Effects of Problem-Based Learning in a Higher Education Electronics Course

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Open Universiteit
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ISBN 978-94-92739-98-8

Cover design: Martin Podges

Effects of Problem-Based Learning in a Higher Education Electronics Course

Effecten van Probleemgestuurd Leren in een Cursus Electronica voor het Hoger Onderwijs

PROEFSCHRIFT

ter verkrijging van de graad van doctor aan de Open Universiteit
op gezag van de rector magnificus prof. dr. Th. Bastiaens
ten overstaan van een door het College voor promoties
ingestelde commissie in het openbaar te verdedigen

op vrijdag 4 oktober 2019 te Heerlen
om 13:30 uur precies

door

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geboren op 18 september 1960 te Standerton

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ACKNOWLEDGMENTS

I would like to acknowledge all the participants of this study. Without their contribution, this study would not have been possible.

First of all, I wish to take this opportunity to express my sincere gratitude to my supervisor, Dr Piet Kommers, who read my numerous revisions and helped me to make sense of the confusion. I never would have made it through without you. You challenged me to think in new ways and gave me a push when I needed it. I am forever grateful.

I would like to express my sincere gratitude and appreciation to Professor Maarten de Laat. Thank you for accepting the role as a promotor. Your guidance and suggestions was instrumental in 'fine-tuning' my thesis and reaching my final goal.

To the faculty of Science, Engineering, and Technology (FSET) at Walter Sisulu University (WSU) who allows and encouraged me to work on this study, especially Dr Ferdie Gerber, Dr Msimelelo Siswana and Mr Sam Frimpong. Thank you so much.

In particular, I would like to give thanks to my colleagues at the Department of Electrical Engineering for accommodating me to do this research and especially Mr. Ovid Ndondo and Mr. Zwelibanzi Swana for allowing me to 'hijack' their classes during some of the experiments. Also to my wonderful students who agreed to be my guinea pigs without complaint, we had wonderful times together.

To Dr Stoffel Fourie who offered guidance, support and for reading and re-reading my work. Thank you so much. I would like to express my appreciation and deep gratitude to the Open University of the Netherlands for awarding me a Dissertation Completion Fellowship and Nuffic (NPT ZAF 237 / 267) for providing me with the financial means to complete this project.

And finally, thanks to my wife (Joan), children (Benji, Tian and Juan), and numerous friends who endured this long process with me, always offering support and love. To my Heavenly Father for His guidance to begin and complete this study (2 Tim 4:7).

Mr. J.M. Podges

SUMMARY

Many of today's newly graduates are not able to meet the expectations of future employees. This include the 'application of knowledge', 'communication skills', 'decision-making skills', 'analytical skills', 'teamwork skills', 'well-practiced leadership skills' and 'good interpersonal skills' and 'entrepreneurial skills'. Most universities make use of the traditional lecturing style that necessitate rote learning. This passive learning style leads to students with underdeveloped critical thinking and other skills as required by employers. Problem-Based Learning (PBL) can address these problems and develops the skills required by employers when implemented at a reasonably realistic scale.

The primary aim of this study was to investigate the outcome when the PBL mode was applied in different arrangements within an engineering subject. The study was, undertaken at the Walter Sisulu University of Technology (WSU) in South Africa and it consists of three main experiments. These experiments were pragmatic based and students in the first year 'analogue electronics course' participated in the experimental procedures.

In the first experiment, the PBL and the lecturing mode was compared in terms of attitudinal effect, the amount of reflection and learning outcome effects. The second experiment investigates how PBL can be used as supplementary to the lecturing mode. In this Experiment, the lecturing mode has been followed by PBL in contrast to PBL followed by the lecturing mode. Three different groups had to solve a problem based on a project by applying the distinctive PBL approach during the third experiment. After successful completion and demonstration, the project was passed on to a different group who had to study and continue on with the 'new – already made' project, inherited from one of the other groups before presenting it to the class. This emulate a real-life situation where employee's sometimes had to continue working, developing or improving an existing project from for instance an ex-colleague.

The amount of attitude, motivation and reflection was used as a measure to determine the success of an intervention and existing validated surveys were adopted and used as instruments to measure these. Test scores were also used in some cases to determine the learning outcomes. Blackboard was used to collect all data and the statistical analyses of this study was performed by using the statistical package program for social sciences (SPSS). A pilot was undertaken to test all facets of the experiments. The PBL mode was organized as student-driven projects and integrates various concepts, in order to match a real-life situation.

A correlation was found between the students' attitudes and project marks for those who underwent the PBL method during experiment 1. It was found that students who followed the PBL method learned to do research, learned better how to work in groups and developed greater confidence. They learned how to apply their knowledge and they had a more positive attitude towards learning goal orientation, task value, self-efficacy and self-regulation. They also reflect more, but there were no significant knowledge improvements during traditional-like tests and exams.

