	2.81 (1.00)	2.86 (0.90)	2.84 (0.95)	-0.20 (0.85)	-0.60 (0.55)
B3.2 Installing software and application *(e.g. installing printer software, scanner software, SPSS software, etc)*	3.33 (1.07)	3.21 (0.96)	3.27 (1.01)	0.48 (0.63)	-0.77 (0.44)
B3.3 Troubleshooter *(e.g. maintenance problem, software problem, virus problem and networking problem)*	2.96 (1.08)	2.45 (0.97)	2.71 (1.05)	1.96 (0.06)	-1.63 (0.10)
B3.4 Handling technology and multimedia equipment *(e.g. LCD projector, OHP, etc)*	2.67 (1.07)	2.69 (0.88)	2.68 (0.97)	-0.09 (0.93)	-0.32 (0.75)
B3.5 Usage of 'BIOS SETUP'	2.04 (0.91)	2.07 (0.91)	2.05 (0.90)	-0.14 (0.89)	-0.06 (0.95)
LEVEL OF NETWORKING SKILL					
B4.1 E-mail usage	3.96 (0.80)	3.69 (0.95)	3.83 (0.88)	1.22 (0.23)	-0.88 (0.38)
B4.2 Internet surfing	3.96 (0.71)	3.93 (0.74)	3.95 (0.72)	0.18 (0.86)	-0.15 (0.88)
B4.3 Microsoft networking	3.30 (0.89)	2.86 (0.90)	3.08 (0.91)	1.90 (0.06)	-2.17 (0.03*)
B4.4 Novell	1.93 (1.00)	2.07 (0.87)	2.00 (0.93)	-0.60 (0.55)	-1.13 (0.26)
B4.5 Differentiate using external modem and card modem	2.44 (1.16)	2.76 (1.16)	2.60 (1.17)	-1.06 (0.30)	-1.18 (0.24)
B4.6 Develop web-page	2.33 (1.07)	2.03 (1.03)	2.19 (1.05)	1.11 (0.27)	-1.25 (0.21)
B4.7 HTML/Javascript Usage	2.53 (1.11)	2.07 (1.05)	2.30 (1.09)	1.65 (0.10)	-1.73 (0.08)
B4.8 Uploading/Downloading file	3.71 (0.89)	3.48 (1.10)	3.60 (1.00)	0.87 (0.39)	-0.59 (0.56)
B4.9 Develop your own blog	2.44 (1.08)	2.66 (1.09)	2.55 (1.08)	-0.76 (0.45)	-0.86 (0.39)
B4.10 Testimonial /comment *(e.g., Friendster, MySpace, facebook, xanga, tagged, hi5, and blogger)*	3.93 (0.93)	3.48 (1.16)	3.71 (1.07)	1.65 (0.10)	-1.32 (0.19)
B4.11 Using Yahoo Messenger (YM)	4.07 (0.85)	3.48 (1.16)	3.78 (1.05)	2.27 (0.03*)	-2.25 (0.03*)
B4.12 Using of SKYPE	3.15 (1.38)	2.76 (1.38)	2.96 (1.39)	1.10 (0.28)	-1.25 (0.21)
B4.13 Attach and send file using YM/SKYPE	3.41 (1.37)	2.97 (1.27)	3.19 (1.33)	1.30 (0.20)	-1.49 (0.14)
B4.14 Plug-ins, web-cam, sharing photos on-line, conference	3.78 (1.08)	3.17 (1.18)	3.48 (1.16)	2.10 (0.05)	-1.99 (0.05)

The Table 13 and Table 14 above shows all the data outputs for mean, standard deviation, Independent Sample t-Test and also the Mann Whitney U test statistics test (in case of non-parametric test). The table shows there were no significant differences recorded, except for ten statements, most of them favour the PBL group.

5.4.4.2 Pre-Service Teachers (SESD)

Similarly, for SESD students, the researcher analysed the surveys according to subchapter 5.9 (Data Analyses). Thus, only the result will be mentioned in this section.

Table 15
Part A: SESD students' skills and readiness for learning through the use of a computer or to work with online learning

Statement	Traditional (N = 21)	PBL (N = 20)	Total (N=41)	t (df=39) [Sig. (2-tailed)]	z [Asymp. Sig.(2-tailed)]
COMPUTER SKILLS	Mean (SD)	Mean (SD)	Mean (SD)		
1.1 I have easy access to a PC	4.16 (0.65)	4.45 (0.67)	4.30 (0.67)	-1.40 (0.17)	-1.42 (0.16)
1.2 I am comfortable about using a PC	4.26 (0.76)	4.61 (0.58)	4.43 (0.69)	-1.65 (0.11)	-1.53 (0.13)
1.3 I am very skilful in handling basic PC use	3.58 (0.86)	4.01 (0.65)	3.79 (0.78)	-1.79 (0.08)	-1.95 (0.05)
INTERNET SKILLS					
2.1 I have easy access to the Internet	3.84 (0.73)	3.67 (0.80)	3.76 (0.76)	0.71 (0.48)	-0.90 (0.37)
2.2 I am competent in usage of the Internet	3.68 (0.84)	3.77 (0.52)	3.73 (0.70)	-0.41 (0.68)	-0.34 (0.73)
2.3 My Internet skills are sufficient for taking a web-based course	3.16 (0.73)	3.72 (0.54)	3.43 (0.70)	-2.79 (0.01*)	-2.55 (0.01*)
STUDENTS' READINESS					
3.1 I feel comfortable learning via a PC and in online learning	3.42 (0.73)	3.88 (0.72)	3.65 (0.75)	-2.05 (0.05)	-1.42 (0.16)
3.2 I feel comfortable working with a PC *(e.g. doing assignments, assessment, etc.)*	3.74 (0.83)	4.22 (0.77)	3.97 (0.83)	-1.94 (0.06)	-2.34 (0.02*)
3.3 I feel comfortable communicating with other classmates online	3.32 (1.00)	3.99 (0.80)	3.64 (0.96)	-2.37 (0.02*)	-2.14 (0.03*)
3.4 I feel comfortable communicating with my instructor online	3.26 (0.83)	3.93 (0.83)	3.59 (0.88)	-2.60 (0.01*)	-2.24 (0.03*)
3.5 I feel comfortable searching for information online	4.26 (0.53)	4.28 (0.78)	4.27 (0.66)	-0.06 (0.95)	-0.53 (0.60)
3.6 I feel comfortable sharing my knowledge with friends and facilitators online	3.42 (1.02)	3.87 (0.85)	3.64 (0.96)	-1.54 (0.13)	-1.19 (0.23)
3.7 I am comfortable changing my source of learning with friends via online	3.63 (0.91)	3.93 (0.61)	3.78 (0.78)	-1.25 (0.21)	-0.98 (0.33)
3.8 I know how to use a standard word processor, such as Microsoft Word, Microsoft Works, or Word Perfect	4.05 (0.74)	4.01 (0.80)	4.03 (0.76)	0.20 (0.84)	-0.13 (0.90)
3.9 I feel capable of determining main ideas and concepts when reading notes, text books or other knowledge sources online	3.53 (0.73)	3.82 (0.74)	3.67 (0.74)	-1.26 (0.22)	-1.04 (0.30)
3.10 I feel I am a self-motivated, independent learner, when it comes to learning online	3.42 (0.80)	3.72 (0.63)	3.57 (0.73)	-1.35 (0.19)	-1.26 (0.22)
3.11 I am comfortable with file management on a PC, such as moving files around different directories and drives, saving files, or deleting files.	4.26 (0.62)	4.01 (0.83)	4.16 (0.73)	0.92 (0.37)	-0.61 (0.54)
STUDENT PERSONALITIES					
4.1 I have very strong motivation towards learning online learning	3.42 (1.02)	3.78 (0.89)	3.60 (0.96)	-1.20 (0.24)	-0.92 (0.36)
4.2 I can improve my problem-solving skill ability via online learning	3.21 (0.98)	3.89 (0.64)	3.54 (0.89)	-2.59 (0.01*)	-2.02 (0.05*)

4.3 I can improve my ability to work independently	3.74 (0.70)	3.77 (0.77)	3.76 (0.72)	-0.16 (0.87)	-0.20 (0.92)
4.4 I can improve myself in terms of my task management and organization	3.79 (0.68)	3.95 (0.76)	3.87 (0.71)	-0.69 (0.49)	-0.36 (0.72)
CULTURAL FACTORS					
5.1 I find face-to-face learning more convenient than online learning	3.74 (1.04)	3.66 (0.56)	3.70 (0.83)	0.28 (0.78)	-0.34 (0.73)
5.2 I believe that my cultural beliefs about online learning are acceptable	3.63 (0.57)	3.66 (0.65)	3.65 (0.60)	-0.17 (0.87)	-0.03 (0.98)
5.3 I believe that my culture is consistent with learning via online learning	3.42 (0.58)	3.77 (0.61)	3.59 (0.61)	-1.87 (0.07)	-1.53 (0.13)
5.4 My family support my learning through online learning	3.42 (0.73)	3.49 (0.74)	3.46 (0.73)	-0.31 (0.76)	-0.68 (0.50)
LEARNING STYLE					
6.1 I feel that online learning is important in classroom discussion	3.16 (0.79)	4.00 (0.80)	3.57 (0.89)	-3.40 (0.00*)	-3.07 (0.00*)
6.2 I think that online learning has improved my reading comprehension	3.53 (0.86)	3.84 (0.74)	3.68 (0.81)	-1.25 (0.22)	-0.83 (0.41)
6.3 I think that online learning has improved my written expression	3.37 (0.79)	3.67 (0.65)	3.51 (0.73)	-1.32 (0.19)	-0.97 (0.33)
6.4 I think that online learning has improved my communication skills	3.26 (0.83)	3.72 (0.63)	3.49 (0.77)	-2.00 (0.05)	-1.60 (0.11)
ANXIETY/ TRUST					
7.1 I am very uncomfortable about disclosing personal information online	3.21 (0.81)	2.95 (0.83)	3.08 (0.82)	1.04 (0.31)	-1.49 (0.14)
7.2 I believe that I can trust Internet security	2.68 (1.00)	3.11 (0.72)	2.89 (0.89)	-1.56 (0.13)	-1.58 (0.11)
7.3 I am not anxious or nervous about working in an online environment	3.53 (0.66)	3.78 (0.52)	3.65 (0.60)	-1.36 (0.18)	-1.24 (0.21)
7.4 I think the quality of information posted online can be trusted	3.05 (0.74)	3.39 (0.48)	3.22 (0.64)	-1.71 (0.09)	-1.26 (0.22)

Table 16

Part B: SESD competencies when using a personal computer (PC)

Statement	Trad (N = 21)	PBL (N = 20)	Total (N = 41)	t (df=39) [Sig. (2-tailed)]	z [Asymp Sig.(2-tailed)]
LEVEL OF SOFTWARE KNOWLEDGE	Mean (SD)	Mean (SD)	Mean (SD)		
B1.1 Word processor software usage *(e.g. MS word, Ampiro/Word pro, Word Perfect etc.)*	3.42 (0.73)	3.55 (0.67)	3.49 (0.69)	-0.60 (0.55)	-0.37 (0.71)
B1.2 Electronic motherboard usage *(e.g. MS Excel, Lotus 123 etc.)*	2.58 (0.73)	2.89 (1.02)	2.73 (0.89)	-1.12 (0.27)	-0.92 (0.36)
B1.3 Software presentation usage *(e.g. MS Power Point, Freelance etc.)*	3.58 (0.80)	3.45 (0.87)	3.51 (0.83)	0.51 (0.62)	-0.42 (0.68)
B1.4 Database usage *(e.g. MS Access, Dbase etc.)*	2.05 (0.81)	2.18 (0.93)	2.11 (0.86)	-0.46 (0.65)	-0.38 (0.70)
B1.5 Graphic software usage *(e.g. Corel Draw, Autocard, Harvard Graphics etc.)*	1.95 (0.87)	2.06 (0.95)	2.00 (0.90)	-0.40 (0.69)	-0.57 (0.57)
B1.6 Statistic software usage *(e.g. SAS, SPSS etc.)*	2.53 (0.97)	2.29 (0.85)	2.41 (0.92)	0.84 (0.41)	-0.84 (0.40)
B1.7.1 Operation system using DOS	1.58 (0.86)	2.11 (0.85)	1.84 (0.89)	-2.00 (0.05*)	-2.29 (0.02*)
B1.7.2 Operation system using Windows	2.84 (0.91)	3.49 (1.04)	3.16 (1.03)	-2.14 (0.04*)	-2.02 (0.04)
B1.7.3 Operation system using MAC OS	1.42 (0.73)	1.94 (0.76)	1.67 (0.78)	-2.23 (0.03*)	-2.43 (0.02*)
B1.7.4 Operation system using UNIX	1.37 (0.65)	1.83 (0.59)	1.59 (0.65)	-2.38 (0.02*)	-2.52 (0.01*)
B.1.7.5 Operation system using NT/MS2000	1.37 (0.65)	1.83 (0.67)	1.59 (0.69)	-2.24 (0.03*)	-2.30 (0.02*)

B1.7.6 Operation system using Novell	1.33 (0.63)	1.88 (0.64)	1.60 (0.69)	-2.77 (0.01*)	-2.76 (0.01*)
B1.8 Utility software usage *(e.g. Norton Anti-Virus, Norton Utilities etc.)*	2.89 (1.04)	3.12 (1.07)	3.00 (1.05)	-0.69 (0.50)	-0.90 (0.37)
B1.9 Multimedia package usage *(e.g. MM Director, MM Authorware etc.)*	2.00 (1.14)	2.44 (1.22)	2.22 (1.19)	-1.20 (0.24)	-1.30 (0.19)
B1.10 Programming *(e.g. C/C++, Java etc.)*	1.58 (0.86)	1.55 (0.67)	1.57 (0.76)	0.11 (0.91)	-0.23 (0.82)
B1.11 Perisian matematik *(e.g. Matlab, etc)*	2.05 (0.81)	2.01 (0.92)	2.03 (0.85)	0.18 (0.86)	-0.33 (0.74)
B1.12 Desktop publishing software *(e.g. Publisher, pagemaker, etc)*	1.94 (1.16)	2.40 (1.26)	2.16 (1.23)	-1.20 (0.24)	-1.42 (0.16)
LEVEL OF COMPUTER HARDWARE SKILL					
B2.1 Upgrading a computer component *(e.g. memory, floppy disk, motherboard)*	1.84 (0.91)	2.95 (1.00)	2.38 (1.20)	-3.70 (0.00*)	-3.28 (0.00*)
B2.2 I understand specifications needed to make a good decision about buying a computer	2.89 (0.89)	3.72 (0.85)	3.30 (0.96)	-3.06 (0.00*)	-2.69 (0.01*)
B2.3 I know how to install/use every piece of equipment for each unit of computer. *(e.g. monitor, CPU, mouse, CD ROM, key board, etc.)*	2.79 (1.33)	3.73 (0.78)	3.25 (1.18)	-2.75 (0.01*)	-2.53 (0.01*)
B2.4 I know every type of card that is connected to the PC mother board and the function for each card *(e.g. display card, sound card, modem etc.)*	2.21 (1.17)	2.62 (0.74)	2.41 (0.99)	-1.33 (0.19)	-1.64 (0.10)
B2.5 Using scanner	2.32 (1.05)	2.84 (1.04)	2.57 (1.07)	-1.60 (0.12)	-1.32 (0.19)
B2.6 Using printer and plotter	3.47 (0.97)	3.83 (0.81)	3.65 (0.90)	-1.29 (0.21)	-1.24 (0.22)
B2.7 Using CD-RW	3.74 (0.83)	3.95 (0.83)	3.84 (0.82)	-0.81 (0.43)	-0.93 (0.35)
LEVEL OF SKILL OF PERSONAL COMPUTER MAINTENANCE					
B3.1 Computer hardware/equipment maintenance *(e.g. computer, maintenance, printer, scanner etc)*	2.79 (1.03)	3.50 (0.87)	3.13 (1.01)	-2.37 (0.02*)	-2.40 (0.02*)
B3.2 Installing software and applications *(e.g. installing printer software, scanner software, SPSS software, etc)*	3.32 (1.10)	3.65 (0.97)	3.48 (1.04)	-1.03 (0.31)	-0.89 (0.37)
B3.3 Troubleshooter *(e.g. maintenance problem, software problem, virus problem, networking problem)*	2.96 (1.08)	2.45 (0.97)	2.71 (1.05)	-1.02 (0.31)	-0.92 (0.36)
B3.4 Handling technology and multimedia equipment *(e.g. LCD projector, OHP, etc)*	2.47 (1.16)	2.82 (0.99)	2.64 (1.08)	0.23 (0.82)	-0.241 (0.81)
B3.5 Usage of 'BIOS SETUP'	2.68 (1.23)	2.61 (0.86)	2.65 (1.05)	-2.41 (0.02*)	-2.32 (0.02*)
LEVEL OF NETWORKING SKILL					
B4.1 E-mail usage	3.95 (0.87)	4.06 (0.95)	4.00 (0.90)	-0.40 (0.69)	-1.00 (0.32)
B4.2 Internet surfing	3.68 (1.14)	4.39 (0.58)	4.03 (0.97)	-2.47 (0.02*)	-2.45 (0.01*)
B4.3 Microsoft networking	3.00 (1.23)	3.39 (1.03)	3.19 (1.14)	-1.11 (0.28)	-1.01 (0.31)
B4.4 Novell	1.79 (1.03)	2.17 (0.87)	1.97 (0.96)	-1.26 (0.22)	-1.91 (0.06)
B4.5 Differentiate using external modem and card modem	2.11 (1.14)	2.28 (1.02)	2.19 (1.07)	-0.52 (0.60)	-0.49 (0.63)
B4.6 Develop web-page	1.95 (0.97)	2.34 (0.97)	2.14 (0.98)	-1.30 (0.20)	-1.60 (0.11)
B4.7 HTML/Javascript Usage	1.95	2.28	2.11	-1.30	-1.66

	(0.87)	(0.78)	(0.83)	(0.20)	(0.10)
B4.8 Uploading/Downloading file	3.68 (1.19)	4.17 (0.99)	3.92 (1.12)	-1.41 (0.17)	-1.74 (0.08)
B4.9 Develop your own blog	2.68 (1.19)	3.23 (1.05)	2.95 (1.14)	-1.55 (0.13)	-1.77 (0.08)
B4.10 Testimonial /comment *(e.g., Friendster, MySpace, facebook, xanga, tagged, hi5, and blogger)*	3.74 (0.94)	3.89 (1.07)	3.81 (2.00)	-0.48 (0.63)	-0.53 (0.60)
B4.11 Using Yahoo Messenger (YM)	3.74 (1.04)	4.22 (0.95)	3.97 (1.01)	-1.54 (0.13)	-1.74 (0.08)
B4.12 Using SKYPE	2.79 (1.36)	3.05 (1.20)	2.92 (1.23)	-0.67 (0.51)	-0.84 (0.40)
B4.13 Attach and send file using YM/SKYPE	3.47 (1.28)	3.71 (1.16)	3.59 (1.21)	-0.63 (0.53)	-0.05 (0.62)
B4.14 Plug-ins, web-cam, sharing photos on-line, conference	3.42 (1.24)	3.71 (1.16)	3.56 (1.20)	-0.78 (0.44)	-0.63 (0.53)

The Table 15 and Table 16 above show all the data outputs for mean, standard deviation, Independent Sample t-Test and also the Mann Whitney U statistics test (in case of non-parametric test). The tables show sixteen statements for Independent Sample t-Test which recorded significant difference all favour the PBL group.

5.4.5 Pre-test of Creative Thinking (Torrance Test of Creative Thinking - TTCT)

5.4.5.1 Science Physics Students (SST)

Table 17 shows N value, mean marks and standard deviation for each group. Mean marks for both PBL and traditional group are 43.88 and 55.62, respectively. The table also reveals the value of t (59) = 1.64, p =0.11>0.05, which indicates no significant difference exists in SST students' prior knowledge of creative thinking test between PBL and traditional group.

Table 17
Report mean and test statistics of pre-test creative thinking for SST students

Group	Mean Marks (SD)	Independent Samples t-Test Test Statistics (a) for Equality of Means	
		t(df = 59) { Sig.(2-tailed)}	z {Asymp.Sig.(2-tailed)}
Traditional (N=31)	55.62 (27.73)	1.64 {0.11}	-1.63 {0.10}
PBL (N=30)	43.88 (28.05)		
Total (N=61)	49.85 (28.28)		

Note. (a) Grouping Variable: Type of Approach

5.4.5.2 Pre-Service Teachers (SESD)

Table 18 also shows the N value, mean marks and standard deviation for each group. Mean marks for PBL and traditional group are 37.05 and 47.21 respectively. The table also reveals the value of t (39) = -1.59, p =0.12>0.05, which indicates no significant difference exists in SESD students' prior knowledge of creative thinking between PBL and traditional group.

Table 18

Report mean and test statistics of pre-test creative thinking for SESD students

Group	Mean Marks (SD)	Independent Samples t-Test Test Statistics (a) for Equality of Means	
		t (df = 39) {Sig.(2-tailed)}	z {Asymp.Sig.(2-tailed)}
Traditional (N=21)	47.21 (21.63)	-1.59 {0.12}	-1.40 {0.16}
PBL (N=20)	37.05 (19.28)		
Total (N=41)	42.26 (20.90)		

Note. (a) Grouping Variable: Type of Approach

5.4.6 Pre-test of Critical Thinking (Watson Glaser of Critical Thinking Appraisal - WGCTA)

5.4.6.1 Science Physics Students (SST)

Table 19 indicates group statistics by showing N value, mean marks and standard deviation for each group. Mean marks for both PBL and traditional group are 27.37 and 32.00 respectively. The table also reveals the value of t (59) = 1.26, p =0.21>0.05, which indicates no significant difference exists in SST students' prior knowledge of critical thinking test between PBL and traditional group.

Table 19

Report mean and test statistics of pre-test critical thinking for SST students

Group	Mean Marks (SD)	Independent Samples t-Test Test Statistics (a) for Equality of Means	
		t (df=59) {(Sig. (2-tailed)}	z {Asymp.Sig.(2-tailed)}
Traditional(N=31)	32.00 (12.82)	1.26 {0.21}	-1.01 {0.31}
PBL (N=30)	27.37 (15.73)		
Total (N=61)	29.72 (14.39)		

Note. (a) Grouping Variable: Type of Approach

5.4.6.2 Pre-Service Teachers (SESD)

Table 20 below indicates group statistics by showing N value, mean marks and standard deviation for each group. Mean marks for both PBL and traditional group are 39.16 and 40.20 respectively. The table also reveals the value of t (39) = 0.39, p =0.70>0.05, which indicates no significant difference exists in SESD students' prior knowledge of critical thinking test between PBL and traditional group.

Table 20
Report mean and test statistics of pre-test critical thinking for SESD students

Group	Mean Marks (SD)	Independent Samples t-Test Test Statistics (a) for Equality of Means	
		t (df=39) {Sig. (2-tailed)}	z { Asymp.Sig.(2tailed)}
Traditional (N=21)	40.20 (10.45)	0.39 {0.70}	-1.58 {0.11}
PBL (N=20)	39.16 (6.10)		
Total (N=41)	39.69 (8.53)		

Note. (a) Grouping Variable: Type of Approach

5.4.7 Physics Basic Concepts Test

5.4.7.1 Science Physics Students (SST)

Table 21 indicates group statistics by showing N value, mean marks and standard deviation for each group. Mean marks for both PBL and traditional group are 17.93 and 14.81 respectively. The table also reveals the value of t (59) = -1.91, p =0.06>0.05, which indicates no significant difference exists in physics basic concept test between PBL and traditional group among SST students.

Table 21
Report mean and test statistics of physics basic concepts test for SST Student

Group	Mean Marks (SD)	Independent Samples t-Test Test Statistics (a) for Equality of Means	
		t (df = 59) {Sig.(2-tailed)}	z { Asymp.Sig.(2tailed)}
Traditional (N=31)	14.81 (7.04)	-1.91 {0.06}	-2.01 {0.04}
PBL (N=30)	17.93 (5.62)		
Total (N=31)	16.35 (6.52)		

Note. (a) Grouping Variable: Type of Approach

5.4.7.2 Pre-Service Teachers (SESD)

Table 22 indicates group statistics by showing N value, mean marks value and standard deviation for each group. Mean marks for both PBL and traditional group are 15.60 and 16.42 respectively. The table also reveals that $t(39) = 0.47$, $p = 0.64 > 0.05$, which indicates that no significant difference exists in physics basic concept test between PBL and traditional group among SESD students.

Table 22
Report mean and test statistics of physics basic concepts test for SESD Student

Group	Mean Marks (SD)	Independent Samples t-Test Test Statistics (a) for Equality of Means	
		t (df = 39) { Sig.(2-tailed)}	z { Asymp.Sig.(2tailed)}
Traditional (N=21)	16.42 (6.60)	0.47	-0.13
PBL (N=20)	15.60 (4.37)	{0.64}	{0.90}
Total (N=41)	16.02 (5.57)		

Note. (a) Grouping Variable: Type of Approach

5.5 MEASURES TAKEN TO ENHANCE INTERNAL VALIDITY

In this thesis, there were four types of validity considered: face validity, content validity, construct validity and criterion related validity. Prior to the use of all instruments, the validity of these instruments was evaluated as is detailed in this section. This was deemed important to ensure the instruments measure what was intended and approximate truthfulness. The researcher tested the instruments' validity prior to the study. Some of the instruments were tested by other researchers, like the Watson Glaser Critical Thinking Appraisal Forms A and B and also the Torrance Test of Creative Thinking Forms A and B (see Juremi, 2003). Previous research using these instruments suggests the instruments have acceptable validity, and the researcher also tested the validity of questionnaire instruments by means of a pilot test that took place prior to the study intervention. This revealed that these instruments have adequate validity. The details of the instruments validation are reported in the following paragraphs.

The selection of participants as the subjects of this research was based on existing classes; however, as noted above (Section 5.3), the demographic and other data suggest the PBL and traditional groups are very similar in terms of physics ability, background and familiarity with computers, the Internet, and so on. To decrease threats to internal validity caused by the maturation of subjects, the intervention took place over 16 weeks. This is considered neither a long, nor a short time. From the demographic survey, it seems that that the students' experiences of their teaching and learning of physics are much the same. In addition, the researcher found that as the intervention occurred, there were no other outside or university activities taking place related to physics learning. The participants were required to report to the facilitator if they engaged in any kind of academic activities outside the classes.

The literature suggests that exposure to repeat tests may influence research outcomes (Juremi, 2003). To reduce the influence of repeated test effects, the pre- and post-tests for creative and critical thinking were conducted in two alternative forms, Form A and Form B. The pre-test was conducted one week before the intervention (Week 1), and the post-test one week after the intervention (Week 16). This was intended to help ensure the samples were not contaminated by trying to remember the same questions in previous pre-test.

The literature suggested participants may be influenced by what is termed the Hawthorne effect; that is, the fact that they are part of an intervention of itself, can lead to improvement in learning outcomes (i.e., as opposed to the particular features of the intervention itself). The Hawthorne effect was mitigated in this work by undertaking the research during usual class times specified in the program. This helped reduce a feeling of being subject to an experiment. To decrease research mortality (i.e., loss of participants during the study), students were required to attend every online class, and their attendance was recorded.

The nature of the research instruments may also influence internal validity in a study. Here, all of the instruments were subject to a variety of validity tests (face validity, content validity, construct validity, and criterion related validity) and all were administered by the researcher. The pre- and post-tests were marked by the researcher, guided by a script which was validated by a panel of experts in advance of marking.

5.6 THE INSTRUMENTS

This section discusses in detail the quantitative and qualitative instruments used in this thesis. Additionally, the data collection methods employed in the thesis also are elaborated here. In total some 11 instruments were used in this research; five were test-question papers, and the rest were surveys. The administration of the instruments was conducted in two broad phases, before and after the intervention.

<u>Before the intervention</u>

i. Pre-test of creative thinking using Torrance Test of Creative Thinking − Form A (TTCT, Torrance, 1990) (Appendix IX)

ii. Pre-test of critical thinking using Watson Glaser Critical Thinking Appraisal – Form A (WGCTA, Watson & Glaser, 1980) (Appendix XI)

iii. Physics basic concept test (Appendix XIII)

iv. Survey of student demographics (Appendices V and VI)

v. Survey of students' pre-concept of Modern Physics (Appendix VII)

vi. Survey of students' level of computer usage in learning (Appendix VIII)

vii. Survey of students' readiness for learning via online learning (Appendix VIII)

<u>After the intervention</u>

i. Post-test of creative thinking using Torrance Test of Creative Thinking − Form B (TTCT, Torrance, 1990) (Appendix X)

ii. Post-test of critical thinking using Watson Glaser Critical Thinking Appraisal − Form B (WGCTA, Watson & Glaser, 1980) (Appendix XII)

iii. Survey of students' perceptions of PBL approach (Appendix XIV)

iv. Survey of students' perception of learning via online learning (Appendix XV)

5.6.7 Quantitative Data Collection Methods

As noted above, the quantitative data were collected using two main instruments − tests and surveys. Details of these instruments follow.

5.6.7.1 Test Instruments

The five instruments used here were: Torrance Test of Creative Thinking (TTCT, Form A & B) (Torrance, 1990); Watson Glaser Critical Thinking Appraisal (WGCTA, Form A & B) (Watson & Glaser, 1980); and the Physics Basic Concept Test. Each of these is now described in turn.

i. <u>Torrance Test of Creative Thinking (TTCT) (Torrance, 1990)</u>

Torrance (1966; 1990) suggested that creative thinking means the capability of thinking using a variety of mental operations such as fluency, flexibility, originality and explaining details of ideas/ideas description to generate new ideas; ideas that are original and valuable. This means that, according to Torrance, to generate new ideas, the brain must keep thinking and yield more and more ideas (i.e., be fluent), and include a variety of different ideas (i.e., be flexible), unique ideas (i.e., original ideas), and that such ideas are specific, detailed and useful (i.e., they are valuable). To measure these skills, the TTCT in Form A and Form B was used. In these tests there are six activities:

i. <u>Activity 1: Asking</u> - students need to ask as many questions as possible regarding the activities seen in a picture provided;

ii. <u>Activity 2: Guessing the causes</u> - students need to guess as many causes as possible, about what caused the event/occurrence as shown in the picture provided;

iii. <u>Activity 3: Guessing the cause of an occurrence or an event</u> – students need to list as many causes as possible of the causes or outcomes of what will happen because of the event/occurrence shown in the picture provided;

iv. Activity 4: Improving the product – students need to list the best and most extraordinary ways to change a given form of a product to produce a more interesting form of the product;

v. Activity 5: Extraordinary uses - students need to list as many possible functions or ways in which a product can be utilized in a given picture;

vi. Activity 6: Supposing – students need to list other things that might happen through or be caused by an occurrence that has already happened.

Each answer in this instrument is marked and accounted for based on the following criteria (i) fluency, (ii) flexibility, (iii) originality, and (iv) elaboration. Two sets of TTCT were used in this study - Form A (Appendix IX) and Form B (Appendix X). Juremi (2003) tested these instruments for construct validity and criterion related validity, and reported good validity for both validations, meaning they are likely to be suitable for use in the present study. Work by Ghouse (1996), confirmed the construct validity for a creative group of students, who evidenced higher mean marks compared with students in a less creative group. Content validity in this administration was checked by a lecturer in the area of creative thinking (at another university) who checked the instrument for suitability in evaluating creative thinking skills, and an English language teacher checked the instrument for clarity of English language.

ii. Watson Glaser Critical Thinking Appraisal (WGCTA) (Watson & Glaser, 1980)

This instrument used in this thesis was adapted from the Watson Glaser Critical Thinking Appraisal (WGCTA) (Watson & Glaser, 1980). In the WGCTA instrument, the concept of critical thinking is defined in terms of attitude aggregation, knowledge, and capability that embraces i) a curious attitude and the ability to recognize the existence of problems and adoption of evidence that corroborates things claimed as true and relevant; ii) the knowledge of signals to construct authentic conclusions; iii) generating and generalising ideas that have been corroborated by logical evidence; and iv) capability to apply the attitude and the knowledge. This means, new knowledge is analysed and evaluated first using a variety of critical thinking skills, and subsequently corroborated with logical reasoning before being accepted. This instrument contains 80 items distributed across five sub-tests/sections (Table 23).

Table 23
The WGCTA distribution of contents

Sub-tests	Items	Statements
1. Making inferences	16 items	Tests the capability to differentiate the degree of false and truth of inference, based on data given. Students decide whether any suggested inference is true, false or that there is not enough information to come up with a conclusion.
2. Recognition of assumption	16 items	Students need to recognise assumptions and early expectations based on the statement given
3. Making deductions	16 items	Tests the capability to make deductions and conclusions from a statement given
4. Making interpretations	16 items	Judging the evidence and making decisions, or generalisations based on data given
5. Evaluating arguments	16 items	Differentiate weak and strong arguments for a question given.

Two versions of the WGCTA were used in this study - Form A (Appendix XI) and Form B (Appendix XII). To evaluate the criterion validity (i.e., instrument validity), the critical thinking score was correlated with the highest physics grade in the previous semester for both cohorts of students. Examination of the thinking skills emphasized in the physics syllabus suggests that they are similar to the thinking skills in the critical thinking skill test that is the WGCTA. This conclusion was supported by detailed discussions with several physics lecturers in the department. The value of Pearson Correlation is at the medium level where 0.027 for Form A and 0.273 for Form B at 0.05 significant level. Juremi (2003) tested the criterion validity and construct validity for the WGCTA (N=50) and found it to be valid for both, meaning it is suitable for use in this study.

For construct validity, Juremi (2003) tested this instrument by comparing the mean score of students treated to an intervention and found the mean marks for these students was higher than a control group. Thus it can be assumed that this instrument has a very good validity in general.

iii. Physics Basic Concept Test

The physics basic concept test was developed by the researcher specifically for this work. It is based on basic physics knowledge presented in the relevant syllabus. The main purpose of administering this test was to investigate students' prior knowledge in physics for both groups before the intervention. It was intended that both groups of student would be fairly similar in terms of prior knowledge of basic physics concepts. The development of this test involved reference to numerous relevant documents such as the syllabus at the undergraduate level, physics text books, reference books, Internet references, and past years' exams and test questions. It is worthwhile noting that the researcher taught the course for four years at the same university where the sampling was undertaken. Student performance was evaluated on the basis of a Test Determination Table (TDT) developed based on 40 percent for knowledge and comprehension, and 60 percent on application, analysis and synthesis – the latter based on thinking skills. This instrument consists of 15 multi-choice and 10 structured questions.

The face validity and content validity of the test were checked in three stages. In the first stage, all the content and question/items were evaluated by a physics lecturer who had some 15 years teaching experience. Second, the instrument was pilot tested and the findings analyzed. In the third stage, some items were modified based on the information from the pilot test, and comments from another physic professor.

5.6.7.2 Survey Instrument

The earlier section stated that there are six questionnaire surveys used in this thesis: students' demographic; students' level of computer usage in learning; students' readiness for learning via online learning; students' prior knowledge of Modern Physics; students' perceptions of PBL approach; and students' perceptions of learning process via online learning. Each of these questionnaires consists of closed ended questions using a Likert scale, to interpret several types of responses' meaning. In addition, some of the questionnaire (e.g. students' perceptions towards PBL approach and students' perceptions towards learning process via online learning) also consists of open ended questions to allow and encourage respondents to give their fuller opinion in a way that is more comfortable for them to express (Sudman & Bradburn, 1982).

i. <u>Survey of student demographics</u>

The main objective of this survey was to detail the students' background in terms of gender, subject major (e.g., for SESD this could be physics or mathematics), grades in physic courses for the previous semester, qualification(s) before entering the course, residency (e.g., on- or off-campus), and whether or not they were familiar with a PBL teaching approach, creativity, or critical thinking. The reliability, based on Cronbach alpha scale (α), was 0.57, a little low but acceptable according to the literature (Coakes, 2005). The face validity and content validity were evaluated in terms of their language clarity by an English teacher and some modifications were made after the instrument was pilot tested.

ii. <u>Survey of students' usage of computers in learning and survey of students' readiness for online learning</u>

The main objective of this survey was to understand students' usage of computers in learning before the intervention. In addition, the survey sought to establish and understand their readiness for online learning. The survey was divided into three parts. Part A consists of 33 items to find out what students think about their skills and readiness for learning via computers or online. The items are based on *computer skills; Internet skills; students' readiness; student personalities*; *cultural factors; learning style*; and *anxiety/ trust*. Students were asked to choose from five points of a Likert scale: 1- Strongly Disagree; 2- Disagree; 3- Neutral/Undecided, 4 – Agree; 5- Strongly Agree.

In Part B the intention was to find out what students think are their skills and competencies when using a personal computer. There were four sections in this part (Sections 1, 2, 3 and 4) and these contained 43, 5-point Likert scale items: 1- Not skilled at all; 2- Some skills; 3- Neutral; 4 – Skilled; 5- Strongly skilled. The four sub-sections are *level of IT software knowledge; level of computer hardware skills; level of handling PC maintenance;* and *level of networking skill.* Part C sought to find out what student think about their expertise in online learning and related activities. It contained multiple-choice questions intended to give the researcher an overall picture of the students' daily life activities involving computers and online learning.

The content validity and face validity of the survey was evaluated by measuring the reliability which gave an alpha for items 1 to 76 (i.e., Part A &t B) of 0.81, and the survey was checked for language clarity by an English teacher, and a pilot test. A few minor modifications were made before administration.

iii. <u>Survey of students' prior knowledge of Modern Physics</u>

The main objective of this survey was to better know the students conceptual understanding of the content to be learned (i.e., Modern Physics) before the intervention. There were 35 items which employed a 5-point Likert Scale: 1- No knowledge at all; 2- Little knowledge; 3- Neutral; 4- Some knowledge; 5- A lot of knowledge. The items were constructed based on the syllabus topics in the Modern Physic course for undergraduate physics.

The content validity and face validity of the survey were evaluated by means of Cronbach alpha, which for items 1 to 35 was 0.78. The survey was checked for language clarity by an English teacher, and a pilot test. A few minor modifications were made before administration.

iv. <u>Students' perceptions of and interest in PBL method</u>

The main objective of this survey was to understand students' perception of learning via a PBL approach. There were 49 items on a 5-point Likert Scale and three main parts: Part A, Part B (closed-ended) and Part C (open-ended). Part A consisted of questions about the learning outcomes and was divided into several sub-sections: *knowledge, skills and the application of knowledge and skills; communication; and independent learning*. The Likert Scale consisted of 1- Strongly disagree; 2- Disagree; 3- Neutral, 4- Agree, 5- Strongly agree. These items were based on the learning steps found in a PBL approach, and included creative thinking, critical thinking and learning in modern physics. Part B consisted of questions that ask respondents to reflect on specific features of PBL. It comprises 10 items and a 5-point Likert scale: 1 - Unable to assess; 2 - Strongly disagree; 3 – Disagree; 4 – Agree; and 5 - Strongly disagree. Part C of this survey consists of open-ended questions about the PBL approach used during the intervention. The main objective of these questions was to seek students' opinions about using this PBL approach. The questions consisted of things such as *the learning outcomes that they felt they obtained; students' ability to engage in creative thinking; students' ability to engage in critical thinking; Do students think the PBL approach is a suitable way to learn modern physics?; What did they find to be least useful about learning using this learning approach?;* and *What did they find to be most useful about learning using this learning approach*?

The content validity and face validity of the survey were by means of Cronbach alpha, which for items 1 to 49 was 0.92. The survey was checked for language clarity by an English teacher, and a pilot test. A few minor modifications were made before administration.

v. <u>Students' perceptions of online learning</u>

The main objective of this survey was to develop an understanding of the students' perceptions of learning process via online approach. This survey was divided into three parts: Part A (multiple-choice; 20 items); Part B (closed-ended; 46 items); and Part C (open-ended; 4 items). For Part B, the items were scored on a 5-point Likert scale: 1- Strongly disagree; 2- Disagree; 3- Neutral, 4-Agree, 5- Strongly agree. The items were based on *student's perceived satisfaction*; *student's perception of interaction*; and *student's perceptions of individual features (content available on the Web course; online learning as a communication tool; assignment; and online student assessment)*.

The content validity and face validity of the survey were by means of Cronbach alpha, which for items 1 to 66 (Part A and Part B) was 0.84. The survey was checked for language clarity by an English teacher, and a pilot test. A few minor modifications were made before administration.

5.6.7.3 Summary of Measures taken to enhance Validity and Reliability of the Instruments

Validity and reliability data for data collected in this work, including quantitative measures and pilot studies of instruments, are summarized in Table 24. Together, these data and measures suggest that instruments used in this work were suited to the purpose and possessed adequate reliability and validity.

Table 24
Conclusion of the validity and reliability of quantitative instruments

Type of Instruments	Content Validity	Criterion Related Validity	Construct Validity	Reliability	Conclusion
Torrance Test of Creative Thinking Test (TTCT)	Vetting from an English teacher and a lecturer experienced in lecturing about creative thinking skills at a local university	---	Comparing mean score between Creative Arts Students: Fluency = 78.86 Flexibility = 38.20 Originality = 41.57 Non-Creative Arts Students: Fluency = 46.81 Flexibility = 26.56 Originality = 23.38 (Juremi, 2003)	Form A and Form B, Overall, α = 0.81 Fluency = 0.79 Flexibility = 0.84 Originality = 0.84 Elaboration = 0.78	This instrument has good validity. This instrument has good reliability in general.
Watson-Glaser Critical Thinking Appraisal Test (WGCTA)	Vetting from an English teacher and a lecturer experienced in lecturing about critical thinking skills at a local university	Pearson Correlation scores are Form A;r = 0.02 and Form B; r = 0.27	Score mean comparison between student who has explored the treatment = 42.00 and the students who have not =39.00 Juremi's (2003)	Cronbach Alpha (α) Form A; α= 0.87 and Form B; α = 0.74	This instrument has good validity. This instrument has adequate reliability in general.
Basic Physics Achievement	Vetting from an English teacher, a physics professor and a senior lecturer in physic.	----	----	Cronbach Alpha α = 0.70	This instrument has good validity. This instrument has adequate reliability in general.
Survey of student demographics	Vetting from an English teacher and supervisor.	----	----	Cronbach Alpha α = 0.57	This instrument has good validity. This instrument has adequate reliability in general.
Survey of students' level computer usage in learning and Survey of students' readiness for online learning	Vetting from an English teacher and supervisor.	----	----	Cronbach Alpha Overall, α = 0.81 Part A = 0.50 Part B = 0.83	This instrument has good validity. This instrument has adequate reliability in general.

Survey of students' prior knowledge of Modern Physics	Vetting from an English teacher and supervisor.	----	-----	Cronbach Alpha Overall, α = 0.78	This instrument has very good validity. This instrument has adequate reliability in general.
Students' Perceptions of and Interest in PBL Method	Vetting from an English teacher and supervisor.	----	-----	Cronbach Alpha Overall, α = 0.92 Part A = 0.91 Part B = 0.83	This instrument has good validity. This instrument has good reliability in general.
The students' perceptions of learning process via online learning	Vetting from an English teacher and supervisor.	----	----	Cronbach Alpha Overall, α = 0.84 Part A = 0.81 Part B = 0.87	This instrument has good validity. This instrument has good reliability in general.

5.6.8 Qualitative Data Collection Methods

This section discusses the qualitative data collection methods used in this research. In this work, this included the students who enrolled the Modern Physics for both the School of Science and Technology (i.e., science majors), and the School of Education and Social Development (i.e., pre-service teachers). In addition, as a novice researcher, the researcher required practice in education research methods such as interviewing, making observations, examination of written reports and refinement of research instruments. Prior to interviews with students, the researcher tested the digital video decoder (DVD) and held meetings with selected students. Expertise in purely logistical details was required, and so the researcher spent time with a technician, an expert in video editing at the Educational Technology and Multimedia Unit (ETMU) – and this helped the researcher to see how to work with digital media such as video clips.

The intact weekly class of students enrolled in the Modern Physic courses SF11803 and SP22033 were briefed about the intervention. The synopsis of the course was modified slightly in terms of the content as a result of the PBL approach. During the first week of the intervention, the researcher gave an assignment to the students about the PBL approach, and they were distributed in several groups of 4-6 students for each group. They were given authentic real-world problems which were connected with modern physic topics at the undergraduate level. For the control group, the learning process ran much as usual (i.e., as face to face traditional learning where they need to read lecture's note, do tutorial and assignment), except that the content was delivered by online. For the experimental group, students had to construct their own knowledge, find references through online discussion or by the use of email, or by asking for guidance from a peer or the course facilitator. In addition, they were also provided with sources of information (e.g. scientific journal articles or relevant websites) for their assignments.

Observations of students were conducted during the on-going classes. Observational data served to supplement interview data, and this, in turn, provided support for the interpretation of interview data. During the observation, the entire 50 students' (30 science students and 20 pre-service teachers) dialog while having online discussion was observed online through LMS by the researcher, and also by a trained instructor. For each observation, everything they said or discussed was recorded, and transcribed verbatim.

The researcher conducted focus group interviews with the students in PBL group. The interviews were conducted after finishing the intervention at the end of the course. Here the students were asked about the topics and tasks to do with the PBL and online learning activities. The questions asked things such as their confidence to do the tasks, and their feelings about the learning and teaching process, their views of the modern physics course after finishing the course, and the influence of the learning approach on learning. For this study, a semi-structured interview approach was deemed suitable as interviewees would have the freedom to answer in any manner or the language they wished, English or Malay. In addition, the interviewer is able to make a comparison of responses between the interviewees. As this interview structure is somewhat formal in nature, some interviewees may have felt uncomfortable speaking out in front of their peers or the interviewer. To mitigate this, the researcher employed a mixture of closed and open-ended questions when interviewing and some data were also gathered in on-going meetings using informal interviews. In these latter interviews, the researcher was able to answer questions asked by the interviewees in a more relaxed manner. Data from the closed question interviews were captured and a coded within several main pre-established theme categories (i.e., satisfaction, convenience, the learning outcomes etc.). For the data obtained from the open-ended questions in the informal interviews, the researcher simply attempted to understand the phenomenon or issue without imposing any a priori categorization. These unstructured and semi-structured interviews thus retained a little structure in the sense that there were readily identified informants, meaning the interviewees are clearly discernible.

5.7 PBL TEACHING APPROACH USED IN THIS WORK

The PBL model ran over two weeks of teaching, and how this model was conducted is illustrated in Table 25. At the beginning of the module the facilitator uploaded some problems 2-3 days prior the online learning class. Each problem needed to be solved within two weeks of uploading, and to address these problems the students needed to give explanations and solve the problems themselves. The researcher provided the students with some links and a few of relevant resources to help students to find information.

Table 25
PBL model used in this study

PBL Model	Steps in PBL
1. Overview - Introductory lecture on learning via online	1. Training of students on how to construct data so that they can refer to it when searching other appropriate knowledge resources
2. Tutorial I (Week 1 for each problem – individual/ group process) - Lecturer as a facilitator monitors student's progress for each group and gives cognitive guidance to students using the discussion room during online learning. - Each group has their own time for online chat room with the facilitator.	2. 'Meet' the problems. 1.1 Recognize the problem's scenario 2. Define the problems. 2.1 Brainstorm for learning objectives and hypothesis. 2.2 Recognize the learning objective and hypothesis. 2.3 Discussion and consultations 2.4 Distribute task within group.
3. Self learning - Each student to find resources for information needed from multiple resources via online learning.	3. Discovery Find the appropriate information. This is done individually before group discussion of their finding.
4. Tutorial II (Week 2 for each problem - group process) - Lecturer as a facilitator monitors student's progress for each group and gives cognitive guidance to students using the discussion room during online learning.	4.Solutions 4.1 Apply the new knowledge to new problems 4.2 Discussion and solutions
5.	5. Reflections Evaluations

As noted in Table 25, each PBL group had their own specified time for access to the facilitator through the LMS. Thus the facilitator only monitored one PBL group (4-6 students) at one time when they were scheduled online.

All the information was gathered and discussed in groups, the intention was to expose students to how the information can be applied to solve the problems provided. Students then discussed their ideas back in their own group and revised and checked their ideas when attempting to solve the problem. Throughout this PBL intervention, the facilitator monitored student discussion to facilitate and motivate students to engage in useful discussion. The facilitator was, however, available to help those who really struggled with the tasks. At the end of the class, the facilitator asked the students to engage in reflection and try to come to some conclusions about their findings regarding each problem. To develop their knowledge, the students were asked to improve their early point of view or beliefs about the best answer (i.e., prior to the PBL assessment), with new information and to fully report their views through online.

Whilst Table 26 shows the learning activity in the normal class and the intervention for PBL and traditional group, it details the difference between traditional classes and the intervention classes for this thesis.

Table 27 below details more of the PBL approach in developing students' creative thinking, critical thinking and knowledge. It is also shows of task example for the students and the process and learning outcomes. The PBL approach consists of activities such as problems and examples, how the activities must define the problems in context, discovery, problem-solving skills and also reflections. While the task example giving an example of how a nuclear power can play an important power resource to the first world country. As the process and the learning outcomes shows what is the suitable learning activity that should be done in order to get the intended learning outcomes as aim in PBL process.

Table 26

Learning activity in normal class and the intervention for PBL and traditional group

Face-to-face Class (Traditional) ***Previous Practice***	**Online Learning Class (Traditional-Control Group)**	**Online Learning Class (PBL-Experimental Group)** ***Intervention Class***
2 hour lecture face-to-face classes/week	Classes meet both on online and face-to-face (Level 4 as reported in Bolstad et al., 2008)	Classes meet both online and face-to-face (Level 4 as reported in Bolstad et al., 2008)
1 hour tutorial class/week	Face-to-face activity • Facilitator meets students face-to-face 1 hour/week to get their feedback and comments on the course and its progress.	Face-to-face activity • Facilitator meets students face-to-face 1 hour/week to get their feedback and comment from their intervention.
Some courses have lab experiments, some do not	Online Learning • All learning activities are via online - 2 hours compulsory work required during scheduled times. At this time all students enrolled in that particular course (for both PBL and traditional group) must log in and their attendance is recorded. • Outside these hours, students still can log in, anytime and anywhere they can access the Internet. • Facilitator monitors: 1. How many times students log-in and for how long (recorded by LMS). 2. What learning activity they do in every session (e.g. discussion, forum, e-mail, upload and download resources).	
	Learning Activity: • Students are provided with lecture notes online to read individually • At the end of each topic, students are given tutorial questions they have to answer and send in answers online.	Learning Activity: • The learning activity starts from problems given to students rather than at the end of every chapter/topic. • Students are responsible for their learning activities throughout the semester with little guidance from the facilitator. • Students can engage in discussion, forums, chat rooms, searching for relevant resources from the Internet, uploading notes to share with other group members/downloading notes, etc. • Students engage in independent learning - learning closer to learning in the real world.
	Desired learning outcomes from online learning (PBL and Traditional) • The intention of online learning is to make the learning more flexible, dynamic, and easy, since students can access the learning activities anytime and anywhere they want. • In addition, the students have access to huge resources for knowledge through the Internet (virtual library) from all across the world, making it easier for them to up-date their knowledge. • It is also intended that students' learning activities such as discussion, forum, e-mail, finding resources, brainstorming which are delivered through online learning, will motivate them to participate in their learning more actively. • Students become more independent and responsible in their learning and become more self-directed learners.	

Table 27

PBL approach for developing creative thinking, critical thinking and knowledge

PBL Approach	Task Example (Assignment)	Process and Learning Outcomes
1. Problems and examples 2. Must be localized, authentic and relevant to the Malaysian context	As a scientist, how might you try solve problems associated with nuclear power usage in first world countries?	Students find relevant information, and discuss the issues/problems. Working in groups. Physics knowledge about nuclear weapons and related issues found, and used in discussions.
2. Define problems	• What is nuclear power? • What are the essential features of nuclear power? • What is the function of nuclear power? • What are the advantages of nuclear power? • How might nuclear power be used properly without being misused?	i. Critical thinking is used to find new and relevant information. ii. Problem-solving skills will be used to see the suitable problem-solving approach to solve the problems. This is to recognize the variables to generate hypothesis. iii. Creative thinking and critical thinking are used to recognize the variables and to generate hypothesis. iv. Problem-solving skills will be used to solve the problems
3. Discovery	Find information from a variety of information sources, and evaluate this information.	
4. Problem-Solving	Synthesize and try to give suggestions in order to solve problems.	
5. Reflections	Evaluate whether the proposed solutions are the best way of solving the problems. Are there any other alternatives?	Metacognition will develop: Students will learn to reflect and evaluate

5.8 RESEARCH INTERVENTION

The research intervention was conducted over 16 weeks, and the details of this for the experimental group (PBL group) are provided in Table 28, and those for the control group (traditional group) in Table 29. For both groups, all the learning and teaching exercises formed part of the students' assessment and were delivered using the learning management system (LMS) facilitated by Educational Technology and Multimedia Unit (ETMU) at the Universiti Malaysia Sabah. Specifically, this LMS system is Moodle 2007 and as suggested by Jayasundara, Balbo, Farmer, and Kirley (2007) who argue that PBL online implementation is easier if incorporated into existing course management systems such Blackboard and LMS. As shown in Table 28, all pre-tests (basic physics achievement, creative and critical thinking) were carried out on the first week, and these were followed by the selection of sample based on the results of the pre-test.

Table 28
PBL procedure used in this study

Week	Physics Achievement/ Content Topic	PBL Activity	Creative Thinking Skills	Critical Thinking Skills
1	Pre-test	None	Pre-Test	Pre-Test
2	Physics topic on modern physics	Introduction of Problem-Solving Process	Introduction to the idea generation technique	Introduction of lower and higher critical thinking skills
3	Cell Phones Can Cause Cancer?	Problem 1	Generate Idea	Inference
4	Solar System in Rural Areas	Problem 2	Generate Idea	Assumption
5			Generate Idea	Deduction
7	Wireless Bus	Problem 3	Generate Idea	Evaluate Argument
8			Generate Idea	Interpretation
9	X-Ray Machine Undertaking	Problem 4	Generate Idea	Debate /Argument
10			Generate Idea	Inference/Assumption/ Deduction
11	How to Manage Nuclear Power	Problem 5	Generate Idea	Interpretation/ Debate/Argument
12				
13		Conclusion of problem-solving process	Conclusion of Creative Thinking Skills	Conclusion of Higher Critical Thinking
14	Post-Test 1	End	Post-Test 1	Post-Test 1

The intervention began in the second week, and the experimental group followed the PBL procedure for 14 weeks. Each week there was a lecture class and tutorial session, and all the lecture and tutorial classes were conducted by the researcher and delivered through e-learning. The same situation occurred for the traditional, control group except they followed the normal assessment procedures.

During the PBL activities, a facilitator monitored students' discussion and discursive activities. The facilitator was responsible for encouraging and motivating students to seek out their own information and references, learning to access and use relevant websites, and to drive interactive dialogue between participants. When students asked something, the facilitator did not just give answers, but instead posed new questions to try and make the students think more deeply, and encourage them to find solutions themselves. They were constantly encouraged and motivated to keep thinking and make judgments about potential solutions to the problems or issues that formed the focus of the activities. At all phases of the problem-solving activities, the students were required to plan first before they moved on to develop their problem-solving strategies. If a student changed a part of the problem-solving plan, this then had to be merged with the other phases in the approach proposed initially. Once in every two weeks, an informal meeting was held between the facilitator and PBL group to discuss any problem arising during the intervention. With the traditional group, the lecture still played an important role, and this was predominantly to give students lecture material, consider tutorial questions and answers and provide assignments. The lecturer here then played a quite different role, that of a conveyer of information with the result that the students acted as passive recipients. There were few questions and answers dealt with during these traditional classes. The differences between the PBL group involved in the intervention and the traditional group are showed in Table 29.

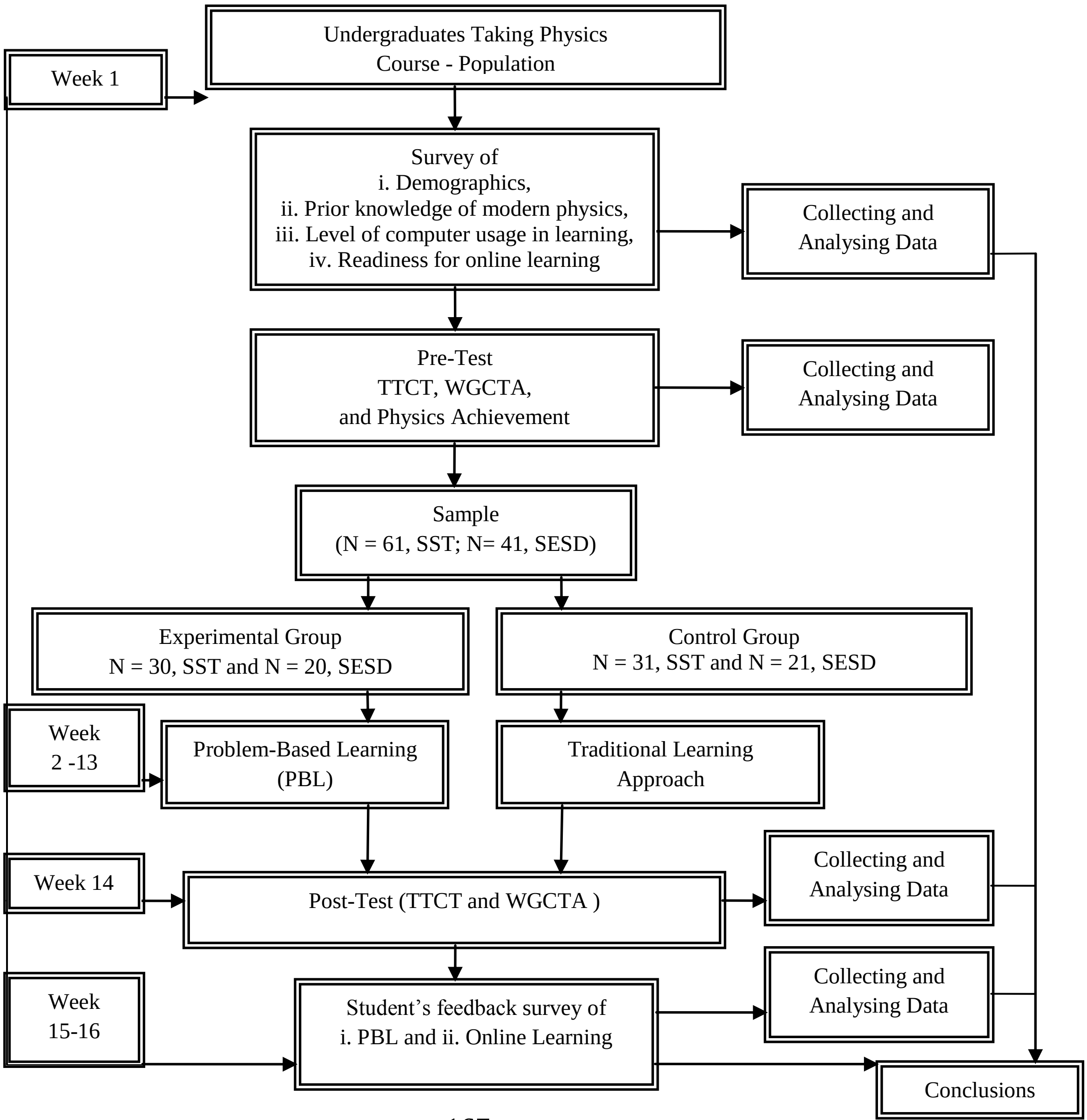
Table 29
Differences between PBL group and traditional group

	Traditional Group	PBL Group
Learning Activity	• Problems only provided after the content delivered. • Problems all are based on what the lecturers/tutor deliver in lecture class, and are based on algorithm and simple theoretical problem-solving.	• In PBL groups student start their learning with problems. • Students 'learn how to learn' throughout the semester, based on student-centred criteria. • Learning is guided by challenging, open-ended problems, with no one 'right' answer needed to solve problems • Problems/cases are context- specific for the Malaysian situation. • Student learning activities in PBL involve students as self-directed, active investigators, engaged in iterative, collaborative, self reflection, becoming self monitoring, and problem-solvers of authentic problems as they work in small collaborative groups (4-5 students). • A key problem is identified and a solution is agreed upon and implemented.
Syllabus Structure	• Syllabus provides structure • Student's knowledge depends on content given in lectures or tutorials.	• Syllabus is unstructured (or ill-structured). • Students have to structure and generate their learning processed following the elements embraced in PBL. • Student is responsible for his/her standalone learning (one of the PBL elements is they have to find their own knowledge resources before they meet together to discuss and evaluate their findings). • Students gain knowledge and they learn deeply the knowledge they search for.
Teacher's Role	• Teacher plays a major role, to teach and tell students how to learn and what to learn for the topics within the physics domain. • Students given tutorial questions to answer at end of chapters/topics. • Students given assignment to do, and pass in at the end of the semester for evaluation by lecturer. • Lecturer plays a major role in developing students' learning process and activity.	• Teachers take the role as facilitators of learning. • Lecturers/teachers guide the learning process and promote an inquiry-based environment of learning. • The guiding process involves minimal input form the lecturers/teachers since the students themselves construct their own learning process - hunting for good solutions for the problems given. • The intention of facilitator here is to make sure students' learning activities do not deviate from the topic to be discussed. • The facilitator must be trained first in process skills, handling group dynamics, being energetic, in questioning skills, facilitating meta-cognition, etc.
Expected Learning Outcomes	The expected outcomes of traditional learning are based on the normal teaching and learning outcomes: • Student learning based on rote online learning; students only mastering physics content via memorisation and rarely understanding the real situation or the science concepts. • National tests, student self reports, objective tests, and essay exam scoring focus on indirect manifestations of PBL skills. • Students generally incapable of thinking creatively and critically, because the elements of learning activities contained in PBL which might enhance	The intended outcomes from PBL group • Students will have better understanding, integration, and retention of concepts, facts, and skills in a particular domain of physics. • Students will acquire knowledge and they will learn how to solve problems creatively, and critically evaluate evidence and draw reasonable conclusions. • Students gain in both creative and critical thinking by experiencing problem-solving learning activities. • Students learn to become more creative and better critical thinkers when they face authentic real life problems.

	capability in students' creative and critical thinking are not embraced in this teaching and learning approach. • This approach typically produces graduate students that do not use any creative and critical thinking when they join the workforce.	
Significance of Learning Outcomes	Based on past performance, the expected learning outcomes do not meet the needs of Malaysian employers: • The learning outcomes produce graduate students that are only capable of answering some specific algorithms or simple conceptual problems based on what they learned in their courses. • When it comes to real life situations, graduates are not capable of deciding how to solve problems creatively - crucial skills in Malaysian industries.	• The current curriculum in most Malaysian colleges and universities is little concerned with equipping students to lead the lives they will actually lead (i.e. workers, as citizens, and as responsible individuals) • Creative and critical thinking are two very significant skills for every graduate student if they wish to gain good employment in Malaysian industry. 1. Creative thinking - ability to produce work that is both novel (i.e., original, unexpected) and appropriate (i.e., useful. adaptive concerning task constraints) 2. Critical thinking - Skilful and responsible thinking in which students study the problem from all angles and perspectives, and then do investigation and exercise and eventually come up with the best judgment, assessment, opinion and perspicacity to draw conclusions • Based on these criteria, it is hoped that we will produce physics graduates capable of adapting to the outside world upon graduation, in terms of their level of thinking and scientific process skills.

Post-tests of creative and critical thinking were conducted for both the experiment and control group after the intervention. A survey also was administered seeing to understand students' perceptions about online learning for both groups. In addition a survey of students' conceptual of learning and perceptions of PBL were administered for the PBL group after completing the post-test. All test papers were marked by the researcher guided by schema test. All data were analyzed using SPSS Windows Version 12.0. The research procedure and data collection procedures are summarized in the following presented in Figure 18.

Figure 18
Summary of research intervention and data collection used in this thesis



5.9 DATA ANALYSES

Both descriptive statistics and inference statistics are used to describe the research outcomes. Inference statistics were used to make inferences from the sample data about the populations. The quantitative statistics were done using the Statistical Program for Social Science (SPSS) Version 12.00.

5.9.1 Test Data

All of the pre-test and post-test data were analyzed and means and standard-deviations calculated. The data also were examined for adherence to a normal distribution before deciding what statistical tests should be applied. The students were measured repeatedly via pre- and post-tests for the dependant subject variables (creative and critical thinking). According to Coakes (2005), it is best to employ the 'independent samples t-test' if the data is in normal distribution, and the 'Mann Whitney U-test' if the distribution is not normal and in a small number of the sample to investigate differences between groups. However, in this thesis the data were analysed using both (Mann-Whitney U-test and Independent Sample t-Test) in order to make comparison to identify if there were any great difference if data analysed separately.

The test-instruments (pre-test and post-test) were labelled as the *within subjects factor*, whereas the teaching and learning approach (PBL and traditional) were labelled as *between subjects factor*. This procedure makes all the data analysis simultaneous. Nevertheless, the entire data will be reported separately according to the research questions. All of these data analyses are used to answer the research questions number one and two (RQ1 and RQ2).

5.9.2 Survey Data

There were four different surveys administered to the students during this research. Two of the surveys were distributed before, and two after the intervention. The detail of the data analysis for each questionnaire is discussed in the following paragraphs.

A. Students' readiness for online learning, and student's competencies and skills in using a personal computer.

This survey is divided into three separate parts. Part A is intended to find out *what you think are your skills and readiness for learning through the use of a computer or to work with online learning*. Whereas Part B is intended to find out *what you think are your skills and competencies are for using Personal Computer*. There are 5-item Likert scale choices for Part A (1 – Strongly disagree; 2 - Disagree; 3 - Neutral/undecided; 4 - Agree; and 5 - Strongly disagree*)*. There also are 5-item Likert scale choices for Part B (1- No skill at all; 2 - Some skill; 3 - Neutral; 4 - Skilled; and 5 - Strongly skilled). Part C consists of open-ended questions and is discussed below under the qualitative data.

B. Students' views of learning (comprehension) in modern physics.

The main purpose of this survey is to better understand students' background in Modern Physics before attending the Modern Physics course. There is a 5-item Likert Scale to represent the students' comprehension (1 - No knowledge at all; 2 - Little knowledge; 3 - Neutral; 4 - Some Knowledge; 5 - A lot of knowledge).

C. The students' perceptions of and interest in PBL method.

This survey is divided into three separate parts. Part A consists of questions concerning the learning outcomes (1 - Strongly disagree; 2 - Disagree; 3 - Neutral/undecided; 4 - Agree; and 5 - Strongly disagree*)*. Part B consists of questions that reflect on problem-based learning's (PBL) specific features (1 - Unable to assess; 2 - Strongly disagree; 3 - Disagree; 4 - Agree; and 5 - Strongly disagree). Part C consists of open-ended questions about the problem-based learning approach used during this semester which is discussed below under the qualitative data. The open-ended questionnaire was analyzed qualitatively, and separated according to several main themes. This data analysis was used to answer the research question number three (RQ3).

D. <u>The students' perceptions of learning process via online learning.</u>

This survey also was divided into three separate parts. Part A contains multiple-choice questions relevant to learning in this Modern Physics course via online learning. Part B contains questions about student's perceived satisfaction; student's perception of interaction; students' perceptions of individual features (i.e., content available on the web course; online learning as a communication tool; assignment; and online student assessment) (Responses were 1 - Strongly disagree; 2 - Disagree; 3 - Neutral/undecided; 4 - Agree; and 5 - Strongly disagree). Part C contains open-ended questions about students' opinions of online learning delivery. The open-ended questions were analyzed qualitatively and separated according to several main themes. This data analysis was used to answer the research question number four (RQ4).

Before the researcher analyzed any Likert-scale survey data, the data were checked for the distribution characteristics. If the data were distributed normally then the Independent Sample t-Test value of mean score between the control group and the experimental group under the significant value of $p < 0.05$ was used. If not, then the non-parametric data analysis, viz., the Mann-Whitney U rank test was used. This is the appropriate technical approach to statistical analyses in education research. However, Rennie (2000), notes education researchers are fairly pragmatic in terms of adherence to technical correctness, arguing for example, that strict adherence to such procedures can obscure interesting differences. Part of the argument here is that statistical tests should be used as guide when doing calculations involving human subjects. Hence, the researcher typically ran both parametric and non-parametric tests, and if there was little difference or much different yield, used the independent sample t-test. For Surveys in Appedices VII and VIII, the main objective is to determine if there were any statistically significant differences in means between these two groups before the intervention. However, for Surveys in Appendices XIV and XV, the main objective was to see whether there were any statistically significant differences between traditional and PBL groups after the intervention. Moore and McCabe (1999) recommend researchers prepare histograms as well as the mean and standard deviation to illustrate any unusual outcomes (e.g., bi-modal distributions etc.). The analyses for these surveys are provided in the appendices, and Table 30 provides a summary of the statistical analyses used.

Table 30

Statistic tests for answering the research questions

Research Question (RQ)	Test- types	Explanations
The outcomes will answer Research Question 1 (RQ1) and Research Question 2 (RQ2)	Independent Sample T-Test Value (for normal distribution) or Mann-Whitney U Test (Wilcoxon rank sum W test) (for not normal distribution)	In Between Group Factor: (1 Factor, 2 Stages) Teaching Method 1. PBL 2. Traditional Within Group Factor: (1 Factor, 2 Stages) 1. Pre-Test Creative Thinking 2. Post-Test Creative Thinking
		In Between Group Factor: (1 Factor, 2 Stages) Teaching Method 1. PBL 2. Traditional Within Group Factor: (1 Factor, 2 Stages) 1. Pre-Test Critical Thinking 2. Post-Test Critical Thinking
The outcomes will answer Research Question 3 (RQ3)	Mean Score of Likert Scale	Students' perception of and interest in PBL method PART A Learning Outcomes; *Knowledge, Skills and the Application of Knowledge & Skills Communication Independent Learning* 1 - Strongly Disagree; 2 - Disagree; 3 - Neutral; 4 - Agree; 5 - Strongly Agree $0<M<2.99$; Low perceptions = Disagree M = 3 ; Neutral $3.01<M<5$; High perception and interest = Agree
		Students' perceptions and interest towards PBL method Part B Learning Outcomes; *Students reflection on problem based learning (PBL) approach.* 1 - Unable to Assess; 2 - Strongly Disagree; 3 - Disagree; 4 - Agree; 5 - Strongly Agree $2<M<3.50$; Low perceptions = Disagree $3.51<M<5$; High perception and interest = Agree
The outcomes will answer Research Question 4 (RQ4)	Mean Score of Likert Scale	Students' perceptions of learning process via online. Part A Contains multiple-choice questions relevant to learning in this Modern Physics course which happens to involve online learning. Only using Description
		Students' perceptions towards learning process via online. Part B Contains questions about: *student's perceived satisfaction; student's perception of interaction; Students' perceptions of individual features (i.e. Content Available on the Web Course; Online learning as a Communication Tool; Assignment; and Online Student Assessment)* 1 - Strongly Disagree; 2 – Disagree; 3 – Neutral; 4 - Agree; 5 - Strongly Agree $0<M<2.99$; Low perceptions = Disagree M = 3; Neutral $3.01<M<5$; High perception and interest = Agree

5.9.3 Interview Data

Data from focus-group question interviews were captured on audiotape and digital video decoder (DVD) and coded within pre-established categories. However, the data from open-ended questions in the 'on-going meetings' were different and the researcher attempted to understand a phenomenon without imposing any a prior categorisation. These unstructured and semi-structured interviews retained a little structure in the sense that there is a setting, there are identified informants, and the interviewees are clearly discernible.

5.10 CHAPTER SUMMARY

This chapter described the research methodology used in the thesis, and this consisted of a mixed methods approach. The research reported in this thesis employed a quasi-experimental method based on a non-same level of group design pre-test-post 'mixed between-within-subjects repeated measures design'. For the 'between subject factors', the independent variables are the teaching and learning methods for the PBL and traditionally taught students. The 'within subjects repeated measures factor' is the score of pre-test and post-test for the dependent variables; namely creative thinking skill and critical thinking skills. The research drew upon the undergraduate physics classes at Universiti Malaysia Sabah, and took 16 weeks, and involved 102 students in total. The experimental group and control groups were chosen based on intact classes. The experimental group experienced the teaching and learning process using the PBL method in a particular physics domain which is Modern Physics, whereas the control group experienced the traditional method of teaching and learning for the same topics.

A number of statistical tests were used to interrogate the data and help address the research questions: *Mann – Whitney U test, Indepenent Sample t-Test value,* and the *mean score* (and associated measures of dispersion). The statistical tests were employed using the Statistical Package for the Social Science (SPSS) version 12. Qualitative data from closed-question focus group interviews were captured and coded thematically using pre-established categories. Other qualitative data from open-ended questions and from in 'on-going meetings' also were captured, and used to triangulate other qualitative data. These unstructured and semi-structured interviews retained a little structure in the sense that there is a setting, identified informants, and the interviewees were clearly noticeable. The observation of online learning helped to derive conclusions for the research questions.

The next chapter begins description of the research outcomes comprehensively for the thesis.

CHAPTER 6: RESEARCH FINDINGS

6 CHAPTER OVERVIEW

This chapter presents the research findings for data collected at the School of Science and Technology (SST) and School of Education and Social Development (SESD). Both schools are located at the Main Campus at University Malaysia Sabah (UMS). The chapter comprises several sections and answers the four research questions. Research Question 1: Does PBL online improve undergraduate physic students' and pre-service science teachers' creative thinking? Research Question 2: Does PBL online improve undergraduate physic students' and pre-service science teachers' critical thinking? Research Question 3: What are Malaysian undergraduate science physics students' and pre-service science teachers' perceptions about learning via PBL? Research Question 4: What are Malaysian undergraduate science physics students' and pre-service science teachers' perceptions about online learning? The last section is the chapter summary, concluding the entire research findings.

6.1 EFFECTIVENESS OF PBL ONLINE IN ENHANCING CREATIVE THINKING

Research Question 1 for this thesis concerned the impact on creative thinking of PBL online on undergraduate science physics students (SST) and pre-service science teachers (SESD). Specifically it sought to ascertain if the intervention described in Chapter 5 (Section 5.8 Research Intervention) led to improvements in students' creative thinking as measured by an instrument, the Torrance Test Creative Thinking (TTCT) (see Section 5.6).

In this section, the researcher thus seeks to discover if students taught PBL online are able to engage better in creative thinking compared with students taught using traditional teaching methods. At first the comparison was made in general, where the data are analysed overall for both SST and SESD students. Next the analysis considers each cohort in turn. Students from the SST program are considered first, followed by those from the SESD program. In each case, comparison is made with the traditional group, and differences based on gender also are investigated.

6.1.1 Comparison of Creative Thinking in General

Table 31 shows the comparison of creative thinking overall. These data show the combination of SST and SESD student's total mean marks pre- and post-test overall and for each criterion. The data were analysed by the non-parametric Mann-Whitney U test followed by the Independent Sample t-Test. The intention was to seek whether there is any difference between these two methods of analysis for the reasons discussed in the methodology (see Section 5.9.1 Test Data). After the intervention, both groups performed (PBL mean = 150.35, SD = 74.79; traditional mean = 116.65, SD = 44.26) in a way that was statistically significant differences noted between the traditional and PBL group in both Mann-Whitney U test (z = -2.95, asymp. sig (2 tailed) = 0.01*<0.05) and Independent Sample t-Test (sig. 2 tailed, t = -2.78, p = 0.01*<0.05) in post-test. These findings were based on *flexibility*, *originality* and *elaboration* criterion, where the PBL group achieved higher mean marks - again for both analyses (Mann-Whitney U test z = -3.16, asymp. sig (2 tailed) = 0.00*<0.05; z = -3.86, asymp. sig (2 tailed) = 0.00*<0.05; z = -3.16, asymp. sig (2 tailed) = 0.00*<0.05; and Independent Sample t-Test, t = -3.16, p = 0.00*<0.05; t = -3.97, p = 0.00*<0.05; t = -4.57, p = 0.00*<0.05; respectively). No significant difference noted for fluency criterion

Table 31
Report of mean marks for creative thinking in general

Creative Thinking Criterion		Approach: Traditional Pre-Test (N = 52)	Approach: Traditional Post-Test (N = 52)	Approach: PBL Pre-Test (N = 50)	Approach: PBL Post-Test (N = 50) Mann-Whitney U-Test	Approach: PBL Post-Test (N = 50) Independent Sample t-Test	Difference in Post-Test
Fluency	Mean	27.41	55.12	21.27	56.71		-1.59
					z = -0.77, Asymp. Sig = 0.44	t = 3.22, p=0.75	
	SD	*12.98*	*24.16*	*13.80*	*25.73*		*-1.57*
Flexibility	Mean	18.40	36.33	13.75	47.03*		-10.70
					z = -3.16, Asymp. Sig = 0.00*	t=-3.16, p=0.00*	
	SD	*8.86*	*11.42*	*7.67*	*21.47*		*-10.05*
Originality	Mean	3.43	15.21	3.80	28.31*		-13.1
					z = -3.86, Asymp. Sig = 0.00*	t= -4.57, p=0.00*	
	SD	*4.71*	*9.19*	*3.99*	*18.42*		*-9.23*
Elaboration	Mean	2.98	9.98	2.32	18.31*		-8.33
					z = -3.16, Asymp. Sig = 0.00*	t=-3.97, p=0.00*	
	SD	*3.00*	*5.41*	*2.54*	*14.09*		*-8.68*

Overall	Mean	52.22	116.65	41.82	150.35*		-33.70
					z= -2.59, Asymp. Sig = 0.01*	t=-2.78, p=0.01*	
	SD	*25.55*	*44.26*	*14.11*	*74.79*		*-30.53*

Note: *Statistically significant differences between PBL and traditional groups for post-test scores (Independent Sample t-test and Mann-Whitney U test)
This was an open-ended test, and so there are no maximum or minimum scores, as occurs with other closed-item instruments.

6.1.2 Science Physics Students (SST)

The performance of students from the SST program in the Torrance Test of Creative Thinking is provided in Table 32. These data suggest that the students who took part in the intervention performed about the same as the traditional group prior to the intervention. After the intervention, both groups performed better in a way that was statistically significant (PBL mean = 135.04, SD = 63.41; traditional mean = 110.23, SD = 47.88). PBL cohort performed better, where there were statistically significant differences between the groups when the instrument is considered overall for Mann-Whitney U test (z = -2.13, asymp. sig (2-tailed) = 0.03*<0.05) but not for Independent Sample t-Test analysis (sig. (2-tailed) t=-1.73, p = 0.89>0.05). However, since the data were not normally distributed, in this case the researcher accepted the data from the Mann-Whitney U test analyses. More detailed analysis of the instrument scales shows some interesting differences between the groups.

Table 32 shows there are statistically significant differences between the PBL and traditional groups in three scales, with the PBL group performing better for *flexibility*, *originality* and also *elaboration* (Mann-Whitney U test; z = -2.40, asymp. sig (2-tailed) = 0.02*<0.05; z = -2.81, asymp. sig (2-tailed) = 0.01*<0.05; z = -1.73, asymp. sig (2-tailed) = 0.04*<0.05 respectively). The same situation occurs when the data are analyzed with the Independent Sample t-Test where the PBL cohort produced better means in *flexibility*, *originality* and *elaboration* significantly (t=-2.22, p=0.03*<0.05; t=-3.06, p=0.00*<0.05; t=-2.44, p=0.02*<0.05 respectively). No significant difference noted for fluency criterion.

Table 32
Report of SST's mean marks for creative thinking pre- and post-test by criterion

Creative Thinking Criterion		Approach: Traditional Pre-Test (N = 31)	Post-Test (N = 31)	PBL Pre-Test (N = 30)	Post-Test (N = 30) Mann-Whitney U Test	Post-Test (N = 30) Independent Sample t-Test	Difference in Post-Test
Fluency	Mean	27.93	50.32	22.96	50.39		-0.07
					z=-0.56, Asymp.Sig =0.58	t=-0.01, p=0.99	
	SD	*13.61*	*24.29*	*15.95*	*20.36*		*3.93*
Flexibility	Mean	20.21	36.48	13.80	45.00*		-8.5
					z= -2.40, Asymp. Sig = 0.02*	t=-2.22, p=0.03*	
	SD	*9.50*	*12.08*	*7.89*	*17.48*		*-5.4*
Originality	Mean	3.62	14.05	4.72	24.44*		-10.4
					z = -2.81, Asymp. Sig = 0.01*	t=-3.06, p=0.00*	
	SD	*5.25*	*9.91*	*4.54*	*15.98*		*-6.0*
Elaboration	Mean	3.86	9.38	2.40	15.22*		-5.8
					z = -1.73, Asymp. Sig = 0.04*	t=-2.44, p=0.02*	
	SD	*3.25*	*5.54*	*2.95*	*12.09*		*-6.6*

Overall	Mean	55.62	110.23	43.88	135.04*		-24.81
					z = -2.13, Asymp. Sig = 0.03*	t = -1.73, p = 0.89	
	SD	*27.73*	*47.88*	*28.05*	*63.41*		*-15.53*

Note: *****Statistically significant differences between PBL and traditional groups for post-test scores (independent sample t-test an Mann-Whitney U test)
This was an open-ended test, and so there are no maximum or minimum scores, as occurs with other closed-item instruments

Investigation of gender differences pre- and post-test for both the traditional and PBL groups show no statistically significant difference between the groups (Table 33 and Table 34).

Table 33
Report of SST's mean marks for creative thinking post-test by gender of PBL group by criterion

Creative Thinking Criterion		Gender			Independent Samples Test t-test for Equality of Means		
		Male (N=15)	Female (N=15)	Total (N=30)	t (df = 28)	Mean Difference	Sig. (2-tailed)
Fluency	Mean	44.98	55.80	50.39	-1.49	-10.82	0.15
	SD	*16.70*	*22.74*	*20.36*			
Flexibility	Mean	40.67	49.33	45.00	-1.38	-8.67	0.18
	SD	*15.20*	*19.01*	*17.48*			
Originality	Mean	22.27	26.60	24.43	-0.74	-4.33	0.47
	SD	*15.18*	*16.97*	*15.98*			
Elaboration	Mean	13.03	17.40	15.22	-0.99	-4.37	0.33
	SD	*11.22*	*12.91*	*12.09*			
Overall	Mean	120.95	149.13	135.04	-1.23	-28.18	0.23
	SD	*56.52*	*68.62*	*63.41*			

Table 34
Report of SST's mean marks for creative thinking post-test by gender of traditional group by criterion

Creative Thinking Criterion		Gender			Independent Samples Test t-test for Equality of Means		
		Male (N=12)	Female (N=19)	Total (N=31)	t (df = 29)	Mean Difference	Sig. (2-tailed)
Fluency	Mean	75.21	72.07	73.29	0.23	3.15	0.82
	SD	*49.00*	*35.88*	*36.72*			
Flexibility	Mean	37.41	15.78	36.48	0.34	1.53	0.74
	SD	*27.85*	*9.50*	*12.08*			
Originality	Mean	13.84	14.18	14.05	-0.09	-0.34	0.93
	SD	*12.63*	*8.14*	*9.91*			
Elaboration	Mean	9.90	9.06	9.38	0.41	0.84	0.69
	SD	*6.27*	*5.18*	*5.54*			
Overall	Mean	136.37	131.19	133.19	0.23	5.18	0.82
	SD	78.61	46.63	59.81			

6.1.3 Pre-Service Science Teachers (SESD)

The performance of students from the SESD program in the Torrance Test of Creative Thinking is provided in Table 35. These data suggest that the students who took part in the intervention performed about the same as the traditional group prior to the intervention. After the intervention, both groups performed better (PBL mean = 173.31, SD = 85.81; traditional mean = 126.13, SD = 37.37 respectively). The PBL group performed better compare to traditional group where there were statistically significant differences between the groups when the instrument is considered overall for Mann-Whitney U-test analysis (z = -1.65, asymp. sig (2-tailed) = 0.04*<0.05) and for Independent Sample t-Test analysis (sig. (2-tailed) t = -2.30, p = 0.03*<0.05) and

More detailed analysis of the instrument scales shows some interesting differences between the groups (Table 35). There are statistically significant differences between the PBL and traditional groups for three scales, with the PBL group performing better for *flexibility*, *originality* and also *elaboration* (Mann-Whitney U test; z = -2.01, asymp. sig (2-tailed) = 0.04*<0.05; z = -2.76, asymp. sig (2-tailed) = 0.01*<0.05; z = -2.65, asymp. sig (2-tailed) = 0.01*<0.05 correspondingly). The same findings are seen when the data are analysed with the Independent Sample t-Test where the PBL performed better in *flexibility*, *originality* and *elaboration* significantly (sig. 2-tailed; t=-2.22, p=0.03*<0.05; t=-3.55; p=0.00*<0.05; and t=-3.31, p=0.00*<0.05 respectively).

Table 35

Report of SESD's mean marks for creative thinking pre- and post-test by criterion

Creative Thinking Criterion		Approach					
		Traditional Pre-Test (N = 21)	Post-Test (N = 21)	PBL Pre-Test (N = 20)	Post-Test (N = 20)		Difference in Post-Test
					Mann-Whitney U Test	Independent Sample t-Test	
Fluency	Mean	26.63	62.19	18.74	66.19		-4.00
					z = 1.02, Asymp. Sig = 0.31	t = 0.48, p = 0.63	
	SD	*12.28*	*22.70*	*9.59*	*30.28*		*-7.28*
Flexibility	Mean	15.74	36.13	13.68	50.06*		-13.93
					z = -2.01, Asymp. Sig = 0.04*	t = -2.22, p = 0.03*	
	SD	*7.23*	*10.67*	*7.53*	*26.57*		*-15.9*
Originality	Mean	3.16	16.94	2.42	34.13*		-17.19
					z = -2.76, Asymp. Sig = 0.01*	t = -3.55, p = 0.00*	
	SD	*3.89*	*7.92*	*2.52*	*20.64*		*-12.72*
Elaboration	Mean	1.68	10.88	2.21	22.94*		-12.06
					z = -2.65, Asymp. Sig = 0.01	t = -3.31, p = 0.00*	
	SD	*2.05*	*5.20*	*1.82*	*15.86*		*-10.66*

Overall	Mean	37.05	126.13	47.21	173.31*		-47.18
					z = -1.65, Asymp. Sig = 0.04*	t = -2.30, p = 0.03*	
	SD	*19.28*	*37.37*	*21.63*	*85.81*		*-48.44*

Note: *****Statistically significant differences between PBL and traditional groups for post-test scores (Independent Sample t-test and Mann-Whitney U test)
This was an open-ended test, and so there are no maximum or minimum scores, as occurs with other closed-item instruments

Investigation of gender differences pre- and post-test for both the traditional and PBL groups showed no statistically significant differences between the groups (Table 36 and Table 37).

Table 36

Report of SESD's mean marks for creative thinking post-test by gender of PBL group by criterion

Creative Thinking Criterion		Gender			Independent Samples Test t-test for Equality of Means		
		Male (N =7)	Female (N =13)	Total (N=20)	t (df =18)	Mean Difference	Sig. (2-tailed)
Fluency	Mean	58.22	70.48	66.19	-0.86	-12.25	0.40
	SD	*22.23*	*33.87*	*30.28*			
Flexibility	Mean	45.17	52.70	50.06	-0.59	-7.53	0.56
	SD	*14.83*	*31.41*	*26.57*			
Originality	Mean	29.91	36.39	34.13	-0.66	-6.48	0.52
	SD	*13.03*	*23.95*	*20.64*			
Elaboration	Mean	24.12	22.30	22.94	0.24	1.81	0.82
	SD	*14.43*	*17.11*	*15.86*			
Overall	Mean	157.45	181.87	173.31	-0.60	-24.45	0.56
	SD	*62.53*	*97.35*	*85.81*			

Table 37

Report of SESD's mean marks for creative thinking post-test by gender of traditional group by criterion

Creative Thinking Criterion		Gender			Independent Samples Test t-test for Equality of Means		
		Male (N=3)	Female (N =18)	Total (N = 21)	t (df = 19)	Mean Difference	Sig. (2-tailed)
Fluency	Mean	91.83	78.32	80.25	0.63	13.51	0.54
	SD	*20.06*	*35.88*	*34.03*			
Flexibility	Mean	35.75	36.19	36.13	-0.06	-0.44	0.95
	SD	*0.65*	*11.57*	*10.67*			
Originality	Mean	19.63	16.49	16.94	0.63	3.14	0.54
	SD	*4.65*	*8.35*	*7.92*			
Elaboration	Mean	8.92	11.20	10.88	-0.70	-2.28	0.50
	SD	*3.39*	*5.45*	*5.20*			
Overall	Mean	156.13	142.20	144.19	0.46	13.93	0.65
	SD	*20.68*	*51.39*	*48.09*			

6.2 IMPACT OF PBL ONLINE ON CRITICAL THINKING

Research Question 2 for this thesis concerned the impact of PBL online on undergraduate science physic and pre-service science students' critical thinking. Specifically, it sought to ascertain if the intervention described in Chapter 5 (Section 5.8 Research Intervention) led to improvements in students' critical thinking when probed with the Watson Glaser Critical Thinking Appraisal (WGCTA) (see Section 5.6).

In this section, the researcher seeks to discover if students taught PBL online are able to engage in better critical thinking compared with students taught using traditional teaching methods. Students from the SST program are considered first, followed by those from the SESD program. In each case, comparison is made with the traditional group, and differences based on gender also are investigated.

6.2.1 Comparison of Critical Thinking in General

Table 38 shows the comparison of critical thinking in general. These data show the combination of SST and SESD total mean marks pre- and post-test overall and by criterion. These data were analysed using the non-parametric Mann-Whitney U test and the Independent Sample t-Test. The intention again was to see whether or not there were any differences between these two methods of analysis. When analysed overall, it appeared that both approaches agree. There are no statistically significant differences noted for both the traditional and PBL group for the Mann-Whitney U test ($z = -1.73$, asymp. sig (2 tailed) = $0.08>0.05$) and for Independent Sample t-Test (sig. 2 tailed, $t = -1.21$, $p = 0.23>0.05$) for the post-test. However, when the data is analysed deeper for both analyses, the PBL group achieved higher marks that were statistically significant for the *inference* criterion (Mann-Whitney U test, $z = -3.52$, asymp. sig (2 tailed) = $0.00^*<0.05$; and Independent Sample t-Test = -3.30, $p = 0.00^*<0.05$). However, for the *assumption* criterion, the traditional group achieved higher mean marks (statistically significant again for both analyses: Mann-Whitney U test $z = -3.01$, asymp. sig (2 tailed) = $0.00^*<0.05$; and Independent Sample t-Test, sig 2-tailed, $t = 2.09$, $p = 0.04^*<0.05$).

Table 38

Report of mean marks for citical thinking in general

Critical Thinking Criterion		Approach					
		Traditional Pre-Test (N = 52)	Post-Test (N = 52)	PBL Pre-Test (N = 50)	Post-Test (N = 50)		Difference in Post-Test
					Mann-Whitney U Test	Independent Sample t-Test	
Inference	Mean	4.61	5.52	3.95	6.74*		-1.22
					z =-3.52 Asymp. Sig = 0.00*	t =-3.30, p = 0.00*	
	SD	*2.10*	*1.54*	*2.59*	*2.15*		*-0.61*
Assumption	Mean	8.28	10.31	8.13	9.54*		0.77
					z =-3.01 Asymp. Sig = 0.00*	t =2.09, p = 0.04*	
	SD	*3.11*	*1.58*	*3.89*	*2.12*		*-0.54*
Deduction	Mean	7.66	9.94	6.89	10.27		-0.33
					z = -0.73 Asymp. Sig = 0.47	t =-1.03, p = 0.31	
	SD	*2.99*	*1.49*	*3.66*	*1.82*		*-033*
Interpretation	Mean	7.68	9.36	7.17	9.27		0.09
					z =-0.52 Asymp. Sig = 0.60	t =0.27, p = 0.79	

	SD	*2.74*	*1.47*	*4.25*	*1.76*		*-0.29*
Evaluation Arguments	Mean	6.95	8.74	6.36	9.16		-0.42
					z =-1.85 Asymp. Sig = 0.07	t =-1.56, p = 0.12	
	SD	*3.15*	*1.49*	*3.86*	*1.22*		*0.27*
Overall	Mean	35.17	43.86	32.50	44.98		-1.12
					z =-1.73 Asymp. Sig = 0.08	t =-1.21, p = 0.23	
	SD	*11.24*	*3.82*	*15.09*	*5.46*		*-1.64*

Note: *Statistically significant differences between PBL and traditional groups for post-test scores (Independent Sample t-Test an Mann-Whitney U test)
Maximum mark is 80

The data above reveal some interesting differences in critical thinking as measured via the WGCT test. In the traditional group, the students were more capable overall in *assumption* when compared with the PBL group. *Assumption* is one of five criterion measured as components of critical thinking in the WGCTA test, the others being *inference*, *deduction*, *interpretation* and *evaluating argument*.

It seems that some interesting things happened to the students' critical thinking development during this intervention. From observation, students probably need more time to develop their critical thinking, and they need more practice and exercise to extend and broaden their capability to become critical thinkers. It seems then, that a positive result can probably only be produced with more exposure to learning by PBL online. It may be that PBL is more successful when delivered face-to-face, as reported by Juremi (2003), even with the four months intervention, similar to the duration used in an online learning environment in this work. In support of this, the PBL group achieved higher means for *inference* when compared with their traditionally taught counterparts.

6.2.2 Science Physics Students (SST)

The performance of students from the SST program in the WGCTA is provided in Table 39. These data suggest that the students who took part in the intervention performed about the same as the traditional group prior to the intervention. After the intervention, both groups performed better (PBL mean = 45.64, SD = 5.99; traditional mean = 43.55, SD = 4.10), and although the PBL cohort performed a little better, there were no statistically significant differences between the groups when the instrument is considered overall by Independent Sample t-Test analyses (sig. 2 tailed, $t=-1.59$, $p=0.12>0.05$). However, when the data are analysed with the more sensitive Mann-Whitney U test, it appears the PBL group performs better than the traditional group ($z=-2.16$, asymp. sig (2 tailed) $=0.03^{*}<0.05$). This is probably because of the relatively modest sample size (N=61), which when analysed with t-Test cannot be detected. Thus, the second analysis using Mann-Whitney U test shows a more useful outcome since it is more appropriate for the small non-parametric sample.

In addition, more detailed analysis of the instrument scales shows some interesting differences between the groups (Table 39). There are statistically significant differences between the PBL and traditional groups for one scale, with the PBL group performing better for *inference* when measured via the independent sample t-test ($t=-3.35$, $p=0.00$*). As for the other scales, there were no statistically significant differences observed. However, when the data were once again analysed with the Mann-Whitney U test, the result indicates that for two out of five criterion the PBL group performed better than the traditionally taught counterparts (*inference*, $z=-3.13$, asymp. sig (2 tailed) = $0.00^{*}<0.05$; and *evaluation argument*, $z=-2.38$, asymp. sig (2 tailed) =$0.02^{*}<0.05$ respectively). Nevertheless, the traditional group has a significantly higher mean in the *assumption* criterion ($z=-2.30$, asymp sig (2 tailed) = $0.02^{*}<0.05$) compared to PBL group. Again, this probably happens because of the small sample.

Table 39
Report of SST's mean marks for critical thinking pre- and post-test by criterion

Critical Thinking Criterion		Approach: Traditional Pre-Test (N = 31)	Post-Test (N = 31)	PBL Pre-Test (N = 30)	Post-Test (N = 30): Mann-Whitney U test	Post-Test (N = 30): Independent Sample t-Test	Difference in Post-Test
Inference	Mean	4.24	5.40	3.77	7.18*		-1.78
					z =-3.13 Asymp. Sig = 0.00*	t =-3.53 p = 0.00*	
	SD	*2.20*	*1.62*	*2.84*	*2.46*		*-0.84*
Assumption	Mean	7.52	10.35	7.37	9.55*		0.80
					z =-2.30 Asymp Sig = 0.02*	t = 1.77 p = 0.82	
	SD	*3.42*	*1.32*	*4.22*	*2.15*		*-0.83*
Deduction	Mean	6.93	10.15	5.87	10.77		-0.62
					z =-1.91 Asymp Sig = 0.06	t = -1.57 p = 0.12	
	SD	*3.37*	*1.47*	*3.97*	*1.64*		*-0.17*
Interpretation	Mean	7.10	9.30	5.53	9.14		0.16
					z =-1.08 Asymp Sig = 0.28	t = 0.47 p = 0.64	

	SD	*3.23*	*1.29*	*4.25*	*1.42*		*-0.13*
Evaluation Argument	Mean	6.55	8.35	5.20	9.00*		-0.65
					z = -2.38 Asymp Sig = 0.02*	t =-1.82 p = 0.74	
	SD	*3.48*	*1.53*	*4.00*	*1.23*		*0.30*
Overall	Mean	32.00	43.55	27.37	45.64*		-2.09
					z =-2.16 Asymp Sig = 0.03*	t =-1.59 p = 0.12	
	SD	*12.82*	*4.10*	*15.73*	*5.99*		*-1.89*

Note: *****Statistically significant differences between PBL and traditional groups for post-test scores (Independent Sample t-Test and Mann-Whitney U test)
Maximum mark is 80

Investigation of gender differences pre- and post-test for both the traditional and PBL groups showed no statistically significant difference between the groups as is shown in Table 40 and Table 41.

Table 40

Report of SST's mean marks for critical thinking post-test by gender of PBL Group by criterion

Critical Thinking Criterion		Gender			Independent Samples Test t-test for Equality of Means		
		Male (N=15)	Female (N =15)	Total (N=30)	t (df = 28)	Mean Difference	Sig. (2-tailed)
Inference	Mean	7.03	7.33	7.18	-0.33	-0.30	0.74
	SD	*1.99*	*2.92*	*2.46*			
Assumption	Mean	8.89	10.20	9.55	-1.73	-1.31	0.10
	SD	*2.11*	*2.04*	*2.15*			
Deduction	Mean	10.48	11.07	10.77	-0.98	-0.59	0.34
	SD	*1.01*	*2.09*	*1.64*			
Interpretation	Mean	8.74	9.53	9.14	-1.57	-0.79	0.13
	SD	*1.47*	*1.30*	*1.42*			
Evaluation Arguments	Mean	8.67	9.33	9.00	-1.52	-0.67	0.14
	SD	*0.72*	*1.54*	*1.23*			
Overall	Mean	43.97	47.31	45.64	-1.73	-3.65	0.10
	SD	*5.34*	*6.32*	*5.99*			

Table 41

Report of SST's mean marks for critical thinking post-test by gender of traditional group by criterion

Critical Thinking Criterion		Gender			Independent Samples Test t-test for Equality of Means		
		Male (N=12)	Female (N =19)	Total (N=31)	t (df =29)	Mean Difference	Sig. (2-tailed)
Inference	Mean	5.77	5.17	5.40	1.00	0.60	0.33
	SD	*1.64*	*1.61*	*1.62*			
Assumption	Mean	9.92	10.62	10.35	-1.46	-0.70	0.16
	SD	*1.22*	*1.35*	*1.32*			
Deduction	Mean	10.37	10.01	10.15	0.66	0.36	0.52
	SD	*0.97*	*1.72*	*1.47*			
Interpretation	Mean	9.49	9.18	9.30	0.65	0.31	0.52
	SD	*1.72*	*0.98*	*1.29*			
Evaluation Arguments	Mean	7.75	8.73	8.35	-1.78	-0.97	0.09
	SD	*1.40*	*1.53*	*1.53*			
Overall	Mean	43.30	43.71	43.55	-0.26	-0.40	0.80
	SD	*4.43*	*3.99*	*4.10*			

6.2.3 Pre-Service Science Teachers (SESD)

The performance of students from the SESD program in the Watson Glaser Critical Thinking Appraisal is shown in Table 42. These data suggest that students who took part in the intervention performed about the same as the traditional group prior to the intervention. After the intervention, both groups performed better (PBL mean = 44.00, SD = 4.51; traditional mean = 45.41, SD = 4.61), and although the traditional group performed a little better, there were no statistically significant differences between the groups when the instrument was considered overall (Mann-Whitney U test, z=-1.70, asymp. sig (2 tailed) =0.28>0.05; and Independent Sample t-Test, sig. (2-tailed) t=0.99, p=0.33>0.05). Additionally, more detailed analysis of the instrument scales also shows no statistically significant differences between the PBL and traditional groups for each criterion.

Table 42
Report of SESD's mean marks for critical thinking pre- and post-test by criterion

Critical Thinking Criterion		Approach: Traditional Pre-Test (N = 21)	Approach: Post-Test (N = 21)	Approach: PBL Pre-Test (N = 20)	Approach: Post-Test (N = 20) Mann-Whitney U Test	Approach: Post-Test (N = 20) Independent Sample t-Test	Difference in Post-Test
Inference	Mean	4.30	5.69	5.11	6.07		-0.38
					z =-1.34 Asymp.Sig = 0.18	t =-0.86 p = 0.38	
	SD	*2.25*	*1.44*	*1.941*	*1.39*		*0.05*
Assumption	Mean	9.40	10.25	9.26	9.53		0.72
					z =-1.88 Asymp.Sig = 0.06	t = 1.13 p = 0.27	
	SD	*3.15*	*1.94*	*2.281*	*2.12*		*-0.18*
Deduction	Mean	8.50	9.63	8.68	9.53		0.10
					z =-0.36 Asymp.Sig = 0.72	t = 0.17 p = 0.86	
	SD	*2.52*	*1.51*	*2.001*	*1.86*		*-0.35*
Interpretation	Mean	9.50	9.44	8.58	9.47		-0.03
					z =-0.34 Asymp.Sig = 0.73	t = -0.05 p = 0.96	
	SD	*2.98*	*1.73*	*1.575*	*2.20*		*-0.47*

Evaluation Argument	Mean	8.10	9.31	7.53	9.40		-0.09
					z =-0.91 Asymp. Sig = 0.36	t = -0.23 p = 0.82	
	SD	*2.94*	*1.25*	*2.695*	*1.21*		*0.04*
Overall	Mean	40.20	45.41	39.16	44.00		1.41
					z =-1.70 Asymp.Sig = 0.28	t = 0.99 p = 0.33	
	SD	*10.45*	*4.61*	*6.10*	*4.51*		*0.10*

Note: *Statistically significant differences between PBL and traditional groups for post-test scores (Independent Sample t-Test an Mann-Whitney U Test)
Maximum mark is 80

Investigation of gender differences pre- and post-test for both the traditional and PBL groups also shows no statistically significant differences between the groups as shown in Table 43 and Table 44.

Table 43
Report of SESD's mean marks for critical thinking post-test by gender of PBL group by criterion

Critical Thinking Criterion		Gender			Independent Samples Test t-test for Equality of Means		
		Male (N= 7)	Female (N=13)	Total (N=20)	t (df=18)	Mean Difference	Sig. (2-tailed)
Inference	Mean	5.47	6.39	6.07	-1.45	-0.92	.163
	SD	*1.42*	*1.32*	*1.39*			
Assumption	Mean	9.88	9.35	9.53	0.52	0.53	0.61
	SD	*1.28*	*2.50*	*2.12*			
Deduction	Mean	9.45	9.58	9.53	-0.15	-0.13	0.89
	SD	*1.77*	*1.98*	*1.86*			
Interpretation	Mean	9.98	9.19	9.47	0.76	0.79	0.46
	SD	*1.59*	*2.48*	*2.20*			
Evaluation Arguments	Mean	9.66	9.26	9.40	0.69	0.40	0.50
	SD	*0.66*	*1.42*	*1.21*			
Overall	Mean	44.43	43.77	44.00	0.30	0.66	0.76
	SD	*2.70*	*5.33*	*4.51*			

Table 44
Report of SESD's mean marks for critical thinking post-test by gender of traditional group by criterion

Critical Thinking Criterion		Gender			Independent Samples Test t-test for Equality of Means		
		Male (N= 3)	Female (N=18)	Total (N=21)	t (df=19)	Mean Difference	Sig. (2-tailed)
Inference	Mean	5.46	5.73	5.69	-0.29	-0.27	0.77
	SD	*0.40*	*1.55*	*1.44*			
Assumption	Mean	11.17	10.10	10.25	0.88	1.07	0.39
	SD	*1.59*	*1.99*	*1.94*			
Deduction	Mean	9.42	9.66	9.63	-0.25	-0.24	0.80
	SD	*0.36*	*1.63*	*1.51*			
Interpretation	Mean	9.96	9.35	9.44	0.55	0.61	0.59
	SD	*0.90*	*1.84*	*1.73*			
Evaluation Arguments	Mean	8.88	9.39	9.31	-0.64	-0.51	0.53
	SD	*0.76*	*1.32*	*1.25*			
Overall	Mean	44.88	45.50	45.41	-0.21	-0.62	0.84
	SD	*0.97*	*4.98*	*4.61*			

6.3 MALAYSIAN UNDERGRADUATE SCIENCE PHYSICS STUDENTS' AND PRE-SERVICE SCIENCE TEACHERS' PERCEPTIONS OF LEARNING VIA PBL ONLINE

Research Question 3 for this thesis concerned Malaysian undergraduate science physics students' and pre-service science teacher perceptions of learning through PBL online. Specifically, it sought to ascertain if students held positive or negative perceptions on the intervention described in Chapter 5 (Section 5.8 Research Intervention).

In this section, the researcher seeks to understand students' perceptions of PBL online in terms of the learning outcomes they felt they gained as a result of the intervention. Students from the SST program are considered first, followed by those from the SESD program. This section is intent on discovering the learning outcome in terms of PBL criteria and the online part will be discussed in the next research question.

6.3.1 Learning Outcomes and Students' Perception of PBL - Part A: Knowledge, Skills & the Application of Knowledge & Skills, Communication, Independent Learning

To analyse these data, two methods of analyses were used: non-parametric techniques, the binomial analysis (cut point value 3), and the t-Test for One Sample (test value = 3). The data, were analysed in general first, then the SST and SESD data analyses were done separately.

6.3.1.1 Comparison of Learning Outcomes for Students' Perception in General

The results are shown in Table 45. It indicates that there are statistically significant differences in perceived learning outcomes for students' in general who participated in the in PBL approach (using the binomial test, based on Z approximation, all the asymp. sig. 2 tailed for all statements indicates that $p^* < 0.05$). Analysis using the One-Sample t-Test for test value = 3 also indicated that the majority of the students agreed their learning outcomes were enhanced by their participation in the PBL approach in terms of Knowledge, Skills and the

Application of Knowledge & Skills; Communication; and Independent Learning categories of the PBL approach.

Table 45

General comparison of undergraduate physics students' and pre-service science teachers' perceptions of PBL –Part A: learning outcomes (knowledge, skills & the application of knowledge & skills, communication, independent learning)

		Observed Proportion (Test Proportion=0.50)	Category (N=50) Group 1 <= 3	Category (N=50) Group 2 > 3	Asymp. Sig. (2-tailed)	Mean (N=50)	SD	Test Value = 3 t (df=19)	Test Value = 3 Sig. (2-tailed)
				Knowledge, Skills and Application of Knowledge & Skills					
1	I was able to search for, and access, information from a variety of sources.		7	43	0.00*(a)	4.11	0.80	9.75	0.00*
		Observed Prop.	0.14	0.86					
2	I was able to recognize the relevance of what I learned to my own daily life.		6	44	0.00*(a)	3.97	0.55	12.35	0.00*
		Observed Prop.	0.12	0.88					
3	I was able to develop my problem-solving ability.		4	46	0.00*(a)	4.06	0.60	12.36	0.00*
		Observed Prop.	0.08	0.92					
4	I was able to identify the critical issues that were being discussed.		5	45	0.00*(a)	4.02	0.48	15.05	0.00*
		Observed Prop.	0.10	0.90					
5	I was able to learn many new knowledge.		4	46	0.00*(a)	4.20	0.62	13.63	0.00*
		Observed Prop.	0.08	0.92					
6	I was able to gain more advantages in knowledge facts.		5	45	0.00*(a)	4.14	0.64	12.63	0.00*
		Observed Prop.	0.10	0.90					
7	I was able to make connections between different facts.		5	45	0.00*(a)	4.03	0.55	13.11	0.00*
		Observed Prop.	0.10	0.90					
8	I was able to choose and apply my own strategy in problem solving.		6	44	0.00*(a)	4.02	0.66	10.94	0.00*
		Observed Prop.	0.12	0.88					
9	I was able to think creatively when using problem-based learning.		5	45.	0.00*(a)	4.13	0.61	13.01	0.00*
		Observed Prop.	0.10	0.90					

10	I was able to think critically.		7	43	0.00*(a)	3.96	0.52	9.86	0.00*
		Observed Prop.	0.14	0.86					
11	My comprehension improved.		8	42	0.00*(a)	3.96	0.63	10.90	0.00*
		Observed Prop.	0.16	0.84					
12	My ability to apply what I have learned improved.		5	45	0.00*(a)	3.99	0.67	10.37	0.00*
		Observed Prop.	0.10	0.90					
13	My ability to analyze data improved.		6	44	0.00*(a)	4.00	0.64	11.02	0.00*
		Observed Prop.	0.12	0.88					
14	I was able to apply my synthesis skill more deeply when using problem-based learning.		11	39	0.02*(a)	3.88	0.67	9.35	0.00*
		Observed Prop.	0.22	0.78					
15	My ability to evaluate findings improved.		7	43	0.00*(a)	3.94	0.57	11.70	0.00*
		Observed Prop.	0.14	0.86					
16	I was able to apply my technical maturity skill more deeply.		11	39	0.00*(a)	3.77	0.63	8.69	0.00*
		Observed Prop.	0.22	0.78					
17	I was able to retain what I had learned.		10	40	0.00*(a)	3.83	0.59	9.96	0.00*
		Observed Prop.	0.20	0.80					
			Communication						
18	I was able to share my ideas clearly within my group during group discussion.		6	44	0.00*(a)	3.96	0.63	10.80	0.00*
		Observed Prop.	0.12	0.88					
19	I was willing to consider the opinions of others, even though I did not fully agree with them.		3	47	0.00*(a)	4.23	0.53	16.36	0.00*
		Observed Prop.	0.06	0.94					
20	I was able to provide logical ideas to my group members, even though they sometimes did not fully agree with me.		5	45	0.00*(a)	4.11	0.60	13.12	0.00*
		Observed Prop.	0.10	0.90					
21	I was able to generate related ideas and information with the group members gradually.		5	45	0.00*(a)	4.01	0.77	9.26	0.00*
		Observed Prop.	0.10	0.90					

22	I had the opportunity to play an important role as one of the main resource contributors during group discussion.		7	43	0.00*(a)	4.09	0.74	10.38	0.00*
		Observed Prop.	0.14	0.86					
23	I was able to listen to the different perspectives and points of view of my group members and keep an open mind about their views.		3	47	0.00*(a)	4.31	0.54	17.15	0.00*
		Observed Prop.	0.06	0.94					
24	I improved in my ability to contribute useful ideas and knowledge in group discussion.		4	46	0.00*(a)	4.20	0.77	11.03	0.00*
		Observed Prop.	0.08	0.92					
	Independent Learning								
25	I was able to work more independently.		7	43	0.00*(a)	3.96	0.83	8.17	0.00*
		Observed Prop.	0.14	0.86					
26	I was able to think of questions that helped me to drive the progress of problem-solving.		8	42	0.01*(a)	4.09	0.64	12.03	0.00*
		Observed Prop.	0.16	0.84					
27	I did my fair share of work in my group.		11	39	0.04*(a)	3.90	0.78	8.08	0.00*
		Observed Prop.	0.22	0.78					
28	I know what I am good at, and used my talents to the fullest.		10	40	0.01*(a)	3.89	0.63	9.95	0.00*
		Observed Prop.	0.20	0.80					
29	I was able to learn new things during problem-solving.		3	47	0.00*(a)	4.26	0.66	13.44	0.00*
		Observed Prop.	0.06	0.94					
30	I was able to demonstrate positive and responsible attitudes towards learning.		7	43	0.00*(a)	4.11	0.66	11.83	0.00*
		Observed Prop.	0.14	0.86					
31	I was able to sustain my interest in solving a problem.		3	47	0.00*(a)	4.19	0.63	13.27	0.00*
		Observed Prop.	0.06	0.94					
32	I was able to choose and apply my own strategy as when learning.		7	43	0.00*(a)	4.13	0.68	11.79	0.00*
		Observed Prop.	0.14	0.86					
33	The learning activities employed		2	48		4.19	0.53	15.85	0.00*

	motivated me to learn more.	Observed Prop.	0.04	0.96	0.00*(a)				
34	I was able to solve interesting and relevant physics problems.		5	45	0.00*(a)	4.05	0.64	11.69	0.00*
		Observed Prop.	0.10	0.90					
35	I was involved actively in the learning activities with the group members.		8	42	0.01*(a)	4.10	0.79	9.83	0.00*
		Observed Prop.	0.16	0.84					
36	I was able to locate my own sources of information.		7	43	0.00*(a)	4.13	0.68	11.79	0.00*
		Observed Prop.	0.14	0.86					
37	I was able to apply much new knowledge in problem-solving process.		4	46	0.00*(a)	4.15	0.69	11.85	0.00*
		Observed Prop.	0.08	0.92					
38	The learning activity was suitable for my level of knowledge.		4	46	0.00*(a)	4.07	0.77	9.85	0.00*
		Observed Prop.	0.08	0.92					
39	The learning activities were fun.		3	47	0.00*(a)	4.45	0.63	16.28	0.00*
		Observed Prop.	0.06	0.94					

Note. (a) Based on Z Approximation.
*****Statistically significant differences between PBL mean on Likert Scale with test value=3 (t-Test for One-Sample Test)

6.3.1.2 Science Physics Students (SST)

The results are shown in Table 46. They indicate that there were also statistically significant differences in perceived learning outcomes for the SST students' who participated in the in PBL approach (using the binomial test, based on Z approximation, all the asymp. sig. 2 tailed for all statements indicates that $p^* < 0.05$). Analysis using the One-Sample t-Test for test value = 3 also indicated that the majority of the students agreed their learning outcomes were enhanced by their participation in the PBL approach. Consequently, overall, SST students also agreed with statements that they gained in terms of a variety of learning outcomes also in all three (i.e., Knowledge, Skills and the Application of Knowledge & Skills; Communication; and Independent Learning) categories of the PBL approach.

Table 46

Comparison of undergraduate physics students' perceptions of PBL - Part A: learning outcomes (knowledge, skills & application of knowledge & skills, communication, independent learning)

		Observed Proportion (Test Prop.=0.50)	Category (N=20) Group 1 <= 3	Category (N=20) Group 2 > 3	Asymp. Sig. (2-tailed)	Mean (N=30)	SD	Test Value = 3 t (df=29)	Test Value = 3 Sig. (2-tailed)
		Knowledge, Skills and Application of Knowledge & Skills							
1	I was able to search for, and access, information from a variety of sources.		6	24	0.00*(a)	4.10	0.78	7.66	0.00*
		Observed Prop.	0.20	0.80					
2	I was able to recognize the relevance of what I learned to my own daily life.		4	26	0.00*(a)	3.90	0.58	8.52	0.00*
		Observed Prop.	0.13	0.87					
3	I was able to develop my problem-solving ability.		2	28	0.00*(a)	4.10	0.69	8.69	0.00*
		Observed Prop.	0.07	0.93					
4	I was able to identify the critical issues that were being discussed.		4	26	0.00*(a)	3.90	0.45	11.07	0.00*
		Observed Prop.	0.13	0.87					
5	I was able to learn many new knowledge.		4	26	0.00*(a)	4.00	0.64	8.52	0.00*
		Observed Prop.	0.13	0.87					
6	I was able to gain more advantages in knowledge facts.		5	25	0.00*(a)	3.90	0.64	7.77	0.00*
		Observed Prop.	0.17	0.83					
7	I was able to make connections between different facts.		5	25	0.00*(a)	4.00	0.69	7.88	0.00*
		Observed Prop.	0.17	0.83					
8	I was able to choose and apply my own strategy in problem-solving.		6	24	0.00*(a)	3.90	0.78	6.32	0.00*
		Observed Prop.	0.20	0.80					
9	I was able to think creatively when using problem-based learning.		3	27	0.00*(a)	4.05	0.61	9.34	0.00*
		Observed Prop.	0.10	0.90					
10	I was able to think critically.		5	25	0.00*(a)	3.86	0.48	9.86	0.00*

		Observed Prop.	0.17	0.83					
11	My comprehension improved.		6	24	0.00*(a)	3.86	0.66	7.13	0.00*
		Observed Prop.	0.20	0.80					
12	My ability to apply what I have learned improved.		5	25	0.00*(a)	3.86	0.80	5.87	0.00*
		Observed Prop.	0.17	0.83					
13	My ability to analyze data improved.		4	26	0.00*(a)	3.95	0.72	7.27	0.00*
		Observed Prop.	0.13	0.87					
14	I was able to apply my synthesis skill more deeply when using problem-based learning.		8	22	0.02*(a)	3.76	0.69	6.05	0.00*
		Observed Prop.	0.27	0.73					
15	My ability to evaluate findings improved.		4	26	0.00*(a)	3.90	0.58	8.52	0.00*
		Observed Prop.	0.13	0.87					
16	I was able to apply my technical maturity skill more deeply.		3	27	0.00*(a)	3.90	0.64	7.77	0.00*
		Observed Prop.	0.10	0.90					
17	I was able to retain what I had learned.		6	24	0.00*(a)	3.76	0.58	7.18	0.00*
		Observed Prop.	0.20	0.80					
			Communication						
18	I was able to share my ideas clearly within my group during group.		4	26	0.00*(a)	3.81	0.62	7.12	0.00*
			0.13	0.87					
19	I was willing to consider the opinions of others, even though I did not fully agree with them.		3	27	0.00*(a)	4.00	0.45	12.04	0.00*
		Observed Prop.	0.10	0.90					
20	I was able to provide logical ideas to my group members, even though they sometimes did not fully agree with me.		1	29	0.00*(a)	4.19	0.56	11.55	0.00*
		Observed Prop.	0.03	0.97					
21	I was able to generate related ideas and information with the group members gradually.		4	26	0.00*(a)	3.86	0.88	5.32	0.00*
		Observed Prop.	0.13	0.87					
22	I had the opportunity to play an important role as one of the main resource contributors during group		3	27	0.00*(a)	4.14	0.80	7.82	0.00*
		Observed Prop.	0.10	0.90					

	discussion.								
23	I was able to listen to different perspectives and points of view of my group members and keep an open mind about their views.		2	28	0.00*(a)	4.19	0.50	13.05	0.00*
		Observed Prop.	0.07	0.93					
24	I improved in my ability to contribute useful ideas and knowledge in group discussion.		3	27	0.00*(a)	4.00	0.83	6.60	0.00*
		Observed Prop.	0.10	0.90					
			Independent Learning						
25	I was able to work more independently.		5	25	0.00*(a)	3.76	0.91	4.61	0.00*
		Observed Prop.	0.17	0.83					
26	I was able to think of questions that helped me to drive the progress of problem-solving.		7	23	0.01*(a)	3.90	0.64	7.77	0.00
		Observed Prop.	0.23	0.77					
27	I did my fair share of work in my group.		9	21	0.04*(a)	3.62	0.76	4.44	0.00*
		Observed Prop.	0.30	0.70					
28	I know what I am good at, and used my talents to the fullest.		7	23	0.01*(a)	3.86	0.71	6.62	0.00
		Observed Prop.	0.23	0.77					
29	I was able to learn new things during problem-solving.		3	27	0.00*(a)	4.14	0.76	8.28	0.00*
		Observed Prop.	0.10	0.90					
30	I was able to demonstrate positive and responsible attitudes towards learning.		6	24	0.00*(a)	4.10	0.78	7.69	0.00*
		Observed Prop.	0.20	0.80					
31	I was able to sustain my interest in solving a problem.		2	28	0.00*(a)	4.19	0.72	9.00	0.00*
		Observed Prop.	0.07	0.93					
32	I was able to choose and apply my own strategy when learning.		4	26	0.00*(a)	4.05	0.67	8.59	0.00*
		Observed Prop.	0.13	0.87					
33	The learning activities employed motivated me to learn more.		2	28	0.00*(a)	4.14	0.60	10.37	0.00*
		Observed Prop.	0.07	0.93					
34	I was able to solve interesting and relevant physics problems.		3	27	0.00*(a)	4.05	0.72	7.99	0.00*
		Observed Prop.	0.10	0.90					

35	I was involved actively in the learning activities with the group members.		7	23	0.01*(a)	3.86	0.84	5.57	0.00*
		Observed Prop.	0.23	0.77					
36	I was able to locate my own sources of information.		5	25	0.00*(a)	4.05	0.72	7.99	0.00*
		Observed Prop.	0.17	0.83					
37	I was able to apply much new knowledge in problem-solving process.		4	26	0.00*(a)	4.05	0.81	7.10	0.00*
		Observed Prop.	0.13	0.87					
38	The learning activity was suitable for my level of knowledge.		3	27	0.00*(a)	3.95	0.89	5.86	0.00*
		Observed Prop.	0.10	0.90					
39	The learning activities were fun.		3	27	0.00*(a)	4.33	0.71	10.27	0.00*
		Observed Prop.	0.10	0.90					

Note. (a) Based on Z Approximation.
*****Statistically significant differences between PBL mean on Likert Scale with test value=3 (t-Test for One-Sample Test)

6.3.1.3 Pre-Service Science Teachers (SESD)

Table 47 also indicates that there are statistically significant differences in perceived learning outcomes for SESD students who were exposed to the PBL learning approach. Based on the binomial test, with the Z approximation, all the asymp. sig. 2 tailed for all statements indicate that $p^* < 0.05$. Likewise, analysis using the One-Sample t-Test with the test value = 3 suggests that the majority of the pre-service students were also agreed that they gained in terms of learning outcomes of the PBL.

Table 47

Comparison of pre-service science teachers' perceptions of PBL - Part A: learning outcomes (knowledge, skills & application of knowledge & skills, communication, independent learning)

		Observed Prop. (Test Prop.=0.50)	Category (N=20)		Asymp. Sig. (2-tailed)	Mean (N=20)	SD	Test Value = 3	
			Group 1 <= 3	Group 2 > 3				t (df=19)	Sig. (2-tailed)
		Knowledge, Skills and Application of Knowledge & Skills							
1	I was able to search for, and access, information from a variety of sources.		1	19	0.00*(a)	4.13	0.85	5.91	0.00*
		Observed Prop.	0.05	0.95					
2	I was able to recognize the relevance of what I learned to my own daily life.		2	18	0.00*(a)	4.06	0.51	9.32	0.00*
		Observed Prop.	0.10	0.90					
3	I was able to develop my problem-solving ability.		2	18	0.00*(a)	4.00	0.46	9.75	0.00*
		Observed Prop.	0.10	0.90					
4	I was able to identify the critical issues that were being discussed.		1	19	0.00*(a)	4.19	0.48	10.99	0.00*
		Observed Prop.	0.05	0.95					
5	I was able to learn many new knowledge.		0	20	0.00*(a)	4.50	0.46	14.62	0.00*
		Observed Prop.	0.00	1.00					
6	I was able to gain more advantages in knowledge facts.		0	20	0.00*(a)	4.50	0.46	14.62	0.00
		Observed Prop.	0.00	1.00					
7	I was able to make connections between different facts.		0	20	0.00*(a)	4.06	0.22	21.39	0.00*
		Observed Prop.	0.00	1.00					
8	I was able to choose and apply my own strategy in problem–solving.		0	20	0.00*(a)	4.19	0.36	14.83	0.00*
		Observed Prop.	0.00	1.00					
9	I was able to think creatively when using problem-based learning.		2	18	0.00*(a)	4.25	0.61	9.21	0.00*
		Observed Prop.	0.10	0.90					
10	I was able to think critically.		2	18	0.00*(a)	4.13	0.55	9.15	0.00*
		Observed Prop.	0.10	0.90					
11	My comprehension improved.		2	18	0.00*(a)	4.13	0.55	9.15	0.00*

		Observed Prop.	0.10	0.90					
12	My ability to apply what I have learned improved.		0	20	0.00*(a)	4.19	0.36	14.83	0.00*
		Observed Prop.	0.00	1.00					
13	My ability to analyze data improved.		2	18	0.00*(a)	4.06	0.51	9.32	0.00*
		Observed Prop.	0.10	0.90					
14	I was able to apply my synthesis skill more deeply when using problem-based learning.		3	17	0.00*(a)	4.06	0.60	7.86	0.00*
		Observed Prop.	0.15	0.85					
15	My ability to evaluate findings improved.		3	17	0.00*(a)	4.00	0.56	7.96	0.00*
		Observed Prop.	0.15	0.85					
16	I was able to apply my technical maturity skill more deeply.		8	12	0.50(a)	3.56	0.56	4.50	0.00*
		Observed Prop.	0.40	0.60					
17	I was able to retain what I had learned.		4	16	0.01*(a)	3.94	0.60	6.94	0.00*
		Observed Prop.	0.20	0.80					
			Communication						
18	I was able to share my ideas clearly within my group during group.		2	18	0.00*(a)	4.19	0.58	9.12	0.00*
			0.10	0.90					
19	I was willing to consider the opinions of others, even though I did not fully agree with them.		0	20	0.00*(a)	4.56	0.45	15.35	0.00*
		Observed Prop.	0.00	1.00					
20	I was able to provide logical ideas to my group members, even though they sometimes did not fully agree with me.		4	16	0.01*(a)	4.00	0.65	6.89	0.00*
		Observed Prop.	0.20	0.80					
21	I was able to generate related ideas and information with the group members gradually.		1	19	0.00*(a)	4.25	0.51	10.90	0.00*
		Observed Prop.	0.05	0.95					
22	I had the opportunity to play an important role as one of the main resource contributors during group discussion.		4	16	0.01*(a)	4.00	0.65	6.90	0.00*
		Observed Prop.	0.20	0.80					
23	I was able to listen to the different perspectives and points of view of my group members and keep an open mind about their views.		1	19	0.00*(a)	4.50	0.56	11.94	0.00*
		Observed Prop.	0.05	0.95					

24	I improved in my ability to contribute useful ideas and knowledge in group discussion.		1	19	0.00*(a)	4.50	0.56	11.94	0.00*
		Observed Prop.	0.05	0.95					
			Independent Learning						
25	I was able to work more independently.		2	18	0.00*(a)	4.25	0.61	9.21	0.00*
		Observed Prop.	0.10	0.90					
26	I was able to think of questions that helped me to drive the progress of problem-solving		1	19	0.00*(a)	4.38	0.55	11.18	0.00*
		Observed Prop.	0.05	0.95					
27	I did my fair share of work in my group.		2	18	0.00*(a)	4.31	0.63	9.38	0.00*
		Observed Prop.	0.10	0.90					
28	I know what I am good at, and used my talents to the fullest.		3	17	0.00*(a)	3.94	0.51	8.23	0.00*
		Observed Prop.	0.15	0.85					
29	I was able to learn new things during problem-solving.		0	20	0.00*(a)	4.44	0.46	14.12	0.00*
		Observed Prop.	0.00	1.00					
30	I was able to demonstrate positive and responsible attitudes towards learning.		1	19	0.00*(a)	4.13	0.44	11.33	0.00*
		Observed Prop.	0.05	0.95					
31	I was able to sustain my interest in solving a problem.		1	19	0.00*(a)	4.19	0.48	10.99	0.00*
		Observed Prop.	0.05	0.95					
32	I was able to choose and apply my own strategy when learning.		3	17	0.00*(a)	4.25	0.69	8.12	0.00*
		Observed Prop.	0.15	0.85					
33	The learning activities employed motivated me to learn more.		0	20	0.00*(a)	4.25	0.40	14.07	0.00*
		Observed Prop.	0.00	1.00					
34	I was able to solve interesting and relevant physics problems.		2	18	0.00*(a)	4.06	0.51	9.32	0.00*
		Observed Prop.	0.10	0.90					
35	I was involved actively in the learning activities with the group members.		1	19	0.00*(a)	4.47	0.55	11.94	0.00*
		Observed Prop.	0.05	0.95					
36	I was able to locate my own sources of information.		2	18	0.00*(a)	4.25	0.61	9.21	0.00*
		Observed Prop.	0.10	0.90					
37	I was able to apply much new knowledge in the problem-solving process.		0	20	0.00*(a)	4.31	0.43	13.80	0.00*
		Observed Prop.	0.00	1.00					
38	The learning activity was suitable for my level of knowledge.		1	19	0.00*(a)	4.25	0.51	10.90	0.00*
		Observed Prop.	0.05	0.95					

39	The learning activities were fun.		0	20	0.00*(a)	4.63	0.44	16.35	0.00*
		Observed Prop.	0.00	1.00					

Note. (a) Based on Z Approximation.
*****Statistically significant differences between PBL mean on Likert Scale with test value = 3 (t-Test for One-Sample Test)

6.3.2 Learning Outcomes and Students' Perception of PBL – Part B: Students' Reflections of PBL

Research Question 3 for this thesis concerned the Malaysian undergraduate science physics students' and pre-service science teacher perceptions of learning through PBL delivered via online. Specifically, it required to ascertain whether students had positive perceptions of the intervention described in Chapter 5 (Section 5.7 Research Intervention).

In this section, the researcher seeks to discover what the students' awareness is regarding PBL online method in terms of 'students' reflections on PBL approach'. Students from the SST program are considered first, followed by those from the SESD program.

To analyse this data, two methods of analysis were used: non-parametric techniques, the binomial analysis (cut point value 3.5), and the t-Test for One Sample (test value = 3). Comparisons in general were analysed first, followed by the separatedata analyses for SST and SESD students.

6.3.2.1 Comparison of Learning Outcomes for Students' Perception in General

The results shown in Table 48 show that, in general, the students' perceptions of learning through PBL were very positive in terms of the affective effects and their process of learning. Statements that attracted means more than 4 from 5 Likert scales include the PBL as an effective students-centered approach; understanding of Modern Physics improved; more engaged in their study; and made better connection within the course. Additionally they enjoyed the study more; became more interested in their learning; and became more motivated.

Table 48

General comparison of undergraduate physics science students' and pre-service science teachers' perception of PBL - Part B: Students' reflection on PBL's specific features.

	Statement	Observed Proportion (Test Proportion = 0.50)	Category (N=50) Group 1 <= 3.5	Category (N=50) Group 2 > 3.5	Asymp. Sig. (2-tailed)	Mean (N=50)	SD	Test Value = 3.5 t (df=49)	Test Value = 3.5 Sig. (2-tailed)
1	PBL is one of the effective student-centred approaches.		5	45	0.00*(a)	4.10	0.69	6.15	0.00*
		Observed Prop.	0.10	0.90					
2	The learning activities in the PBL groups were enjoyable.		6	44	0.00*(a)	4.23	0.75	6.81	0.00*
		Observed Prop.	0.12	0.88					
3	I feel that my understanding of modern physics improved as a result of using this approach to learning.		3	47	0.00*(a)	4.10	0.53	8.09	0.00*
		Observed Prop.	0.06	0.94					
4	I was actively engaged in learning when using this approach to learning.		9	41	0.01*(a)	3.94	0.84	3.69	0.00*
		Observed Prop.	0.18	0.82					
5	My confidence as a problem-solver increased as a result of using this approach to learning.		6	44	0.00*(a)	3.94	0.70	4.48	0.00*
		Observed Prop	0.12	0.88					
6	My interest in learning modern physics increased as a result of using this approach to learning.		3	47	0.00*(a)	4.09	0.62	6.70	0.00*
		Observed Prop	0.06	0.94					
7	My ability to engage in reflective thinking increased as a result of using this approach to learning.		5	45	0.00*(a)	3.98	0.63	5.45	0.00*
		Observed Prop	0.10	0.90					
8	I found the material learned to be of more relevance as a result of using this approach to learning.		4	46	0.00*(a)	4.03	0.62	6.01	0.00*
		Observed Prop	0.08	0.92					

9	My motivation to learn modern physics increased as a result of using this approach to learning.		5	45	0.00*(a)	4.08	0.68	6.04	0.00*
		Observed Prop	0.10	0.90					
10	My perceptions and point of view in regard to learning modern physics lead to a better connection between classroom and real life as a result of using this approach to learning.		3	47	0.00*(a)	4.21	0.73	6.85	0.00*
		Observed Prop	0.06	0.94					

Note. (a) Based on Z Approximation.
*Statistically significant differences between PBL mean on Likert Scale with test value = 3.5 (t-Test for One-Sample Test)

6.3.2.2 Science Physics Students (SST)

The results shown in Table 49 suggest that the students' perceptions of learning through PBL were very positive in terms of the affective effects and their process of learning, as in the general analysis. SST students also found that their reflective thinking had been increased as a result of using this approach to learning. Table 49 indicates that there are statistically significant differences in perceived learning outcomes for SST students' who participated in the in PBL approach (using the binomial test, based on Z approximation, all the asymp. sig. 2 tailed for all statements indicates that $p^* < 0.05$). Analysis using the One-Sample t-Test for test value = 3.5 also indicated that the majority of the students agreed that they had positive reflection responses to the PBL approach. Thus, overall SST students reacted optimistically to the PBL approach.

Table 49

Comparison of undergraduate physics students' perceptions of PBL - Part B: Students' reflections on PBL's specific features

	Statement	Observed Proportion (Test Proportion = 0.50)	Category (N=30) Group 1 <= 3.5	Category (N=30) Group 2 > 3.5	Asymp. Sig. (2-tailed)	Mean (N=30)	SD	Test Value = 3.5 t (df=29)	Test Value = 3.5 Sig. (2-tailed)
1	PBL is one of the effective student-centred approaches.		3	27	0.00*(a)	4.05	0.49	6.13	0.00*
		ObservedProp.	0.10	0.90					
2	The learning activities in the PBL groups were enjoyable.		5	25	0.00*(a)	4.00	0.79	3.48	0.00*
		Observed Prop.	0.17	0.83					
3	I feel that my understanding of modern physics improved as a result of using this approach to learning.		3	27	0.00*(a)	4.05	0.62	4.88	0.00*
		Observed Prop.	0.10	0.90					
4	I was actively engaged in learning when using this approach to learning.		7	23	0.01*(a)	3.81	0.77	2.20	0.04*
		Observed Prop.	0.23	0.77					
5	My confidence as a problem-solver increased as a result of using this approach to learning.		4	26	0.00*(a)	3.90	0.58	3.81	0.00*
		Observed Prop	0.13	0.87					
6	My interest in learning modern physics increased as a result of using this approach to learning.		2	28	0.00*(a)	4.19	0.50	7.57	0.00*
		Observed Prop	0.07	0.93					
7	My ability to engage in reflective		2	28	0.00*(a)	4.10	0.45	7.28	0.00*

	thinking increased as a result of using this approach to learning.	Observed Prop	0.07	0.93					
8	I found the material learned to be of more relevance as a result of using this approach to learning.		3	27	0.00*(a)	4.05	0.49	6.13	0.00*
		Observed Prop	0.10	0.90					
9	My motivation to learn modern physics increased as a result of using this approach to learning.		3	27	0.00*(a)	4.10	0.52	4.35	0.00*
		Observed Prop	0.10	0.90					
10	My perceptions and point of view in learning modern physics lead to the better connection between classroom and real life as a result of using this approach to learning.		2	28	0.00*(a)	4.14	0.60	5.83	0.00*
		Observed Prop	0.07	0.93					

Note. (a) Based on Z Approximation.
*Statistically significant differences between PBL mean on Likert Scale with test value = 3.5 (t-Test for One-Sample Test)

6.3.2.3 Pre-Service Science Teachers (SESD)

In a similar manner to the SST students, two methods of nonparametric analysis to were used to interrogate the data for SESD - the binomial analysis, cut point value 3, and the t-Test for One Sample (with a test value = 3.5). The results shown in Table 50 indicate that there are statistically significant differences in perceived learning outcomes for SESD students who were exposed to the PBL learning approach. Based on the binomial test, with the Z approximation, all the asymp. sig. 2 tailed for all statements indicate that $p^*<0.05$. Likewise, analysis using the One-Sample t-Test with the test value = 3.5 suggests that majority of the students also react positively to PBL approach. Table 50 reveals almost the same findings as with SST students where the students' perceptions of learning through PBL were very positive in terms of affective effects and their process of learning. Statements that produced means more than 4 from 5 Likert scales include the PBL as an effective student-centered approach; understanding of Modern Physics improved; more engaged in their study; and had made better connection and relevancy to each topic they have learnt. Moreover, their learning become more enjoyable; became more interested in their learning; gained more confidence; and became more motivated as the result of the instructional method.

Table 50
Comparison of pre-service science teachers' perceptions of PBL - Part B: Students' reflections on PBL's specific features

	Statement	Observed Proportion (Test Proportion = 0.50)	Category (N=20) Group 1 <= 3.5	Group 2 > 3.5	Asymp. Sig. (2-tailed)	Mean (N=20)	SD	Test Value = 3.5 t (df=19)	Sig. (2-tailed)
1	PBL is one of the effective student-centered approaches.		2	18	0.00*(a)	4.19	0.93	3.31	0.00*
		Observed Prop.	0.10	0.90					
2	The learning activities in the PBL groups were enjoyable.		1	19	0.00*(a)	4.56	0.56	8.50	0.00*
		Observed Prop.	0.05	0.95					
3	I feel that my understanding of modern physics improved as a result of using this approach to learning.		0	20	0.00*(a)	4.19	0.36	8.58	0.00*
		Observed Prop.	0.00	1.00					
4	I was actively engaged in learning when using this approach to learning.		2	18	0.00*(a)	4.13	0.91	3.07	0.01*
		Observed Prop.	0.10	0.90					
5	My confidence as a problem-solver increased as a result of using this approach to learning.		2	0.10	0.00*(a)	4.00	0.86	2.61	0.02*
		Observed Prop	18	0.90					
6	My interest in learning modern physics increased as a result of using this approach to learning.		1	19	0.00*(a)	3.94	0.76	2.58	0.02*
		Observed Prop	0.05	0.95					
7	My ability to engage in reflective thinking increased as a result of		3	17	0.00*(a)	3.81	0.81	1.73	0.10
		Observed Prop	0.15	0.85					

	using this approach to learning.								
8	I found the material learned to be of more relevance as a result of using this approach to learning.		1	19	0.00*(a)	4.00	0.79	2.81	0.01*
		Observed Prop	0.05	0.95					
9	My motivation to learn modern physics increased as a result of using this approach to learning.		2	18	0.00*(a)	4.06	0.89	2.84	0.01*
		Observed Prop	0.10	0.90					
10	My perceptions and point of view of learning modern physics lead to the better connection between classroom and real life as a result of using this approach to learning.		1	19	0.00*(a)	4.31	0.90	4.03	0.00*
		Observed Prop	0.05	0.95					

Note. (a) Based on Z Approximation.
*Statistically significant differences between PBL mean on Likert Scale with test value = 3.5 (t-Test for One-Sample Test)

6.3.3 Learning Outcomes and Students' Perceptions of PBL - Part C: Open-Ended Questions and Interview

In this section, data gathered from the open-ended survey questions and during interviews is used to complement the numerical data described previously to better understand the participants' views of the implementation of the PBL online approach in their Modern Physics course. The qualitative data from the open-ended and the interviews were used to triangulate the questionnaire. These data suggest that as far as the PBL online approach is concerned the students were positive in their feedback about the approach. Feedback for the SST and SESD students is first presented combined and any differences between the cohorts then discussed. This section ends with summaries for both groups of students. This section will mainly discuss the PBL criteria that have been suggested by participants, and not necessarily the online component.

Table 51 shows the themes that have been categorised from the open-ended questionnaire and interview of students' perceptions of PBL. The themes have been separated into six questions: Question 1: *What are the learning outcomes that you felt you obtained?* Question 2: *How has your ability to engage in creative thinking been affected?* Question 3: *How has your ability to engage in critical thinking been affected?* Question 4: *Do you think the PBL approach is a suitable way for you to learn modern physics*? *Explain why, or why not.* Question 5: *What did you find to be least useful about learning using this learning approach*? Question 6*: What did you find to be most useful about learning using this learning approach.*

Table 51

Themes in the open-ended questionnaire and interview regarding students' perception of PBL

Question 1: What are the learning outcomes that you felt you obtained?

Generally

i. Communication and sharing knowledge; ii. Help in understanding concepts in Modern Physics/ Physics content knowledge

SST

i. Problem-solving skills; ii. Being able to connect and build different ideas; iii. Enhancing computer skills

SESD

i. Improved English Language; ii. More hardworking

Question 2: How has your ability to engage in creative thinking been affected?

Generally

i. Creativity increased gradually; ii. It (creativity) helps to solve the problems

SST

i. Able to express their opinion; ii. Know how and when to use creativity; iii. Sustain their interest; iv. Able to use skills in bridging ideas

SESD

i. Can think of solution that never crosses their mind; ii. Use many creative ideas in explaining certain classic concepts

Other Perspective (Negative)

i. Really hard to be a creative thinker

Question 3: How has your ability to engage in critical thinking been affected?

Generally

i. Critical thinking improved; ii. Manage to engage in critical thinking, iii. Manage to generate related ideas

SST

i. Mind activation and brainstorming; ii. Able to think in terms of cause and effect

SESD

i. Think more freely; ii. Answer in more acceptable ways

Other Perspective (Negative)

i. Their critical thinking is not improving; ii. Had headache

Question 4: Do you think the PBL approach is a suitable way for you to learn modern physics? Explain why, or why not.

Generally

i. Easy to understand modern physics theory; ii. Learning becomes more interesting, enjoyable and fun;
iii. Need method of learning which can make them understand better

SST

i. Can expose them to the preparation for responsibility in the workforce

SESD

i. Student-centred approach

Other Perspective (Neutral)

i. Not enough time to study using PBL approach; ii. Depends on individual

Other Perspective (Negative)

i. Need plenty of time and energy to be cope with learning; ii. Tutorial taught us how to answer exam questions

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Question 5: What did you find to be least useful about learning using this learning approach?

Generally

i. There are some technical issues; ii. Lack of cooperation from group members

SST

i. They couldn’t get through enough syllabus; ii. Too much chat session; iii. Perplexed at the beginning of the assessment

SESD

i. Least guidance from facilitator; ii. Out of focus while doing discussion; iii. Lack of visual picture

Other Perspective (Neutral)

i. Nothing unbeneficial

Question 6: What did you find to be most useful about learning using this learning approach?

Generally

i. More understanding; ii. More cooperative; iii. Internet connection as the major medium; iv. Enhanced efficiency on solving problems
v. Enhanced soft skills; vi. Time management

6.3.3.1 Students' Learning Outcomes

Question 1: What were the learning outcomes that you felt you obtained? Analysis of the open-ended questionnaire and interview data indicated that students felt they learned and gained two principle learning outcomes: *i. Communication and sharing knowledge;* and *ii. Help in understanding concepts in Modern Physics/ Physics content knowledge.* Here the researcher provides more detail to support this finding.

i. Communication and Sharing knowledge

One of the key outcomes that the students talked about was their ability to communicate with others, and in particular with other group members.

> Able to communicate and share my knowledge with team members. More responsible to my work. Thinking more deeply and creatively. Sustained interest in one subject. (R9, SST, M, *questionnaire*)

One thing that emerged from this was that they appreciated the importance of cooperation within the team when engaged in communication and sharing knowledge. Thus, enhanced communication resulted in a feeling that they learned how to cooperate with team members.

> I also became able to communicate with much more confidence my opinion to others. More than that, I realize that cooperation between each member is important. (R9, SESD, F, *questionnaire*)

This collaboration helped the participants work better as group members, and they felt that by discussing the problems, they could solve the problems they were presented with during the intervention. The online component of the intervention meant this was not location-dependent:

> By doing this PBL, we can make contact with other group members, we can chat with them although we are in separate places. Thus we can share

> thoughts and information to solve the problems that been given. (R8, F, SESD, *interview*)

ii. Help in understanding concepts in Modern Physics/ Physics content knowledge

The participants also felt that learning through the intervention helped them to understand that physics modern concepts relate to everyday life and activity. It seems this was due, in part, to the online nature of learning, as they could search for the topics on the Internet, and found, to their surprise, many sources which indicated that the physics concepts were related to everyday life:

> I have gained lots of new experience through this programme. I know the concept and theory of modern physics more deeply and clearly. Via Internet searching, I find extra information. Moreover, it also give us a chance to survey and find out the most ideal solution for the task given since our aim is to solve the task given. By having the internet discussion, I can exchange my idea with my group members. This make us know more deeply about the concepts which need to go through. (R13, SST, F, *questionnaire*)

Moreover, they have to critically select their appropriate information sources from the Internet:

> I feel that I become more understand about what modern physics' theory is all about and I know how to apply it into our daily life to solve problems. I also know how to search for information, choose my source of information and decide which information I should take. (R16, SST, F, *questionnaire*)

As well as feeling that they understood the modern physics concepts better, the students also recorded that they felt more motivated during the intervention, and that this led to them becoming more independent learners:

> [the PBL online intervention] helped increase my view of modern physics in real life. [It] introduced me to a new student centred approach which motivated the learning process because I could use the new technology of the Internet to solve physics problems. [I think it] trains the student to be

independent, especially in ways to obtain information. (R10, SESD, M, *questionnaire*)

Although there was feedback common to both cohorts of students as described above, some different comments were made by the different groups. For example, the SST students said that they also gained knowledge on their *i. Problem-solving skills, ii. Their abiltiy to connect and build different ideas,* and the *iii. Enhancment of computer skills,* and this is described below.

i. Problem-solving skills

An interesting example was noted by a participant about how this instructional method helps her in her problem-solving skills, especially when it comes to solving problems online where they need to become accustomed to the online requirements:

> I know how to find information via multimedia. I also know how to submit or send and assignment via e-mail. I also know how to solve a problem even not in 3D. (R2, SST, F, *questionnaire)*

ii. Ablity to connect and build different ideas

Another student commented on how she is now able to connect and build different ideas, saying that:

> From what I had experienced, I felt that I manage to obtain most of the learning outcomes that are supposed to be obtained by each of student that take this kind of learning. Problem based learning makes me tune in with this subject, what I mean is I can develop, connects and build my ideas and this rises my self-confidence in learning modern physics. (R15, SST, F, *questionnaire*)

iii. Enhancment of computer skills

Students' competency in using computers while learning also been improved as it has exposed them to the experience of doing academic activities using technologies.

Skills, like typing efficiently and searching for information using search engines like Google, exposed them to the technology itself, as remarked on by a participant:

> The PBL allow me to get more experience, in how to use the Internet. Because I seldom search information through the Internet before. But now I know how to search information using Google search and Yahoo and so on. Beside that, this also trained me how to type efficiently, because before this I never type like this fast before and never been exposed to any chat room like MSN, Skype etc. (R27, F, SST, *interview*)

In contrast the SESD students felt that they *i. Improved their English language* while experiencing this PBL program and were *ii. More hardworking* than before experiencing this PBL program, probably as a result of what they saw as a more novel and exciting mode of learning.

ii. Improved their English language

Since the PBL intervention was delivered in English, one of participants noted that it is their opportunity to improve their English proficiency in talking, speaking and learning in English:

> Then the second thing, from time to time we also can improve our English language, because usually in traditional class we have very limited vision, so with PBL program we can improve our English usage. (R26, M, SESD, *interview*)

iii. More hardworking

One thing about PBL is the need of students to become self-directed learners and they also need to drive themselves to take full charge of their learning process, thus it managed to motivate them to become more punctilious in their learning activities, as a participant commented:

> By going through the PBL I become more hardworking, because I also go through the Internet to search a lot of things not only to find information for the PBL, but for the others courses assignment. (R26, M, SESD, *interview*)

Besides reporting working harder, the SESD students also commented out that they felt they had become an ‘advanced learner’ compared with traditional students, and in this way they were attracted to the learning process itself.

> Honestly, I had gone through this and that’s why I think this kind of learning will be far more effective than traditional. Also, I had the opportunity to be an advanced learner of modern physics. It is exciting in this way and I prefer it this way for this is the basic idea for the student to begin in liking this subject. Sometimes, I get this kind of excitement when I learn something new. I think if I don’t pick problem based learning, it will be a bit boring doing all those tutorials because I like something that is more independent and a step ahead of all traditional learning styles. (R15, SST, F, *questionnaire*)

6.3.3.2 Students’ Perceptions of Creativity

Question 2: How has your ability to engage in creative thinking been affected? The students’ ability to engage in creativity while experiencing PBL online was also noted in various comments. Analysis of the open-ended questionnaire and interview data indicated that students felt they gained two key learning outcomes: *i. Creativity increased gradually*; and *ii. It (creativity) helps to solve the problems*. Here the researcher provides more detail to support this finding.

i. Creativity increased gradually

Some participants commented that their creativity improved gradually during the intervention. This is because the learning activities embraced in PBL did promote their soft skills like collaborative learning and knowledge acquisition and retention and made them think beyond what they usually did, as a student mentioned:

> My ability to engage in creative thinking increased gradually. This is because all of the problems given need us to think not just about the internal of the problem but also from the outside that I have to make many solutions at a time. So, being in a group discussion gave me a lot of encourage to think creatively. (R16, SESD, M, *questionnaire*)

One student commented that he felt the intervention helped stimulate him to think in different ways:

> I found myself keeping on boosting my mind when participating in these activities. Therefore it has increased and helped me to think “outside the box”. (R1, SST, F, *questionnaire*)

Furthermore, some students noted that they had become more mature in their thinking skills:

> Thinking level increases. More mature mindset and able to find more than one solution. (R9, SST, M, *questionnaire*)

ii. It (creativity) helps to solve the problems

It is important for students to hybridize their thinking in order to solve their problems wisely. Thus students also remarked that this creative thinking really helps them to come up with an acceptable finding. One interesting quote said:

> I can think in many ways and think more about the solution when given a problem to solve. This is because I am given a chance to think the solution by myself (R2, SESD, F, *questionnaire*).

An interesting comment was that the students also said that they found they could think of things that would never have crossed their mind. The definition of ‘mind’ here is the capability for them to give their thinking ‘flexibilty’, where they can give as many different themes of answer as they can. Based on this, they suggested that the reason was because the nature of the intervention meant that they interacted with the views of others which stimulated their creativity, and helped them to solve problems:

> I can think a solution that never crosses my mind. The opinion from other member make my mind work actively - trying to think of answers that were at the same level as them. (R9, SESD, F, *questionnaire*)

As above, in addition to these common themes, there were some differences between the SESD and SST student cohorts. As an example, the SST students noted that they felt they were *i. able to express an opinion; ii. knowledgeable in how and when to use creativity; iii. able to sustain interest;* and *iv. able to use skills in bridging ideas*.

i. Able to express opinion

In every discussion session, all students in groups were required to give their opinion and judgment so that they can come up with the best explanation and solution to their problems. Thus this learning activity does encourage them to be more responsible to their learning by giving as many opinions they have without being hesitant. One motivating quote was:

> I was able to express my own opinion and also discuss with my group members. (R3, SST, F, *questionnaire*)

ii. Knowledge of how and when to use creativity

The soft skills they cultivated by doing the collaborative learning activities also did teach them how to use their creative thinking at the right time, as a student remarked:

> When I try to solve these PBL problems, I found that almost of these problems need my creative thinking to get the best solution. Then I tried to use my creative thinking to get the ideal and logic solutions. From this PBL also I can learn how and when I should use my creative thinking. (R4, SST, F, *questionnaire*)

iii. Able to sustain interest

Sustaining their motivation and interest during the intervention also played an important role to keep their learning group activities as a dynamic environment. From here, they were able to apply knowledge, be more creative and most importantly outline their own learning strategy, as a participant mentioned:

> I was able to work more creatively. I was able to apply much new knowledge in problem solving process. I was able to choose and apply my own strategy

> as when learning. I was able to sustain my interest in solving a problem. (R5, SST, F, *questionnaire*)

iv. Able to use skills in bridging ideas

Bridging and connecting ideas also played an important role to ensure they can come up with an appropriate answer for their problems. One participant noted that:

> So far in being one of the apprentices in this problem based learning, I can develop and improved my creative thinking even though I am not a creative thinker in some ways. I am interested in this way because I am able to use my skills to the fullest in connecting and building my ideas to solve problems in various ways. I can say that this is the medium for me to use my ability. (R15, SST, F, *questionnaire*)

In contrast, the pre-service SESD teachers noted that they felt that they *i. Can think of solutions that had never crossed their mind before;* and also *ii. Use many creative ideas in explaining certain classic concepts.*

i. Can think of solutions that had never crossed their mind before

Different ideas and opinions from group members also played a significant role to stimulate students thinking beyond their ordinary range. A participant commented:

> I can think a solution that never crosses my mind. The opinion from other member make my mind work actively and trying to think the answer that same level as them. (R9, SESD, F, *questionnaire*)

ii. Use many creative ideas in explaining certain classic concepts

Their creativity in finding resources and information via Internet and online were also being tested in order for them to explain old and typical theories, and thus enabling them to produce innovative and ground-breaking testimony. One participant remarked that:

> By searching to the Internet, many creative illustrations on certain concept have been discovered. There is knowledge that has learned before during the secondary school level. However, source from Internet give a wide range of view on the classic concept that had been learned before. Have to use many creative ideas to explain certain concept. This help in creative thinking. (R10, SESD, M, *questionnaire*)

However, one student commented that it was *i. Really hard to be a creative thinker* in this kind of learning activities as is illustrated in the comment:

> Unable to grasp difficult the complicated technical aspect of the problem which made it difficult to utilize what seem to be a lot of information creatively. Unable to creatively use the "big" ideas in modern physics to solve the problems. Difficult to discuss creative ideas with group members. I see that to be creative in something, one need to have a deep understanding of what he is dealing with, which is what I lack. Therefore being creative was difficult. (R23, SST, M, *questionnaire*)

6.3.3.3 Students' Perception of Critical Thinking

Question 3: How has your ability to engage in critical thinking been affected? In a similar way to that described for creative thinking, the students' felt that their ability to engage in critical thinking changed as a result of the intervention. Analysis of the open-ended questionnaire and interview data identified some common themes: *i. Critical thinking has improved; ii. Managed to engage in critical thinking;* and also *iii. Managed to generate related ideas.*

i. Critical thinking has improved

The need for students to use critical thinking during the intervention is really vital since it helps them to unravel problem assigned to them. A participant remarked that:

> My critical thinking is increased. I have to think critically to solve the problems. Thus I can train myself to have more way to solve problems (R7, SST, M, *questionnaire*).

Besides being better able to engage in critically thinking, some students also stated that they learned that they had to carefully synthesize information found from the Internet, and that they needed to process such information to solve their problems:

> It is improving my critical thinking. When I am finding some latest information, or some definition, I have to read the entire file that I downloaded and digest it. In this process, I improve my ability to engage in critical thinking (R12, SESD, F, *questionnaire*).

ii. Managed to engage in critical thinking

There is also mixture of creative and critical thinking noted by a participant that is useful to solve physics problems. One participant noted:

> My ability to engage in creative thinking is increase rapidly where I always use the critical thinking to solve the problem that use the concept of physics. (R4, SESD, F, *questionnaire*)

They also felt that the intervention helped inspire them to learn more from the information resources they used, in order to get to know options for solutions of their problems. This, it seems, was related to the nature of the question or problem posed:

> As the question given are quite challenging, it really makes me to learn more and more either learning it through the Internet or search information from reference books to know the actual solution for the problem which really engage my critical thinking. (R11, SST, M, *questionnaire*)

An interesting point was made by one student, who said that PBL skills like critical thinking are important when searching for suitable sources, since there are rather too many sources of information, and that one needs to be more critical about choices of information sources.

> It is very important to think critically during the process of searching the knowledge through the internet. There are large amount of knowledge in the internet. The same topic may have different point of view from different perspectives and angles. Hence, the critical thinking is useful in analyses the

> information that receive and summarize the entire huge concept to a way which fitted our level. (R10, SESD, M, *questionnaire*)

iii. Managed to generate related ideas

A participant was able to deal with the ideas where she became a more critical thinker by tracking related and associated information and sources of knowledge:

> I was able to work with critical thinking. I was able to generate related ideas and information. I try to find out a lot of information about the problem given to help me think critically to solve the problem. (R5, SST, F, *questionnaire*)

One student also indicated that he felt that the intervention helped him to relate the specific issues or problems that they were dealing with, with other ideas and, in particular, to everyday life and activities:

> After involved in PBL, I am able to think critically about the problem in physics and relate it with the activities in daily life. (R6, SESD, F, *questionnaire*)

This is an interesting finding, since it suggests that this student was given a problem to solve, as and a result of the learning, discussion and the interaction that happened during the intervention, he tried to think in many, creative, ways.

As above, in addition to these common themes, there were some differences between the SESD and SST student cohorts. For example, the SST students noted that they felt the intervention *i. Mind activation and brainstorming;* and that they were ii. *Able to think in terms of cause and effect*

i. Mind activation and brainstorming

Using this instructional method means that students must activate their mind and use brainstorming in order to reach a significant acceptable solution for their problems. A participant stated that:

> In this activity, I found that I really tried my best to understand and solve the problems given. Hence, it does activate my mind to work and think harder. (R1, SST, F, *questionnaire*)

ii. Able to think in terms of cause and effect

PBL causes the students to think in terms of cause and effect in a very effective way.

> Finding the cause and effect by searching every possibility. (R9, SST, M, *questionnaire*)

Some students stated that they felt they had to think and consider any side effects of the solution to their problem:

> The critical thinking is the most important things while solve this problem because we have to think the side effect if we choose the solution for the problem. (R10, SST, F, *questionnaire*)

However, some SESD students pointed out that they were able to *i. Think more freely* and *ii. Answer in more acceptable ways*:

i. Think more freely

Since no longer being driven by a text book, their thinking become more expansive and the way they considered knowledge and learning become open and wider, as noted by a participant:

> I can think freely because not need to be influence by the textbook. (R5, SESD, M, *questionnaire*)

ii. Answer in more acceptable ways

A participant also remarked that the difficulty of problems actually can be handled and she become more confident responding to such problems in more logical and common sense way:

> I can answer question with logic and in accepted way. Before this, I don't think that I can deal a problem such solving a problem about radiation, X-ray, solar energy etc. But right after entering my first discussion with my group member, I realize that I can think and find a solution about a question that I felt I will never answer in my life. (R9, SESD, F, *questionnaire*)

There were some negative responses from some students: *i. Their critical thinking is not improving* and one of the students even said that she *ii. Had headache* after the intervention using this approach.

i. Their critical thinking is not improving

In some other ways, a participant denied that their critical thinking improved by saying it is not enough since she still was not sure about the course itself. She was confused and struggling a bit with the learning contents during the intervention:

> My critical thinking still not improve enough, because lack of knowledge about this course. I'm still explore the formula but did not able to create others formula or idea. (R19, SST, F, *questionnaire*)

ii. Had headache

One participant even commented that she had headache while solving the problem

> I have headache. (R20, SST, F, *questionnaire*)

6.3.3.4 Students' Perception of Suitability of Learning Modern Physics using PBL Online

Question 4: Do you think the PBL approach is a suitable way for you to learn modern physics? Obviously the students could simply answer yes or no this question. But what is of more interest is how they presented their answers and their justifications. In their responses to the open-ended questionnaire, their reactions were first split into those who answered the above question in the affirmative, and in the negative. For those who answered in the affirmative, the reasons they felt attracted to this learning approach were categorized into three themes: *i. Easy to understand modern physics theory*; ii. *Learning becomes more interesting, enjoyable and fun*; and iii. *Need method of learning which can make them understand better*.

i. Easy to understand modern physic theory

The nature of the PBL features that give problems at the beginning of the learning activity and the problem itself is can be encounter in their daily-life situation was able to give opportunity for students to understand learning content easily, making it easier for them to connect it to the learning content, as observed by a participant:

> I think, the PBL approach is a suitable way for you to learn modern physics. It because the PBL approach made easily to student to understand the concept of physics with giving the problem that occurs surrounding. (R1, SESD, F, *questionnaire*)

ii. Learning become more interesting, enjoyable and fun

A participant remarked that the free style of learning that was not forcing them to get the right answer has opened their opportunity to learn in an enjoyable and interesting atmosphere:

> Yes. Student will find out that modern physics is an interesting subject to learn. Attract student to learn more about them. (R18, SST, F, *questionnaire*)

Some participants linked their enjoyment of learning via PBL online to contrast it with previous, more traditional learning experiences. In particular, they talked of being able to participate actively in their learning, compared with the traditional learning where they were treated passively:

> Yes, this is because if I just study in classroom I really do not understand what the lecturer is teaching and feel very boring even sometime really do not listen what he or she is talking about. While if using PBL I can find more

> information and I can get what I want or what I do not understand straight away from the Internet. It is more interesting to use PBL to learn if compares to just sit in the class. It brings more fun to me and I do not feel boring to it. Besides, I can discuss with friends straight away but in class can not talk. (R2, SESD, F, *questionnaire*)

iii. Need method of learning which can make them understand better

A participant brought up a key point here the need to change the presents learning process and activities (e.g., rote learning and lecture-based learning) to a new, challenging one. Students require an instructional method and learning process that helps them to absorb and to understand the physics contents meaningfully:

> Yes indeed because modern physics is not just about reading and to memorize all things and also just doing homework that are related to it but modern physics is far beyond all of this. We need a method of learning that helps us to absorb and to understand all about physics. Physics learners need to be very highly imaginative thinkers so that they know what really in the physics world. Being one of this, I am confident in some ways that this problem based learning will accelerate the minds of each student and they will surely get what they should obtain as stated in the learning outcomes. (R15, SST, F, *questionnaire*).

One student pointed out that she felt her self-esteem was much improved, and felt that this approach is suitable for other science subjects:

> Compare to the tutorial, I think tutorial is just involve the theories, that’s why PBL able to build up our self esteem on how to be confident to approach something new. I think this PBL kind of more suitable for science subject, because science subject we need more research, observation and all the application that we apply from the theory. Compare to the tutorial, we just memorizing and apply the equation, so it’s not really help us in the future. Because from the tutorial it’s just reflect on how good your memorization. (R1, F, SST, *interview*)

In addition to these common themes, there were some differences between the SESD and SST student cohorts. As an example, some SST students felt that the intervention *i. Can expose them to preparation for responsibility in the workforce* and some SESD students said that this learning approach is suitable for university students since it is a *ii. Student-centred approach*.

i. Can expose them to the preparation for responsibility in the workforce

A participant mentioned that it is vital for a physics student to make a connection between what they have learnt in lecture room and the outside world. It will help them much in order to get ready and be more responsible for what will they face in their jobs in the future:

> Because modern physics has more connections to the real life situation. By using PBL approach, we can try to relate both of theoretical and real life. And think of what we will face and see the early picture during the real jobs that needs the applications of modern physics. (R20, SST, F, *questionnaire*)

ii. Student-centered approach

A key feature of PBL is to train students to be more student-centered in their learning activities. Thus a participant remarked that it is very useful, especially to adult students, for them to take charge of their own learning and be more efficient, particularly when arranging their own study timing and what they need to find in order to fulfill their learning content:

> PBL is a student centered approach. This is a very convenient approach for a university student whom was consider as an adult that should be able to arrange their time in learning. When the time comes to be free, it is always a habit to use the time in learning the modern physics. Other than that, the wide range of view expands our knowledge on certain theory and concept. (R10, SESD, M, *questionnaire*)

However, from a different perspective, some of the students also were more neutral in their feedback regarding the suitability of using PBL Online:

i. Not enough time to study using PBL approach

A participant mentioned that, a disadvantage of PBL is the long process that they need to follow in order to solve a problem, thus they do not have enough time to cover all the learning contents within the period given. However, she also remarked that the key features in PBL learning activities that need them to think actively do help them to become more creative and think like a scientist:

> I think if we want to learn modern physics, it is not enough if we just learn it via PBL. But PBL approach give a bigger impact for me individually, it is because during solve one problem in PBL question; we need to imagine, try to think creative and try to solve it using our way as a physicist. But this PBL approach more interesting if we can see the problem in front of our eyes, it can be increase our thinking skill to solve it. (R2, SST, F, *questionnaire*)

ii. Depends on individual

A participant strongly suggested that if one student learns well using PBL, it is not necessarily so that another student will be equally successful and comfortable with the method. It all depends on the acceptance by each individual and the needs of each student:

> In my opinion of this PBL, since the name itself is PBL, at first it will give us the problems, and we have to solve it by ourself in a group. So in my opinion it depends on individual. For those who really love to read, loves to surf the Internet, I think these kinds of activity suit them. But for those who likes to only wait for lecturer to give them notes, questions and resources, maybe they didn't feel comfortable with this kind of learning. (R30, SST, M, *interview*)

There was one participant who was quite negative in his feedback and he responded that this approach *i. Needs plenty of time and energy to be cope with learning* and *ii. Tutorial taught us how to answer exam questions.*

i. Needs plenty of time and energy to be cope with learning

An unsatisfied participant claimed that there was time limitation while experiencing the PBL online since they need to do many learning activities in their mission to find a solution for each problem:

> No, because needs a lot of time and energy for identifying, reflecting, creating, etc. Problems and solutions even for a little bit of progress. Didn't have adequate knowledge and proper understanding of modern physics to be able actually gain anything substantial from the problems presented. (R23, SST, M, *questionnaire*)

ii. Tutorial taught us how to answer exam questions

The response here reflected that the education system at the university is still driven by the tutorial and exam-oriented system. Thus, some students found it hard to study in a situation like the one presented in PBL. As remarked by a participant:

> In my opinion this PBL is really different than the tutorial. I am not quite happy with it. Because tutorial we use what we have learn through out in this university, like we use equations to answer questions. But in PBL we only use more on our general knowledge. So for my point of view general knowledge can be read from books and from any resources. (R26, SST, M, *interview*)

6.3.3.5 Consideration on Implementing PBL Online into Modern Physics Course

Question 5: What did you find to be least useful about learning using this learning approach? In addition to the positive feedback above, the survey sought direct feedback about things students did not like about the intervention. A broad classification of the problems that students reported they encountered during this whole PBL assessment shows they consisted of mostly purely practical problems and issues to do with teamwork contribution. Hence two main key themes can be classified as i. *Technical issues*; and ii. *Lack of cooperation from group members*.

There also were complaints about the Internet connectivity when engaged in their chatroom discussion. The description here also reports on the less common comments; viz., that not enough syllabus had been covered; not enough input from team members, and too much monitoring of chat-room activities.

i. Technical issues

Technical issues such as the poor Internet coverage and bandwidth around the university also played important role. A participant noted this and suggested that the system needs to be upgraded:

> It's just that I have problems with Internet connection in my area. So, this activity is very much useful if the student has proper Internet facilities of their own. (R1, SST, F, *questionnaire*)

Thus some students also suggested that face-to-face discussion is more effective:

> Chat room. Sometime when the server down, it meant our group cannot discuss effectively. I also thinking that face to face discussion is more suitable. (R5, SESD, M, *questionnaire*)

Issues to do with some students' computer literacy also were noted, and, for example, one student suggested that students needed at least some basic skills before taking part in the intervention:

> In term of online part it is an interesting part, but it could be problems if students have trouble with IT, for example, for those who has very low computer literacy and don't have confident to study via computer like myself. Since this approach is an advantages for us so that we can learn IT more. (R15, SST, *interview*)

Another student felt that it is not necessary to study via online, since many students still end up doing any problems at the last minute. So, from her point of view, students need to be encouraged to take any new learning approach seriously in order to achieve anything useful:

> For me honestly, this PBL is not too good because from my opinion the best part is we use the Internet. But when students use the Internet they often neglect other sources and information, such as books. Such students not taking it seriously, and mostly do these assignments at the last minute. Since the Internet itself means we can find the solution faster, we do not taking this matter as serious as we should while doing this task. So for me the Internet does not help us to improve ourselves much. (R26, F, SST, *interview*)

As noted above, poor quality of Internet connection at the university occasionally annoyed the students:

> I think the most important in this process is Internet connection. As we can see this PBL involve chat, find information [related to PBL]. So if we [as a student] did not get a good wireless connection, it is hard for us to solve the problem given. (R2, SST, F, *questionnaire*)

ii. Lack of cooperation from group members.

A participant mentioned that despite not really knowing some of their team members that well, it gave them opportunity to arrange some development meetings and to exchange ideas and information that they had never thought of. Besides they also managed to organize their own timetable although each student had their own needs in learning:

> The problem is the teammates. It is really hard to cooperate with teammates because we do not really know each other well. That's the benefits of it because we can learn from them. Because some people learn very fast some are not and maybe that is the problem. Then about the discussion how we manage the timetable, since all of us have other commitment too, so it's hard for us to sometimes gather each other to do the chat room discussion. (R8, SST, M, *interview*)

Some students reported that their team members were indolent and failed to take part in the learning process:

> Not all group members cooperated the in group because they are lazy. (R14, SST, M, *questionnaire*)

It was also reported that it was really hard for some students to get together online with their team members since they often had other commitments:

> Hard to gather all group mate to discuss due to time and clash of other course. (R11, SST, M, *questionnaire*)

Some of the SST students commented on the syllabus, saying they *i. Could not get through enough syllabus;* there was *ii. Too much chat session* and also they were *iii. Perplexed at the beginning of the assessment.*

i. Could not get through enough syllabus

A participant brought up that the lack of time to cover all the syllabus really does not help much in their learning activities.

> Least problem, but yet some topic is not covered: Special relativity, Compton Effect. This PBL just covered radioactive, EM Waves, solar only. (R6, SST, F, *questionnaire*)

ii. Too much chat session

And there was too much chat session to settle a problem, thus the students sometimes lost track while doing their second chat session since they had discussed all the meaningful points in their first meeting, as noted by a participant:

> In my opinion, the chat session which will be held every week is the least useful about this learning. This is because there is nothing can be chat inside the chat room since we are required to discuss the same topic for 2 weeks. Actually, one chat session in two weeks is enough to us to discuss and share all views and ideas. For my group, we are having chat session every week. But we are having some trouble because for the second chat session, we are lack of idea since we already find out the best solution in the first chat session.

> Thus, I think the chat session every week is the least useful in this learning approach. (R13, SST, F, *questionnaire*)

iii. Perplexed at the beginning of the assessment

Students in PBL groups had struggled at the beginning of the intervention since it was a new way of learning for them. However, a participant commented that it is a proper way to encourage and to open their mind to think something that they had never thought before

> The least useful is when the problem at first given is out of range and kind of hard for us to understand. It is not a very bad thing because when given problems like this, this will expand our ways of thinking and try to think outside the box for the positive sides. (R20, SST, F, *questionnaire*)

For the SESD students, there was more emphasis on the responsibilities of the facilitator where they felt *i. Little guidance from facilitator* and that the facilitator did not pay enough attention to their discussion session. They also felt they were *ii. Out of focus during discussions.* One participant also spoke about a *iii. Lack of visible pictures,* while chatting and discussing their problem through the chat room.

i. Little guidance from facilitator

A participant mentioned that the little guidance from the facilitator did not really help much in their learning outcome and they needed more direct instruction from the facilitator:

> The guide from the mentor was least. Sometimes student may get confuse in learning a new theory and concept, the guide and illustration from the mentor may help to clarify the new term. (R10, SESD, M, questionnaire)

ii. Out of focus during discussions

One student remarked that it was hard to justify whether their answer was right or wrong in terms of their final findings. Sometimes this had driven them to talk about a number of things and every so often their discussion covered issues that were unrelated to their research topics:

> But sometime when we discussing academic problem with member, there is a time we will talk something that out of the topic. The time we used to talk about non-related things is wasted. Therefore when doing a discussion problem, we should focus to the problem we facing. (R10, SESD, F, *questionnaire*)

iii. Lack of visible pictures

One disadvantage of online discussion is the difficulty of instantly describing what they are discussing because of the lack and very limited 'space' of the communication medium. Accordingly, a participant mentioned that it is difficult for them to come up with a good discussion:

> Lack of upload visual such as picture while chatting in the chat room. Makes us hard to explain and share our ideas with friends. (R14, SESD, F, *questionnaire and interview*)

Question 6: What did you find to be most useful about learning using this learning approach? There were several themes identified by students as to what they found most useful when learning through a PBL online approach: *i. More understanding; ii. More cooperative; iii. Internet connection as the major medium; iv. Enhanced efficiency in solving problems; v. Enhanced soft skills; and also vi. Time management.*

i. More understanding

A participant commented that, by learning with PBL it helps them to become alert to the recent social matters. This is one of the PBL key points, that problem presented must be a daily life problem that should take place in context. Additionally, the learning activities also make them to really relate cause and effect of every problem they have been given:

> I think the most useful about learning using this learning approach is I can know many problem or latest information that happening recently. At the same time, I can find some information which related to let myself more understanding. Besides that, I also discovered some way to solve the problems. The definition, cause and effect help me to improve my knowledge. (R12, SESD, F, *questionnaire*)

Notwithstanding the technology itself, is the PBL approach which most of the students reported to be the most practical way to deal with such complex topics or problems posed during the intervention. It was felt that the PBL approach involved many self learning activities that drove the students towards independent learning:

> This approach is most practical in understanding a complicated and difficult subject like modern physics because this subject is not entirely in closed discussion. So, this approach will provide student to further the research and discussion of this subject. (R1, SST, F, *questionnaire*)

ii. More cooperative

A participant noted that PBL helps them to practice collaborative learning, thus they can manage to give ideas and opinions to solve a problem:

> The most useful about learning using this learning approach is the co-operate giving the idea to solve the problem. (R1, SESD, M, *questionnaire*)

Despite the reservations about lack of cooperation in the teams mentioned above, some students commented that they learned to be more cooperative with team members when sharing their ideas and judgment about best solutions, meaning they felt they had improved their soft skills:

> From my point of view, the most useful about this learning is the discussion among the group to find out the best solution for the task given. It gives us chance to elaborate our idea according to the information which found. Besides that, during the discussion it also led us to be more active in giving out our ideas and views. Indirectly, it had improved my soft-skill. Moreover, the group work also train me to be more tolerate with my group members and understand the important of co-operative. By having discussion, the brain storming also makes me to think and understand more clearly about the concepts and theory of physics modern. (R13, SST, F, *questionnaire*)

iii. Internet connection as the major medium

One of the main things introducing PBL online in this study is to make sure students manage to find information and sources from the outside world without boundaries, and yet this opportunity has lead students to become more competent with their skill to track appropriate and suitable knowledge for their problem, as noted by a participant:

> The most useful is our efficiency on finding the solution by using the new technology were being far more better. (R2, SST, F, *questionnaire*)

Some students also pointed out that this chat room experience had helped them to better communicate their ideas with other friends, outside the intervention:

> I think at the chatting. This method is really helping me to share the knowledge with my other friends although I'm far away from them. (R11, SST, M, *questionnaire*)

The students commented that their competency and skills improved as they sought to find their best solution by the use of technology.

iv. Enhanced efficiency on solving problems

Creative and critical thinking are two main criteria in order for someone to solve problems in a meaningful way. That is what was noted by a participant saying that it is important to use these characteristics especially when finding, tracking and evaluating useful information that will lead to constructive information on that particular learning content:

> The most useful is the new experience in a way of solving question. It needs our critical and creative thinking. When finding a solution we will search many article about the problem and this will expands the knowledge of the student. (R9, SESD, F, *questionnaire*)

One student also pointed out that the real challenge is when the theories need to be applied in the outside world:

> As I mentioned before, the way we can try to relate the usage of out theoretical information learnt on class and apply it to the real life problems. Theories are easy to understand, but the challenge is how we can apply it into reality. By PBL approach, we can prepare early and will not get "culture shock" During our job days. (R20, SST, F, *questionnaire*)

v. Enhance soft-skills

A participant remarked that she managed to polish her soft skills such as communicating in meaningful way, building self-confidence and improving personal skill. In addition, her competency in computer usage were improving:

> Gain knowledge, besides I manage to improve my computer skill, communication skills. Build my self-confidence, and last but not least I manage to improve my inter- and intra-personal skill. (R3, SESD, F, *questionnaire*)

In addition, some of the students commented on their proficiency and expertise such as how to correspond with others. This skill they saw as vital in order to face real challenges when engaging in communicating with others in the workforce in the outside world after graduation:

> Increased my skill somewhat, to communicate with other people (group members) especially when it come to conveying my ideas to them. Also it forced me to find other ways to manage my time more efficiently. (R23, SST, M, *questionnaire*)

vi. Time management

Students were exposed needing to use and manage their own time through this PBL online, especially when searching very wide for information and sources throughout the Internet. A participant commented that it is very helpful for them to follow the PBL instructions wisely because taught them time to manage their time judiciously:

> Be able to use the computer devices in searching through the Internet. This gives training to the student to be independent and be able to manage their time very well. (R10, SESD, M, *questionnaire*)

A participant commented on the flexibility of time afforded by online learning when arranging their group chat meetings and forum discussions:

> We can prepare our answer and chatting session in our own arrangement, it provide more freedom to us in our solution. Besides that, it can make me more independent and disciplined. (R22, SST, F, *questionnaire*).

6.4 MALAYSIAN UNDERGRADUATE SCIENCE PHYSICS STUDENTS' AND PRE-SERVICE SCIENCE TEACHERS' PERCEPTIONS OF ONLINE LEARNING

Research Question 4 for this thesis concerned the Malaysian undergraduate physics students' and pre-service science teachers' perceptions of learning through online learning. Specifically, it sought to ascertain whether students held positive views of the intervention described in Chapter 5 (Section 5.8 Research Intervention).

In this section, the researcher seeks to see understand students' awareness regarding online learning in terms of students' reflection on their learning of the Modern Physics course which involved online work. Student responses are presented overall and any differences for students from the SST program and SESD program are then detailed.

6.4.1 Learning Outcomes from Online Learning – Part A

In this section, the researcher seeks to see understand students' views regarding online learning in terms of their experiences in learning Modern Physics. There are six key themes which together comprised the survey: students' readiness for online learning; how they were able to access course material; the motivation effects of online learning; time management; understanding of learning contents; and technical issues encountered when learning to use computers. The questions in the survey are not necessarily presented in the above sequence, because the items in the survey were mixed to make it less repetitive for the students.

i. Students' Readiness for Online Learning

The questions of this survey relevant to student's readiness to learn online were statements 1 to 6 (Appendix XV). In general there were no great differences noted between the science students and pre-service teachers regarding their perceptions of readiness for online learning as shown in Table 52. Except for statement 3; *'I know how to use a standard word processor programs such as Microsoft Word, Microsoft Works, or Word Perfect'*, where almost 90 percent of pre-service teachers agreed that they were *pretty comfortable with word processing* compared with only about 60 percent of science students. Additionally, almost 80 percent of the pre-service teachers said they found that interesting working with computers, in contrast to the science students of which approximately half reported being 'comfortable working with computers'.

Table 52
Themes of students' readiness for online learning for SST and SESD

	Statement	Majority of Students' Answer	SST (N=61) Percent (frequency)	SESD (N=41) Percent (frequency)
1	I was able to log on the Internet to work on this course.	At least twice a week.	45.9 (28)	41.5 (17)
2	I know how to use a web browser such as Netscape; Internet Explorer; FireFox Explorer to get around the Internet.	Yes. I browse the net frequently.	97.6 (40)	90.2 (55)
3	I know how to use a standard word processor programs such as Microsoft Word, Microsoft Works, or Word Perfect.	Yes, I am pretty comfortable with word processing.	60.7 (37)	87.8 (36)
4	I have basic knowledge of email.	Yes, I have an e-mail account.	100.0 (61)	100.0 (41)
5	I am comfortable working with computers.	I find working with computers interesting.	52.5 (32)	78.0 (32)
6	I was able to cope when my computer or software broke down during the course.	I will get it fixed immediately and will use another system in the meatime.	75.4 (46)	61.0 (25)

ii. <u>How Students were able to access Course Material</u>

The statement under this theme asked students how they felt about their capability for determining most important ideas and concepts while reading course content online (statement 9). The responses shown in Table 53 suggest that most of the pre-service teachers preferred listening rather than reading the course content, with almost 40 percent of them saying they preferred listening to reading about things, compared with only 25 percent of the science students. Nevertheless, about 40 percent of the science students said that they have to hear information from others in order to retain the main ideas and concepts, compared with about 20 percent of the pre-service teachers.

Table 53
Themes of how students were able to access or figure out stuff used for the course for SST and SESD

	Statement	Majority of Students' Answer	SST (N=61) Percent (frequency)	SESD (N=41) Percent (frequency)
9	How capable are you of determining main ideas and concepts when reading your course notes through the Internet?	I prefer listening to reading about things.	24.6 (15)	36.6 (15)
		I have to hear information in order to retain it.	39.3 (24)	22.0 (9)

iii. Motivation Affects of Online Learning

The statement under this theme queried students about the motivational effect of online learning after experiencing the learning approach (statements 10 and 20). For question 10; *'Are you a self-motivated, independent learner?'* students responded that studying alone was a positive challenge (about 25% from SST and 17% from SESD). However, there was some different feedback where almost 28 percent from SST and roughly 37 percent from the SESD commented that they needed the stimulation of a group. For statement 20; *'I know how to use a web browser such as Netscape; Internet Explorer; FireFox Explorer to get around the Internet,'* there were also two major answers recorded: '*Yes, I look forward to the experience'* (around 50% responded from SST and 68% from SESD); and '*Yes, I don't have time to take a traditional class'* where there is about 20 percent different documentation between science students and pre-service science teacher as shown in Table 54.

Table 54
Themes of Motivation Affect for SST and SESD

	Statement	Majority of Students' Answer	SST (N=61) Percent (frequency)	SESD (N=41) Percent (frequency)
10	Are you a self-motivated, independent learner?	I find studying alone a positive challenge.	24.6 (15)	17.1 (7)
		I need the stimulation of a group.	27.9 (17)	36.6 (15)
20	I know how to use a web browser such as Netscape; Internet Explorer; FireFox Explorer to get around the Internet.	Yes, I look forward to the experience.	49.2 (30)	68.3 (28)
		Yes, I don't have time to take a traditional class.	34.4 (21)	14.6 (6)

iv. Time Management

There were four statements which queried the students concerning this theme (statements 7, 8, 11 and 12). In the responses to Statement 7: *I can meet deadlines without needing frequent prodding* the majority of the pre-service teachers (78%) reported they managed to meet their deadline whilst only about 55 percent of science student thought the same. In addition, almost 10 percent of science students responded that they were likely to postpone their work. As for Statement 8: *Will you be able to set aside some time to participate in weekly online discussions*? almost half of the pre-service teachers answered that they have allowed period for this course compared to around 40 percent from the science cohort who said the same. As for Statement 11 and Statement 12 there was no great difference recorded for both cohorts of students Details are shown in Table 55.

Table 55
Themes of time management on online learning for SST and SESD

	Statement	Majority of Students' Answer	SST (N=61) Percent (frequency)	SESD (N=41) Percent (frequency)
7	I can meet deadlines without needing frequent prodding.	I generally meet my deadlines.	55.7 (34)	78.0 (32)
		I am a terrible procrastinator.	9.8 (6)	-
8	Will you be able to set aside some time to participate in weekly online discussions?	Yes. I have allowed time for this course.	39.3 (24)	51.2 (21)
11	Which of the following describes your time management skills?	For the most part, I get things done on time.	70.5 (43)	68.3 (28)
12	How much time do you expect to spend studying for this course?	The same amount as attending and studying for a traditional course.	45.9 (28)	46.3 (19)

v. <u>Understanding of Learning Contents</u>

In this theme, students were asked regarding their understanding of learning content Statement 13: *How good are you at following directions on assignments?* About 20 percent difference (favoring SESD) was recorded as saying that they can read and follow directions on their own: whilst 15 percent difference (favoring SST) responded that they have difficulty understanding directions and frequently need clarification. Details are shown in Table 56.

Table 56

Themes of student understanding of learning content in online learning for SST and SESD

	Statement	Majority of Students' Answer	SST (N=61) Percent (frequency)	SESD (N=41) Percent (frequency)
13	How good are you at following directions on assignments?	I can read and follow directions on my own.	32.8 (20)	51.2 (21)
		I have difficulty understanding directions and frequently need clarification.	44.0 (27)	31.7 (13)

vi. <u>Technical Issues encountered when learning Use of Computers</u>

Under this theme there were no major differences noted between the science students and pre-service teachers for all six statements, as detailed in Table 57. The only wide difference between the cohorts is from Statement 16: *My keyboarding skills are good,* where there was approximately 15 percent in difference, favoring the pre-service teachers who responded that they were capable typists and they typed their own task. This indicated that both cohorts of students managed handling the technology while experiencing the online learning.

Table 57
Themes of handling technology while learning computer use in online learning for SST and SESD

	Statement	Majority of Students' Answer	SST (N=61) Percent (frequency)	SESD (N=41) Percent (frequency)
14	I know how to turn on and off the computer system on my computer.	Yes. I know my system's shut down process.	98.4 (60)	100 (41)
15	I am comfortable using a mouse.	Yes, I use a mouse all the time.	93.4 (57)	87.8 (36)
16	My keyboarding skills are good.	Yes I am a capable typist. I type my own work.	73.8 (45)	85.4 (35)
17	I am comfortable with file management on my computer, such as moving files around different directories and drives, saving files, and deleting files.	Yes, I am pretty comfortable.	95.1 (58)	95.1 (39)
18	I have used a browser to surf the Internet.	Yes. I spend a lot of time on the net.	58.5 (24)	60.7 (37)
19	I can handle the situation when my Internet connection is interrupted for a period of time.	Yes, I will just use another lab on-campus, or a friend.	63.9 (39)	63.4 (26)

6.4.2 Learning Outcomes from Online Learning – Part B: Students' Perception of Satisfaction, Perception of Interaction and Perceptions of Individual Features of Online Learning

To analyse these data, the researcher used two methods of analyses: the Mann Whitney U Test; and the Independent Sample t-Test. Comparisons in general were done first followed by the data analysis for SST and SESD students separately.

6.4.2.1 Comparison of Students' Perception Overall: PBL and Traditional

The results shown in Table 58 suggest that, overall, the PBL students' perceptions of learning online were more positive than the traditional group in four broad categories*: students' perception of satisfaction*; *students' perception of interaction*; *student's perceptions of individual features of online learning as a communication tool* (except for Statement 38: *I would rather do an assignment than a discussion*), and *Student's Perceptions of Individual Features (Online Student Assessment)* (except for Statement 47: *I prefer taking my tests, quizzes and exams on paper rather than online*).

In the other two categories, *Student's Perceptions of Individual Features (Content Available on the Online Course),* and *Assignment*, for the majority of the statements there were no great differences between the groups, except for Statement 19: *I was satisfied with the content available on this online web-course* and Statement 25: *I found the calendar section of the LMS Website a valuable resource* under the *Content available on the online course* category, where the PBL group reported higher means.

Table 58

Comparison in general of undergraduate science students and pre-service science teachers' perceptions of online learning: PBL and Traditional

No	Statement	Group Traditional (N= 52) PBL (N=50) Total (N=102) [PBL/Traditional] Mean (SD)	Z [Asymp. Sig. (2-tailed)]	t [(df=100) [Sig. (2-tailed)]	Mean Difference
	Students' Perception of Satisfaction				
1	I was satisfied with the overall experience of online learning.	[3.94(0.64)/3.35(0.62)]	-4.25 (0.00*)	-4.66 (0.00*)	-0.59
2	I enjoy the portion of the course on online learning.	[3.88(0.76)/3.33(0.53)]	-4.23 (0.00*)	-4.25 (0.00*)	-0.55
3	The online learning portion stimulated my desire to learn.	[4.08(0.47)/3.35(0.52)]	-6.48 (0.00*)	-7.38 (0.00*)	-0.72
4	I was satisfied with online learning in regards to the quantity (knowledge input) of my learning experience.	[3.96(0.63)/3.36(0.60)]	-4.41 (0.00*)	-4.99 (0.00*)	-0.61
5	I was satisfied with online learning in regards to the quality (knowledge input) of my learning experience.	[3.97(0.59)/3.20(0.56)]	-5.59 (0.00*)	-6.77 (0.00*)	-0.77
6	The online learning component of this course allowed for social interaction.	[3.97(0.66)/3.51(0.67)]	-3.59 (0.00*)	-3.53 (0.00*)	-0.46
7	Online learning provided a reliable means of communication with other group members.	[4.08(0.65)/3.66(0.68)]	-4.80 (0.00*)	-3.17 (0.00*)	-0.42
8	Online learning provided a reliable means of communication with facilitator/lecturer.	[3.45(0.82)/3.44(0.50)]	-0.16 (0.88)	-0.11 (0.92)	-0.01
9	I found the online learning course to be a helpful resource.	[3.96(0.60)/3.69(0.59)]	-3.10 (0.00*)	-2.30 (0.02*)	-0.27
10	I used the online learning to help me understand course information.	[4.02(0.56)/3.60(0.60)]	-4.08 (0.00*)	-3.72 (0.00*)	-0.43
11	I regularly used online learning to answer my questions to other group members.	[3.81(0.72)/3.06(0.82)]	-3.82 (0.00*)	-4.96 (0.00*)	-0.76
12	I believe that online learning enhanced my learning in Modern Physics	[3.97(0.72)/3.22(0.77)]	-4.37	-5.03	-0.74

	course.		(0.00*)	(0.00*)	
13	I would like to see all of my courses involve at least some online learning.	[3.99(0.68)/3.33(0.80)]	-3.63 (0.00*)	-4.48 (0.00*)	-0.66
14	I believe that online learning will play an important role in education in the future.	[4.18(0.64)/4.02(0.85)]	-1.50 (0.14)	-1.06 (0.30)	-0.16
	Students' Perception of Interaction				
15	The online learning component of this course helped to create a sense of community among the students in the course.	[4.05(0.70)/3.58(0.64)]	-3.57 (0.00*)	-3.51 (0.00*)	-0.47
16	The online learning component of this course increased my interactions with the instructor.	[3.90(0.81)/3.35(0.60)]	-4.28 (0.00*)	-3.94 (0.00*)	-0.56
17	The online learning component of this course increased my interactions with my fellow coursemates / classmates.	[4.13(0.71)/3.47(0.67)]	-5.10 (0.00*)	-4.85 (0.00*)	-0.66
18	The online learning component of this course extended my personal interactions.	[4.02(0.69)/3.28(0.61)]	-4.80 (0.00*)	-5.74 (0.00*)	-0.74
	Students' Perceptions of Individual Features (Content Available on the Web Course)				
19	I was satisfied with the content available on this online learning web-course.	[3.76(0.72)/3.30(0.55)]	-3.43 (0.00*)	-3.57 (0.00*)	-0.45
20	I was satisfied with the online lectures note included on the course Website.	[3.60(0.74)/3.55(0.80)]	-0.60 (0.55)	-0.34 (0.74)	-0.05
21	The online lecture notes on the Learning Management System (LMS) Website were a valuable resource.	[3.71(0.73)/3.70(0.71)]	-0.58 (0.56)	-0.06 (0.95)	-0.01
22	The lecture note/finding notes were easy to print.	[3.79(0.64)/3.60(0.79)]	-0.47 (0.64)	-1.31 (0.19)	-0.19
23	I like the fact that PowerPoint slides of the lecture notes were available on the LMS Website.	[3.84(0.66)/3.94(0.71)]	-1.50 (0.13)	0.73 (0.47)	0.10
24	I regularly visited the calendar section of the LMS Website.	[3.46(0.85)/3.19(0.76)]	-0.64 (0.52)	-1.65 (0.10)	-0.26
25	I found the calendar section of the LMS Website a valuable resource.	[3.81(0.70)/3.49(0.67)]	-1.86 (0.06)	-2.38 (0.02*)	-0.32
26	I felt the links contained on the LMS Website were valuable.	[3.68(0.81)/3.47(0.65)]	-1.68 (0.09)	-1.47 (0.14)	-0.21
27	I regularly visited the links contained on the LMS Website.	[3.51(0.81)/3.19(0.86)]	-1.76 (0.08)	-1.93 (0.06)	-0.32
28	The LMS Website is a great place for the instructor to place handouts.	[3.87(0.76)/3.72(0.79)]	-1.08	-0.97	-0.15

			(0.28)	(0.34)	
	Student's Perceptions of Individual Features (Online Learning as a Communication Tool)				
29	I e-mailed the instructor through the LMS Website.	[3.49(0.95)/2.97(1.02)]	-3.33 (0.00*)	-2.64 (0.01*)	-0.52
30	I regularly checked my mailbox through the LMS Website.	[3.17(0.93)/2.74(0.98)]	-2.10 (0.04*)	-2.28 (0.03*)	-0.43
31	I regularly used the discussion section of the LMS Website.	[3.64(0.95)/2.30(0.77)]	-6.42 (0.00*)	-7.89 (0.00*)	-1.34
32	I found the discussion section of the LMS Website easy to use.	[3.58(0.90)/2.73(0.89)]	-4.88 (0.00*)	-4.78 (0.00*)	-0.85
33	The discussion section of the course content using LMS helps me better understand course content.	[3.75(0.83)/2.72(0.96)]	-5.83 (0.00*)	-5.79 (0.00*)	-1.03
34	The discussion section of the course content using LMS is a great way to interact with my fellow classmates.	[3.83(0.75)/3.03(0.90)]	-4.71 (0.00*)	-4.89 (0.00*)	-0.80
35	The discussion sections of the course content using LMS is a great way to interact with the facilitator/lecturer.	[3.78(0.58)/3.28(0.83)]	-2.91 (0.00*)	-3.55 (0.00*)	-0.51
36	The discussion section of the course using LMS helps me to ask and answer questions more efficiently.	[3.65(0.87)/2.85(0.88)]	-4.55 (0.00*)	-4.58 (0.00*)	-0.79
37	I am glad the discussion section of the LMS Website was factored into my final grade. (**for PBL group only*)	[3.80(1.05)/2.90(0.69)]	-5.41 (0.00*)	-5.17 (0.00*)	-0.90
38	I would rather do an assignment than a discussion.	[3.27(1.02)/3.22(0.95)]	-0.01 (1.00)	-0.26 (0.80)	-0.05
	Student's Perceptions of Individual Features (Assignment)				
39	I found it easy to submit my assignment online.	[4.13(0.87)/3.91(0.80)]	-1.70 (0.09)	-1.32 (0.19)	-0.22
40	I prefer the online submission of assignments.	[4.00(0.94)/3.97(0.78)]	-0.31 (0.76)	-0.16 (0.88)	-0.03
41	I found the online submission of assignments simple.	[4.05(0.89)/3.88(0.86)]	-1.35 (0.18)	-0.97 (0.34)	-0.17
42	I found the online submission of assignments convenient.	[4.08(0.93)/3.97(0.78)]	-0.48 (0.63)	-0.63 (0.53)	-0.11
	Student's Perceptions of Individual Features(Online Student Assessment)				
43	I took the online test (critical and creative thinking test).	[4.05(0.73)/3.58(0.72)]	-3.69	-3.24	-0.47

			(0.00*)	(0.00*)	
44	I found taking online tests convenient.	[3.63(1.00)/3.22(0.75)]	-2.40 (0.02*)	-2.35 (0.02*)	-0.41
45	I found the test section easy to use.	[3.73(0.83)/3.22(0.73)]	-3.28 (0.00*)	-3.31 (0.00*)	-0.51
46	The tests worked during my visit.	[3.55(0.72)//3.22(0.66)]	-1.99 (0.05)	-2.37 (0.02*)	-0.33
47	I prefer taking my tests, quizzes and exams on paper rather than online.	[3.66(0.78)/3.38(0.87)]	-1.20 (0.23)	-1.68 (0.10)	-0.28

Note. (a) Grouping Variable and

* Statistical difference ($p < 0.05$)

6.4.2.2 Science Physics Students (SST): PBL and Traditional

The results shown in Table 59 suggest that for the SST cohort the PBL students' perceptions of learning online were more positive than the traditional group for three categories*: Students' Perceived Satisfaction* (except for Statement 9: *I found the online learning course to be a helpful resource*); *Students' Perception of Interaction,* and *Student's Perceptions of Individual Features (Online Learning as Communication Tools)* (except for Statement 38: *I would rather do an assignment than a discussion*). As for *Student's Perceptions of Individual Features (Online Student Assessment)* category, three out of five statements showed significant difference (Statements: 43, 44 and 45). For the rest no great difference was recorded.

For the other categories: *Student's Perceptions of Individual Features (Content Available on the Online Course;* and *Assignmen)* the majority of the statements showed no statistically significant differences between groups, except for Statements 19: *I was satisfied with the content available on this online learning web-course* and 22: *The lecture notes/finding notes were easy to print* under the *Content available on the online course* category, where the PBL group were more positive.

Table 59
Comparison of undergraduate science students' perceptions of online learning: PBL and Traditional Groups

No	Statement	Group Traditional (N= 31) PBL (N=30) Total (N=61) [PBL/Traditional] Mean (SD)	Z [Asymp. Sig. (2-tailed)]	t [(df=59) [Sig. (2-tailed)]	Mean Difference
	Students' Perception of Satisfaction				
1	I was satisfied with the overall experience of learning via online learning.	[3.77 (0.69)/3.10 (0.44)]	-3.47 (0.00*)	-4.58 (0.00*)	-0.68
2	I enjoy the portion of the course on online learning.	[3.64 (0.81)/3.19 (0.42)]	-2.58 (0.01*)	-2.71 (0.01*)	-0.45
3	The online learning portion stimulated my desire to learn.	[4.05 (0.56)/3.35 (0.39)]	-4.80 (0.00*)	-5.68 (0.00*)	-0.70
4	I was satisfied with online learning in regards to the quantity (knowledge input) of my learning experience.	[3.86 (0.66)/3.29 (0.53)]	-2.99 (0.00*)	-3.75 (0.00*)	-0.57
5	I was satisfied with online learning in regards to the quality (knowledge input) of my learning experience.	[3.91 (0.64)/3.33 (0.47)]	-3.32 (0.00*)	-4.02 (0.00*)	-0.58
6	The online learning component of this course allowed for social interaction.	[3.91 (0.64)/3.43(0.55)]	-2.19 (0.03*)	-3.15 (0.00*)	-0.48
7	Online learning provided a reliable means of communication with other group members.	[4.09 (0.64)/3.70 (0.64)]	-3.84 (0.00*)	-2.39 (0.02*)	-0.39
8	Online learning provided a reliable means of communication with facilitator/lecturer.	[3.09 (0.76)/3.40 (0.46)]	-2.93 (0.00*)	1.92 (0.06)	0.31
9	I found the online learning course to be a helpful resource.	[3.77 (0.58)/3.67 (0.54)]	-1.24 (0.22)	-0.74 (0.46)	-0.11
10	I used the online learning to help me understand course information.	[3.90 (0.58)/3.63 (0.53)]	-2.31 (0.02*)	-1.92 (0.06)	-0.27
11	I regularly used online learning to answer my questions to other group members.	[3.77 (0.74)/3.05 (0.87)]	-2.77 (0.01*)	-3.49 (0.00*)	-0.73
12	I believe that online learning enhanced my learning in Modern Physics course.	[3.82 (0.77)/3.24 (0.85)]	-2.27 (0.02*)	-2.78 (0.01*)	-0.58

13	I would like to see all of my courses involve at least some online learning.	[3.77 (0.64)/3.14 (0.91)]	-2.06 (0.04*)	-3.13 (0.00*)	-0.63
14	I believe that online learning will play an important role in education in the future.	[4.05 (0.61)/3.76 (0.93)]	-2.45 (0.01*)	-1.40 (0.17)	-0.28
	Students' Perception of Interaction				
15	The online learning component of this course helped to create a sense of community among the students in the course.	[3.91 (0.64)/3.70 (0.52)]	-2.02 (0.04*)	-1.40 (0.17)	-0.21
16	The online learning component of this course increased my interactions with the instructor.	[3.59 (0.73)/3.45 (0.60)]	-2.17 (0.03*)	-0.82 (0.41)	-0.14
17	The online learning component of this course increased my interactions with my fellow coursemate / classmate.	[4.05 (0.67)/3.60 (0.60)]	-3.81 (0.00*)	-2.74 (0.01*)	-0.45
18	The online learning component of this course extended my personal interactions.	[3.95 (0.67)/3.25 (0.57)]	-3.71 (0.00*)	-4.43 (0.00*)	-0.70
	Students' Perceptions of Individual Features (Content Available on the Online Course)				
19	I was satisfied with the content available on this online learning web-course.	[3.64 (0.67)/3.29 (0.53)]	-2.61 (0.01*)	-2.28 (0.03*)	-0.35
20	I was satisfied with the online lectures note included on the course Website.	[3.59 (0.73)/3.48 (0.76)]	-1.14 (0.25)	-0.60 (0.55)	-0.11
21	The online lecture notes on the Learning Management System (LMS) Website were a valuable resource.	[3.77 (0.64)/3.55 (0.75)]	-1.88 (0.06)	-1.24 (0.22)	-0.22
22	The lecture notes/finding notes were easy to print.	[3.82 (0.62)/3.33 (0.79)]	-2.23 (0.03*)	-2.66 (0.01*)	-0.48
23	I like the fact that Power-Point slides of the lecture notes were available on the LMS Website.	[3.77 (0.69)/3.85 (0.79)]	-0.93 (0.36)	0.41 (0.69)	0.08
24	I regularly visited the calendar section of the LMS Website.	[3.13 (0.84)/3.19 (0.76)]	-1.12 (0.26)	0.26 (0.79)	0.05
25	I found the calendar section of the LMS Website a valuable resource.	[3.76 (0.64)/3.50 (0.75)]	-1.06 (0.29)	-1.46 (0.15)	-0.26
26	I felt the links contained on the LMS Website were valuable.	[3.64 (0.89)/3.33 (0.65)]	-1.97 (0.05)	-1.52 (0.13)	-0.30
27	I regularly visited the links contained on the LMS Website.	[3.27 (0.88)/3.19 (0.88)]	-0.31 (0.76)	-0.37 (0.72)	-0.08
28	The LMS Website is a great place for the instructor to place handouts.	[3.82 (0.86)/3.57 (0.80)]	-1.37	-1.16	-0.25

			(0.17)	(0.25)	
	Student's Perceptions of Individual Features (Online Learning as a Communication Tool)				
29	I e-mailed the instructor trough the LMS Website.	[3.23 (1.01)/2.90 (0.96)]	-2.39 (0.02*)	-1.27 (0.21)	-0.32
30	I regularly checked my mailbox through the LMS Website.	[2.95 (0.96)/2.43 (0.88)]	-2.31 (0.02*)	-2.23 (0.03*)	-0.53
31	I regularly used the discussion section of the LMS Website.	[3.36 (1.07)/2.19 (0.71)]	-4.24 (0.00*)	-5.06 (0.00*)	-1.17
32	I found the discussion section of the LMS Website easy to use.	[3.38 (0.93)/2.68 (0.82)]	-3.35 (0.00*)	-3.11 (0.00*)	-0.70
33	The discussions section of the course content using LMS helps me better understand course content.	[3.55 (0.86)/2.71 (0.94)]	-4.06 (0.00*)	-3.61 (0.00*)	-0.8
34	The discussion section of the course content using LMS is a great way to interact with my fellow classmates.	[3.64 (0.77)/3.05 (0.84)]	-2.83 (0.01*)	-2.86 (0.01*)	-0.59
35	The discussion sections of the course content using LMS is a great way to interact with the facilitator/lecturer.	[3.64 (0.56)/3.19 (0.76)]	-1.93 (0.05)	-2.61 (0.01*)	-0.45
36	The discussion section of the course using LMS helps me to ask and answer questions more efficiently.	[3.45 (0.94)/2.61 (0.86)]	-3.92 (0.00*)	-3.66 (0.00*)	-0.84
37	I am glad the discussion section of the LMS Website was factored into my final grade. (**for PBL group only*)	[3.71 (1.02)/3.00 (0.52)]	-4.35 (0.00*)	-3.46 (0.00*)	-0.71
38	I would rather do an assignment than a discussion.	[3.23 (1.05)/3.14 (0.98)]	-0.18 (0.86)	-0.33 (0.75)	-.084
	Student's Perceptions of Individual Features(Assignment)				
39	I found it easy to submit my assignment online.	[3.91 (1.01)/3.81 (0.88)]	-1.38 (0.17)	-0.41 (0.68)	-0.10
40	I prefer the online submission of assignments.	[3.77 (1.08)/3.90 (0.85)]	-0.70 (0.48)	0.53 (0.60)	0.13
41	I found the online submission of assignments simple.	[3.82 (1.04)/3.85 (0.90)]	-0.57 (0.57)	0.13 (0.89)	0.03
42	I found the online submission of assignments convenient.	[3.82 (1.04)/3.90 (0.85)]	-1.01 (0.31)	0.36 (0.72)	0.09
	Student's Perceptions of Individual Features (Online Student Assessment)				
43	I took the online test (critical and creativity test).	[4.00 (0.74)/3.62 (0.71)]	-2.57	-2.05	-0.38

			(0.01*)	(0.04*)	
44	I found taking online tests convenient.	[3.55 (1.04)/3.10 (0.68)]	-2.21 (0.03*)	-2.01 (0.04*)	-0.45
45	I found the test section easy to use.	[3.59 (0.82)/3.00 (0.63)]	-3.19 (0.00*)	-3.17 (0.00*)	-0.59
46	The tests worked during my visit.	[3.45 (0.73)/3.24 (0.63)]	-1.32 (0.19)	-1.24 (0.22)	-0.22
47	I prefer taking my tests, quizzes and exams on paper rather than online.	[3.82 (0.82)/3.55 (0.66)]	-1.56 (0.12)	-1.42 (0.16)	-0.27

Note. (a) Grouping Variable and
* Statistical difference ($p < 0.05$)

6.4.2.3 Pre-Service Science Teachers' (SESD): PBL and Traditional

The data shown in Table 60 suggests that PBL students' (SESD cohort) perceptions of learning through online were significantly high and recorded a significant difference compared to the traditional group in three categories: *Students' Perceived Satisfaction* (except for Statement 14: *I believe that online learning will play an important role in education in the future*, which showed no significant difference); *Students' Perception of Interaction; Student's Perceptions of Individual Features (Online Learning as A Communication Tools)* (except for Statements: 29, 30 and 38, which showed no significant difference); and also *Student's Perceptions of Individual Features (Assignment)* (except for Statement 40: *I prefer the online submission of assignments*, which also showed no significant difference).

As for *Student's Perceptions of Individual Features (Content available on the Web Course;* and *Online Student Assessment)* categories, there were no great differences shown between both cohorts except for Statements: 19, 24, 27 and 43 for both categories.

Table 60
Comparison of pre-service science teachers' perceptions of online learning: PBL and Traditional Groups

No.	Statement	Group Traditional (N= 21) PBL (N=20) Total (N=41) [PBL/Traditional] Mean (SD)	Z [Asymp. Sig. (2-tailed)]	t (df = 39) Sig. (2-tailed)	Mean Difference
		Student's Perception of Satisfction			
1	I was satisfied with the overall experience of learning via online learning.	[4.19 (0.48)/3.73 (0.67)]	-3.24 (0.00*)	-2.48 (0.02*)	-0.45
2	I enjoyed the portion of the course on online learning.	[4.25 (0.51)/3.53 (0.62)]	-3.85 (0.00*)	-4.01 (0.00*)	-0.72
3	The online learning portion stimulated my desire to learn.	[4.13 (0.30)/3.36 (0.68)]	-4.31 (0.00*)	-4.64 (0.00*)	-0.77
4	I was satisfied with online learning in regards to the quantity (knowledge input) of my learning experience.	[4.13 (0.55)/3.47 (0.70)]	-3.43 (0.00*)	-3.34 (0.00*)	-0.66
5	I was satisfied with online learning in regards to the quality (knowledge input) of my learning experience.	[4.06 (0.51)/3.00 (0.63)]	-4.59 (0.00*)	-5.90 (0.00*)	-1.06
6	The online learning component of this course allowed for social interaction.	[4.06 (0.69)/3.67 (0.82)]	-2.57 (0.01*)	-1.68 (0.10)	-0.40
7	Online learning provided a reliable means of communication with other group members.	[4.06 (0.69)/3.60 (0.76)]	-2.88 (0.00*)	-2.04 (0.04*)	-0.46
8	Online learning provided a reliable means of communication with facilitator/lecturer.	[4.00 (0.56)/3.50 (0.55)]	-3.26 (0.00*)	-2.89 (0.01*)	-0.50
9	I found the online learning course to be a helpful resource.	[4.25 (0.51)/3.73 (0.67)]	-3.26 (0.00*)	-2.77 (0.01*)	-0.52
10	I used the online learning to help me understand course information.	[4.19 (0.48)/3.53 (0.70)]	-3.64 (0.00*)	-3.47 (0.00*)	-0.65
11	I regularly used online learning to answer my questions to other group members.	[3.88 (0.72)/3.07 (0.74)]	-2.65 (0.01*)	-3.55 (0.00*)	-0.81
12	I believe that online learning enhanced my learning in Modern Physics course.	[4.19 (0.58)/3.20 (0.65)]	-4.12 (0.00*)	-5.12 (0.00*)	-0.99

13	I would like to see all of my courses involve at least some online learning.	[4.31 (0.63)/3.60 (0.53)]	-3.79 (0.00*)	-3.94 (0.00*)	-0.71
14	I believe that online learning will play an important role in education in the future.	[4.38 (0.64)/4.40 (0.53)]	-0.27 (0.79)	0.14 (0.89)	0.03
	Student's Perception of Interaction				
15	The online learning component of this course helped to create a sense of community among the students in the course.	[4.25 (0.76)/3.40 (0.76)]	-3.20 (0.00*)	-3.57 (0.00*)	-0.85
16	The online learning component of this course increased my interactions with the instructor.	[4.38 (0.72)/3.20 (0.57)]	-4.14 (0.00*)	-5.84 (0.00*)	-1.18
17	The online learning component of this course increased my interactions with my fellow coursemate / classmate.	[4.25 (0.76)/3.27 (0.74)]	-3.41 (0.00*)	-4.20 (0.00*)	-0.98
18	The online learning component of this course extended my personal interactions.	[4.13 (0.72)/3.33 (0.68)]	-3.21 (0.00*)	-3.62 (0.00*)	-0.79
	Student's Perceptions of Individual Features (Content Available on the Web Course)				
19	I was satisfied with the content available on this online learning web-course.	[3.94 (0.76)/3.33 (0.61)]	-2.32 (0.02*)	-2.83 (0.01*)	-0.60
20	I was satisfied with the online lectures note included on the course Website.	[3.63 (0.79)/3.67 (0.88)]	-0.30 (0.77)	0.16 (0.87)	0.04
21	The online lecture notes on the Learning Management System (LMS) Website were a valuable resource.	[3.63 (0.85)/3.93 (0.59)]	-1.12 (0.27)	1.36 (0.18)	0.31
22	The lecture notes/finding notes were easy to print.	[3.75 (0.69)/4.00 (0.63)]	-1.98 (0.05)	1.21 (0.23)	0.25
23	I like the fact that Power-Point slides of the lecture notes were available on the LMS Website.	[3.94 (0.60)/4.07 (0.59)]	-1.96 (0.05)	0.69 (0.49)	0.13
24	I regularly visited the calendar section of the LMS Website.	[3.88 (0.79)/3.20 (0.79)]	-2.05 (0.04*)	-2.75 (0.01*)	-0.68
25	I found the calendar section of the LMS Website a valuable resource.	[3.75 (0.69)/3.47 (0.54)]	-1.46 (0.14)	-1.48 (0.15)	-0.28
26	I felt the links contained on the LMS Website were valuable.	[3.88 (0.55)/3.67 (0.61)]	-1.16 (0.25)	-1.15 (0.26)	-0.21
27	I regularly visited the links contained on the LMS Website.	[3.94 (0.60)/3.20 (0.85)]	-2.50 (0.01*)	-3.191 (0.00*)	-0.74
28	The LMS Website is a great place for the instructor to place handouts.	[3.88 (0.72)/3.93 (0.74)]	-0.59 (0.56)	0.26 (0.80)	0.06

	Student's Perceptions of Individual Features (Online Learning as a Communication Tool)				
29	I e-mailed the instructor trough the LMS Website.	[3.50 (0.79)/3.07 (1.12)]	-1.25 (0.21)	-1.43 (0.16)	-0.43
30	I regularly checked my mailbox through the LMS Website.	[3.75 (0.83)/3.20 (0.96)]	-1.88 (0.06)	-1.96 (0.06)	-0.55
31	I regularly used the discussion section of the LMS Website.	[4.07 (0.51)/2.47(0.83)]	-4.91 (0.00*)	-7.402 (0.00*)	-1.60
32	I found the discussion section of the LMS Website easy to use.	[3.88 (0.79)/2.80 (1.01)]	-3.53 (0.00*)	-3.790 (0.00*)	-1.08
33	The discussions section of the course content using LMS helps me better understand course content.	[4.06 (0.69)/2.73 (1.02)]	-4.24 (0.00*)	-4.86 (0.00*)	-1.33
34	The discussion section of the course content using LMS is a great way to interact with my fellow classmates.	[4.13 (0.64)/3.00 (1.00)]	-3.96 (0.00*)	-4.27 (0.00*)	-1.13
35	The discussion sections of the course content using LMS is a great way to interact with the facilitator/lecturer.	[4.00 (0.56)/3.40 (0.94)]	-2.50 (0.01*)	-2.47 (0.02*)	-0.60
36	The discussion section of the course using LMS helps me to ask and answer questions more efficiently.	[3.94 (0.69)/3.21 (0.79)]	-2.40 (0.02*)	-3.13 (0.00*)	-0.72
37	I am glad the discussion section of the LMS Website was factored into my final grade. (**for PBL group only*)	[3.94 (1.10)/2.75 (0.88)]	-3.68 (0.00*)	-3.83 (0.00*)	-1.19
38	I would rather do an assignment than a discussion.	[3.33 (1.01)/3.33 (0.93)]	-0.04 (0.97)	0.00 (1.00)	-0.00
	Student's Perceptions of Individual Features (Assignment)				
39	I found it easy to submit my assignment online.	[4.47 (0.44)/4.07 (0.67)]	-1.65 (0.10)	-2.25 (0.03*)	-0.40
40	I prefer the online submission of assignments.	[4.33 (0.53)/4.07 (0.67)]	-1.16 (0.25)	-1.41 (0.17)	-0.27
41	I found the online submission of assignments simple.	[4.40 (0.44)/3.93 (0.80)]	-2.90 (0.00*)	-2.29 (0.03*)	-0.47
42	I found the online submission of assignments convenient.	[4.47 (0.55)/4.07 (0.67)]	-1.83 (0.07)	-2.09 (0.04*)	-0.40
	Student's Perceptions of Individual Features (Online Student Assessment)				

43	I took the online test (critical and creativity test).	[4.13 (0.72)/3.53 (0.77)]	-2.67 (0.01*)	-2.55 (0.02*)	-0.59
44	I found taking online tests convenient.	[3.75 (0.95)/3.40 (0.82)]	-1.13 (0.26)	-1.27 (0.21)	-0.35
45	I found the test section easy to use.	[3.93 (0.83)/3.53 (0.77)]	-1.44 (0.15)	-1.61 (0.12)	-0.40
46	The tests worked during my visit.	[3.69 (0.70)/3.20 (0.72)]	-1.55 (0.12)	-2.19 (0.04*)	-0.49
47	I prefer taking my tests, quizzes and exams on paper rather than online.	[3.42 (0.69)/3.13 (1.09)]	-0.99 (0.32)	-0.99 (0.33)	-0.28

Note. (a) Grouping Variable and

* Statistical difference ($p < 0.05$

In conclusion, it seems that although a majority of the science students and pre-service teachers overall and separately were satisfied with their online learning experiences, there were some issues of concern. The main issue seems to be the nature of the online assignment arrangements, and the content available on the Web. These two issues need careful thought in any future iteration.

6.4.3 Learning Outcomes from Online Learning - Part C: Open-Ended Questions and Interview

In this section, data gathered from the open-ended survey questions and during interviews is used to complement the statistical data described previously to better understand the participants' views of the implementation of the PBL online approach in their Modern Physics course. Thus, the qualitative data from the open-ended questions and the interviews were used to triangulate the quantative sections of the questionnaire. These data suggest that as far as the PBL online approach is concerned the student feedback varied from satisfied to not satisfied, for convenience, future expectations and also knowledge gained through the online learning. Feedback for the SST and SESD students is first presented combined and any differences between the cohorts are then discussed. This section ends with summaries for both groups of students.

Table 61 shows the theme categories of the open-ended questionnaire and interview for students' perception of online learning. The themes clustered into four questions: Question 1: *Student's satisfaction;* Question 2*: Convenience of learning through online;* Question 3: *Knowledge gained from online learning*; and Question 4: *Future expectations of online learning*.

Table 61

Themes in the open-ended questionnaire and interview of student perception of online learning

Question 1: Students' satisfaction?
Generally
i. Satisfied; ii. Improving soft skills; iii. Time saving; iv. Interesting
SST
i. New experience of learning; ii. Challenging; iii. Can get lots of information
SESD
i. New way of learning; ii. Can be more independent
Question 2: Convenience?
Generally
i. Convenient and ease; ii. Using online to search for information; iii. Not satisfied with the Internet coverage
SESD
i. Enhanced communication
Question 3: Knowledge gained from online learning
Generally
i. Gain lots of knowledge; ii. Learning activities help enhance understanding in Modern Physics;
iii. Improve computer skills
SST
i. Gained little knowledge/ did not gain anything
SESD
i. Hard to explain some knowledge via online
Question 4: *Future expectations of learning via online*
Generally

i. Use videoconference while chatting in chat room; ii. Improve Internet facilities within UMS; iii. Incorporate this approach to other physics courses

6.4.3.1 Students' Satisfaction in Online Learning

Question 1: Students' satisfaction in learning via online learning. Analysis of the open-ended questionnaire and interview data indicates that majority of students felt they were satisfied with this program: however, a minority of students were not. Their responses can be categorized into *i. Satisfied; ii. Improving soft skills; iii. Time saving; iv. Interesting*; and *v. Not satisfied*.

i. Satisfaction

Overall students felt satisfied with the online environment. One of the reasons was that they do not have to waste money and paper on printing and writing while undergoing this learning, as mentioned by a participant:

> Satisfied because I won't have to waste money on printing out the hard copy. (R1, SST, F, PBL, *questionnaire*)

The second thing students remarked that they have been actively involved in learning activities not subjected to passive learning by the traditional approach, as commented:

> I am satisfied with the online learning program. This is because I can learn a lot and the most important thing is I can learn through the way I like and learn with freedom means not in the class where we will be control by the lectures and must stay quiet to listen to the lecturer. (R2, SESD, F, PBL, *questionnaire*)

ii. Improving soft skills

A participant remarked that she improved her understanding in modern physics because the learning activities (PBL features) really forced her to do some self-directed learning activity such as finding and searching for information and knowledge. In addition, her interpersonal skills and confidence strengthened as a result of the instructional design:

> I have gained lots of new experience through this online learning programme. Besides that, I can know the concept and theory of physics

> modern more deeply and clearly. This is because the PBL question which given to us is related to our daily life situation. Moreover, it also gives us a chance to survey and find out the most ideal solution for the task given. In this process, I also learn lots of soft-skills, which help me lots in communication skill and group work. As a conclusion, I am very satisfied with all I learn through this programme, not just in my knowledge but also my personality growth. I confirm this experience will not gain for the course-mates which taking traditional tutorial group. (R13, SST, F, PBL, *questionnaire*)

Hence online learning is seems convenient, and searching for information become easy. The improvement in their English comprehension was also stressed by a participant:

> Very satisfied, can have a time to go through the Internet and search information there. Can learn new thing in the Internet which I never did before. Improve our reading skill and the understanding of English. (R10, SESD, F, PBL, *questionnaire*)

Enhanced computer skills also were credited by a member through this approach:

> I am very much satisfied learning through online learning because at the same time it help a lot in my skills about computers and net. (R15, SST, F, PBL, *questionnaire*)

iii. Time Saving

Since online learning is capable of saving student's time, some student remarked that this method really saved time and thus they can do plenty of work, as stated by a participant:

> I am very satisfied with online learning since it gives me more time to do other work because it save times for me to go find the lecturer for information about the coursework. I just need to go to the nearest cyber café to connect and do my assignment and online learning also save my energy. (R22, SESD, F, Traditional, *questionnaire*)

One member also focused on the practicality of saving their precious time and money when learning online:

> By learning via online learning, I feel that anything is easy to be done. It is fast and easier for me. It saves my time and money. For example, the assignment that I do can pass through e-mail it save my time that not need go to print out and go to find the lecturer to pass up my assignment. It also saves my print out money. So that I feel very satisfied learning via online learning. (R32, SST, M, Traditional, *questionnaire*)

iv. Interesting

A participant remarked it is an enjoyable experience to learn online:

> I satisfy with it. It brings more fun for me. I think it interesting. (R3, SESD, F, PBL, *questionnaire*).

Another participant commented that finding information was getting easier through Internet compared to books text or other hardcopy material. She also added that the Mega Lab is a very useful for them should they have problems with their own computer:

> Learning via online learning is fun. I can get more information (fast and fresh). I can get new information by surfing the net. Finding information about a topic would be easier than finding a data from a book. The Mega Lab is really helpful when there is a problem occurred with my laptop. (R18, SST, F, PBL, *questionnaire*)

v. Not Satisfied

However, the few unsatisfied responses that arose here are basically from the technical issues. One participant commented that sometimes it is hard to get the online document:

> Not very satisfied, because not all information is complete. Some of the document can not open online. (R24, SESD, F, Traditional, *questionnaire*)

The frequency of communication between group mates was also being remarked on. A participant in PBL group stated that there was not enough material for them to study:

> Not satisfied with the amount of interaction involved between me and my fellow class-mates. Not satisfied with the material that can be studied online. (R23, SST, M, PBL, *questionnaire*)

In other perspectives, a traditional participant said that inadequate information is delivered through the LMS, making her feel unhappy with this approach:

> I am not quite satisfied with the online learning because I rarely got the chance to check on the latest information on the net. I don't get all the information I needed at times (R40, SST, F, Traditional, *questionnaire*)

The most difficult part of the online course was problem with the Internet connection which sometimes annoyed students. The Internet access and the bandwidth within the university every so often were not functioning well, as elaborated by a participant:

> Our problem actually got a big problem with internet connection. Since this PBL activities are very related to Internet usage for chatting, finding information and etc (relating to PBL learning activities), so there is a problem when we want to solve the PBL question. So, the very important to let this learning approach success is get a good internet connection first. (R2, SST, F, PBL, *questionnaire*)

Though there was common feedback, some different comments were also made by both cohorts of students. For instance, SST students expressed the view that they *i. found* a *new experience of learning; ii. challenging;* and *iii. can get lots of information.*

i. New experience of learning

A participant felt that she advanced her skill in handling basic software while learning online. This approach also exposed her to group mates thus providing them with a friendly learning environment:

> I am very satisfied about Online learning. I got an experience about the Internet (find information; submit an assignment via e-mail and etc.). I also know more about my member group, which is before this I am not very close with them. I also can feel how to solve a problem even not in 3D (means in front my eyes.) but at least I got an experience to solve some problem. (R2, SST, F, PBL, *questionnaire*)

ii. Challenging

The nature of the PBL problem which is challenging and happens in their daily life context been brought up by a participant. He added that it triggered himself motivation to learn more about the matter. He was also happy with the way they needed to respond to the problem, never being forced to think about the right answer for the problem:

> I am really satisfied about this learning via online learning that I get involved in during this semester. Most of the question sometimes really challenging our knowledge and that will make us to study more about it. I love the way we going to answer it in simple way but correct and fit. (R38, SST, M, Traditional, *questionnaire*)

A participant sensed this kind of learning really suited him and trained him to be more independent in his learning:

> It is convenient for learners of modern physics because we just have to click to get any kind of information in the net at an instant. It is a suitable and appropriate way of learning for me because I like to learn independently and take all this as a challenge. It is useful to use e-learning like in overseas study method. (R44, SST, M, Traditional, *questionnaire*).

iii. Can get plenty of information

A participant also compared this kind of learning with the learning approach that is being practiced in Singapore. He felt that learning level in Singapore was much better than Malaysia since their practice was at an advanced stage:

> I am very satisfied with the online learning, because I feel higher level of learning and more creative with doing internet text or Internet knowledge. In the online learning also got many source that can help me improve my

> course knowledge and help me learn more. I will feel more high degree of learning like Singapore (all document also written in black and white) (R25, SST, M, Traditional, *questionnaire*).

Some SESD students saw online learning as a *i. New way of learning;* and also fact that they *ii. Can be more independent.*

i. New way of learning

> I'm really satisfied learning via Online learning because I give me a new method or style of learning which is through online system. (R7, SESD, F, PBL, *questionnaire*)

A participant added that also saves time, since they do not have to waste time by walking or waiting for a bus, just to get to a place like library or lecture room to get vital information about the course:

> I'm satisfied with the way of learning. I learn the new experience way of learning that is via Internet. It was good and don't make use to walk anywhere and wasting time waiting for the bus. Just find the nearest cc and the problem is settled. (R9, SESD, F, PBL, *questionnaire*)

ii. Can be more independent

The students need to be more capable, and to take charge of their learning process and be trained to be a self-directed learner. One participant commented:

> The notes given via online learning maybe not complete enough; I need to found the notes myself maybe via internet or sources in library. This trained me to be independent and give much satisfaction to me (R19, SESD, F, Traditional, *questionnaire*).

6.4.3.2 Conveniences of Online Learning

Question 2: Convenience. Analysis of the open-ended questionnaire and interview data indicated that a majority of students felt satisfied with this program. However, there are minority of students who did not. The responses can be categorised into several main arguments: *i. Convenient and ease; ii. Using online to search for information;* and *iii. Not satisfied with the Internet coverage*.

i. Convenient and ease

A participant felt that this kind of learning has provided a useful method to learn and she even compared it to overseas styles of learning:

> It is convenient for learners of modern physics because we just have to click to get any kind of information in the net at an instant. It is a suitable and appropriate way of learning for me because I like to learn independently and take all this as a challenge. It is useful to use e- learning like in overseas study method. (R15, SST, F, PBL, *questionnaire)*

A member added that this approach gave them the ability to take charge of their own learning process: they can study the way they want, and at their leisure.

> Overall I can say it is convenien. I am comfortable to study this way. I can study any way I want. I need no rush to go to class. Only the line in the hostel is sometime too bad. (R3, SESD, F, PBL, *questionnaire*)

ii. Using online to search for information

A participant gave several advantages that she gets from online learning, from the technology to knowledge acquisition. This suggests that the online learning had upgraded her convenience and speed while learning modern physics:

> This programme is fully conducted through Internet. For me, there is no problem because I always surf the Internet by using the WIFI facility. We always need to login into LMS and update the task given inside physics modern side. I feel this is very convenient because we can get the information and instruction given wherever and whenever we want. Besides that, the chat session which provided by LMS also give us a chance to discuss our solution without need attend any meetings. The submission through Internet also easier compare than need print out and send to the lecturer. In campus life which provided with WIFI facility, PBL is a convenien programme for me. (R13, SST, F, PBL, *questionnaire*)

A participant also stressed that collaborative learning with group mates and facilitator contributed to her learning:

> Knowledge will be gained via online learning as students can download a comprehensive note or receive any announcement or the information need

> from the instructor. Two-way interaction and discussion available among students n with instructor so that some unclear information can be validated (R25, SESD, F, Traditional, *questionnaire*).

One student also commented that it is not necessary to gather in one place at the same time, since there were times that it was really hard for them to gather the team at the same time and place to discuss a matter:

> Yes. I am more convenient using this kind of learning. We can talk to each other without holding a discussion in round table like a meeting. Just turn on the Internet and we can discuss it online. (R9, SESD, F, PBL, *questionnaire)*

iii. Not satisfied with the Internet coverage

Again, the unsatisfied feeling of this approach arose from the technical aspects. The Internet access inside the university is sometimes bad as mentioned by some participants:

> Not satisfied because of the coverage of campus (R14, SESD, F, PBL, *questionnaire*).

Some SESD students felt they *i. Enhanced their communication skills,* by inquiring synchronously though the facilitator who was in another place made it easier for her, as stated by a participant:

i. Enhanced communication

> Enhance my communication with others. I can ask the questions to lecturer and answer me immediately via web site. Lecturer posted class assignments, directions to me and others, so no need to meet her/his at office. (R32, SESD, F, Traditional, *questionnaire*)

Apart form enhancing their communication skills, a participant also added that she enjoyed the idea of integrating learning activities with the ICT and not depending too much on the normal lecture class all the time:

> It is convenient to learning via online learning cause we don't have to get busy in getting information and instruction from the lecture. Plus it is more

> interesting because we can integrate the use of ICT in learning. (R30, SESD, F, Traditional, *questionnaire*)

6.4.3.3 Knowledge Gained Learning from Online Learning

Question 3: Knowledge gained from online learning. Analysis of the open-ended questionnaire and interview data indicated that majority of students felt they *i. Gained a large amount of knowledge; ii Learning activities helped enhance understanding in Modern Physics;* and iii. *Improved computer skills.*

i. Gained a large amount of knowledge

A participant responded that her knowledge acquisition was better than the typical class, and that she managed to apply the learning contents to everyday life situations that happen:

> From learning via online learning, I had gained more knowledge compared to tutorial class. For example, I know more clearly on how to apply physics concept in the real situation rather than just read from the text book. (R4, SESD, F, PBL, *questionnaire*)

A participant commented that she can expand her medium resources rather than books and hardcopy material:

> Increase my knowledge in learning new things in multiple sources, not only limiting myself to refer in books but also websites, journals, articles and so on. (R7, SESD, F, PBL, *questionnaire*)

One female participant also managed to relate information and resources:

> Nearly to its fullest. I combined facts and resources that I get from the net and form a good understanding. (R15, SST, F, PBL, *questionnaire*)

iv. Learning activities helped enhance understanding in Modern Physics

The students said online learning helped them to understand their learning content more deeply. With help from the Internet, it made searching for information easier, they discovered plenty of information outside of lecture times, and they exchanged ideas and valuable sources through group members, as remarked by a participant:

> I have gained lots of new experience through this online learning programme. Besides that, I can know the concept and theory of modern physics more deeply and clearly. This is because the PBL question which given to us is related to our daily life situation. Via Internet searching, I find that many extra information which do not given during lecture time. Moreover, it also give us a chance to survey and find out the most ideal solution for the task given since our aim is to solve the task given. Through the internet discussion, I can exchange my idea with my group members. All of us would like to share all the information which we found, and make us know more deeply about the concept. (R13, SST, F, PBL, *questionnaire*)

Thus, to gain knowledge, a female participant remarked that from online learning, they (within group members) shared everything through the discussion room, and found latest information easily:

> I can gain knowledge by sharing the information with group members by online, find the information from the Internet; discuss the problem with group members, and by chat through the Internet. (R6, SESD, F, PBL, *questionnaire*)

Another female participant also noted that there is a wide variety of information that can be found through the Internet. Thus it is much easier for them to pick and to choose suitable information in order to solve their problems:

> I also can find the knowledge by exchanging facts with other members. Furthermore when we trying to find the solution in the Internet, I open the browser, and gained much new information to me. (R9, SESD, F, PBL, *questionnaire*).

iii. Improved computer skills

This approach also was capable of improving students' computer competency. For example, a female participant said she learned how to send her assessment electronically. This made hunting for facts and knowledge online easier, as stated:

> Now I know how to submit or send any assignment by e-mail. Know more how to find an information using Internet, by learning via online learning. I realize that there is Wikipedia to find any information easier. I also realize there are many things that relate to physics that I didn't know before. (Thanks to PBL). For the first problem, we feel it so hard to solve, we were afraid if the solution that we give are wrong, but when the facilitator said that our solution is not about wrong or right, it is all about our opinion and also our thinking skill to solve it, we feel very excited to wait the next problem…Thanks to our facilitator. (R2, SST, F, PBL, *questionnaire*)

Again, this approach trained students to be more proficient using computers particularly when learning through, it as noted by a participant:

> I can find the address bar in a browser, enter an address, and go to a site; Download text, graphics, and plug-ins from an Internet site; Bookmark Internet sites for later reference; Navigate through Internet sites; Use the refresh button; Download and save text, graphics, audio, and video files; Display downloaded files in appropriate applications. All of this can improve my Internet skills. (R32, SESD, F, Traditional, *questionnaire*)

From another point of view, SST students generally *i. Gained little knowledge/ did not gain anything* from this approach and SESD students said that it is *i. Hard to explain some knowledge via online.*

SST

i. Gained little knowledge/ did not gained anything

A traditional female participant was not satisfied with her knowledge acquisition, and she had to work hard for it:

> I have gained a little knowledge in online learning and I have to work on my own way to understand this course. (R31, SST, F, Traditional, *questionnaire*)

Another participant prefers to study in the traditional way since she felt that learning via traditional approach gives her better knowledge:

> The knowledge gained from online learning is not as good as the knowledge you learn when you attend lectures. (R40, SST, F, Traditional, *questionnaire*)

SESD

i. Hard to explain some knowledge via online

There were sometimes participants from SESD who faced difficulty explaining and elaborating physics terms and concepts in the chat room, as noted by one member:

> Although students can post their questions on net and the lecturer will answer it, but some of the explanation just can't be done by using text, maybe need diagram to explain it, and this is hard to do via online learning. (R19, SESD, F, Traditional, *questionnaire*)

6.4.3.4 Future Expectations of Online Learning

***Question 4: Future expectations of online learning*.** Analysis of the open-ended questionnaire and interview data indicated that a common student suggestion was that the designer should *i. Use videoconference while chatting in chat room; ii Improve Internet facilities within UMS;* and also *iii. Incorporate this approach into other physics course.*

i. Use videoconference while chatting in chat room

A participant suggested that using videoconferencing might help them while doing their chat room activities such as discussion, elaboration, and even presenting their findings:

> In my opinion, I know our technology is limited, but I suggest, videoconference will be more interesting. We just apply videoconference but have no lecture, I mean all of our team members, after we have discussed the problems and then after they find the solution they present it in front of the lecturer using videoconference (lecturer will just listen not participate in that presentation). (R15, F, SST, *interview*)
>
> If we use the web cam also the conversation will be more interesting. (R17, F, SST, PBL, *interview*)

Using Yahoo Messenger (YM) or Skype also might help them learn in the future:

> I have suggestions about the chat room, maybe we should use the more user friendly chat room like YM, Skype so that we can make our conference, use voice mail. Because I think it is better when we discuss something thru chat

> room we also can speak directly to other team members, because it is very hard for us to express our opinion only by the chat room and not accompany with verbal discussion. (R8, F, SESD, *interview*)

ii. Improve Internet facilities within UMS

Technical issues such as the Internet access and bandwidth within the university area need to be upgraded for student's and user's convenience and to improve the effectiveness of this approach in the future, as suggested by several participants:

> Improve and upgrade the Internet connection. (R30, M, SST, *interview*)
>
> Improve the poor Internet sources, than we can continue this PBL via online. (R17, M, SESD, *interview*)

iii. Incorporate this approach into other Physics Courses

Some participants suggested that this instructional design could be incorporated into other university courses, especially for those courses that need sources from outside the lecture room to learn:

> I think we should incorporates this kind of program to the others physics course, for example optic. Because optic course involve al lot of nature and phenomena that we don't even know. So if the question about the natural phenomena comes out in the future we may be now being able to know what it even we are physics students is. So I think about the optics and also the electromagnetism these two subjects I think can join in PBL. Because this two course involve a lot of complex and interesting things that can allow us to think and learn more from this. (R12, M, SST, *interview*)

A participant also urged that this approach should be enforced fully in certain physics courses and would be interested to join this learning approach in the future:

> Apply this PBL approach to other subject for the next semester like physics optic. Enforce it100% PBL assessment for PBL approach only in one particular course. Want to continue this PBL system (with enthusiastic). (R7, F, SESD, PBL, *interview*)

6.5 CHAPTER SUMMARY

This chapter presented the research findings for the research questions. The research questions concern the effectiveness of PBL online used to improve physics undergraduates' and pre-service science teachers' creative and critical thinking. Additionally, this chapter also considered Malaysian physics undergraduates' and pre-service science teachers' perceptions of PBL and online learning. There are obvious differences between the PBL group and traditional groups with respect to the flexibility, originality and elaboration components of creative thinking. For critical thinking, there were no major differences revealed for the PBL and traditional groups for both cohorts (i.e., physics undergraduates & pre-service science teachers) except for the *inference* criterion for SST students (which favored the PBL group). In respect of their perceptions and adoption of PBL, it seems that despite the fact that PBL is a very new learning activity and requires more time, the students enjoyed it. Moreover, students felt they gained benefits from PBL compared with traditional learning. They expected to take greater control of their learning, felt they were self-directed in their learning, were ready to learn, and wanted information that is immediately available. Above all, the participants felt that learning online helped them to use their time more effectively, and to be more engaged in learning. The next chapter provides a discussion of the research findings in relation to the literature.

CHAPTER 7: DISCUSSION

7 CHAPTER OVERVIEW

This chapter discusses the research findings, and begins with a discussion of the effectiveness of PBL online with regard to students' creative thinking following the implementation of the intervention for students who registered in a Modern Physics course during Semester II, for the 2009/2010 academic year. The impact of this instructional design on students' critical thinking also is discussed. The next section discusses the students' perceptions and acceptance of learning via PBL and the last part of the discussion elaborates on the students' perceptions of online learning. The chapter ends with a summary.

7.1 EFFECTIVENESS OF PBL ONLINE ON STUDENTS' CREATIVE THINKING

The research findings reported in this thesis suggest that students' achievement as measured by the Torrance Creative Thinking Test (TCTT) when engaged with PBL online scored better when compared with the traditional group. The overall sum showed there is a significant difference when the combined for both SST and SESD students are considered favour the PBL group. It seems that the PBL online students did better for the scales *flexibility*, *originality* and *elaboration*. Separate analyses for SST and SESD students also shows higher mean marks with statistically significant differences for *flexibility*, *originality* and *elaboration* criteria, for the PBL group.

In addition, the differences in performance in creative thinking were positive in both surveys and interviews about PBL learning. Students said PBL helped them learn how to generate many ideas; that they found they managed to solve the problems posed; they were able to make connections between different facts; and they felt that their ability to evaluate their findings improved. This is consistent with the features that are captured in *flexibility*, *originality* and *elaboration* elements of creative thinking in the Torrance Test. These findings are similar to work reported by Tan (2000) and Juremi (2003), who say that PBL online increases students' creative thinking. Furthermore, through online learning, the students in the present study also saw PBL online as a new way of learning, that gave them many benefits (i.e. they felt that the benefits of demonstrated learning effectiveness, justify the extra resourcing), consistent with work by King (2008) who reported PBL online students reported high satisfaction even with increased workload. Overall, this suggests that students need to be well prepared for PBL online teaching approaches, before any advantages of online learning and using the Internet can play an important role in learning. Only then will they know how to choose, select, decide and evaluate their findings, and subsequently manage their information and knowledge appropriately. The literature suggests that students have to be able to think creatively in order to produce a high-quality answer and solution to their problems (see e.g., Awang & Ramly, 2008; Claxton et al., 2006). Thus, in order to enhance students' creative thinking, Miller (2001) and Denning (1997) suggest using online learning because it assists in making the topic comprehensible, and allows rapid and accurate representation of scientific data. This allows the focus of a lesson to move to a discussion of the implications of the results. The present study suggests that students become more resourceful and creative when working online, as is reported by other researchers and teachers. It also seems that students are able to work more independently when using computers and engaging in online learning activities (see e.g., Neo & Neo, 2009; Rovai, 2003; Seng & Mohamad, 2002). In summary, it seems that creative thinking in science can be nurtured by emphasizing the solving of problems, with less rote learning.

As indicated in the conceptual framework for the research (see Section 4.6), the PBL approach possesses the elements that might encourage students to be more active in terms of creative thinking processes. In this study, the students did practice creative thinking when trying to solve problems. Because the problems are not from their textbooks, but more related to their daily lives, the students have the opportunity to find the solutions by using content that was specified for them in that particular domain. Thus, the student has to study, read and find relevance sources, try to use the information and modern physics content gathered in order to explain the phenomena, and try to solve the problems, either quantitatively or experimentally. As a result, this learning process will continue on and on until they have found solutions to the problem. In order to generate the solution, students are exposed to a variety of mental activities such as brainstorming, discussion, asking questions, and they tried to generate as many original and new ideas as they could. These learning activities encourage creative thinking, in the process of generating as many different ideas as possible (*flexibility*), suggesting or coming up with new, innovative and novel solutions (*original*), and also trying to think of the consequences of the cause and effect of each solution proposed (*elaboration*).

Equally important, PBL also provides a relatively unstressful learning environment, which is more fun, interesting, and enjoyable, and tends to not penalize students (see e.g., Ahmad, 2008; Juremi, 2003; Pepper, 2008). This may be why students feel comfortable with this new learning atmosphere. If a student feels more relaxed, they can easily give their factual and convincing ideas during small group discussion, and not in the whole class. Motivation and support from other group members also can push students to build their self esteem, meaning they may improve in self motivation and be less afraid to generate more ideas and convey them in a meaningful way.

7.1.1 Comparison between SST and SESD students

The research findings suggest that the students from both schools, the School of Science and Technology (SST) and the School of Education and Social Development (SESD) in TTCT improved in terms of creativity for the PBL group. Both PBL groups are of the opinion that the PBL approach is useful and that it improved their thinking especially in terms of the criteria *flexibility*, *originality* and *elaboration*. Moreover, the survey findings suggest that they felt that their *knowledge, skills and the application of knowledge skills* in their learning process were improved. The students gave positive feedback, saying the learning process they experienced contributed to their creative thinking, and knowledge skill of learning generally.

In comparison, the SST students from the PBL group gained lower mean marks for three criteria; *flexibility* (45.0), *originality* (24.4) and *elaboration* (15.2) compared to the SESD students; *flexibility* (50.1), *originality* (34.1) and *elaboration* (22.9). These findings suggest that the PBL group of the SST students are less in control of their creative thinking skills when compared to the SESD students. This finding also agreed with Juremi's (2003) study where the PBL group noted higher mean marks significant difference in *flexibility* and *originality* but not in *fluency*.

The qualitative data suggest that both cohorts of students believed that their *creative thinking increased gradually,* and that it really *helps them in solving their problem*. These findings suggest that students felt PBL online was empowering and helped them to understand modern physics concepts. This is similar to work by Stone (2007) who reported that the PBL approach, whilst challenging and time consuming, is still appreciated, valued and enjoyed by students 'as an educational experience.' Students in the present study also commented that learning using PBL based on real life situations was practical and more realistic compared with lecture–based learning. The problems posed in the PBL online approach helped them to narrow the gap between theory and practice. These findings are consistent with work by Jayasuriya and Evans (2007), whose students were positive about PBL, and who, on average, performed better in their courses than when learning by a more traditional approach. Additionally, in their work students said they need to be better at working in a dynamic team, and at assessing group work and evaluating individual performances against required learning outcomes.

While there was common feedback, some different comments also were made by a few students from both cohorts. As an example, some SST students felt that they were *able to express their opinion freely*, *know how and when to use creative thinking* – PBL also managed *to sustain their interest* and they were *able to use this skill in bridging ideas*. Likewise, some SESD students added they *can think of something that never crossed their* mind while solving problems, and also they felt that they were able *to use many creative ideas in explaining certain physics concept*. However, one a participant commented, saying that it is really *hard to be a creative thinker*.

Overall, the design of the interactive learning tool described in this study brings together a range of modern physics practices, including collaborative learning and a PBL approach to the construction of learning in an environment in which students were not only exposed to the modern physics issues but these were contained within the subject knowledge, but were also given the opportunity to develop their interpersonal and creative evaluation skills, necessary for effective advancing into this field in the future.

According to the literature, the willing participation of the learner facilitates the acquisition of knowledge and self-motivated learning is the key to success in PBL learning (Lee et al., 2003). In the learning process, students are required to distance themselves from extant forms of knowledge and approach their foreknowledge as an object for analysis and exploration. In this way, students test the validity of both knowledge claims and reasoning. Indeed, it seems that at the heart of any reasoning model is reflective critical thinking (Pesut & Herman, 1998; Wong & Lee, 2000; Wooldridge, Brown, & Herman, 1998). The findings reported here seem to indicate that the students in this study have realized this aspect of learning. Some students reported that this method of learning helped them to analyse problems in a systematic way, and to then creatively analyse their own strengths and weaknesses in problem-solving.

These findings also support work by Gibbings (2008) who recommended this kind of pedagogy (i.e., PBL online) saying it can help develop students' ability to effectively manage their learning experience. For graduates and the ease with which they transition into professional work and later professional competence in terms of problem solving, the ability to transfer basic knowledge to real-life scenarios, the ability to adapt to changes and apply knowledge in unusual situations, the ability to think creatively, and a commitment to continuous life-long learning and self-improvement are crucial (Gibbings, 2008). Pausch (Pausch, 2007, September 18), describing how important it is for someone to experience and undergo learning activity on their own, says "the great thing is they [i.e., Pauche's parents] let me do it [drawing and writing on the wall], and they felt letting me express my creativity was more important than the pristine nature of the wall".

7.2 EFFECTIVENESS OF PBL ONLINE ON STUDENTS' CRITICAL THINKING

The research findings reported in this thesis indicate little difference overall for critical thinking when both SST and SESD data were combined. However, the *inference* criterion shows a difference in favour of the PBL group, in contrast to the *assumption* criterion, where the traditional group noted a higher difference. Upon further analysis, it is evident there is no significant difference for both cohorts of students in critical thinking when analysed using the Independent Sample t-Test. However, when the data are analysed using the Mann-Whitney U test, it appears that critical thinking for the PBL group for the SST cohort increased in contrast to the traditional group overall. Moreover, for the SST students, there are differences for the *inference* criterion (measured using both the Independent Sample t-Test and Mann-Whitney U test) and *evaluation argument* criterion (for the Mann-Whitney U test), with the PBL group performing better compared to their traditional counterparts. Although the PBL group achieved higher mean marks for the same criteria than the SESD, no great difference was observed. In the case of the *assumption* criterion, the traditional group from the SST cohort scored higher compared with the PBL group. In summary, these findings suggest that, overall, students who engaged with the PBL method showed positive improvement in critical thinking compared to the students treated with traditional method. However, it seems the intervention was more effective for science students than pre-service science teachers. Thus, the next section discusses the findings for the SST and SESD students separately.

7.2.1 Comparison between SST and SESD students

<u>SST Students</u>

The research findings suggest that the achievement of students from the School of Science and Technology (SST) improved their critical thinking for certain criteria (i.e., *inference* and *evaluation argument*). These findings are consistent with research findings reported by Zohar et al. (1994), who say that students exposed to PBL improved their critical thinking. Likewise, Juremi (2003) reports improved critical thinking for three criteria (i.e., *inference*, *interpretation* and *evaluation argument*) for a face-to-face PBL group.

Kamin, O'Sullivan, Deterding, and Younger (2003) report that a PBL group employing virtual media were more engaged in critical thinking than a traditional cohort. This might be because the PBL students were exposed to explicit critical thinking learning process skills. In PBL, the *inference* element requires students to differentiate the falsity and truth of inference, based on data provided. Students decide whether or not the suggested inference is true, false or fake, or if not enough information is provided to reach a conclusion. Additionally, students have to *evaluate arguments* when dealing with problems. They have to differentiate between weak and strong arguments, and identify the best solution. Through PBL learning activities, these elements of critical thinking are explicated. Thus, students always practice these skills when using PBL. As a result, this learning method enables students to more easily answer the questions in the Watson Glaser Critical Thinking Test even though sometimes this involves outside knowledge, that is, other than subject content knowledge - in this case from a modern physics context. This may be due the nature of the science students learning experiences, in which they are nurtured in science thinking (such as science process skills) more deeply compared with pre-service teachers and engaging with learning activities that are consistent with this approach.

However, the situation is different for the *assumption* criterion, where the traditional group did well compared with PBL group. For the *assumption* criterion, students need to recognise assumptions and early expectations, based on the statement given. The research findings in this thesis suggest that some of traditional learning activities students are exposed to involve recognizing assumptions and early expectations. For example, students learning science in a traditional fashion are taught to predict, and may try to guess what kind of question or how many questions will appear in their exams or tests. This may explain why they managed to do better compared with the PBL group. PBL students learned to justify and apply more rational thinking when engaging with their learning content during the PBL learning process.

<u>SESD Students</u>

The research findings indicate that achievement based on the WGCT for students from the School of Education and Social Development (SESD) are such that there were no significant differences noted for any criterion of critical thinking. This begs the question as to why none of the criteria shows improvement for this group of students, and why there are some contradictary outcomes between the SST and SESD students. There are two main reasons suggested for this. First, the PBL group increases their critical thinking ability by a small amount or second, that the traditional group also increased their critical thinking. To consider these reasons, the educational context at the UMS needs to be examined. The SESD students were in their second year, and during the intervention this was their fourth semester. They were more experienced in how to study at university compared with the SST students who were freshman at that time. This factor is stressed by Lee et al. (2003) who report that students obtain knowledge based on their adulthood and maturity, as well as their study experiences. This might mean these more 'canny' students learn more independently, whether they were in PBL or the traditional group

Another factor that may contribute to this situation is that the SESD student intake is carefully managed by the Minister and university administration. Each candidate had to take several qualification tests, and all were interviewed before being accepted as pre-service science teachers, due to the high demand of teaching as a career. For this reason, those in SESD group actually were selected, and arguably more capable students. They are reported to be very hard working (D Gabda, personal communication, September 7, 2010), and will work very hard to make sure they get good marks in their course, including this course on Modern Physics. This is in contrast with the SST students, the majority of whom do not want to do physics or electronics courses. The researcher established that roughly 10 out of the 61 students selected this course as their first choice when applying for university. This suggests such students are not that enthusiastic about learning physics. This could be why the pattern of the critical thinking is quite different between the SST and SESD students.

Interestingly, the qualitative findings contrast with the quantitative findings for both cohorts. All students felt that *their critical thinking improved,* that *they managed to engage in critical thinking* and that they *managed to generate related ideas*. In addition, the SST students also said they felt that this kind of learning activity *does mind activation and brainstorming*, and that it helps them to be *able to think in terms of cause and effect* for each problem they encountered in the study; whilst the SESD students said that they *can think more freely* and *answer questions in more acceptable ways*. Despite such positive responses, some students noted that *their critical thinking is not improving* and that they *had a headache* when they encountered problems using PBL.

In conclusion, the positive feedback may be because the student themselves experience a mutual learning process, and at the same time it does contribute to some elements of their critical thinking. Meyers (1986) stresses that to develop critical thinking in students, course work must encourage discussion, questioning, evaluation, and reflection. Thus, in this study, these learning activities worked well in online group discussion about daily-life issues, and the students were provided with convenient space and freedom in which to conduct their investigation, and learn to communicate with others in a professional and productive manner – similar to what is reported in the literature (Thompson, Martin, Richards, & Branson, 2003). In contrast, the learning activities used in the traditional approach do not emphasize this kind of learning explicitly. Therefore, the opportunity to learn and to develop these skills is modest. Hence, there is not much improvement in critical thinking for the traditional group.

Additionally, critical thinking is something that is quite different to creative thinking. In this case students had a bigger task - they had to learn, understand, practice and perform the skills more openly in order to become a critical thinker. One particular issue of relevance arose here; some of the students needed a lot of time to become accustomed to learning to use computers, although they said they had fun and enjoyed this type of learning. Because students come from different backgrounds and have had different learning experiences, and different sub-cultures and capabilities, the assumption that all students can learn from the same materials or processes, classroom instructional techniques and modes of evaluation is not substantiated (Smith, 1999a). A group of students may engage in a the same learning experience, but they probably do not learn the same or to the same extent (Wong, Kember, Chung, & Yan, 1995).

It is not simply the opportunity to solve problems, but rather learning opportunities where solving problems is the focus or starting point for students' learning (Davis & Harden, 1999). Students work on a problem which has the sort of benefits noted above, but a common issue of PBL is that, because it moves away from the traditional lecture, reading, and discussion approach, less subject matter may be covered. The good news is that effective online learning environments have already been recognised as beneficial (see e.g., Ambotang & Shukery, 2005; Mohamad Said, Ali, Sidek, & Md Noor, 2005; Puteh & Hussin, 2007), and embrace a new pedagogy that puts the student in the 'driver's seat' on the journey that is their learning path. In the PBL approach, the content (e.g., traditional lecture materials or assigned readings) is sought out as a part of the larger process of solving a problem. Students decide, often with the help of the instructor, what they need to know in order to successfully devise a solution, and then actively seek it out (using resources that may or may not be provided by the instructor). According to the literature, in this way, students are actually defining their own learning objectives, and the knowledge acquisition becomes a means to an end, rather than the end goal itself (Gurrie, 2003), as happened in this study.

This PBL model also is consistent with critical thinking in terms of attitude improvement, knowledge, and also the development of student capability in i.) curiosity and the capability to recognize the existence of problems and acceptance of things that might be truthful or accurate solutions; ii.) the knowledge required to make appropriate conclusions; iii.) generating ideas supported by logic; and iv.) ability to then apply this knowledge and attitude (Watson & Glaser, 1980). As a result, students have the opportunity to practice critical thinking during PBL. To analyze and choose relevant information to define problems requires critical thinking to play a role. All of the information that is gathered from a variety of sources also has to be authenticated. In the knowledge searching process when trying to solve problems, critical thinking skills have to be applied to evaluate the relevant information and knowledge. In problem solving steps, students have to find the relevant information first. Through this hunting process, students engage in activities such as choosing and evaluating the necessary information and notification. Thus, this phase involves the application of critical thinking in such things as making inferences, assumptions, deductions, interpretations and evaluation of argument: whereas for the traditional learning, students typically are assigned problem-solving activities that they can find the answer to in textbooks, meaning they are seldom given any opportunity to analyze and to evaluate all the information and do not really learn how to apply critical thinking.

The students in the PBL group at the same time were exposed to study and learning in a collaborative online environment. They were able to change and discuss ideas whenever or wherever they wanted. That the PBL groups were fairly small (4-6 students) made discussion more manageable, and made it easier to complete the assessment and tasks provided. Equally important, this small group helps to fertilize their individual enthusiasm, and can encourage them to broaden their critical thinking skills, as reported in the literature (Gokhale, 1995). Therefore, sharing their own learning means they were able to work with other group members giving them chances to discuss their ideas, and become more responsible for their own learning and able to become a critical thinker (Totten, Sills, Digby, & Russ, 1991). Conversely, for the traditional group, since their learning activities were already planned by the lecturer or teacher, the students could only learn in a passive way, and more individually.

7.3 AFFECTIVE EFFECTS: STUDENTS' PERCEPTIONS OF AND INTEREST IN PBL ONLINE

The research findings reported in Chapter 6 suggest that the student were keen on and engaged with their learning under the PBL method, although some found learning through PBL harder than their usual learning. In some ways, all the students commented that, at the beginning, learning via the PBL approach was difficult. For some, it was both threatening and confusing initially, but as time went by, they felt that this was a normal reaction to PBL. Stone (2007) similarly reports that students found PBL using electronic books challenging and time consuming. This is because the approach itself is typically new to them, and they need more time to get used to it. Typically, since being in primary school, they have only been exposed to a lecture-based, teacher-centred and well-structured syllabus, involving rote-learning. Hence, when they are introduced to a new challenging environment of learning like PBL, they felt uneasy and a bit overwhelmed.

In terms of learning outcomes, the majority of the students felt that their *communication improved* gradually. For that reason, they felt able to share their knowledge with team members more effectively. Additionally, *PBL helped in understanding concepts in Modern Physics/ Physics content knowledge* in particular, and they felt their understanding was improved. The science program physics majors generally noted that this approach improved their *problem-solving skills* and helped in their *being able to connect and build different ideas and points of view*. Pea (1993) notes that in PBL, students work together on complex problems, thus sharing the cognitive load among group members, as well as reaping the benefit of distributed expertise within the group. Swapping knowledge and information is a vital part of learning together, as knowledge is constructed socially through joint efforts towards common objectives. However, Rochelle disagreed, saying the very essence of collaboration is the construction of shared meaning (1996). Thus, from a sociocultural perspective, as learners participate in activities, they internalise what they have learned from working together (Palincsar & Herrenkohl, 1999; Vygotsky, 1978). In this study the pre-service teachers all agreed that PBL has *improved their communication in English* language and felt that they became *more positive and hardworking* on their course project.

In terms of the connection between creative thinking and PBL, in general, students were of the opinion that this method of learning *increased their creativity gradually*. They said it helped them *solve their project problems*, and the majority of students in the science class said that they *were able to express their opinion* as a consequence came to *know how and when they should come up with their creative ideas* to be address their problems. They also felt PBL *sustained their interest* in the course problems, and hence they managed better when *implementing their skills of learning in bridging ideas*. Gijbels, Dochy, Den Bossche, and Segers (2005) and Shore, Shore and Broggs (2004) report similar results, saying that learning via PBL (face-to-face) can lead to long-term retention of knowledge, and can improve the combination of knowledge resulting in an increased intrinsic interest in the course subject. In contrast, the pre-service teachers report they *could think of solution that had never crossed their mind*, and *use many creative ideas in explaining certain classic concepts* - concepts they never knew before. But one student noted that it is *really hard to be a creative thinker* in this environment.

In terms of the association between critical thinking and PBL, in general, the students were of the same opinion, noting that they felt that their *critical thinking improved*. This is because they *managed to use their critical thinking* in *generating related ideas* in solving their course problems. Some of the science students said that these learning activities helped in *activation and brainstorming* of ideas, and as a result, the activities helped them to *think in terms of cause and effect* for every problem they considered. As for the pre-service teachers, they said they felt that they now *can think more freely* and were able to *answer each question in more acceptable ways*. However, in another different view, there were some criticisms, with some students saying that *their critical thinking did not improve*, with one student saying she *had headache* when trying to solve confusing physics problems.

With regard to their adoption of implementing PBL online in this course, generally, the students remarked that they found it *easy to understand the content of modern physics theory*, and asserted that *learning became more interesting, enjoyable and fun*. One participant declared that students need *this kind of learning approach in order for them to better understand* the course concepts. Additionally, it was felt that PBL online can *expose them to the preparation for responsibility in the workforce* as one might expect of a science major. PBL online also was tagged as a *student-centred approach* as noted by pre-service teachers. However, not surprisingly, some students also commented that they *needed more time to study* when using PBL, and they felt that it all really *depended on the individual* to make things work well in their learning process. This is similar to work reported by Norman and Schmidt (2000), who described PBL that was pesented face-to-face as a more challenging environment of learning, yet one that is a motivating and enjoyable approach.

Technical issues in the online environment also contributed to the development of students' thinking skills, particularly when solving problems. Each individual (i.e., group member) in different places will have the opportunity of developing the solutions and the projects together in a problem-based atmosphere. Sometimes, however, these learning situations also trigger *lack of cooperation from group* members, since they have to take responsibility in the problem solving, as been noted by some participants. Additionally, the students also commented on *losing focus during group discussion, lack of visualization of* physics concepts while learning through online was an issue.

One other problem is that they felt *perplexed at the beginning of the assessment*. This is similar to what Chernobilsky, Nagarajan and Hmelo-Silver's (2005) report - that when the online problems are first presented to student, they are lost, and do not understand that active involvement in the problem-solving process is necessary for them to be successful in finding solution to their problems via online collaboration. Similarly in this study, by failing to work out Problem 1 successfully and on time, the group became strained, and had to re-think their performance and reflect on the reasons for their lack of success. The facilitator had to show them what was expected of them, and help them understand what the assignment required of them. This transformed understanding of the task, and subsequently motivated them to engage with Problem 2 at a different level. The modelling of various questions provided by the facilitator allowed the group to both ask a variety of good questions, and appropriate some of the necessary language. This is similar to work by Bechtel, Davidhizar and Bradshaw (1999) who report that PBL is more time-consuming than traditional instruction, and it thus can reduce the student enthusiasm at the beginning of study. Similar findings are reported by Pearson (2006), where more time to research and think about responses within PBL online discussions were considered 'painful' by students. As well as needing more time and energy to cope with learning, the main obstacle students report about PBL online is also when the first problem they are lost and confused, thus they need more time and guidance from facilitator to get the 'chemistry' right when working with PBL online. As noted above, this kind of approach is totally different from traditional lecture-based learning, where tutorial classes in Malaysia are generally used to help students know how to answer the exam questions.

Finally is the consideration of the students' perceptions of the most useful gain from working with the PBL online approach. The students remarked they are *more able to understand* certain physics concepts, and the majority of the students comments pointed to the perception that they had gained soft skills in terms of *cooperation within groups* and *managing their time better*. This is consistent with research findings reported by Luck and Norton (2004) who say there was not much difference in the group or individual achievements during PBL intervention whether it is online or face-to-face modality, but that *the online problem-based group had shown better performance in terms of their cooperation* compared with face-to-face problem-based learning groups. Another finding is that the students said that they managed to *improve their problem-solving skills* as a result of the PBL online learning process. These findings are supported by the study of Schank, Berman and Macpherson (1999) who suggest that this approach also encourages better student learning, through learning by doing and enables problem-solving, analysis, creativity and communication to take place in the classroom (Bates, 2000). Many scholars who use PBL (e.g., Camp, 1996; Edens, 2000; Major & Palmer, 2001; Rhem, 1998) report that it must be student-centred and consist of self-directed learning if the students are to be more efficient in problem solving. Others argue that, in a PBL online situation, students ought to be active in discovering the problem situation themselves, instead of having the problem given to them (King, 2008). This may be one reason why the students in the present work felt their *efficiency and competence in solving problem* was better than before.

In conclusion, it seems that the students in this work were satisfied with PBL in general, and PBL online in particular. Even though it requires more work, self-direction, independent thinking, and has some technical issues with the Internet, and time constraints, at the same time they felt it provides valuable learning experiences.

7.4 AFFECTIVE EFFECTS: STUDENTS' PERCEPTIONS OF AND INTEREST IN ONLINE LEARNING

The research findings reported in Chapter 6 reveal several themes regarding the students' perceptions of learning through online learning. Overall, it seems that the majority of the science students and pre-service teachers were satisfied with their online learning experience. They presented several main themes: the *students' readiness for online learning* (e.g., always eager to log on to the online course material, having an e-mail account, and comfortable with word processing, etc); *how students were able to access or figure out stuff used for the course* (e.g., managed to read directions directly from the LMS); *motivation effect of online learning* (e.g. stimulation from group study, preferring online learning to face-to-face learning); *time management on online learning* (e.g., can meet deadlines without frequent prodding, allowed time for this course); *understanding of learning content in online learning* (e.g., good at following directions on assignments); and *handling technology while learning computer use in online learning* (e.g., knowing how to handle computers when something goes wrong). In general, the students from either the PBL or traditional group were positive about online learning and it seems there was good engagement while learning this way. Razak (2005), in her work based in the Malaysian context, also reported that students who were involved in online learning were receptive of the intervention. This is also supported in work by Coleridge (2005) who stressed that using ICT had an positive overall impact on students' learning or access to learning, for example, ease and quick access to data and information from the Internet, that is, students were able to construct cognitive activities and develop a mental picture of the problem and the conceptual network upon which it was based. Additionally, the literature suggests that online learning can facilitate the clear, fast and accurate representation of scientific data, allowing the focus of a lesson to move to a meaningful discussion (Miller, 2001). It also seems that online leaning is highly motivating because of access to information and ways to communicate that information effectively.

However, there were some issues of concern which arose in this work. The main issue appears to be the nature of the online assignments (i.e., PBL content knowledge) arrangements, and the content available on the web - particularly for the students in the PBL group. This is not an especially surprising outcome, since the PBL model itself was presented in an 'ill-structured' syllabus with the learning, far from typical learning, which, as noted above, is more usually well-structured and involves rote-learning. Moreover, the learning content delivered using online learning is new for the students. Ambotang and Shukery (2005) suggest that students are sometimes annoyed with e-learning because of initial experiences of difficulty with the technology. In the present work, the students were 'perplexed' at the beginning of the intervention, and needed close of guidance from the instructor on how to do their task individually and in their group. This situation may have contributed to some student dissatisfaction (as noted in Chapter 6).

Along with the development of modern communication technology, the Internet has also effectively influenced students' experiences in terms of collaboration and satisfaction. The findings reported in this work indicate that, in general, students are *satisfied* with this kind of learning since they believe it *improves soft skills* (e.g., communication through computers, how to manage critical meetings online, more confidence when presenting ideas, getting acquainted with the system), *saving time* (e.g., no need to go to the lecturer's office just to ask simple questions, able to make appointments with friends and lecturers through the LMS) and also study in an *interesting environment* (e.g., can use many terms related to modern physics since they can get more electronic resources easily, be able to post interesting relevant pictures and figures to support their statements so as to explain something). Several examples from the literature also have reported successful integration of online learning with PBL, where students were provided with opportunities to use the Internet for achieving content integration as well as communication (see e.g., Liu, Hsieh, Cho & Schallert, 2006; Oberlender & Talbert-Johnson, 2004; Taradi, Taradi, Radi, & Pokrajac, 2005).

In addition, the SST group said that they had *new experiences of learning* (e.g. getting their own knowledge by searching for information by themselves through online journals, Google Scholar, library databases and archives) and managed to *get plenty of relevant information*. On the other hand, learning online also put them into a *challenging environment for learning*. This is because some places at the University either lacked Internet coverage, or had very slow connections, and there was not enough bandwidth for them to download or upload large files. In consequence, sometimes students needed to sit in a particular place to connect to the Internet. This situation was even worse when they set up meetings late (e.g., when this was the only time that all members were available), and sometimes it was hard for them to get transport to places where Internet could be accessed easily. This was the main reason why some of the students claimed they were not comfortable when learning online.

On the other hand, the SESD students also felt that online learning is a *new way of learning* (e.g., learning through computer, getting information by themselves, setting their own group and individual timetables through the LMS, sending and accepting content from friends and the facilitator, and constructing their own learning activities) which, as a consequence, made them *more independent* and able to take full responsibility for their learning online. This is in line with work by Neo and Neo (2001), who report that students become engaged in more student-centered learning after experiencing PBL in a multimedia-oriented classroom.

In terms of convenience, students reported feeling *really comfortable* learning through the Internet and using computers. The massive amount of information available from the Internet played important role in developing their critical thinking, as they had to synthesise and analyse their results and consider carefully what they needed to report in their final findings. This is in line with work by Chan Lin and Chi Chan (2007) who report that students have to use divergent thinking when a variety of sources and information are accessible for analysing problems. Additionally, although most of the students reported previous experience in using Internet Messenger, Facebook, Skype and so on, to chat with others, conversing on academic work was new to them. Students posted queries about technical issues, for example, the use of special fonts and symbols in science terms, writing formulae for physics such as $H\psi = E\psi$ or $E = mc^2$. Students also first learned how to register, sign-in, and manage their own personal data electronically through the LMS.

Another concern regarding the convenience of an online learning approach is *the communication linkage* between group members when they were apart (in space and time). Although they were not at the same place and time they still managed to have meetings (e.g., asynchronous meetings via a forum) to gather relevant information in the process for writing up the final findings. From this, they shared experiences of searching, investigating - in addition to gathering information and identifying diverse resources. Thus, advanced searching strategies were observed among students as they became more knowledgeable about a topic. Due to their familiarity with the topic, more relevant keywords were also used during the search for resources. This is in line with work by Gursul and Keser (2009) whose students working in a PBL environment were able to share their tasks and cooperate in the solution of problems using online learning compared using face-to-face learning.

Notwithstanding this, like many other online learning strategies, the use of the learning management system (LMS) and Internet for the study had some limitations. As noted above, some students complained about a *poor Internet connection* in some places within the campus making them more irritated when learning on-line. Though they have the facilities, the difficulty of getting reliable Internet access coverage suggests that the campus requires some improvement in this area, and needs to upgrade some facilities if the University is to see this new approach of learning as successful in the future. Finally, some students from the SESD group said that it was *very hard to visualize what they were talking about through online* (i.e., synchronously), since they conversed in a very limited online chat room provided by the LMS.

In terms of knowledge gained when learning via online, the findings suggest that PBL online is *capable of exposing students to many things and allows them to have access to information from numerous outside sources*. Additionally, it seems that the learning activities help them to *understand Modern Physics concepts* and the PBL online approach that requires group cooperation in an online environment results in a constructive process through which students create new knowledge in a socially-mediated process. This finding is in line with that of Chan Lin and Chi Chan's (2007) work, where students' final projects in a PBL online integration project involving research design show that they had obtained a deep understanding of the content they had studied. Thus, students were able to construct their own knowledge based on the problem defined, and information gathered and explored.

7.5 CHAPTER SUMMARY

With the advent of electronic learning technology, students are facing new challenges with respect to perceiving knowledge and setting new goals to manage today's global knowledge. In the Modern Physics course, an innovative approach using LMS and facilitated by the lecturer was implemented in order to enrich the PBL online experience. The course was problem-based so that students could engage in substantial and meaningful interaction with team members and facilitator. This chapter has discussed the effectiveness of PBL online amongst science physics students and also pre-service science teacher at the Universiti Malaysia Sabah during the semester II, 2009/2010 Session of learning. It has shown clearly that students welcome the PBL online, though it still has obstacles and deficiencies in the process of learning. This chapter also discussed in detail the effectiveness of this pedagogy, in that it has improved students' creative and critical thinking in certain ways. Through the help from the online discussion forums and the help from group members and the facilitator, students shifted towards independent learning establishing more regular self-directed learning practices in PBL. They were also exposed to the virtual library and information science fields, particularly in the modern physics domain by exploiting the advantages of information communication and technology (ICT). They not only achieved the learning objectives, but were also able to extend their knowledge to a more practical and useful level. In the next chapter, implications and suggestions for further study are detailed, and the conclusions of the thesis are discussed.

CHAPTER 8: IMPLICATIONS, SUGGESTIONS AND CONCLUSIONS

8 CHAPTER OVERVIEW

This last chapter concludes the study by discussing the implications, suggestions and conclusions. It begins with suggestions arising from the study that are of a practical nature, along with the theory-based implications and suggestions for future research. The chapter ends with conclusions that summarize the thesis.

8.1 IMPLICATIONS AND SUGGESTIONS

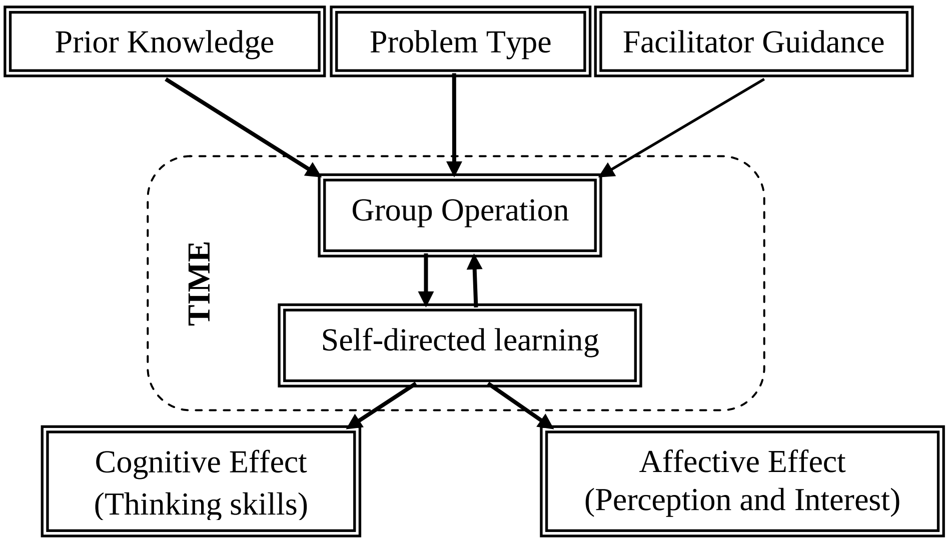
In this twenty-first century, the teaching and learning process in science have been subject to an enormous amount of research, much of which suggests the learning of science is not as it should be. The process of globalisation, the development of information communication and technologies, and a 'world without boundaries' means we need students who can do more than apply the knowledge they have learned, but who can think and are capable of investigation of problems and able to produce the best judgement, assessment, opinion and use perspicacity to draw conclusions. For this reason, the teaching and learning science process needs to be shifted from rote learning to the thinking skills, especially when teaching science subjects. Moreover, as noted at the beginning of this thesis, the Malaysian government is keen to change the teaching and learning approaches by using the information technologies and computers, so that Malaysian students are not left behind by the rapid development elsewhere. The findings in this study suggest that it is possible to implement a PBL online approach in Malaysia, and that this provides educational benefits, particularly for undergraduate physics students. Some specific implications directed to this paradigm shift are now presented.

8.1.1 Practical Implications: Potential on Performing PBL Online in Malaysia

The findings from this thesis suggest that PBL online can be employed in Malaysia, at the tertiary level. At this level, students are seemingly ready to accept such a teaching and learning approach because they have already developed some independent learning skills.

PBL stresses adult learning principles, such as the mixing of knowledge and skills, cumulative learning, self-directed learning, learning through experience, learning by objectives, focused learning, learning based on problems and reflection. Hence, undergraduate students need to be trained so that they can study independently, with minimal guidance (comparatively speaking) from lectures or teachers. These elements of PBL must be prepared so that the implementation can generate a holistic and effective education system to improve students' creative and critical thinking. Figure 19 shows the concept of a holistic approach to PBL that the present study indicates can be implemented at a tertiary level in Malaysia. It appears that this model can produce a positive impact on students' creative thinking and critical thinking skills.

Figure 19
Factors that influence learning and its cognitive and affective effect



a) Problem type for PBL

It is suggested in this work that the problem given must be an authentic problem, based on daily life and current issues. This kind of problem is more meaningful to students, and thereby more likely to show how the learning is relevant and can be applied in real life situations. Second, the problem must first be fairly easy, followed by harder problems, appropriate to the students' level of capability. The way the problems are presented also should be interesting, for example, using relevant big and colourful pictures, slides, videos and so on. These problems must use the real facts or something that is genuine and not just a replication from another source.

In this study, PBL was implemented only in a university setting. It is suggested that this method could be adjusted so that students can do their learning activities outside the university. This kind of activity may well be more interesting and serve to motivate students to engage more with their learning. As been remarked by some participants, this might include field trips, or other off-campus activities.

b) Implementing PBL online in other subjects

Additionally, it is proposed here that other subjects might benefit from this teaching and learning approach. Some of the participants suggested the same thing, suggesting other physics topics like optics, and other subjects entirely.

Consequently, it is proposed that this approach be put into practice across the curriculum at the tertiary level. Lecturers from different subjects (e.g. chemistry, biology, mathematics, environmental science etc) may wish to plan and create problems that embrace appropriate topics in their subject. As in the real world, the real knowledge from other fields will be needed to solve a particular problem.

c) Time allocation

In terms of time, lecturers can allocate time in the same way they do during traditional semester learning classes. If only a little time has been assigned, then lecturers will only be able to pose fairly simple real life problems. Lecturers might present a problem that can be solved in a month or more, depending on the requirements of curriculum, students' readiness and the suitability of the topic. However, it is suggested here that the PBL method can actually save time because it can go across topics, and mix several subjects (e.g., physics and biology might be combined to biophysics), meaning two subjects can be thought of or delivered as one subject.

Additionally, it proposed that the time allocated to complete the problem is suitable to students' capability. Otherwise, students may run into trouble with their time management, making it unlikely the learning process will be successful.

Students require time to think, interpret and achieve mutually-agreed understanding of the problem and potential solutions. Thus, the problem must be well designed and suited to the student's capability and competency, allowing adequate time.

d) Facilitator practice

This research also suggests that, to be effective, PBL online requires the facilitator to be trained so that they know how to be prepared to play an important role in the guidance of solving problems, particularly during the reflection stage – and not to teach in their usual way. At the end of the learning process (i.e., the reflection stage) the facilitator needs to emphasise strengthening students' knowledge.

To make PBL online a successful teaching and learning approach, lecturers also need to be assisted in learning how to develop and construct meaningful problems, learning appropriate questioning techniques, understanding how to handle collaborative learning, and helping students engage in reflexive practice and metacognition. Lecturers in different subjects or departments can cooperate to create genuine, authentic problems in their context, suitable for the curriculum objectives. At the same time, they need know how to empower students in collaborative learning. Facilitators need to be prepared mentally in order to implement this learning approach. They need to be brave, as PBL online involves something of a paradigm shift away from rote learning to the thinking learning. Lecturers also are advised not to focus too much on exam-based or test-oriented assessment activities in order to give students a chance to deepen their own content knowledge. In PBL online then, lecturers or facilitators sometimes are also act like students where they learn from their students in direct or indirect ways.

e) Resource and facilities for PBL

Since the PBL learning activities in this study were implemented online, it is clear that students have the capacity to become connected to a large source of information worldwide, anytime and anywhere. Despite the apparent ease of collecting relevant information through the Internet, the quality of the Internet connection is paramount. Hence, not surprisingly, if PBL online is to be utilized widely in Malaysia or elsewhere, the Internet provider to any university has to maintain and support quality Internet communication system utility (e.g., provide many places where easy Internet coverage is available, provide high speed to the Internet access, and capacity to download or upload files). The main complaint from the students in this work related to that technical problems regarding to the Internet and Wifi. If such technical problems are encountered routinely, this can inhibit effective engagement with PBL online, meaning that it is hard for students to engage in their PBL learning activities, at their own leisure and free time. This might then lead to them under value what might otherwise be seen as a valuable learning approach.

f) Evaluation system

To support the implementation of PBL online in the Malaysian tertiary education system, the present evaluation system requires modification. Student learning needs be evaluated across different skills and facets of learning (e.g., present knowledge, capability of tackling problems, thinking skills, and communication skills). Perhaps attitude, motivation, self efficacy also might be considered for evaluation. In any case, evaluation of student learning should be related to desired graduate attributes, and, in this work, this appears not to be the case for the university involved.

8.1.2 Theoretical Implications

The research findings suggest that activities in PBL such as defining problems, searching for information, solving problems, and reflection, that are done collaboratively with team members and facilitated by a staff member have a positive influence on students' thinking and learning. Students' style of thinking can be improved to a level similar to that of adults' through the questions and inquiries posed by the facilitator. In PBL, problem is the main focus of the learning, and learning occurs through problem-solving activities. Declarative knowledge and skills are nurtured in this method, meaning creative and critical thinking are required by students to solve problems. These learning processes will be on going, and may help students store knowledge and skills in their long term memory. For this reason, it is likely easier to recall such knowledge when students need it in the future.

8.1.3 Research Implications

There is a serious lack of PBL online research done in Malaysia. Given the emphasis that the Malaysian Government is placing on education generally, and the use of online and ICT in learning, this is surprising and concerning. Hence, the next implication is that we need more research about online learning, PBL, and PBL online in order to recognize its effectiveness at different levels, such as primary school, secondary school and off-campus, and for different subjects.

Given that the present work points to a positive effect for affective variables such as students' self-dedicated learning, and soft skills (i.e., communication skills, analytical skills, team work, lifelong learning and information management skills), we need more investigation in detail of these aspects in PBL online. Thus, the researcher strongly suggests that other researchers throughout Malaysia engage in qualitative research in order to seek deeper understanding of some of the issues investigated here, particularly on holistic development of the individual as a learner.

If this research were replicated, the researcher also suggests using other instruments to quantify the creative and critical thinking. Other instruments that can might used to measure creativity thinking include the *Scientific Creative Thinking* instrument (Weiping, 2002). Similarly, for critical thinking, one might use other instruments such as the *California Critical Thinking Inventory* and *Critical Thinking Disposition* instrument. Additionally, other researchers might seek to develop instruments that are particularly suitable to learning in the Malaysian context.

This study used only the learning management system (LMS) provided by the University as the vehicle for the entire learning processes. From this LMS, a PBL model instruction was constructed suited to the capacity of the LMS. Further research might consider a standalone PBL web-page used to promote key elements of PBL clearly and in a more interesting way. They could also create special instructional methods following the PBL criteria to make the teaching and learning process more motivating and meaningful for both students and facilitators or lecturers.

Regarding problems of quality, additional research also could be done in order to trial different problems suitable for Malaysian students' background. This also needs to be consistent with student capabilities so that they can solve the problems within the timeframes given. As suggested by Schmidt and Moust (2000), the quality of problems in PBL plays an important role affecting students' achievement and interest towards their learning. In summary, there are many more research projects that need to be implemented by researchers in Malaysia to maximize the potential benefits of PBL online. This is because the field of PBL online and, indeed, online learning is in its infancy, at least in terms of research, in the Malaysian tertiary education system. As the Government invests heavily in online learning, it is essential this is informed by research, such as that conducted in this work and new projects as suggested here.

8.2 CONCLUSIONS

The cognitive effectiveness of PBL online has been investigated throughout this study. From the research, it appears that PBL online has the potential to improve undergraduate of science physic students' and pre-service science teachers' creative thinking. At the same time, it is also observed that students' critical thinking was impacted positively, as has been students' motivation and interest in learning.

In conclusion, through PBL online, students were engaged in a holistic form of the teaching and learning process (e.g., content learning; skill of learning; also learning with minds-on and hands-on), which is quite different to their traditional experiences. Although at the beginning students were a bit overwhelmed, the outcomes from this study suggest that PBL online can be useful for undergraduate science students and pre-service science teachers.

PBL online, then, has high potential for improvement of learning, and it seems to help shift from rote-learning to learning with thinking; from passive learning to active learning; from surface learning to deep learning; and from forced learning to meaningful learning. PBL online has shifted the minds of students from rote-learning and memorising to a notion where they see value and engaging more higher level cognitive activity like creative and critical thinking that comes through PBL online. Online learning and PBL help student learn how to consider engagement of higher level thinking and consider thinking as mentioned before, we see improvement in creative thinking and also some but less in critical thinking. If we look at the critical thinking, it is a complex thing typical to do that the effect not likely will come out in a course (in this case modern physics). However in order to this works well overall, maybe PBL online should be implemented by a whole programme approach rather than delivery via a single course. Because during the intervention, student learnt only one course that is using PBL online, and the rest of their courses still using the rote-learning approache. Hence students get mixed messages.

Students also report feeling more self-directed as learners, that they became used to and referred more to references and resources, and became more independent learners. All of these attributes are likely to contribute to lifelong learning. Moreover, students had the opportunity to improve their interpersonal communication skills, and also how they might deliver their own judgments and opinions effectively - an important characteristic for life in today’s challenging world.

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APPENDIX I - The Letter of Approval from the Universiti Malaysia Sabah

05-11-08;12:21 ; # 1/ 1

UNIVERSITI MALAYSIA SABAH
Sekolah Sains dan Teknologi
School of Science and Technology

CERTIFIED TO MS ISO 9001

Reference : UMS/SK6.1/K23

Date : 4 November 2008

Ms. Fauziah Sulaiman
Centre for Science and Technology
Education Research (CSTER)
Private Bag 3105
University of Waikato
Hamilton, New Zealand

Ms,

TO SEEK AN APPROVAL TO CONDUCT INTERVENTION OF THE MODERN PHYSICS COURSE (SEMESTER ii, SESSION 2008/2009)

Your letter dated 28 October 2008 regarding the above matter refers.

I am pleased to inform you that the School has no objection for you to conduct the intervention as per request.

Thank you.

Yours sincerely,

PROF. DR. MOHD HARUN ABDULLAH
Dean

Copy File

BERTEKAD CEMERLANG

BEG BERKUNCI NO. 2073, 88999 KOTA KINABALU, SABAH, MALAYSIA.
• Tel : 6088-320 000 samb. 5887 • Faks : 6088-435 324 • E-mel : pejsst@ums.edu.my • Laman web : http://www.ums.edu.my

APPENDIX II - The Letter of Approval from the Economic Planning Unit

UNIT PERANCANG EKONOMI
Economic Planning Unit
JABATAN PERDANA MENTERI
Prime Minister's Department
BLOK B5 & B6
PUSAT PENTADBIRAN KERAJAAN PERSEKUTUAN
62502 PUTRAJAYA
MALAYSIA

EPU
ECONOMIC PLANNING UNIT
PRIME MINISTER'S DEPARTMENT, MALAYSIA

Telefon : *603-8888 3333*
Telefax : *603-888*

Ruj. Tuan:
Your Ref.: UPE: 40/200/19/2345

Ruj. Kami:
Our Ref.: 20 October 2008

Tarikh:
Date:

Fauziah Sulaiman
Unit 3, 4A Baffles House
Baffles Cres, 3216 Silverdale Hamilton
New Zealand

APPLICATION TO CONDUCT RESEARCH IN MALAYSIA

With reference to your application dated 23 September 2008, I am pleased to inform you that your application to conduct research in Malaysia has been approved by the **Research Promotion and Co-Ordination Committee, Economic Planning Unit, Prime Minister's Department.** The details of the approval are as follows:

Researcher's name	:	**FAUZIAH SULAIMAN**
Passport No. / I. C No:		**780616-12-5144**
Nationality	:	**MALAYSIAN**
Title of Research	:	**"IMPROVING LEARNING IN UNDERGRADUATE PHYSICS USING PROBLEM-BASED LEARNING (PBL) AND E-LEARNING"**

Period of Research Approved: **THREE YEARS**

2. Please collect your Research Pass in person from the Economic Planning Unit, Prime Minister's Department, Parcel B, Level 4 Block B5, Federal Government Administrative Centre, 62502 Putrajaya and bring along two (2) passport size photographs. You are also required to comply with the rules and regulations stipulated from time to time by the agencies with which you have dealings in the conduct of your research.

3. I would like to draw your attention to the undertaking signed by you that you will submit without cost to the Economic Planning Unit the following documents:

a) A brief summary of your research findings on completion of your research and before you leave Malaysia; and

b) Three (3) copies of your final dissertation/publication.

4. Lastly, please submit a copy of your preliminary and final report directly to the State Government where you carried out your research. Thank you.

Yours sincerely,

(**MUNIRAH ABD. MANAN**)
For Director General,
Macro Economic Section,
Economic Planning Unit.
E-mail: munirah@epu.gov.my
Tel: 88882809/2818/2958
Fax: 88883798

ATTENTION

This letter is only to inform you the status of your application and **cannot be used as a research pass**.

C.c:

Ketua Setiausaha,
Kementerian Pengajian Tinggi,
Aras 7, Blok E3, Parcel E,
Pusat Pentadbiran Kerajaan Persekutuan,
62505 Putrajaya
(u.p: En. Chuah Bee Leng) (Ruj. Tuan: KPT.R.620-1/1/1Jld.9 (55)

APPENDIX III - Information to Students

	INFORMATION TO STUDENTS **PARTICIPANT RIGHT TO DECLINE USE OF RESEARCH MATERIAL**

This information for students enrolled in course 'Modern Physics' Semester II, Session 2008/2009 at the School of Science and Technology (SST) and School of Education and Social Development (SESD), of the University Malaysia Sabah. In this study those who volunteer will be involved in research canvassing their views about several types of learning and teaching activities. Agreement to be involved in this research means commitment to participation in surveys and interviews (both individual and focus group, each of about 10-15 minutes duration), and observation of two classes.

All the data will be gathered and interpreted by the researcher for her PhD studies. The researcher also intends to submit articles to research journals, conference proceeding and the like. No student will be identified by name in any reports or in the thesis, the researchers use of this information will not affect student progress in the course.

If any of you are not willing to allow the researcher to use these data for her research, you have the right to decline, and you will not be disadvantaged in any way.

Your cooperation is very much appreciated. Thank You.

Yours sincerely

(Fauziah Sulaiman)

APPENDIX IV - Consent Form for the Participants

Consent form for the participants

Improving Learning in Undergraduate Physics using Problem-Based Learning (PBL) Online.

I have read the information sheet concerning this project and understand what the project is about and what I am committing to if I chose to be involved in the study. All my questions have been answered to my satisfaction, and I understand that I am free to request further information at any stage and to withdraw at any stage.

I understand that:

- My participation in the project is entirely voluntary.
- I am free to withdraw from the project at any time without any penalty.
- The data will be destroyed at the conclusion of the project but any raw data on which the results of the project depend will be retained in secure storage for three years, after which they will be destroyed.
- I am able to read the transcripts of my interview reports and delete any information I do not wish to have included in the project.
- This project involves a semi-structured interview. The questions which will be asked have not been determined, but will depend on the way in which the interview develops and that in the event that the line of questioning develops in such a way that I feel hesitant or uncomfortable I may decline to answer any particular question(s) and/or may withdraw from the project without any penalty of any kind.
- The results of the study will be treated in strict confidence, and that I will remain anonymous. Within this restriction, results of the project will be made available to me at my request.
- Any personal information gathered during the project will be confidential and will only be seen by the researcher's supervisor, Assoc. Prof. Dr. Richard K. Coll and Assoc. Prof. Dr. Mike Forret, and the researcher, Ms. Fauziah Sulaiman.
- The result of the project may be published but my anonymity will be preserved.

I agree to take part in this project.

____________________________ ________________________

(Signature of participant) (Date)

This project has been reviewed and approved by the CSTER Ethics Committee of the University of Waikato.

APPENDIX V - Demographic Survey for SESD Students

The intention of this survey is to obtain some demographic background to describe the sample used in this study. Please tick [√] or fill in the blanks with written answer.
(SESD Students)

1	Your are currently in group		**[ ] Traditional**	**[ ]PBL**
2	Gender		[ ] Male	[ ] Female
3	Major	[ ] Physics *(go to question no .4)*	[ ] Mathematics *(go to question no .4)*	[ ] others *(please state)* ________________ *(go to question no.5)*
4	What is your best Physic's grade for the last semester?	Name of Course: ____________________________ Grade: ______________________		
5	What semester is this semester of your enrolment	: ___________________________ *(e.g. Sem.1; Sem. 2; Sem. 3; etc.)*		
6	Is this the first time you have taken this course?		[ ] Yes	[ ] No *(please state)* ___________________
7	Is this your first time taking this course?	[ ] Yes	[ ] No *(please state)* ________________________	
8	Scholarship type	[ ] PTPTN [ ] MARA	[ ] MOHE *(Ministry of Higher Education of Malaysia)*	[ ] State government [ ] others *(please state)* ________________________
9	Qualification	[ ] STPM/HSC [ ] Matriculation	[ ] Diploma	[ ] others *(please state)* _____________________________ _______________________
10	Where do you live	[ ] On campus (hostel residents)	[ ] outside campus/tenant	[ ] live with family outside campus
11	Which state do you came from?	Please state: ____ *(e.g. Sabah; Sarawak; Selangor; Johor; etc.)*		

12	Do you have a personal computer at your home/residence	[ ] Yes	[ ] No
13	Do you have Internet connection at your home/residence	[ ] Yes	[ ] No
14	Have you ever heard about Problem-Based-Learning (PBL)?	[ ] Yes	[ ] No
15	Have you ever heard about creative thinking?	[ ] Yes	[ ] No
16	Have you ever heard about critical thinking?	[ ] Yes	[ ] No

Your cooperation is very much appreciated. Thank you

APPENDIX VI - Demographic Survey for SST Students

The intention of this survey is to seek your demographic background as the sample of this study. Please tick [√] or fill in the blanks with suitable answer.
(SST Students)

1	Your are currently in group		**[ ] Traditional**	**[ ]PBL**
2	Gender		[ ] Male	[ ] Female
3	What semester is this semester in your enrolment	: ____________________ *(e.g. Sem.1; Sem. 2; Sem. 3; etc.)*		
4	What is your best Physic's grade for the last semester?	Name of Course: ____________________ Grade: ________________		
5	Is this your first time taking this course?		[ ] Yes	[ ] No *(please state)* ______________
6	Scholarship	[ ] PTPTN [ ] MARA	[ ] MOHE *(Ministry of Higher Education of Malaysia)*	[ ] State Government [ ] others *(please state)* __________________
7	Qualification	[ ] STPM/HSC [ ] Matriculation	[ ] Diploma	[ ] others *(please state)* ______________________ __________________
8	Where do you live	[ ] Inside campus (hostel residents)	[ ] outside campus/tenant	[ ] live with family outside campus
9	Which state are you came from?	Please state: ____________________________________ *(e.g. Sabah; Sarawak; Selangor; Johor; etc.)*		

10	Do you have computer/personal computer at your home/residence	[ ] Yes	[ ] No
11	Do you have Internet connection at your home/residence	[ ] Yes	[ ] No
12	Have you ever heard about Problem-Based-Learning (PBL)?	[ ] Yes	[ ] No
13	Have you ever heard about creativity thinking?	[ ] Yes	[ ] No
14	Have you ever heard about critical thinking?	[ ] Yes	[ ] No

Your cooperation is very much appreciated. Thank you

APPENDIX VII - Survey of Students' Pre-Concept of Modern Physics

Students' Pre-Concept of Modern Physics

Circle your learning group: **Traditional** **PBL**

The main purpose of this survey is to better understand students' background about Modern Physics before attending the Modern Physics course. Please circle ONE number on the right of the question. Chose the number that best describes your view of your knowledge for each of the topics listed, according to the following scale:

1	2	3	4	5
No knowledge at all	**Little knowledge**	**Neutral**	**Some Knowledge**	**A lot of knowledge**

Chapter	Topic	Sub-Topics	Likert Scale				
1	*Introduction*	Review of Classical Physics	1	2	3	4	5
		Unit and dimensions	1	2	3	4	5
		Significant Figures	1	2	3	4	5
		Theory, Experiment, Law	1	2	3	4	5
2	*The Special Theory of Relativity*	Postulates of Relativity	1	2	3	4	5
		Einstein's postulates	1	2	3	4	5
		Simultaneity and Ideal Observers	1	2	3	4	5
		Time dilation	1	2	3	4	5
		Length contraction	1	2	3	4	5
		Velocities in different reference frames	1	2	3	4	5
		Relativistic momentum	1	2	3	4	5
		Mass and energy	1	2	3	4	5
		Relativistic kinetic energy	1	2	3	4	5
3	*Quantization*	The wave-particle duality	1	2	3	4	5
		Matter waves	1	2	3	4	5
		Electron microscopes	1	2	3	4	5
		The Uncertainty Principle	1	2	3	4	5
		Wave functions for a confined particle	1	2	3	4	5
		The hydrogen atom: Wave functions and quantum numbers	1	2	3	4	5

		The exclusion principle	1	2	3	4	5
		electron configurations for atoms other than hydrogen	1	2	3	4	5
		Understanding the periodic table	1	2	3	4	5
4	*Nuclear physics*	Nuclear structure	1	2	3	4	5
		Binding energy	1	2	3	4	5
		Radioactivity	1	2	3	4	5
		Radioactive decay rates and half-lives	1	2	3	4	5
5	*Particle Physics*	Fundamental particles	1	2	3	4	5
		the weak nuclear force	1	2	3	4	5
		the electromagnetic force	1	2	3	4	5
		the strong nuclear force	1	2	3	4	5
		Strong Interaction	1	2	3	4	5
		Weak Interaction	1	2	3	4	5
		Weak forces and electromagnetic	1	2	3	4	5
		Strong force with the electroweak force	1	2	3	4	5
		The *quarks, lepton, muon* particle	1	2	3	4	5

APPENDIX VIII - Survey of Students' Level of Computer Usage in Learning and Students' Readiness for Learning via Online Learning

	Students' Readiness for Learning via Online and Student's Competencies and Skills in Using a Personnel Computer **The objective of this survey is to seek views about your readiness, competencies, skills, online expertise and online activities before working in the online learning classroom. This survey consists of three parts: Part A; Part B and Part C.** **Please read and follow the instructions carefully.**

Part A is intended to find out what you think are your skills and readiness for learning through the use of a computer or to work with online learning

Part B is intended to find out what you think are your skills and competencies are for using Personnel Computer. There are four sections in this part (Section 1, 2, 3 and 4 respectively).

Part C is intended to find out what you think is your expertise in online learning and related activities.

Your responses in this questionnaire are completely confidential and will not in any way contribute to the assessment of the course, SF108303. Thus, your cooperation is very much appreciated. Thank you.

Circle your learning group: Traditional PBL

Part A: Please circle ONE number on the right of the question. Chose the number that best describes your view for each of the topics listed, according to the following scale:

1	2	3	4	5
Strongly Disagree	Disagree	Neutral/Undecided	Agree	Strongly Agree

1	***COMPUTER SKILLS***					
1.1	I have easy access to a PC	1	2	3	4	5
1.2	I am comfortable about using a PC	1	2	3	4	5
1.3	I am very skilful in handling basic PC use	1	2	3	4	5
	**PC = personal computer*					
2	***INTERNET SKILLS***					
2.1	I have easy access to the Internet	1	2	3	4	5
2.2	I am competent in usage of the Internet	1	2	3	4	5
2.3	My Internet skills are sufficient for taking a web-based course	1	2	3	4	5
3	***STUDENTS' READINESS***					
3.1	I feel comfortable learning via a PC and in online learning	1	2	3	4	5
3.2	I feel comfortable working with a PC *(e.g. doing assignments, assessment, etc.)*	1	2	3	4	5
3.3	I feel comfortable communicating with other classmates online	1	2	3	4	5
3.4	I feel comfortable communicating with my instructor online	1	2	3	4	5
3.5	I feel comfortable searching for information online	1	2	3	4	5
3.6	I feel comfortable sharing my knowledge with friends and facilitator online	1	2	3	4	5
3.7	I am comfortable changing my source of learning with friends via online	1	2	3	4	5
3.8	I know how to use a standard word processor, such as Microsoft Word, Microsoft Works, or Word Perfect	1	2	3	4	5
3.9	I feel capable of determining main ideas and concepts when reading notes, text books or other knowledge sources online	1	2	3	4	5
3.10	I feel I am a self-motivated, independent learner, when it comes to learning online	1	2	3	4	5
3.11	I am comfortable with file management on a PC, such as moving files around different directories and drives, saving files, or deleting files.	1	2	3	4	5

4	***STUDENT PERSONALITIES***					
4.1	I have very strong motivation towards online learning	1	2	3	4	5
4.2	I can improve my problem-solving skill ability via online learning	1	2	3	4	5
4.3	I can improve my ability to work independently	1	2	3	4	5
4.4	I can improve myself in terms of my task management and organization	1	2	3	4	5

5	***CULTURAL FACTORS***					
5.1	I find face-to-face learning more convenient than online learning	1	2	3	4	5
5.2	I believe that my cultural beliefs about online learning are acceptable	1	2	3	4	5
5.3	I believe that my culture is consistent with learning via online learning	1	2	3	4	5
5.4	My family support my learning through online learning	1	2	3	4	5

6	***LEARNING STYLE***					
6.1	I feel that online learning is important in classroom discussion	1	2	3	4	5
6.2	I think that online learning has improved my reading comprehension	1	2	3	4	5
6.3	I think that online learning has improved my written expression	1	2	3	4	5
6.4	I think that online learning has improved my communication skills	1	2	3	4	5

7	***ANXIETY/ TRUST***					
7.1	I am very uncomfortable about disclosing personal information online	1	2	3	4	5
7.2	I believe that I can trust Internet security	1	2	3	4	5
7.3	I am not anxious or nervous about working in an online environment	1	2	3	4	5
7.4	I think the quality of information posted online can be trusted	1	2	3	4	5

Part B: Please circle ONE number on the right of the question. Chose the number that best describes your view for each of the topics listed, according to the following scale:

1	2	3	4	5
No Skill at All	Some Skill	Neutral	Skilled	Strongly Skilled

1	*LEVEL OF SOFTWARE KNOWLEDGE*					
1.1	Word processor software usage *(e.g. MS word, Ampiro/Word pro, Word Perfect etc.)*	1	2	3	4	5
1.2	Electronic motherboard usage *(e.g. MS Excel, Lotus 123 etc.)*	1	2	3	4	5
1.3	Software presentation usage *(e.g. MS Power Point, Freelance etc.)*	1	2	3	4	5
1.4	Database usage *(e.g. MS Access, Dbase etc.)*	1	2	3	4	5
1.5	Graphic software usage *(e.g. Corel Draw, Autocard, Harvard Graphics etc.)*	1	2	3	4	5
1.6	Statistic software usage *(e.g. SAS, SPSS etc.)*	1	2	3	4	5
1.7	Operation system usage					
	1. DOS	1	2	3	4	5
	2. Windows	1	2	3	4	5
	3. MAC OS	1	2	3	4	5
	4. UNIX	1	2	3	4	5
	5. NT/MS2000	1	2	3	4	5
	6. Novell	1	2	3	4	5
1.8	Utility software usage *(e.g. Norton Anti-Virus, Norton Utilities etc.)*	1	2	3	4	5
1.9	Multimedia package usage *(e.g. MM Director, MM Authorware etc.)*	1	2	3	4	5
1.10	Programming *(e.g. C/C++, Java etc.)*	1	2	3	4	5
1.11	Perisian matematik *(e.g. Matlab, etc)*	1	2	3	4	5
1.12	Desktop publishing software *(e.g. Publisher, pagemaker, etc)*	1	2	3	4	5

2	*LEVEL OF COMPUTER HARDWARE SKILL*					
2.1	Upgrading a computer component *(e.g. memory, floppy disk, motherboard)*	1	2	3	4	5
2.2	I understand specifications needed to make a good decision about buying a computer	1	2	3	4	5
2.3	I know how to install/using every piece of equipment for each unit of computer. *(e.g. monitor, CPU, mouse, CD ROM, key board, etc.)*	1	2	3	4	5

2.4	I know every type of card that is connected to the PC mother board and the function for each card *(e.g. display card, sound card, modem etc.)*	1	2	3	4	5
2.5	Using scanner	1	2	3	4	5
2.6	Using printer and plotter	1	2	3	4	5
2.7	Using CD-RW	1	2	3	4	5

3	***LEVEL OF SKILL OF PERSONAL COMPUTER MAINTENANCE***					
3.1	Computer hardware/equipment maintenance *(e.g. computer, maintenance, printer, scanner etc)*	1	2	3	4	5
3.2	Installing software and application *(e.g. installing printer software, scanner software, SPSS software, etc)*	1	2	3	4	5
3.3	Troubleshooter *(e.g. maintenance problem, software problem, virus problem and networking problem)*	1	2	3	4	5
3.4	Handling technology and multimedia equipment *(e.g. LCD projector, OHP, etc)*	1	2	3	4	5
3.5	Usage of 'BIOS SETUP'	1	2	3	4	5

4	***LEVEL OF NETWORKING SKILL***					
4.1	E-mail usage	1	2	3	4	5
4.2	Internet surfing	1	2	3	4	5
4.3	Microsoft networking	1	2	3	4	5
4.4	Novell	1	2	3	4	5
4.5	Differentiate using external modem and card modem	1	2	3	4	5
4.6	Develop web-page	1	2	3	4	5
4.7	HTML/Javascript Usage	1	2	3	4	5
4.8	Uploading/Downloading file	1	2	3	4	5
4.9	Develop your own blog	1	2	3	4	5
4.10	Testimonial/comment *(e.g., Friendster, MySpace, facebook, xanga, tagged, hi5, and blogger)*	1	2	3	4	5
4.11	Using Yahoo Messenger (YM)	1	2	3	4	5
4.12	Using SKYPE	1	2	3	4	5
4.13	Attach and send file using YM/SKYPE	1	2	3	4	5
4.14	Plug-ins, web-cam, sharing photos on-line, conference	1	2	3	4	5

***Part C*: Multiple choice questions.** Please circle ONE number on the left of the question. Chose the number that best describes your view for each of the topics listed, or add your own response:

1	Computer expertise	A	Computer expert
		B	Intermediate users
		C	Had some experience
		D	Computer novices
		E	Other:__________________
			______________________________
2	Did you study keyboarding	A	Never
		B	Yes
		C	Other:__________________
			______________________________
3	Day spent online	A	Daily
		B	2-3 days
		C	4-5 days
		D	Other:__________________
			______________________________
4	Time spent online	A	None
		B	1-5 hours/day
		C	6-10 hours/day
		D	11-15 hours/day
		E	Other:__________________
			______________________________
5	Frequent online activities (for this particular question you can circle more than one answer)	A	Online course/school work
		B	e-mail
		C	Music/Move downloading
		D	Instant messaging
		E	Games
		F	Other:__________________
			______________________________

Your cooperation is very much appreciated. Thank you.

APPENDIX IX - Torrance Test of Creative Thinking Form A

	School of Science and Technology (SST), University Malaysia Sabah

TORRANCE TEST OF CREATIVE THINKING

FORM A

TIME: 45 MINUTES

DON NOT OPEN THIS BOOK UNTIL YOU ARE TOLD TO DO SO

INSTRUCTION: There are six activities all together

You are required to execute all activities as been told to do so.

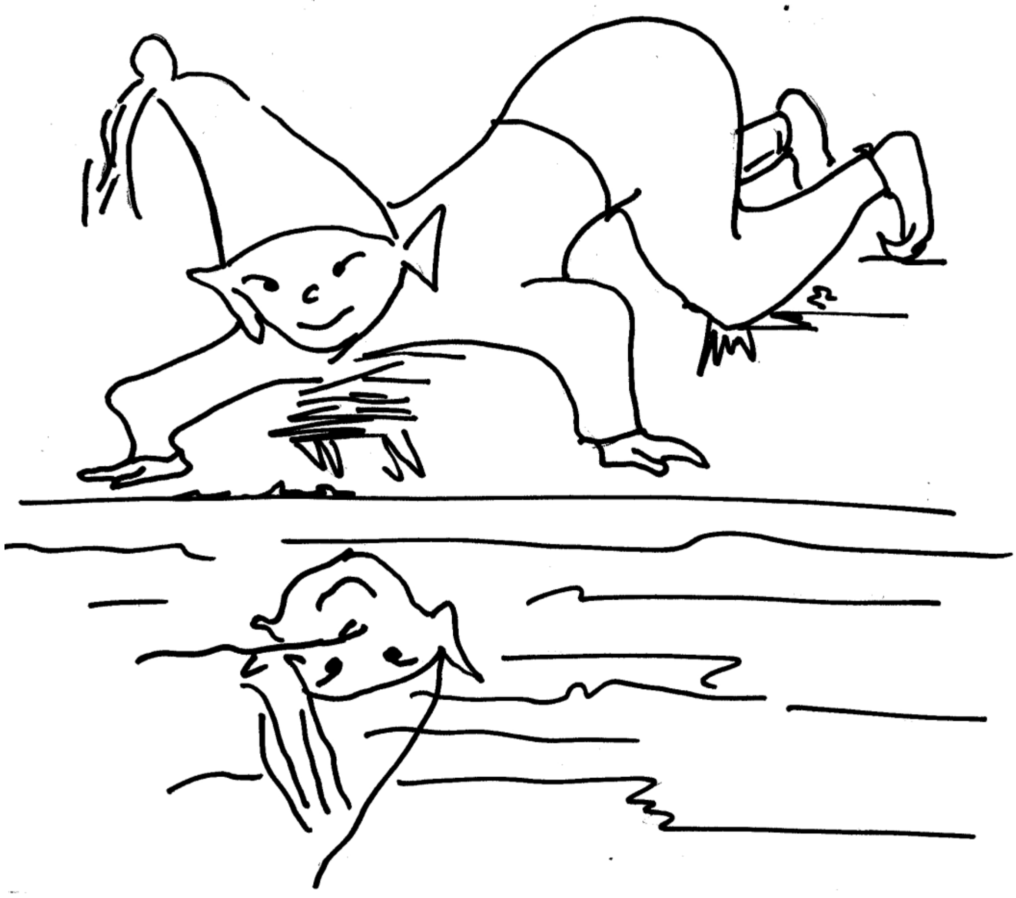
Name ____

Gender ____

Learning group *(*circle your learning group)*	***Traditional***	***PBL***

ACTIVITY 1- 3: LOOK AND PREDICT

For activities 1-3 please look at the picture below.



Please give as many answers as you can.

Nevertheless your answer must be reasonable and sensible.

Example:

I see a person who is about to drink water.

I can a reflection of the persons face in the water.

ACTIVITY 1: ASKING

List down all the questions that you can think based on the picture given. Write your answer in the blanks available.

1 ____________________________________
2 ____________________________________
3 ____________________________________
4 ____________________________________
5 ____________________________________
6 ____________________________________
7 ____________________________________
8 ____________________________________
9 ____________________________________
10 ____________________________________

ACTIVITY 2: ASKING THE CAUSE

List down as many incidents as you can think might be the cause concerning to the picture given before. Write your answer in the blanks available.

1 ____________________________________
2 ____________________________________
3 ____________________________________
4 ____________________________________
5 ____________________________________
6 ____________________________________
7 ____________________________________
8 ____________________________________
9 ____________________________________
10 ____________________________________

Activity 3: GUESSING THE EFFECTS OF AN INCIDENT

Lists down as many effects as you can think cause by the incident happen in the picture given before. Write your answer in the blanks available.

1 ____________________________________
2 ____________________________________
3 ____________________________________
4 ____________________________________
5 ____________________________________
6 ____________________________________
7 ____________________________________

8 ____
9 ____
10 ____

ACTIVITY 4: IMPROVING PRODUCTS

In this activity you are asked to consider a small toy elephant. These toys can be brought in many small shops in Malaysia and cost no more than one or two dollars each. The height of the toy elephant is about 15cm and the weight is about half a kilogram.

On this page and the next, list the steps that you think you could use to change the toy elephant so that children would have more fun when playing with it. Do not worry about the price when considering your suggestions and ideas. The key thing is the toy must be more fun for children to play with.

1 ____
2 ____
3 ____
4 ____
5 ____
6 ____
7 ____
8 ____
9 ____
10 ____

ACTIVITY 5: ALTERNATIVE USES OF COMMON MATERIALS (Cardboard Box)

Many people throw away cardboard boxes when they have finished with them, without thinking how they could be used in other ways.

In this page and in the next page, list down as many fun and interesting uses as you can for cardboard boxes. The size and the number of the boxes are unlimited. Try to think beyond the original purpose of the cardboard box.

1 ______________________________
2 ______________________________
3 ______________________________
4 ______________________________
5 ______________________________
6 ______________________________
7 ______________________________
8 ______________________________
9 ______________________________
10 ______________________________

ACTIVITY 6: JUST ASSUME

Now, you will be given with a situation that will not happen by any change. Nevertheless, you are been required to think this situation already happen. Thus, you can get the opportunity to use your thinking skills to think about other matters that will also happen IF this 'not happening' situation is happening.

In your mind, just assume the situation state earlier is already happen. AFTER THAT, try to think other matters that will happen because of the first situation already happen. In other words, what is the impact and effect from the incident? Make as many assumptions as you can.

The 'none happening' situation state earlier describe as follows:

Assume there are many ropes bond and hang from the sky. The rope hangs straight up to down to the earth as pictured below. What will occur if this situation happens? List down all of your ideas and assumptions in the blanks given.

1 ____

2 ____

3 ____

4 ____

5 ____

6 ____

7 ____

8 ____

9 ____

10 ____

APPENDIX X - Torrance Test of Creative Thinking Form B

	School of Science and Technology (SST), University Malaysia Sabah

TORRANCE TEST OF CREATIVE THINKING

FORM B

TIME: 45 MINUTES

DO NOT OPEN THIS BOOK UNTIL YOU HAVE BEEN TOLD TO DO SO

INSTRUCTION: There are six activities all together

You are required to execute all activities as been told to do so.

Name ____

Gender ____

Learning group *(*circle your learning group)*	***Traditional***	***PBL***

ACTIVITY 1-3: ASK AND GUESS.

Please look closely at the drawing below and use this to answer the question in the first three activities.

The idea of these activities is to look at your ability to ask questions to find out things that you don't know. It is intended also to look at your ability to consider the idea of cause and effect for a particular incident or example.

ACTIVITY 1: ASKING QUESTIONS

Look closely at the drawing and list all the questions that you can think of using the blanks lines below. Avoid asking questions that can be directly answered by looking at the picture. You can keep looking at the picture while you thinking about your questions You need to ask questions that have to be asked in order to know what has happened in the drawing.

1 ______________________________
2 ______________________________
3 ______________________________
4 ______________________________
5 ______________________________
6 ______________________________
7 ______________________________
8 ______________________________
9 ______________________________
10 ______________________________

ACTIVITY 2: ASKING THE CAUSES

List down as many incidents or things that might have happened that caused what you see in the drawing given above. You can speculate what happened *just before the incident* **or** what happened *long before the incident*. You can list as many ideas as you like, and don't be afraid to give unusual ideas.

1 ______________________________
2 ______________________________
3 ______________________________
4 ______________________________
5 ______________________________
6 ______________________________
7 ______________________________
8 ______________________________
9 ______________________________
10 ______________________________

ACTIVITY: GUESSING THE EFFECTS OF AN INCIDENT

Lists as many effects that could happen as a result of the incident depicted in the drawing provided above in the blanks available. You can speculate what will happen *just after the incident* **or** the will happen *a long time in the future after the incident occurred*. You can list as many ideas as you like, and don't be afraid to give unusual ideas.

1 ______________________________
2 ______________________________

3 ______________________________
4 ______________________________
5 ______________________________
6 ______________________________
7 ______________________________
8 ______________________________
9 ______________________________
10 ______________________________

ACTIVITY 4: IMPROVING PRODUCTS

In this activity you are asked to consider a small toy monkey. Such toys can be brought in many small shops in Malaysia, and cost no more than 10 or 15 Malaysian Ringgit each. The height of the toy monkey is about 25 cm and the weight is about half a kilogram.

On this page and the next, list the steps that you think you could use to change the toy monkey so that children would have more fun when playing with it. Do not worry about the price when considering your suggestions and ideas. The key thing is the toy must be more fun for children to play with.

1 ______________________________
2 ______________________________
3 ______________________________
4 ______________________________
5 ______________________________
6 ______________________________
7 ______________________________
8 ______________________________
9 ______________________________
10 ______________________________

ACTIVITY 5: ALTERNATIVE USES OF COMMON MATERIALS (Aluminium Containers)

Many people will throw away aluminium tin containers used to hold soft drinks such as Coca Cola when they have finished with them, without knowing they could be used in many other interesting and extraordinary ways.

In this page and in the next page, list as many fun and interesting uses as you can for waste aluminium containers. You can acts as if the size and the number of aluminium containers available to you is unlimited. Try to think beyond the original purpose of the aluminium containers.

1 ______________________________
2 ______________________________
3 ______________________________
4 ______________________________
5 ______________________________
6 ______________________________
7 ______________________________
8 ______________________________
9 ______________________________
10 ______________________________

ACTIVITY 6: JUST ASSUME

In this activity you are presented with a situation that you cannot change; in other words some specific thing has already happened. You are then asked to think about what else will also happen. So you are asked to consider what are the consequences and effects that arise from the incident? We call these assumptions, and you are asked to make as many assumptions as you can.

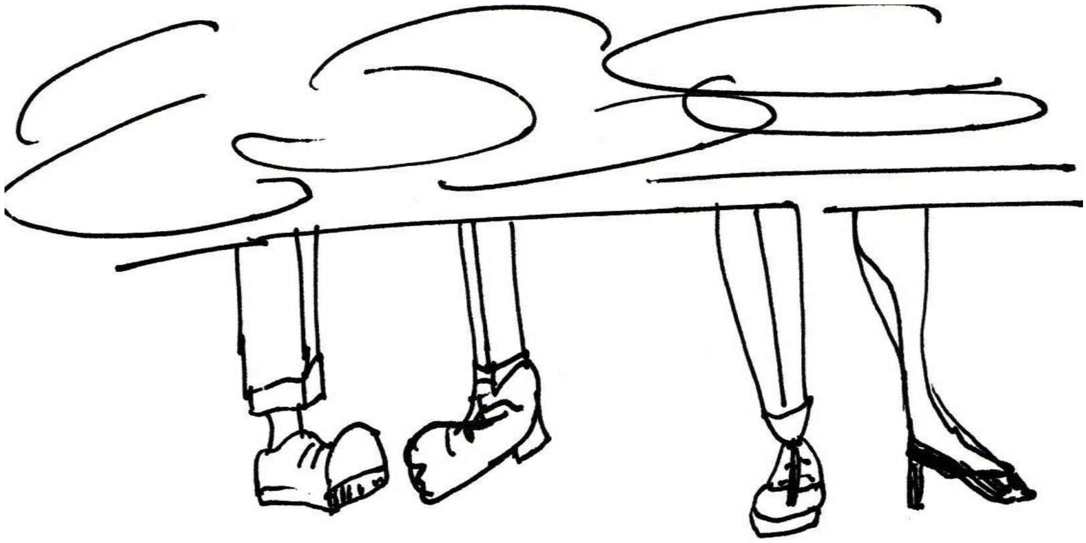
The situation is that a thick fog has covered the earth and it only human legs are visible.

What will happen if this situation really happens?

How would this situation change life on earth?

What will occur if this situation happens?

List all of your ideas and assumptions in the blanks provided below.



1 ____

2 ____

3 ____

4 ____

5 ____

6 ____

7 ____

8 ____

9 ____

10 ____

APPENDIX XI - Watson Glaser Critical Thinking Appraisal Form A

	School of Science and Technology (SST), University Malaysia Sabah *Centre of Science and Technology Education Research (CSTER)* *University of Waikato, Hamilton, New Zealand*

WATSON GLASER CRITICAL THINKING

APPRAISAL FORM A

TIME: 90 MINUTES

DO NOT OPEN THIS BOOK UNTIL YOU HAVE BEEN TOLD TO DO SO

INSTRUCTION:

This booklet contains five types of tests designed to find out how well you are able to reason analytically and logically. Each test has separate directions that should be read carefully.

Do not turn this page until instructed to do so.

Do not make any marks in this test booklet.

Please tick your answer in the table given.

.

TEST 1: INFERENCE

DIRECTION

An inference is a conclusion a person can draw from certain observed or supposed facts. For example, if the lights are on in a house and music can be heard coming from the house, a person might infer that someone is at home. But this inference may not be correct. Possibly the people in the house did not turn the lights and the radio off when the left the house.

In this test, each exercise begins with a statement of facts that you are to regard as true. After each statement of facts you will find several possible inferences-that is, conclusions that some persons might draw from the stated facts. Examine each inference separately, and make a decision as to its degree of truth or falsity.

For each inference you will find spaces will find spaces on the answer sheet labeled T, PT, ID, PF, and F. for each inference make a mark on the answer sheet under the appropriate heading as follows:

T	If you think the inference is definitely **TRUE**; that it properly follows beyond a reasonable doubt from statement of facts given.
PT	If, in the light of the facts given, you think the inference is **PROBABLY TRUE**; that it is more likely to be true than false.
ID	If you decide that there are **INSUFFICIENT DATA**; that you cannot tell from the facts given whether the inference is likely to be true or false; if the facts provide no basis for judging one way or the other.
PF	If, in the light of the facts given, you think the inference is **PROBABLY FALSE**; that it is more likely to be false than true.
F	If you think the inference is definitely **FALSE**; that it is wrong, either because it misinterprets the facts given, or because it contradicts the facts or necessary inference from those facts.

Sometimes, in deciding whether an inference is probably true or probably false, you will have to use certain commonly accepted knowledge or information that practically every person has. This will be illustrated in the example that follows.

Look at the example in the column; the correct answers are indicated in the block at the right.

Example
Two hundreds students in their early teens voluntarily attended a recent weekend student conference in a Midwestern city. At this conference, the topics of race relation and means and achieving lasting world peace were discussed, since these were the problems the students selected as being most vital in today's world.

1. As a group the students who attended this conference showed a keener interest in board social problems than do most others students in their early teens.
2. The majority of the students had not previously discussed the conference topics in their schools
3. The students came from all sections of the country.
4. The students discussed mainly labour relations problems
5. Some teenage students felt it worthwhile to discuss problems of race relations and ways of achieving world peace.

	T	PT	ID	PF	F
1		√			
2				√	
3			√		
4					√

In the above example, inference 1 is probably true (PT) because (as is common knowledge) most people in their early teen do not show so much serious concern with board social problems. It cannot be considered definitely true form the facts given because these facts do not tell how much concern other young teenagers may have. It is also possible that some of the students volunteered to attend mainly because they wanted a weekend outing.

Inference 2 is probably false (PF) because the students' growing awareness of these topics probably stemmed at least in part from discussion with teachers and classmates.

There is no evidence for inference 3. thus there are insufficient data (ID) for making a judgment on the matter.

Inference 4 is definitely false (F) because it is given in the statement of facts that the topics of race relations and means of achieving world peace were the problems chosen for discussion.

Inference 5 necessarily follows from the given facts; it therefore is true (T)

In the exercises that follow, more than one of the inferences from a given statement of facts may be true (T), or false (F), or probably true (PT), or probably false (PF), or have insufficient data (ID) to warrant any conclusion. Thus you are to judge each inference independently.

Make a heavy black mark in the space under the heading that you think best describes each inference. If you change an answer, erase it thoroughly. Make no extra marks on the answer sheet.

EXERCISES

1n 1946 the United States Armed Forces conducted an experiment called "Operation Snowdrop" to find out what kind of military men seemed to function best under severe arctic climatic conditions. Some of the factors examined were weight, age, blood pressure, and national origin. All of the participants in "Operation Snowdrop" were given a training course in how to survive and function in extreme cold. At the conclusion of the experiment it was found that only two factors among those studied distinguished between men whose performance was rated as "not effective" on the arctic exercise. These factors were: (1) desire to participate in the experiment, and (2) degree of knowledge and skill regarding how live and protect oneself under arctic conditions.

1. Despite the training course given to all of the participants in "Operation Snowdrop", some participants exhibited greater arctic survival knowledge or skill than others.
2. It was believed by the Armed Forces that military operations might someday be carried out in an arctic-like environment.
3. A majority of the men who participated in "Operation Snowdrop" thoroughly disliked the experience.
4. As a group, the men of Scandanavian origin were found to function more effectively under severe arctic conditions than those of Latin origin.
5. Participants having normal weight and blood pressure were rated as significantly more effective on the arctic exercises than were the other participants.

	T	PT	ID	PF	F
1					
2					
3					
4					
5					

Mr. Lim, who lives in the town of Kota Kinabalu, was brought before the Kota Kinabalu municipal court for the sixth time in the past month on a charge of keeping his pool hall open after 1 a.m. he again admitted his guilt and was fined the maximum RM 500, as in each earlier instance.

6. On some nights it was to Mr. Lim's advantage to keep his pool hall open after 1 a.m., even at the risk of paying a RM 500 fine.
7. Mr. Lim's pool hall was held by the municipal court to be within the legal jurisdiction of the town of Kota Kinabalu.
8. Mr. Lim repeatedly flouted the 1 a.m. closing law in hopes of getting it repealed.
9. The maximum fine of RM500 was fully effective in keeping all pool halls in Salem and its vicinity closed after 1 a.m.
10. There was one week during the past month when Mr. Lim observed the legal closing time each night.

	T	PT	ID	PF	F
6					
7					
8					
9					
10					

Sometime ago a crowd gathered in Middletown to hear the new president of the local Chamber of Commerce speak. The president said, "I am not asking, but demanding, that labor unions now accept their full share of responsibility for civic improvement and community welfare. I am not asking, but demanding, that they join the Chamber of Commerce". The members of Central Labor Unions who were present applauded enthusiastically. Three months later all the labor unions in Middletown were represented in the Chamber of Commerce. These representatives worked with representatives of other groups of committees, spoke their minds, participated actively in the civic improvement projects, and helped the Chamber reach the goals set in connection with those projects.

11. Both the labor union representatives and the other members of the committees came to a better recognition of one another's viewpoints through their Chamber of Commerce contacts.
12. Union participants in the Middletown Chamber of Commerce greatly reduced worker-management disputes in that town.
13. The active participation of the labor unions resolved many controversies at all the committee meetings of the Chamber of Commerce.
14. Most of the Union representatives regretted having accepted the invitation to participate in the Chamber of Commerce.
15. Some of the Chamber of Commerce members came to feel that their president had been unwise in asking the union representatives to join the Chamber.
16. The new president indicated in the speech that the town's labor unions had not yet accepted their full responsibility for civic improvement.

	T	PT	ID	PF	F
11					
12					
13					
14					
15					
16					

TEST 2: RECOGNITION OF ASSUMPTION

An assumption is something presupposed or taken for granted. When you say, “I’ll graduate in August,” you take for granted or assume that you’ll be alive in June, that your school will judge you to be eligible for graduation in August, and similar things

Below are a number of statements. Each statement is followed by several proposed assumptions. You are to decide for each assumption. You are decide for each assumption whether a person, in making the given statement, is really making that assumption-that is, taking it for granted, justifiability or not.

If you think that the given assumption is taken for granted in the statement, make a heavy black mark under “ASSUMPTION MADE” in the proper place on the answer sheet. If you think the assumption is *not* necessarily taken for granted in the statement, blacken the space under “ASSUMPTION NOT MADE”. Remember to judge each assumption independently.

Below is an example. The block at the right shows how these items should be marked on the answer sheet.

EXAMPLE

Statement: “We need to save time in getting there so we’d better go by plane”.

Proposed assumption:

1. Going by plane will take less time than going by some other means of transportation. (*It is assumed in the statement that the greater speed of a plane over the speeds of other means of transportation will enable the group to reach its destination in less time*.)
2. there is plane service available to us for at least part of the distance to the destination. (*This is necessarily assumed in the statement since, in order to save time by plane, it must be possible to go by plane.*)
3. Travel by plane is more convenient than travel by train. (*This assumption is not made in the statement-the statement has to do with saving time, and says nothing about convenience or about any other specific mode of travel*.)

Answer:

Assumption:

	Made	Not Made
1		
2		
3		√

EXERCISE

Statement: "In the long run, the discovery of additional uses for atomic energy will prove a blessing to humanity."

Proposed assumption*:*

17. Additional and beneficial ways of using atomic energy will be discovered.
18. The discovery of additional uses for atomic energy willrequire large, long term investments of money.
19. The use of atomic energy represents a serious environmental hazard.

	Made	Not Made
1		
2		
3		

Statement: "Zenith is the city to move to-it has the lowest taxes."

Proposed assumption:

20. Lowest taxes imply efficient city management.
21. In deciding where to live, it is important to avoid high taxes.
22. The majority of the residents in Zenith are content with their present city government.

	Made	Not Made
20		
21		
22		

Statement: "We have permitted ourselves to be stampeded into a life of unnatural and dangerous high pressure. We pace ourselves by machines instead of by our natural rhythm".

Proposed assumption:

23. We can resist being pushed into a life of unnatural high pressure.
24. The way of life we have adopted is not in tune with the way human begins were meant to live.
25. The rapid pace of our lives does not help us to achieve goals.

	Made	Not Made
23		
24		
25		

Statement: "I'm traveling to South America. I want to be sure that I do not get typhoid fever, so I shall go to my physician and get vaccinated against typhoid fever before I begin my trip".

Proposed assumption:

26. If I don't take the injection, I shall become ill with the fever.
27. By getting vaccinated against typhoid fever, I decrease the chances that I will get the disease.
28. Typhoid fever is more common in South America than it is where I live.
29. My physician can provide me with a vaccination that will protect me from getting typhoid fever while I am in South America.

	Made	Not Made
26		
27		
28		
29		

Statement: "If war is inevitable, we'd better launch a preventive war now while we have the advantage."

Proposed assumption:

30. War is inevitable.
31. If we fight now, we are more likely to win than we would be if forced to fight later.
32. If we don't launch a preventive war now, we'll lose any war that may be started by an enemy later.

	Made	Not Made
30		
31		
32		

TEST 3: DEDUCTION

In this test, each exercise consists of several statements (premises) followed by several suggested conclusions. *For the purpose of this test, consider the statements in each exercise as true without exception*. Read the first conclusion beneath the statements. If you think it necessarily follows from the statements given, make a heavy black mark under the "CONCLUSION FOLLOWS" in the place on the answer sheet. If you think it is not a necessary conclusion from the statements given, put a heavy black mark under "CONCLUSION DOES NOT FOLLOW", even though you may believe it to be true from your general knowledge.

Likewise, read and judge each of the other conclusions. Try not to let your prejudices influence your judgment – just stick to the given statements (premises) and judge each conclusion as to whether it *necessarily* follows from them.

The word "some" in any of these statements means an indefinite part or quantity of a class of things. "Some" means at least a portion, and perhaps all of the class.

Thus, "some holidays are rainy" means at least one, possibly more than one, and perhaps even all holidays are rainy.

Study the example carefully before starting the test.

EXAMPLE
Some holidays are rainy. All rainy days are boring. Therefore –

1. No clear days are boring.(The conclusion does not follow. You cannot tell from the statements whether or not clear days are boring. Some may be.)
2. Some holidays are boring. (The conclusion necessarily follows from the statements since, according to them; the rainy holidays must be boring.)
3. Some holidays are not boring. (The conclusion does not follow even though you may know that some holidays are very pleasant.)

Answer:
Conclusions:

	Follows	Does Not Follow
1		√
2	√	
3		√

EXERCISES

No person who thinks scientifically places any faith in the predictions of astrologers. Nevertheless, there are many people who rely on horoscopes provided by astrologers. Therefore –

33. People who lack confidence in horoscopes think Scientifically.
34. Many people do not think scientifically.
35. Some scientifically thinkers trust some astrologers

	Follows	Does Not Follow
33		
34		
35		

All members of symphony orchestras enjoy playing classical music. All members of symphony orchestras spend long hours practicing. Therefore –

36. Musicians who play classical music do not mind spending long hours practicing.
37. Some musicians who spend long hours practicing enjoy playing classical music.

	Follows	Does Not Follow
36		
37		

Rice and celery must have a good deal of moisture in order to grow well, but rye and cotton grow best where it is relatively dry. Rice and cotton grow where it is hot, and celery and rye where it is cool. In Timbuktu, it is very hot and damp. Therefore –

38. Neither the temperature nor the moisture conditions in Timbuktu are favorable for growing a celery and corp.
39. The temperature and moisture conditions in Timbuktu are more favorable for growing rice than for growing celery, cotton, or rye.
40. Conditions in Timbuktu are not altogether favorable for growing cotton or a rye crop.

	Follows	Does Not Follow
38		
39		
40		

Most persons who attempt to break their smoking habit find that it is something that they can accomplish only with difficulty, or cannot accomplish at all. Nevertheless, there is a growing number of individuals whose strong desire to stop smoking has enabled them to break the habit permanently. Therefore –

41. Only smokers who strongly desire to stop smoking will succeed in doing so.
42. A strong desire to stop smoking helps some people to permanently break the habit.

	Follows	Does Not Follow
41		
42		

In one town there are 52 classes in the five elementary schools. Each class contains from 10 to 40 pupils. Therefore –

43. There are at least two classes in the town with exactly the same number of pupils.
44. Most elementary school classes in the town contain more than 15 pupils.
45. There are at least 550 pupils in these elementary schools.

	Follows	Does Not Follow
43		
44		
45		

Some Russians would like to control the world. All Russians seek a better life for themselves. Therefore –

46. Some people who would like to control the world seek a better life for themselves.
47. Some people who seek a better life for themselves would like to control the world.
48. If the Russians controlled the world, they would be assured of a better life.

	Follows	Does Not Follow
46		
47		
48		

TEST 4: INTERPRETATION

DIRECTIONS

Each exercise below consists of a short paragraph followed by several suggested conclusions.

For the purpose of this test, assume that everything in the short paragraph is true. The problem is to judge whether or not each of the proposed conclusions logically follows beyond a reasonable doubt from the information given in the paragraph.

If you think that the proposed conclusion follows beyond a reasonable doubt (even though it may not follow absolutely and necessarily), then make a heavy black mark under "CONCLUSION FOLLOWS" in the proper place on the answer sheet. If you think that the conclusions does *not* follow beyond a reasonable doubt from the facts given, then blacken the space under "CONCLUSIONA DOES NOT FOLLOW". Remember to judge each conclusion independently.

Look at the example below; the block at the right shows how the answers should be marked on the answer sheet.

EXAMPLE

A study of vocabulary growth in children from eight months to six years old shows that the size of spoken vocabulary increases from zero words at age eight months to 2562 words at age six years.

1. None of the children in this study had learned to talk by the age of six months. (The conclusions follows beyond a reasonable doubt since, according to the statement, the size of the spoken vocabulary at eight months was zero words).
2. Vocabulary growth is slowest during the period when children are learning to walk. (The conclusion does not follow since there is no information given that relates growth of vocabulary to making).

Answer:
Conclusions:

	Follows	Does Not Follow
1	√	
2		√

EXERCISE

The history of last 2000 years shows that wars have steadily become more frequent and more destructive. The twentieth century has the worst record thus for on both these counts.

49. Mankind has not advanced much in the ability to keep peace.
50. If past trends continue, we can expect that there will be more wars in the twenty-first century than there were in the twentieth century.
51. Wars have become more frequent and more destructive because the world's natural resources have become more valuable.

When the United States Steel Corporation was created in 1902, it was the largest corporation America had known up to that time. It produced twice as much steel as all of its domestic competitors put together. Today, the United States Steel Corporation produces about 20 percent of the steel that is made in this country.

52. In 1902, the United States Steel Corporation produced not less than 66 percent of the total domestic output of steel.
53. Today, domestic competitors produce more than three times as much steel as does the United States Steel Corporation.
54. The United States Steel Corporation produces less steel today than it did in 1902.

	Follows	Does Not Follow
52		
53		
54		

Pat had poor posture, had very few friends, was ill at ease in company, and in general was very unhappy. Then a close friend recommended that Pat visit Dr. Baldwin, a reputed expert on helping people improve their personalities. Pat took this recommendation and, after three months of treatment by Dr. Baldwin, developed more friendships, was more at ease, and in general felt happier.

55. Without Dr. Baldwin’s treatment, Pat would not have improved.
56. Improvements in Pat’s life occurred after Dr. Baldwin’s treatment started.
57. Without a friend’s advice, Pat would not have heard of Dr. Baldwin.

	Follows	Does Not Follow
55		
56		
57		

In a certain city where school attendance laws are strictly enforced, it was found that only 15 percent of the students had a perfect attendance record during a single school semester. Among those who sold newspapers, however, 25 percent had a perfect attendance record during the same semester.

58. Students who sold newspapers were more likely to have perfect attendance records during the semester than students who did not.
59. Strict enforcement of school attendance laws in this city did not prevent 85 percent of the students from being absent sometime during the semester.
60. If truants were given jobs selling newspapers, their school attendance would improve.
61. The low rate of perfect attendance by students in that school system was due mainly to illness or injury.

	Follows	Does Not Follow
58		
59		
60		
61		

When I go to bed at night, I usually fall asleep quite promptly. But about twice a month I drink coffee during the evening, and whenever I do. I lie awake and toss for hours.

62. My problem is mostly psychological; I expect that the coffee will keep me awake and therefore it does.
63. I don’t fall asleep promptly at night after drinking coffee because the caffeine in it overstimulates my nervous system.
64. On nights when I want I want to fall asleep promptly. I’d better not drink coffee in the evening.

	Follows	Does Not Follow
62		
63		
64		

TEST 5: EVALUATION OF ARGUMENT

DIRECTION

In making decisions about important questions, it is desirable to be able to distinguish between arguments that are strong and arguments that are weak, as far as the question at issue is concerned. For an argument to be strong, it must be both important and directly related to the question.

An argument is weak if it is not directly related to the question (even though it may be of great general importance), or if it is of minor importance, or if it is related only to trivial aspects of the question.

Below is a series of questions. Each questions followed by several arguments. For the purpose of this test, you are to regard each argument as true. The problem then is to decide whether it is a strong or a weak argument.

Make a heavy black mark on the answer sheet under “ARGUMENT STRONG” if you think the argument is strong, or under “ARGUMENT WEAK” if you think the argument is weak. Judge each argument separately on its own merit. Try not to let your personal attitude toward the question influence your evaluation of the argument, since each argument is to be regarded as true.

In the example, note that the argument is evaluated as to how well it supports the side of the question indicated.

EXAMPLE
Should all young men go to college?

1. Yes: college provides an opportunity for them to learn school songs and cheers. (This would be a silly reason for spending years in college).
2. No; a larger percent of young men do not have enough ability or interest to derive any benefit from college training. (If this is true, as the directions require us to assume, it is a weighty argument against all young men going to college).
3. No; exercise studying permanently, warps an individual's personality. (This argument, although of great general importance when accepted as true, is not directly related to the question, because attendance at college does not necessarily require excessive studying).

Answer:
Conclusions:

	Strong	Weak
1		√
2	√	
3		√

When the word "should" is used as the first word in any of the following questions, its meaning is, "Would the proposed action promote the general welfare of the people in the United States?"

EXERCISE

Would a strong labor party promote the general welfare of the people of Malaysia?

65. No; a strong labor party should make it unattractive for private investors to risk their money in business ventures, thus causing sustained large-scale unemployment.
66. Yes; at the moment the Malaysian government already administrates all communication, highway project, military, medical services.
67. No; labor unions have called strikes in a number of important industries.

	Strong	Weak
65		
66		
67		

Should groups in this country who are opposed to some our government's policies be permitted unrestricted freedom of press and speech?

68. Yes; a democratic state thrives on free and unrestricted discussion, including criticism.
69. No; the countries opposed to our form of government do not permit the free expression of our points of view in their territories.
70. No; if given full freedom of press and speech, opposition groups would cause serious internal strife, making our government basically unstable, and eventually leading to the loss of our democracy.

	Strong	Weak
68		
69		
70		

Should the Malaysian government keep the public informed of its anticipated scientific research programs by publicizing ahead of time the needs that would be served by each program?

71. No; some become critical of the government, when widely publicized projects turn out unsuccessfully.
72. Yes; only a public so informed will support vital research and development activities with its tax dollars.
73. No; it is essential to keep certain military developments secret for national security and defense reasons.

	Strong	Weak
71		
72		
73		

Do juries decide court cases fairly when one of the opposing parties is rich and the other is poor?

74. No; because rich people are more likely to settle their cases out of court.
75. No; most jurors are more sympathetic to poor people than to the rich, and the jurors' sympathies affect their findings.
76. No; because rich people can afford to hire better lawyers than poor people, and juries are influenced by the skill of the opposing lawyers.

	Strong	Weak
74		
75		
76		

Should pupils be excused from public schools to receive religious instruction in their own churches during school hours?

77. No; having public-school children go off to their separate churches during school hours would seriously interfere with the educational process and create friction among children of different religious.
78. Yes; religious instruction would help overcome moral emptiness, weakness, and lack of consideration for other people, all of which appear to be current problems in our nation.
79. Yes; religious instruction is very important to the preservation of our democratic values.
80. No; religious instruction during school hours would violate our constitutional separation of church and state; those who desire such instruction are free to get it after school hours.

	Strong	Weak
77		
78		
79		
80		

THE END
You may go back and check your work.

APPENDIX XII - Watson Glaser Critical Thinking Appraisal Form B

	School of Science and Technology (SST), University Malaysia Sabah *Centre of Science and Technology Education Research (CSTER)* *University of Waikato, Hamilton, New Zealand*

WATSON GLASER CRITICAL THINKING

APPRAISAL FORM B

TIME: 90 MINUTES

DO NOT OPEN THIS BOOK UNTIL YOU HAVE BEEN TOLD TO DO SO

INSTRUCTION:

This booklet contains five types of tests designed to find out how well you are able to resistance annalistically and logically. Each test has separate directions that should be read carefully.

Do not turn this page until instructed to do so.

Do not make any marks in this test booklet.

Please tick your answer in the table given.
.
.

TEST 1: INFERENCE

DIRECTION

An inference is a conclusion a person can draw from certain observed or supposed facts. For example, if the lights are on in a house and music can be heard coming from the house, a person might infer that someone is at home. But this inference may not be correct. Possibly the people in the house did not turn the lights and the radio off when they left the house.

In this test, each exercise begins with a statement of facts that you are to regard as true. After each statement of facts you will find several possible inferences-that is, conclusions that some persons might draw from the stated facts. Examine each inference separately, and make a decision as to its degree of truth or falsity.

For each inference you will find spaces will find spaces on the answer sheet labeled T, PT, ID, PF, and F. for each inference make a mark on the answer sheet under the appropriate heading as follows:

T	If you think the inference is definitely **TRUE**; that it properly follows beyond a reasonable doubt from the statement of facts given.
PT	If, in the light of the facts given, you think the inference is **PROBABLY TRUE**; that it is more likely to be true than false.
ID	If you decide that there are **INSUFFICIENT DATA**; that you cannot tell from the facts given whether the inference is likely to be true or false; if the facts provide no basis for judging one way or the other.
PF	If, in the light of the facts given, you think the inference is **PROBABLY FALSE**; that it is more likely to be false than true.
F	If you think the inference is definitely **FALSE**; that it is wrong, either because it misinterprets the facts given, or because it contradicts the facts or necessary inference from those facts.

Sometimes, in deciding whether an inference is probably true or probably false, you will have to use certain commonly accepted knowledge or information that practically every person has. This will be illustrated in the example that follows.

Example

Two hundred students in their early teens voluntarily attended a recent weekend student conference in a Malaysian city. At this conference, the topics of race relation and means and achieving lasting world peace were discussed, since these were the problems the students selected as being most vital in today's world.

1. As a group the students who attended this conference showed a keener interest in board social problems than do most others students in their early teens.
2. The majority of the students had not previously discussed the conference topics in their schools.
3. The students came from all sections of the country.
4. The students discussed mainly labor relations problems
5. Some teenage students felt it worthwhile to discuss problems of race relations and ways of achieving world peace.

	T	PT	ID	PF	F
1		√			
2				√	
3			√		
4					√
5	√				

In the above example, inference 1 is probably true (PT) because (as is common knowledge) most people in their early teen do not show so much serious concern with board social problems. It cannot be considered definitely true form the facts given because these facts do not tell how much concern other young teenagers may have. It is also possible that some of the students volunteered to attend mainly because they wanted a weekend outing.

Inference 2 is probably false (PF) because the students' growing awareness of these topics probably stemmed at least in part from discussion with teachers and classmates.

There is no evidence for inference 3. Thus there are insufficient data (ID) for making a judgment on the matter.

Inference 4 is definitely false (F) because it is given in the statement of facts that the topics of race relations and means of achieving world peace were the problems chosen for discussion.

Inference 5 necessarily follows from the given facts; it therefore is true (T)

In the exercises that follow, more than one of the inferences from a given statement of facts may be true (T), or false (F), or probably true (PT), or probably false (PF), or have insufficient data (ID) to warrant any conclusion. Thus you are to judge each inference independently.

Make a heavy black mark in the space under the heading that you think best describes each inference. If you change an answer, erase it thoroughly. Make no extra marks on the answer sheet.

EXERCISES

An English teacher show a movies called *Surat Untuk Takdir* based on a Malaysian novelist known as Aina Emir in one of her class. Her other classes only read the book without watching the movie. The teacher wants to know whether by showing the movie can be as an effective tool of teaching and learning in literature. After every class, a test been given to students to check their comprehension and understanding of the story. In all tests, the class who watch the video shows highest achievement. This class attracted with the *Surat Untuk Takdir* movie hence many of the students voluntarily wants to read the book before the semester ended. The teacher thinks that her study has success.

1. The tests given in this study intended to measure more than remembering back the facts about that book.
2. Students that been thought by watching the movie have been asked to read the book in the early semester.
3. Other English teacher whose maybe try this study will get the same result.
4. Teacher who's done this study will continue use the movies teaching aid in an appropriate condition.
5. There is no prove that the class whose watching the movie has deeper understanding and appreciated the *Surat Untuk Takdir* story more than the class whose only read the book without watching the movie.
6. Students can learn more in other subjects from movie shows other than what they can learn from by reading books.

	T	PT	ID	PF	F
1					
2					
3					
4					
5					
6					

The first newspaper in Malaya edited by Ramli Jaafar appeared in Singapore on May 29th, 1939, but banned on the same day by the *Datuk Bandar* Kassim Selamat. The fight continued to resume the newspaper publication and printing within the editors wish which shows the important event in the continue struggling to maintain the free newspaper.

7. After his newspaper was banned on the May 29, 1939, the first newspaper editor has passed away couples of days later.
8. The information about the first news papers issue of Ramli Jaafar is known about by Datuk Bandar Kassim Selamat.
9. The editor of these news papers has written a paper that criticizes Datuk Bandar Kassim Selamat.
10. Ramli Jaafar keeps on his objectives.
11. Datuk Bandar Kassim Selamat objected for some of published papers in Ramli Jaafar's newspapers.

	T	PT	ID	PF	F
7					
8					
9					
10					
11					

Fifteen years ago, Sandakan and Tawau City start take back the land farm grant not owns by its owner because of not paying tax. Until now, the town has provided 3600 acre community forest on part of the farm land. Palm oil trees growth well. The forest produced palm oil product in the last year and also RM 2,000,000 the year before. The local authority gain clean profit on the palm wood and will be developed until it reach RM 300,000 annually only from this 3600 acre land.

12. The town spent more money on cutting and selling the palm-wood compare to the selling profit gain from selling the palm-oil.
13. If every farm-land owner growth trees before they lost their land, they maybe will gain enough profit instantly from the trees to pay their tax debt and will be able to perpetuate their own farm-land.
14. Sandakan and Tawau community forest consists of many types of trees than potential to market.
15. In certain situation, Sandakan and Tawau town possess the authority to take law act to take back the personal possession of land farm land which is failed paying the tax.
16. The land lord not intercepts the authority of Sandakan and Tawau to take back their land possession because they are really guilty.
17. The Sandakan and Tawau community forest will produce clean profit annually as much as RM 300,000 from land of 3600 acre that they already have in two or three years.

	T	PT	ID	PF	F
12					
13					
14					
15					
16					
17					

TEST 2: RECOGNITION OF ASSUMPTION

An assumption is something presupposed or taken for granted. When you say, "I'll graduate in August," you take for granted or assume that you'll be alive in June, that your school will judge you to be eligible for graduation in August, and similar things

Below are a number of statements. Each statement is followed by several proposed assumptions. You are to decide for each assumption. You are decide for each assumption whether a person, in making the given statement, is really making that assumption-that is, taking it for granted, justifiability or not.

If you think that the given assumption is taken for granted in the statement, make a heavy black mark under "ASSUMPTION MADE" in the proper place on the answer sheet. If you think the assumption is *not* necessarily taken for granted in the statement, blacken the space under "ASSUMPTION NOT MADE". Remember to judge each assumption independently.

Below is an example. The block at the right shows how these items should be marked on the answer sheet.

Example

Statement: "We need to save time in getting there so we'd better go by plane".

Proposed assumption:

4. Going by plane will take less time than going by some other means of transportation. (*It is assumed in the statement that the greater speed of a plane over the speeds of other means of transportation will enable the group to reach its destination in less time*.)
5. there is plane service available to us for at least part of the distance to the destination. (*This is necessarily assumed in the statement since, in order to save time by plane, it must be possible to go by plane.*)
6. Travel by plane is more convenient than travel by train. (*This assumption is not made in the statement-the statement has to do with saving time, and says nothing about convenience or about any other specific mode of travel*.)

Answer:

Assumption:

	Made	Not Made
1	√	
2	√	
3		√

EXERCISE

Statement: "It seems like it is not enough to fulfill everyone's needs".

Proposed assumption:

18. The household item stocks that think needed are not the same with the need of necessary of these stocks.
19. People should not expect to get something free.

	Made	Not Made
18		
19		

Statement: "There are many new energy sources that will be discovered in the future, if we discover new sources of energy this will prevent lack of energy sources in the future".

Proposed assumption:

20. A new source of energy wills not overloading the power more than the new power has generated.
21. New sources of energy are limited.
22. After the new source of energy is discovered, the demand for energy will not exceed the supply.

	Made	Not Made
20		
21		
22		

Statement: "Development in science, the environment conversation, and education will be maximized if all countries work together rather than independently".

Proposed assumption:

23. If all countries work together in these fields, there will be less likelihood of armed conflict.
24. Ethnic and politic differences between human beings will not prevent them from working together on related humanly affairs.
25. International cooperation in science and education will lead to less independent societies.

	Made	Not Made
23		
24		
25		

Statement: "If you not believe in me, I will prove it to you logically".

Proposed assumption:

26. Logic proof will make you change your opinions.
27. What I prove something to you using logic this will influence your thinking.
28. There are some beliefs that cannot be proved by logic.

	Made	Not Made
26		
27		
28		

Statement: "A wise person will save some money every week from his/her weekly salary".

Proposed assumption:

29. No some unintelligent people are still sensible enough to save some money every week.
30. Someone must be wise to keep money every week.

	Made	Not Made
29		
30		

Statement: "Since more students intend to go to college in the future, we need to build more buildings".

Proposed assumption:

31. The number of college buildings required in the future depends on students plans about pursuing college study.
32. The current college buildings are crowded now.
33. If more students pursue college study, buildings must be prepared for them.

	Made	Not Made
31		
32		
33		

TEST 3: DEDUCTION

In this test, each exercise consists of several statements (premises) followed by several suggested conclusions. *For the purpose of this test, consider the statements in each exercise as true without exception*. Read the first conclusion beneath the statements. If you think it necessarily follows from the statements given, make a heavy black mark under the "CONCLUSION FOLLOWS" on the answer sheet. If you think it is not a necessary conclusion from the statements given, put a heavy black mark under "CONCLUSION DOES NOT FOLLOW", even though you may believe it to be true from your general knowledge.

Likewise, read and judge each of the other conclusions. Try not to let your prejudices influence your judgment – just stick to the given statements (premises) and judge each conclusion as to whether it *necessarily* follows from them.

The word "some" in any of these statements means an indefinite part or quantity of a class of things. "Some" means at least a portion, and perhaps all of the class. Thus, "some holidays are rainy" means at least one, possibly more than one, and perhaps even all holidays are rainy.

Study the example carefully before starting the test.

Example
Some holidays are rainy. All rainy days are boring. Therefore –

4. No clear days are boring.(The conclusion does not follow. You cannot tell from the statements whether or not clear days are boring. Some may be.)
5. Some holidays are boring. (The conclusion necessarily follows from the statements since, according to them, the rainy holidays must be boring.)
6. Some holidays are not boring. (The conclusion does not follow even though you may know that some holidays are very pleasant.)

Answer
Conclusions:

	Follows	Does Not Follow
1		√
2	√	
3		√

EXERCISES

An opinion which is not held confidently by a person will not be held for very long. Many of our opinions are not held confidently but are hastily made. Therefore –

34. We will find it difficult to defend most of our opinions.
35. Many of our opinions will fade away before they are even subject to discussion or debate.
36. If a person's opinion is cast into doubt easily by means of an argument, then the opinion is not held confidently.

	Follows	Does Not Follow
34		
35		
36		

All great novels are works of art. Our imagination is capture by all great novels. Therefore –

37. All things that capture our imagination are works of art.
38. If the novel Gone with the Wind is a great novel, it will capture our imagination.
39. Our imagination can be captured by many works of art.

	Follows	Does Not Follow
37		
38		
39		

In 1955 it was found that in one city that every person who was infected with polio was aged less than 10 years old. Residents of the city that had been given a polio vaccine did not have serious polio infection in that particular year. Therefore –

40. Some children aged less than 10 years old did not receive polio vaccine.
41. The Polio vaccine is more effective for adults than children aged less than 10 years.
42. Some people aged less than 10 years received a Polio vaccine injection that particular year.

	Follows	Does Not Follow
40		
41		
42		

Some people who support giving more money to schools are fighting against compulsory school attendance at secondary school. Only people working in the field of education field are in favor of allocating more money to secondary schools. Therefore –

43. Some people working in education do not support compulsory attendance in secondary schools.
44. Several people who are against compulsory attendance at secondary school work in education.
45. Someone cannot be against compulsory attendance at secondary school because all people work in education.

	Follows	Does Not Follow
43		
44		
45		

Every radical person belongs to a minor political party. No patriotic citizen is a radical person. Therefore –

46. No person belonging to a minor politic party is a patriotic citizen.
47. No radical person is a member of a major political party.
48. No patriotic citizen is a member of a minor political party.
49. Some members of minor political parties are patriotic citizens.

	Follows	Does Not Follow
46		
47		
48		
49		

TEST 4: INTERPRETATION

DIRECTIONS

Each exercise below consists of a short paragraph followed by several suggested conclusions.

For the purpose of this test, assume that everything in the short paragraph is true. The problem is to judge whether or not each of the proposed conclusions logically follows beyond a reasonable doubt from the information given in the paragraph.

If you think that the proposed conclusion follows beyond a reasonable doubt (even though it may not follow absolutely and necessarily), then make a heavy black mark under "CONCLUSION FOLLOWS" in the proper place on the answer sheet. If you think that the conclusions does *not* follow beyond a reasonable doubt from the facts given, then blacken the space under "CONCLUSIONA DOES NOT FOLLOW". Remember to judge each conclusion independently.

Look at the example below; the block at the right shows how the answers should be marked on the answer sheet.

Example
A study of vocabulary growth in children from eight months to six years old shows that the size of spoken vocabulary increases from zero words at age eight months to 2562 words at age six years.

1. None of the children in this study had learned to talk by the age of six months. (The conclusions follows beyond a reasonable doubt since, according to the statement, the size of the spoken vocabulary at eight months was zero words).
2. Vocabulary growth is slowest during the period when children are learning to walk. (The conclusion does not follow since there is no information given that relates growth of vocabulary to making).

Answer:
Conclusions:

	Follows	Does Not Follow
1	√	
2		√

EXERCISE

A salesman is demonstrating the product *Minyak Cap Kapak*, an ointment he says will reduce pain in muscles deep inside the body by penetration into the muscle. The salesman put 10 drops onto a leather shoe, and the ointment went inside the leather rapidly.

50. The salesman has shown that his product will heal deep muscle pain.
51. The salesman is implying if the ointment can penetrate a leather shoe it also can penetrate into muscle.
52. The salesman's demonstration is a good evidence to support his statement that his product will reduce pain in muscles deep inside body by penetrating into those muscles.

	Follows	Does Not Follow
50		
51		
52		

From a number of 2,550,761 students of high schools in a country in a particular year, only 830,000 registered for science courses and only 660,000 registered for mathematic courses.

53. Some secondary schools in the country do not require both science and mathematics to be taught in that particular year.
54. One of the reasons why students did not do science and mathematic courses in that year are because they have already done the courses in lower secondary school.
55. A large proportion of high school students in the year are not learning science and mathematics.

	Follows	Does Not Follow
53		
54		
55		

A national weekly magazine published a series of articles related to divorce issues and women's quality of life. The article was banned by the education department immediately in all secondary schools in a particular city.

56. The members of the School boards think the issues raised in the magazine articles are justified.
57. The magazine should not publish such articles.

	Follows	Does Not Follows
56		
57		

A woman had a dream in which fell but was not badly hurt. Late that night her husband came home from fishing. He told his wife that he broke his arm when he fell on his boat. the husband and wife found that the incident they experienced happened at exactly the same time.

58. There is no reasonable way to explain why the accident and dream happened simultaneously.
59. The actual time when the wife woke is not known.
60. The dream is only coincidence and there is no connection between the accident experienced by both husband and the dream of the wife.

	Follows	Does Not Follow
58		
59		
60		

A magazine in Kuala Lumpur did a study about taxi drivers involved in car crashes in Kuala Lumpur over a particular time span. The data revealed that male drivers were involved in 1210 accidents and female drivers in 920. It also found that twenty-percent of drivers were aged less than twenty-years.

61. In a typical car accident in Kuala Lumpur the probability of male drivers being involved is high over the time of the study.
62. In Kuala Lumpur, over the time of the study, male teenager drivers were involved in more accidents than female teenage drivers
63. In a typical car accident in Kuala Lumpur the probability of male drivers being involved is high over any time span.

	Follows	Does Not Follow
61		
62		
63		

The mean mark in the final mathematics exam for the semester, students from Miss Gayah's class was 10 percent higher than for the students in Mr. Wahab class. Miss Gayah and Mr. Wahab used different teaching methods during the semester.

63. Miss Gayah and Mr. Wahab are teaching in the same school.
64. As a group, the students from Miss Gayah's class are more intelligent than those from Mr. Wahab's class.
65. Miss Gayah's method of teaching is better than Mr. Wahab's method of teaching.

	Follows	Does Not Follow
63		
64		
65		

TEST 5: EVALUATION OF ARGUMENT

DIRECTION

In making decisions about important questions, it is desirable to be able to distinguish between arguments that are strong and arguments that are weak, as far as the question at issue is concerned. For an argument to be strong, it must be both important and directly related to the question.

An argument is weak if it is not directly related to the question (even though it may be of great general importance), or if it is of minor importance, or if it is related only to trivial aspects of the question.

Below is a series of questions. Each question followed by several arguments. For the purpose of this test, you are to regard each argument as true. The problem then is to decide whether it is a strong or a weak argument.

Make a heavy black mark on the answer sheet under "ARGUMENT STRONG" if you think the argument is strong, or under "ARGUMENT WEAK" if you think the argument is weak. Judge each argument separately on its own merit. Try not to let your personal attitude toward the question influence your evaluation of the argument, since each argument is to be regarded as true.

In the example, note that the argument is evaluated as to how well it supports the side of the question indicated.

EXAMPLE
Should all young men go to university?

1. Yes: university provides an opportunity for them to learn school songs and cheers. (This would be a silly reason for spending years in college).
2. No; a larger percent of young men do not have enough ability or interest to derive any benefit from college training. (If this is true, as the directions require us to assume, it is a weighty argument against all young men going to college).
3. No; exercise studying permanently, warps an individual's personality. (This argument, although of great general importance when accepted as true, is not directly related to the question, because attendance at college does not necessarily require excessive studying).

Answer:
Conclusions:

	Strong	Weak
1		√
2	√	
3		√

When the word "should" is used as the first word in any of the following questions, its meaning is, "Would the proposed action promote the general welfare of the people in the Malaysia?"

EXERCISE
Is there any probability to create a full control of fatal or lethal - ray in a particular situation?

66. No; several physicist have tried to create a controllable fatal or lethal-ray ray but not succeeded.
67. No; if a ray like that being created, the act to reduce or prevent its affect must also be created together.
68. Yes; the outcome form this particular experiment shows that energy wavelength are capable to kill plants, ants and small animals in 500 meters of length area.

	Strong	Weak
66		
67		
68		

Is it reasonable to maintain the quality of air and water to a very high level even though this would mean very high cost of electricity and cost to the manufacturing industry?

69. Yes; because if we lower the quality of air and water we may cause considerable loss of life.
70. No; a modest decrease in water and air quality will have little health effect of people's health, but the extra cost of having very high quality air and water will bring about worse effects.
71. Yes; all opposition to improving the quality of water and air is based on short term profit.

	Strong	Weak
69		
70		
71		

Should the Malaysian government keep the public informed of its anticipated scientific research programs by publicizing ahead of time the needs that would be served by each program?

72. No; some become critical of the government, when widely publicized projects are unsuccessful.
73. Yes; only an informed public will support vital research and development activities with its tax dollars.
74. No; it is essential to keep certain military developments secret for national security and defense reasons.

	Strong	Weak
72		
73		
74		

The Malaysian Government should pay costs for land conservation for private farm land:

75. Yes; farmers do not own land privately anymore.
76. No; any cost for the conservation of land are lower than neglecting the land.
77. Yes; government has already got money from tax payers, and this tax money should be used for god purposes like conservation of land whether private or public.

	Strong	Weak
75		
76		
77		

The expenditure of the central Malaysian government and state governments should be limited so that it does not exceed its income:

78. Yes; we should live the way we can afford to prevent serious inflation that will reduce our purchasing power and make our unemployment situation worse.
79. Yes; it is better for people to learn to sacrifice and stop wasting money based on old habits and bad lifestyle.
80. No; limiting funding will affect economic development of the country and will reduce economic growth.

	Strong	Weak
78		
79		
80		

THE END
You may go back and check your work.

APPENDIX XIII - Physics Basic Concept Test

Physics Basic Concept Test

Instruction: Answer all the questions.
Please write down your answer in the available box/blank.
These questions **are not** to test your achievement in your Modern Physics course, but merely to test your prior knowledge of conceptual understanding in basic physics concept. Read each question carefully, and try to answer as correctly as possible.
This test sheet contains 15 objectives questions (Multiple Choice Questions) and 10 subjective questions (Open Ended Questions).

Circle your learning group: Traditional PBL

Matrix No: ______________________________

Part A: 15 Objective Questions

1 What is the correct abbreviation of the term "kilometer" according to SI system of units?

A) k.m; B) k-m; C) Km; D) km; E) KM

ANSWER[ ]

2 A physic student watching the Star Wars films knows that according to the laws of physics:

A) the Rebel heroes can see the flash of an explosion in space.
B) the Rebel heroes can hear the sound of an explosion in space.
C) the Rebel heroes can hear each other over their radios in space.
D) both the Rebel heroes can see the flash of an explosion in space AND the Rebel heroes can hear each other over their radios in space.
E) both the Rebel heroes can see the flash of an explosion in space AND the Rebel heroes can hear the sound of an explosion in space.

ANSWER[ ]

3 A record player rotates at 45 rpm (revolutions per minute). Through how many degrees does it rotate in 1 second?

A) 200°; B) 150°; C) 270°; D) 300°; E) 315°

ANSWER[ ]

4 Three objects experience interactions. Object A has mass, object B has electrical charge, and object C has both mass and electrical charge. Which of the following statements is true?

A) Object A and object B experience an electrical interaction.
B) Object A and object C experience a gravitational interaction.
C) Object C experiences an electrical interaction with itself.
D) Object A and object C experience an electrical interaction.
E) Object A and object B experience a gravitational interaction.

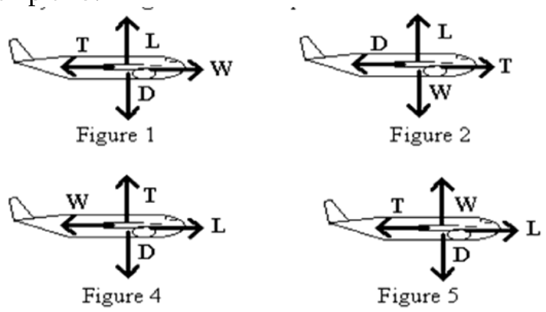
ANSWER[ ]

5 A 3.0-kg block is at rest on a horizontal floor. If you push horizontally on the 3.0-kg block with a force of 12.0 N, it just starts to move. (a) What is the coefficient of static friction? (b) A 7.0-kg block is stacked on top of the 3.0-kg block. What is the magnitude F of the force, acting horizontally on the 3.0-kg block as before that is required to make the two blocks start to move?

A) (a) 0.41 ; (b) 98 N; B) (a) 0.37; (b) 68 N; C) (a) 0.25; (b) 98 N; D) (a) 0.41 ; (b) 40 N
E) (a) 0.37; (b) 40 N

ANSWER[ ]

6 An airplane is traveling in level flight at a constant velocity. L is the lift, W is the weight, T is the thrust, and D is the drag. Which of the diagrams is the correct free body force diagram for the airplane?



A) Figure 1; B) Figure 2; C) Figure 3; D) Figure 4; E) Figure 5

ANSWER[ ]

11 Vector *A* has a magnitude of 3.0 units and makes an angle of -90.0° with the positive x-axis, vector *B* has a magnitude of 4.0 units and makes an angle of -120° with the positive x-axis. What is the magnitude of the vector sum of *A* + *B*?

A) 1.0 units; B) 6.8 units; C) 4.0 units; D) -6.8 units; E) -6.9 units

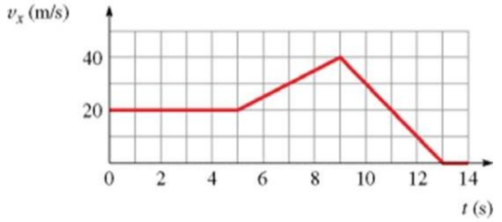
ANSWER[ ]

12 Which of the following specifications would allow you to precisely meet someone for an appointment?

A) Meet me at my car.
B) Meet me at my office, room 53 in School of Science and Technology on campus.
C) Meet me at my office, room 53 in School of Science and Technology on campus at 2:30 PM.
D) Meet me at my office.
E) Meet me at 2:30 PM.

ANSWER[ ]

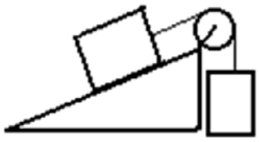
13 The graphs shows v_x versus t for an object moving along a straight line. What is the average velocity from $t = 0s$ to $t = 11s$?



A) 25 m/s^2; B) 36 m/s^2; C) 30 m/s$^{2;}$ D) 23 m/s$^{2;}$ E) 25 m/s2

ANSWER[ ]

14 Two masses are connected by a string which passes over a pulley with negligible mass and friction. One mass hangs vertically and one mass slides on a 30.0 degree incline. The vertically hanging mass is 6.00 kg and the mass on the incline is 4.00 kg. The acceleration of the 4.00 kg mass is:



A) 2.98 m/s^2; B) 3.92 m/s^2; C) 5.75 m/s^2; D) 6.86 m/s^2; E) 7.84 m/s^2.

ANSWER[ ]

15 An object moving in a circle at a constant speed is:

A) accelerating in the direction of motion.
B) accelerating toward the center of the circle.
C) accelerating away from the center of the circle.
D) not accelerating because its speed is constant.
E) not accelerating because its speed is not constant.

ANSWER[ ]

Part B: 11 Subjective Questions

16 Under what conditions can you apply the law of:

i. Conversation of energy?
ii. Conversation of linear momentum?
iii. Conversation of angular momentum?

ANSWER

17 What is the difference between electrical potential and electrical potential energy? Do they have different dimensions? Different units?

ANSWER

18 What is the difference between dimensions and units?

ANSWER

19 A large massive rock is in contact with the ground surface that is a flat surface on the earth. Draw a force diagram for the rock and the earth.

ANSWER

20 An ion's position vector is initially
R = 5.0i-6.0j+2.0k and 10 s later it is
R = -2.0i+8.0j-2.0k, all in meters. What was its average position vector during 10 s?

ANSWER

21 A block of wood is compressed 2.0 nm when inward forces of magnitude 120 N are applied to it on two opposite sides.

(a) What is the effective spring constant of the block?

(b) Assuming Hooke's law still holds how much would the block be compressed by inward forces of magnitude 480 N?

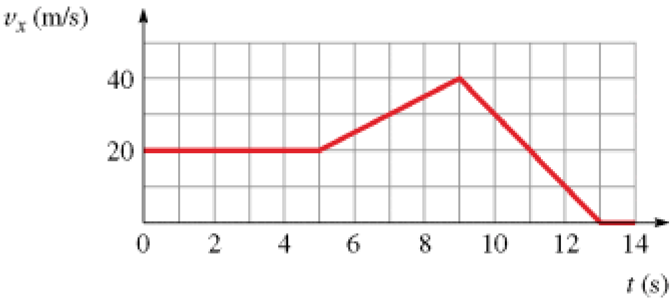
ANSWER

22 A person is standing on a bathroom scale. Identify the third-law partner of each of the forces

exerted on the scale. In other words, for every interaction involving the scale, identify the force that the scale exerts on another object.

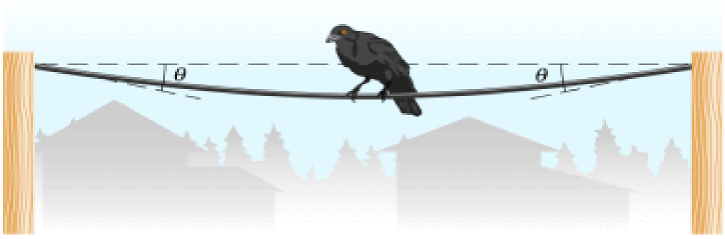
ANSWER

23 15. The figure below shows a graph of v_x vs. t for a body moving along a straight line. (a) What is a_x at t = 11 s? (b) What is a_x at t = 3 s? (c) How far does the body travel from t = 12 to t = 14 s?



ANSWER

24 A crow sits on a clothesline midway between two poles (the figure below). Each end of the rope makes an angle of θ below the horizontal where it connects to the pole. If the combined weight of the crow and the rope is *W*, what is the tension in the rope?



ANSWER

25 A ball is thrown from a point 1.0 m above the ground. The initial velocity is 19.6 m/s at an angle of 30.0° above the horizontal.

(a) Find the maximum height of the ball above the ground.
(b) Calculate the speed of the ball at the highest point in the trajectory.
ANSWER

APPENDIX XIV - Survey of Students' Perception of Learning Using Problem-Based Learning

Students' Perceptions of Learning Using Problem-Based Learning

Dear beloved retrospective student

The objective of this survey is to seek students' view of working with the problem-based learning (PBL) method.

Please read and follow the instructions that follow.

This survey consists of three parts:

Part A: **Consists of questions concerning to the *learning outcomes*.**

Part B: Consists of questions that reflect on problem-based learning (PBL) specific features.

Part C: **Consists of open-ended questions about *the problem-based learning (PBL) approach used during this semester.***

PART A Learning Outcomes

Instructions: Please circle the number **1, 2, 3, 4** or **5** that best describes how you feel about the knowledge and skills you gained when using problem-based learning this semester:

1 - Strongly Disagree
2 - Disagree
3 - Neutral
4 - Agree
5 - Strongly Agree

	Knowledge, Skills and Application of Knowledge & Skills					
1	I was able to search for, and access, information from a variety of sources.	1	2	3	4	5
2	I was able to recognize the relevance of what I learned to my own daily life.	1	2	3	4	5
3	I was able to develop my problem-solving ability.	1	2	3	4	5
4	I was able to identify the critical issues that were being discussed.	1	2	3	4	5
5	I was able to learn many new knowledge.	1	2	3	4	5
6	I was able to gain more advantages in knowledge.	1	2	3	4	5
7	I was able to make connections between different facts.	1	2	3	4	5
8	I was able to choose and apply my own strategy in problem-solving.	1	2	3	4	5
9	I was able to think creatively when using problem-based learning.	1	2	3	4	5
10	I was able to think critically.	1	2	3	4	5
11	My comprehension improved.	1	2	3	4	5
12	My ability to apply what I have learned improved.	1	2	3	4	5
13	My ability to analyze data improved.	1	2	3	4	5
14	I was able to apply my synthesis skill more deeply when using problem-based learning.	1	2	3	4	5
15	My ability to evaluate findings improved.	1	2	3	4	5
16	I was able to apply my technical maturity skill more deeply.	1	2	3	4	5
17	I was able to retain what I had learned more.	1	2	3	4	5
	Communication					
18	I was able to share my ideas clearly within my group during group discussion.	1	2	3	4	5
19	I was willing to consider the opinion's of others, even though I did not fully agree with them.	1	2	3	4	5
20	I was able to provide logical ideas to my group members, even though they sometimes did not fully agree with me.	1	2	3	4	5
21	I was able to generate related ideas and information with the group members gradually.	1	2	3	4	5
22	I had the opportunity to play an important role as one of the main resource contributor during group discussion.	1	2	3	4	5
23	I was able to listen to different perspectives and points of view of my group members and keep an open mind about their views.	1	2	3	4	5

24	I improved in my ability to contribute useful ideas and knowledge in group discussion.	1	2	3	4	5
	Independent Learning					
25	I was able to work more independently.	1	2	3	4	5
26	I was able to think of questions that helped me to drive the progress of problem-solving.	1	2	3	4	5
27	I did my fair share of work in my group.	1	2	3	4	5
28	I know what I am good at, and used my talents to the fullest.	1	2	3	4	5
29	I was able to learn new things during problem-solving.	1	2	3	4	5
30	I was able to demonstrate positive and responsible attitudes towards learning.	1	2	3	4	5
31	I was able to sustain my interest in solving a problem	1	2	3	4	5
32	I was able to choose and apply my own strategy as when learning.	1	2	3	4	5
33	The learning activities employed motivated me to learn more.	1	2	3	4	5
34	I was able to solve interesting and relevant physics problems.	1	2	3	4	5
35	I was involved actively in the learning activities with the group members.	1	2	3	4	5
36	I was able to locate my own sources of information.	1	2	3	4	5
37	I was able to apply much new knowledge in problem-solving process.	1	2	3	4	5
38	The learning activity was suitable for my level of knowledge.	1	2	3	4	5
39	The learning activities were fun.	1	2	3	4	5

PART B Students reflection on problem-based learning (pbl) approach.

Instructions: Please circle the number **1, 2, 3, 4** or **5** that best describes what is your reflection on problem-based learning (pbl) approach.

1 - Unable to Assess
2 - Strongly Disagree
3 - Disagree
4 - Agree
5 - Strongly Agree

	Feature					
1	PBL is one of the effective student-centered approaches.	1	2	3	4	5
2	The learning activities in the pbl groups were enjoyable.	1	2	3	4	5
3	I feel that my understanding of modern physics improved as a result of using this approach to learning.	1	2	3	4	5
4	I was actively engaged in learning when using this approach to learning.	1	2	3	4	5
5	My confidence as a problem-solver increased as a result of using this approach to learning.	1	2	3	4	5
6	My interest in learning modern physics increased as a result of using this approach to learning.	1	2	3	4	5
7	My ability to engage in reflective thinking increased as a result of using this approach to learning.	1	2	3	4	5

8	I found the material learned to be of more relevance as a result of using this approach to learning.	1	2	3	4	5
9	My motivation to learn modern physics increased as a result of using this approach to learning.	1	2	3	4	5
10	My perceptions and point of view in regard to learning modern physics lead to a better connection between classroom and real life as a result of using this approach to learning.	1	2	3	4	5

PART C Please answer the questions below accordingly.

Question 1: What are the learning outcomes that you felt you obtained?

Question 2: How has your ability to engage in creative thinking been affected?

Question 3: How has your ability to engage in critical thinking been affected?

Question 4: Do you think the PBL approach is a suitable way for you to learn modern physics? Explain why, or why not.

Question 5: What did you find to be least useful about learning using this learning approach?

Question 6: What did you find to be most useful about learning using this learning approach.

Thank you very much for your co-operation in completing this survey.

APPENDIX XV - Survey of Students' Perception of Learning via Online Learning

Students' Perception of Learning of This Course via Online Learning

Dear beloved retrospective student

The objective of this survey is to seek on your overall perceptions towards online learning.

Please read and follow the instructions that follow.

This survey consists three parts.

Part A Contains multiple choices questions relevant to learning in this Modern Physics course which happens to involve online learning.

Part B Contains questions about: student's perception of satisfaction; student's perception of interaction; students' perceptions of individual features; students' perceptions of individual features; students' perceptions of individual features; student's perceptions of individual features.

Part C Contains open-ended question about students' opinions of online learning delivery.

Please Circle Which Learning Group You Were in This Semester:

Traditional **PBL**

Part A Please circle the answer A, B, C, D or E, which you feel best, represents your view about each statement.

1 I was able to log on the Internet to work on this course:

A Only once a week
B At least twice a week
C Probably once every two week
D I don't know for sure
E Other - Please Specify:

____
____
____

2 I know how to use a web browser such as Netscape; Internet Explorer; FireFox Explorer to get around the Internet

A Yes. I browse the net frequently
B Somewhat. I have not had much exposure to it
C I have only seen my friends use it
D No, but I am willing to learn
E Other - Please Specify:

____
____
____

3 I know how to use a standard word processor programs such as Microsoft Word, Microsoft Works, or Word Perfect

A Yes, I am pretty comfortable with word processing
B Somewhat. I rely on the help lab aides
C I don't know the name of my word processor
D No, I prefer my typewriter
E Other - Please Specify:

____
____
____

4 I have basic knowledge of email

A Yes, I have an e-mail account
B No, but I can learn
C No. I prefer 'snail mail'
D I don't know how email works
E Other - Please Specify:

____
____
____

5 I am comfortable working with computers

A I find working with computers interesting
B I always seem to mess up my system's settings
C I don't like computers, but understand that they are important today
D I am not sure how I feel about computers
E Other - Please Specify:

____
____
____

6 I was able to cope when my computer or software broke down during the course

A I expect my instructor to be understanding and give me extensions
B I will get fixed immediately and will use another system in the meanwhile
C I cannot afford for things to go wrong
D Nothing will go wrong. I have good equipment
E Other - Please Specify:

7	I can meet deadlines without needing frequent prodding	A	I tend to fall behind most of the time
		B	I am a terrible procrastinator
		C	I generally meet my deadlines
		D	It depends on whether or not I like the project
		E	Other - Please Specify:
8	Will you be able to set aside some time to participate in weekly online discussions?	A	Yes. I have allowed time for this course
		B	Not weekly. I am too busy
		C	Not Sure. My schedule varies from week to week
		D	I do not know or sure
		E	Other - Please Specify:
9	How capable are you of determining main ideas and concepts when reading your course notes through Internet?	A	I am a good reader
		B	I prefer listening to reading about things
		C	I have to hear information in order to retain it
		D	I usually don't remember what I read
		E	Other - Please Specify:
10	Are you a self-motivated, independent learner?	A	I find studying alone a positive challenge
		B	I need the stimulation of a group
		C	I like working alone, but I need frequent prodding
		D	It depends on the season
		E	Other - Please Specify:
11	Which of the following describes your time management skills?	A	I need to be reminded of deadlines
		B	For the most part, I get things done on time
		C	I often miss deadlines because I am doing too much
		D	I am not very organized with my time
		E	Other - Please Specify:
12	How much time do you expect to spend studying for this course?	A	I can dedicate about four to six hours a week for studying.
		B	The same amount as attending and studying for a traditional course
		C	Less time since the class does not meet
		D	I do not know what to expect
		E	Other - Please Specify:

13	How good are you at following directions on assignments?	A	I like it when instructors go over homework directions orally
		B	I have difficulty understanding directions and frequently need clarification
		C	I can read and follow directions on my own
		D	I cannot following directions very well
		E	Other - Please Specify: ______________________________ ______________________________ ______________________________
14	I know how to turn on and off the computer system on my computer	A	Yes. I know my system's "shut down' process
		B	Yes. I just press the power switch
		C	No, but I am willing to learn
		D	I am not sure what you mean by "properly"
		E	Other - Please Specify: ______________________________ ______________________________ ______________________________
15	I am comfortable using a mouse	A	Yes, I use a mouse all the time
		B	Somewhat, but I need to work on it
		C	No, I prefer using the keyboard
		D	I don't like rodents.
		E	Other - Please Specify: ______________________________ ______________________________ ______________________________
16	My keyboarding skills are good	A	Yes I am a capable typist. I type my own work
		B	Sort of, I use the "hunt and peck" approach; it's very slow, but I get the job done.
		C	No, I have others type my papers for a small fee
		D	No, I am an awful typist!
		E	Other - Please Specify: ______________________________ ______________________________ ______________________________
17	I am comfortable with file management on my computer, such as moving files around different directories and drives, saving files, and deleting files	A	Yes, I am pretty comfortable
		B	Somewhat. I cannot always find my files
		C	No, but I can get help from friend or family members
		D	No, but I am a quick learner
		E	Other - Please Specify: ______________________________ ______________________________ ______________________________ ______________________________
18	I have used a browser to surf the Internet	A	Yes. I spend a lot of time on the net
		B	To some extent, my friends seem to spend endless hours on it
		C	Very little, but I can learn how to use it
		D	I don't know what a "browser" is
		E	Other - Please Specify: ______________________________

19	I can handle the situation when my Internet connection is interrupted for a period of time	A	Yes, I will just use another lab on-campus, or a friend's computer
		B	No, I will wait until the connection is reestablished
		C	No, I will ask the instructor for extensions on the assignments
		D	No, I will get very upset. I do not like it when things go wrong
		E	Other - Please Specify:
20	I am happy to take a class that is taught using Internet	A	Yes, I look forward to the experience
		B	Yes, I don't have time to take a traditional class
		C	Yes, but I am a bit nervous about it. I am not sure it is for me
		D	No, I do not, but I have to do this course
		E	Other - Please Specify:

Part B Please circle the answer 1, 2, 3, 4 or 5 which you feel best represents your view about each statement:

1- Strongly Disagree
2- Disagree
3- Neutral
4- Agree
5- Strongly Agree

	Student's Perception of Satisfaction					
1	I was satisfied with the overall experience of online learning.	1	2	3	4	5
2	I enjoy the portion of the course on online.	1	2	3	4	5
3	The online learning portion stimulated my desire to learn.	1	2	3	4	5
4	I was satisfied with online learning in regards to the quantity (knowledge input) of my learning experience.	1	2	3	4	5
5	I was satisfied with online learning in regards to the *quality* (knowledge input) of my learning experience	1	2	3	4	5
6	The online learning component of this course allowed for social interaction.	1	2	3	4	5
7	Online learning provided a reliable means of communication with other group members.	1	2	3	4	5
8	Online learning provided a reliable means of communication with facilitator/lecturer.					
9	I found the online learning course to be a helpful resource.	1	2	3	4	5

10	I used the online learning to help me understand course information.	1	2	3	4	5
11	I regularly used online learning to answer my questions to other group members.	1	2	3	4	5
12	I believe that online learning enhanced my learning in Modern Physics course.	1	2	3	4	5
13	I would like to see all of my courses involve at least some online learning.	1	2	3	4	5
14	I believe that online learning will play an important role in education in the future.	1	2	3	4	5
	Student's Perception of Interaction					
15	The online learning component of this course helped to create a sense of community among the students in the course.	1	2	3	4	5
16	The online learning component of this course increased my interactions with the instructor.	1	2	3	4	5
17	The online learning component of this course increased my interactions with my fellow coursemates/classmates.	1	2	3	4	5
18	The online learning component of this course extended my personal interactions.	1	2	3	4	5
	Student's Perceptions of Individual Features (Content Available on the Web Course)					
19	I was satisfied with the content available on this online learning web-course.	1	2	3	4	5
20	I was satisfied with the online lectures note included on the course Website.	1	2	3	4	5
21	The online lecture notes on the Learning Management System (LMS) Website were a valuable resource.	1	2	3	4	5
22	The lecture note/finding notes were easy to print.	1	2	3	4	5
23	I like the fact that Power-Point slides of the lecture notes were available on the LMS Website.	1	2	3	4	5
24	I regularly visited the calendar section of the LMS Website.	1	2	3	4	5
25	I found the calendar section of the LMS Website a valuable resource.	1	2	3	4	5
26	I felt the links contained on the LMS Website were valuable.	1	2	3	4	5
27	I regularly visited the links contained on the LMS Website.	1	2	3	4	5
28	The LMS Website is a great place for the instructor to place handouts.	1	2	3	4	5
	Student's Perceptions of Individual Features (E-learning as a Communication Tool)					
29	I e-mailed the instructor trough the LMS Website.	1	2	3	4	5
30	I regularly checked my mailbox through the LMS Website.	1	2	3	4	5
31	I regularly used the discussion section of the LMS Website.	1	2	3	4	5
32	I found the discussion section of the LMS Website easy to use.	1	2	3	4	5
33	The discussions section of the course content using	1	2	3	4	5

	LMS helps me better understand course content.					
34	The discussion section of the course content using LMS is a great way to interact with my fellow classmates.	1	2	3	4	5
35	The discussion sections of the course content using LMS is a great way to interact with the facilitator/lecturer.	1	2	3	4	5
36	The discussion section of the course using LMS helps me to ask and answer questions more efficiently.	1	2	3	4	5
37	I am glad the discussion section of the LMS Website was factored into my final grade. (**for PBL group only*)	1	2	3	4	5
38	I would rather do an assignment than a discussion.	1	2	3	4	5
	Student's Perceptions of Individual Features (Assignment)					
39	I found it easy to submit my assignment online.	1	2	3	4	5
40	I prefer the online submission of assignments.	1	2	3	4	5
41	I found the online submission of assignments simple.	1	2	3	4	5
42	I found the online submission of assignments convenient.	1	2	3	4	5
	Student's Perceptions of Individual Features (Online Student Assessment)					
43	I took the online test (critical and creative test).	1	2	3	4	5
44	I found taking online tests convenient.	1	2	3	4	5
45	I found the test section easy to use.	1	2	3	4	5
46	The tests worked during my visit.	1	2	3	4	5
47	I prefer taking my tests, quizzes and exams on paper rather than online.	1	2	3	4	5

Part ***C*** Write describe in your own words how you felt about online learning that you were involved in during this semester, in terms of:

1. Satisfaction

2. Convenience

3. Knowledge gained from online learning

4. Future expectations of online learning

Thank you very much for your co-operation in completing this survey

APPENDIX XVI – Student's Problem-Based Learning (PBL) Assessment Booklet

	Students ***Problem-Based Learning (PBL)*** ***Assessment Booklet***

Name : ______________________________

Class : ______________________________

This booklet contains:

Appendix A: The flow-chart on how PBL operate in this study

Appendix B: The steps on how the PBL working

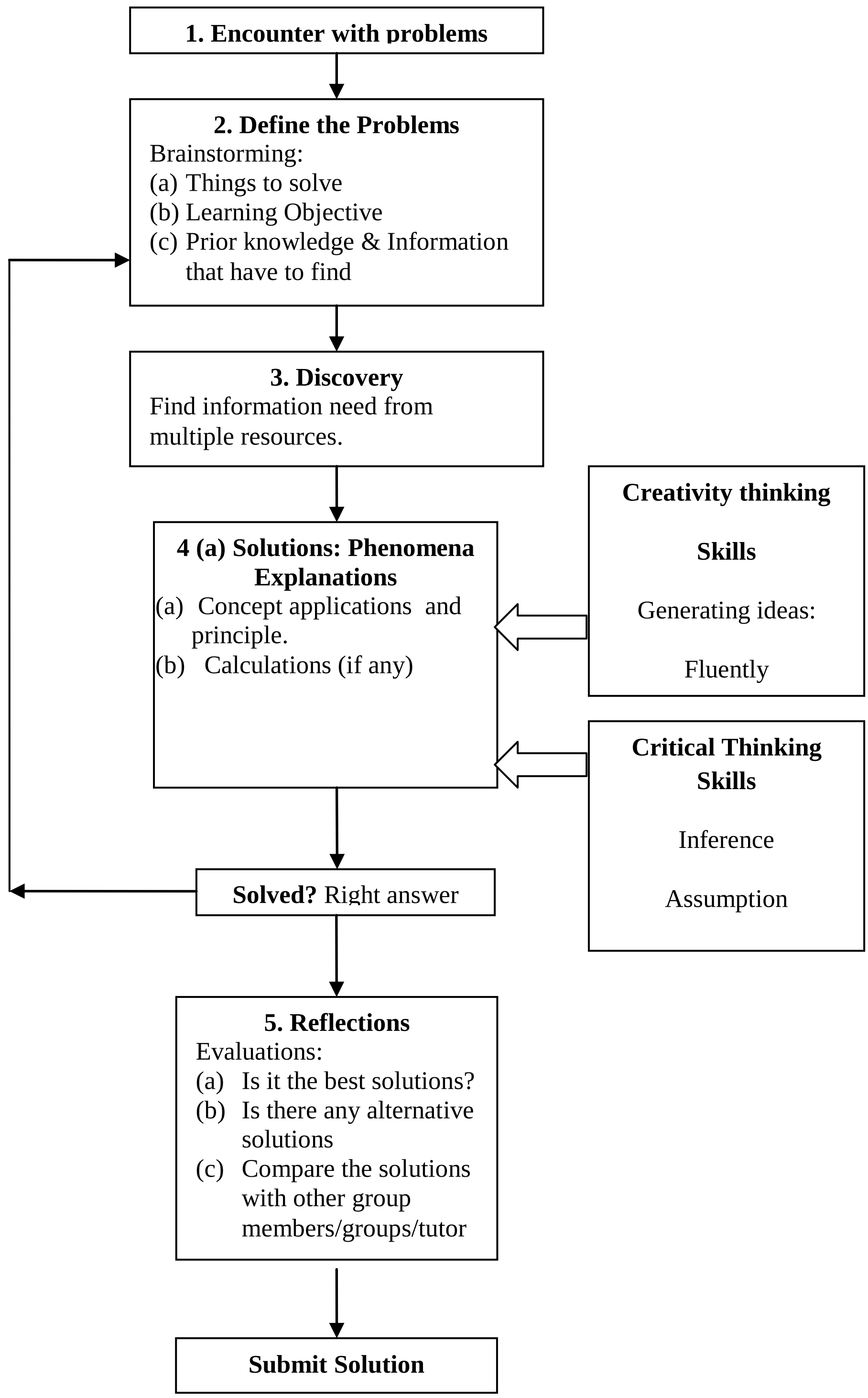
Appendix C: The example on how to apply the PBL learning

Please read it contains carefully as it will helps and guide you on how to experience this whole study.

Your cooperation is very much appreciated. Thank you

Appendix A

Flow-Chart of Problem-Based Learning Process that used by Students in this PBL Module.



Appendix B

1 **Meet the problem**

Read the problem/scenario

2 **Define the problem**

a. Things need to be solved/ learning objectives

b.

Prior knowledge	Information need to be find

3 **Discovery**

Students have to find knowledge and information from other resources (appendix, text books, and etc) individually. Read carefully and try to get as many require relevance concepts as you can to explain the phenomena that your encounter.

4 **4.1 Creativity and Critical Thinking**

Try to apply the **creativity** and **critical thinking** whenever need and appropriate:

Creativity	**Critical Thinking**
Generate Ideas:	Inference
Fluency	Assumption
Flexibility	Deduction
Originality	Interpretation
Elaboration	Argument

Term Definition:

Creativity

- *Fluency* is the capability to generate many ideas.
- *Flexibility* is the capability to generate variety of ideas.
- *Originality* is the capability to generate new, genuine and authentic ideas.
- *Elaboration* is the capability to explain things in details.

Critical Thinking

- *Inference* is the reasoning involved in making a logical judgment on the basis of circumstantial evidence and prior conclusions rather than on the basis of direct observation.
- *Assumption* is a statement that is assumed to be true and from which a conclusion can be drawn.
- *Deduction* is something that is inferred (deduced or entailed or implied) or reasoning from the general to the particular (or from cause to effect).
- **Interpretation** ***is a mental representation of the meaning or significance of something without hesitation or an explanation resulting from interpreting something without***

hesitation.

- **Strong argument** ***is related with the prior knowledge. It is important and significant argument with the learning activities.***
- **Weak argument** ***is unrelated even though the knowledge or information is important or not important or the argument is only a simple thing.***

5 Reflection

Compare your answer and findings with other team members

Appendix C

Example of problem solving

1 **Meet the problem**

The Sinking of the Titanic

Why did the Titanic sink? The ship was doomed and it was slowly sliding into its watery grave. But why did the largest, most advanced ship of the century sink? On April 12th, 1912 the White Star luxury liner *Titanic* left Southhampton, England, bound for New York. Constructed with state of the art steam technology and metallurgy, she was declared Unsinkable. The manifest of the *Titanic* listed some 2,208 passengers, including the crew, numerous technical personnel, and wealthy vacationers such as the millionairess Molly Brown.

2 **Problem Definition**

a) (i) Thing to be solved

To get further explanation in physics perspectives why Titanic sank?.

(ii) learning objectives

Can give an appropriate, simple and understandable explanation on why Titanic sank easily.

Prior knowledge	Require knowledge
Titanic sank because the ship collides with a big iceberg.	How the Titanic can sank in physics and engineer perspectives

3 **Discovery**

Final Resting Place

On September 1st, 1985, the research vessel Knor, under the command of Dr. Robert Ballard, located the ruins of the Titanic on North Atlantic seabed. In July of 1986, Ballard and his research staff returned to the Titanic aboard the submarine Alvin, whose robotic camera took pictures of the wreckage.

Ship design changes

The sinking of Titanic changed the way passenger ships were designed. Many existing ships, such as the Olympic, were refitted for increased safety. Besides increasing the number of lifeboats on board, improvements included reinforcing the hull and increasing the height of the watertight bulkheads. The bulkheads on Titatinc extended 10 feet (3 m) above the waterlie; after Titanic sank, the bulkheads on other ships were extended higher to make compartments fully watertight. While Titanic had a double bottom. She did not have a double hull; after her sinking, new ships were designed with double hulls; also, the double bottoms of the ships, including the Olimpic, were extended up the sides of their hulls, above their waterlines, to give them double hulls.

It was the shipbuilder's fault

About three million rivets were used to hold the sections of the Titanic together. Some rivets have been recovered from the wreck and analysed. The findings show that they were made of sub-standard iron. When the ship hit the iceberg, the force of the impact caused the heads of the rivets to break and the sections of the Titanic to come apart. If good quality iron rivets had been used the sections may have stayed together and the ship may not have sunk.

4 Solution

Try to discuss with other team members and facilitator concerning on your problems.

You can either discuss it electronically, through chat room, forum e-mail, or find your further informations via Online Learning or manual text books, books, or other outsources in formations.

a) Assumption

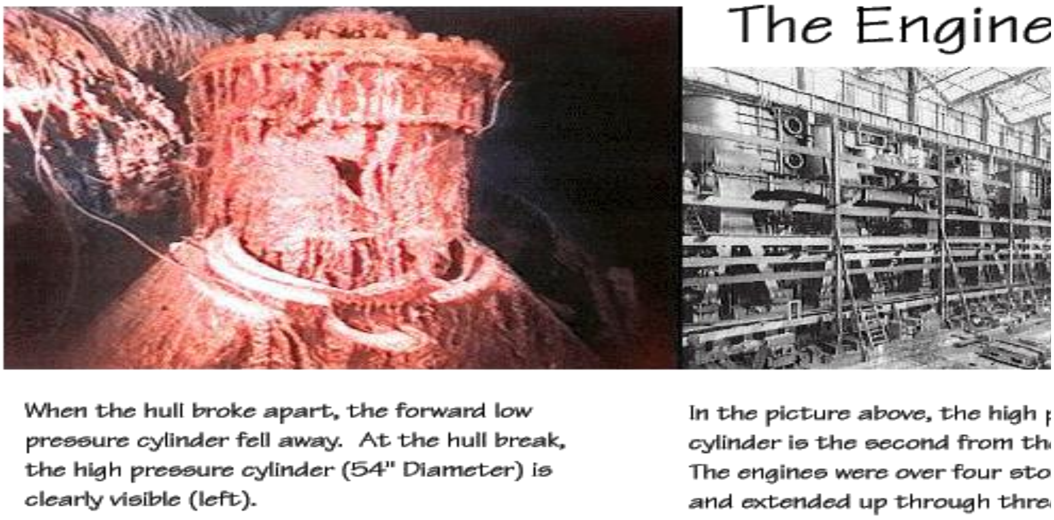
Possible factors in the sinking

Originally, historian thought the iceberg had cut a gash into Titanic's hull: Since the part of the ship that the iceberg damaged is now buried, scientists used sonar to examine the are and discovered the iceberg had caused the hull to buckle, allowing water to enter Titanic between her steel plates

b) Explanation

What caused Titanic to sink?

Titanic was designed with a series of transverse bulkheads, separating her into 16 "water-tight" compartments. Unfortunately, these bulkheads, while extending above the water-line, were not capped with water-tight decks. Her designers considered a breach between two compartments a worst case scenario, and in fact designed her to float with any four compartments flooded.



5 Reflection

Findings

Steel plates and irons rivets

A detailed analysis of small pieces of the steel plating from the Titanic's wreck hull found that it was of a metallurgy that loses its elasticity and becomes brittle in cold or icy water, leaving it vulnerable to dent-induced ruptures. The pieces of steel were found to have very high content of phosphorus and sulphur (4x and 2x respectively, compared to modern steel), with manganese-sulphur ratio of 6.8:1 (compare with over 200:1 ratio for modern steels). High content of phosphorus initiates fractures, sulphur forms grains of iron sulphide that facilitate propagation of cracks, and lack of manganese makes the steel less ductile. The recovered samples were found to be undergoing ductile-brittle transition in temperatures of 32 °C (for longitudinal samples) and 56 °C (for transversal samples—compare with transition temperature of -27 °C common for modern steels—modern steel would became so brittle in between -60 and -70 °C). The anisotropy was likely caused by hot rolling influencing the orientation of the sulphide stringer inclusions. The steel was probably produced in the acid-lined, open-hearth furnaces in Glasgow, which would explain the high content of P and S, even for the times.

Another factor was the rivets holding the hull together, which were much more fragile than once thought. From 48 rivets recovered from the hulk of the Titanic, scientists found many to be riddled with high concentrations of slag. A glassy residue of smelting, slag can make rivets brittle and prone to fracture. Records from the archive of the builder show that the ship's builder ordered No. 3 iron bar, known as “best” — not No. 4, known as "best-best," for its rivets, although shipbuilders at that time typically used No. 4 iron for rivets. The company also had shortages of skilled riveters, particularly important for hand riveting, which took great skill: the iron had to be heated to a precise colour and shaped by the right combination of hammer bloes. The company used steel rivets, which were stronger and could be installed by machine, on the central hull, where stresses were expected to be greatest, using iron rivets for the stern and bow. Rivets of 'best best' iron had a tensile strength approximately 80% of that of steel, 'best' iron some 73%

Rudder and Turning Ability

View of the stern and rudder of one of the Olympic-class ships in dry-dock.

Although Titanic's rudder met the mandated dimensional requirement for a ship her size, the rudder's design was hardly state-of-the-art. According to research by BBC History. "Her stern, with its high graceful counter and long thin rudder, was an exact copy of an 18th-century sailing ship…a perfect example of the lack of technical development. Compared with the rudder design of the Cunaders, Titanic's was a fraction of the size. No account was made for advances in scale and little thought was given to how a ship, 852 feet (260m) in lengths, might turn in an emergency or avoid collision with an iceberg. This was Titanic's Achilles heel.

"A more objective assessment of the rudder provision compares it with the legal requirement of the time: the area had to be within a range of 1.5% and 5% of the hull's underwater profile and, at 1.9% the Titanic was at the low end of the range. However, the tall rudder design was more effective at the vessel's designed cruising speed; short, square rudders were more suitable for low-speed maneuvering.

Perhaps more fatal to the design of the *Titanic* was her triple screw engine configuration, which had reciprocating steam engines driving her wing propellers, and a steam turbine driving her centre propeller. The reciprocating engines were reversible, while the turbine was not. According to subsequent evidence from Fourth Officer Joseph Box hall, who entered the bridge just after the collision, First Officer Murdoch had set the engine room telegraphs to reverse the engines to avoid the iceberg, thus handicapping the turning ability of the ship. Because the centre turbine could not reverse during the "full speed astern' manoeuvre, it was simply stopped. Since the centre propeller was positioned forward of the ship's rudder, the effectiveness of that rudder would have been greatly reduced: had Murdoch simply turned the ship while maintaining her forward speed, the Titianic might have missed the iceberg with meters to spare. Another survivor, greaser Frederick Scott, gave contrary evidence; he recalled that at his station in the engine room all four sets of telegraphs had changes to "stop", but not until after the collision.