The attitudinal effects, motivational effects and the amount of aroused reflection were much higher for those students who were in the lecturing mode followed by PBL during experiment 2. Students who did PBL first found it more strenuous and they became negative once confronted with the lecturing mode. The PBL mode proves to improve the students' teamwork and communication skills whilst they still learn to apply their prior knowledge to solve complex engineering problems.

Students scored mostly higher during a knowledge test on the project they initially worked on and also those projects (from the other groups) that they found interesting during experiment 3. All groups managed to improve their scores during a follow-up knowledge test for those questions related to the project they initially worked on. A great deal of vicarious learning took place in most cases between the different student groups. Students are getting much more exposure when doing several PBL problems (as by the different groups) simultaneously and data confirms that this improves their attitude, motivation and reflection significantly.

This study reveals various benefits in the use of PBL. Students enjoyed it and their attitude, motivation and reflection were enhanced. Students think more critically, learn to communicate and work in groups. Students at WSU should enter PBL with a higher level of prior knowledge, and thus pleads for a hybrid approach of traditional lectures followed by a project-based PBL problem. Using different problems for the various groups encourages vicarious learning and enhances students' attitude, motivation and reflection even further.

The implementation of PBL may require some adjustments, for instance the facilities (as discussed in Chapter 8) and assessment methods (as discussed in APPENDIX BB) so that they fit the key values as targeted by the PBL method. This study creates an expectation that it might be worth for universities to move at least a part of their curricula into the PBL format to overcome the gaps between employer expectations and the outcomes from traditional vocational education formats.

Possible strategy on how to implement PBL, especially at the engineering departments of WSU is discussed in the last chapter. A possible future perspective of what the future hold for education is also discussed in this chapter.

SAMENVATTING

Veel van de afgestudeerden zijn tegenwoordig niet in staat om aan de verwachtingen van hun toekomstige werkgevers te voldoen. Dit betreft ‘het kunnen toepassen van kennis’, het beschikken over vaardigheden om ‘te communiceren’, ‘beslissingen te nemen’, ‘analyses te maken’, ‘te werken in een team’, ‘leiderschap-’, en ‘interpersoonlijke en ondernemerschap’ te tonen. De meeste universiteiten en hogescholen maken nog steeds gebruik van het college als overdrachtsvorm. Deze preludeert op het paraat hebben van feitelijke kennis. Echter, zij werkt ook de receptieve houding in de hand en daarmee een onvoldoende ontplooide kritische denkhouding en onder de maat betreffende de hiervoor genoemde beroepskwalificaties. PBL: Problem-Based Learning, in het Nederlands ‘Probleemgestuurd Leren’ (PGL) genoemd kan hier in de goede richting werken zodat zij als beginnend werknemer bij problemen op beperkte schaal op hun taak zijn toegerust.

Het primaire doel van deze studie was om de effecten in kaart te brengen die optreden tijdens PGL. Hiertoe werd PGL in diverse didactische contexten geïmplementeerd; Dit alles binnen domeinen van een technische ingenieursopleiding. Dit onderzoek vond plaats aan de Walter Sisulu University of Technology (WSU) in Zuid-Afrika om en nabij de stad East London. Er vonden drie hoofdexperimenten plaats. Elk experiment richtte zich op de praktische aspecten van het succesvol implementeren van PGL. De studenten waren eerstejaars tijdens hun onderwijs in ‘analoge elektronica’.

In het eerste experiment werden de PGL- en de collegevorm onderling vergeleken op attitudinale effecten, de mate van optredende reflectie en de bereikte leerresultaten. Het tweede experiment onderzocht hoe PGL idealiter aanvullend op de collegevorm kan worden ingezet. In dit experiment werd de collegevorm opgevolgd door PGL in contrast tot PGL aangevuld met hoorcolleges. De drie onderscheiden groepen moesten elk een ontwerpprobleem oplossen middels de PGL-methode die ook paste in het derde experiment. Na het uitwerken en plenair demonstreren van de aanpak en oplossing werd het betreffende project doorgegeven aan een ander team. Dat team moest zich verdiepen in de aanpak en technische oplossing van het voorgaande team om vervolgens dit plenair duidelijk te maken aan teams die op dit punt volkomen blanco waren. Hiermee werd een natuurgetrouwe situatie nagebootst waarin werknemers op een onafgemaakt project van vertrokken collega’s moesten doorbouwen.

De opgetreden mate van attitude, motivatie en reflectie, in sommige gevallen aangevuld met de scores op de kennistoetsen, werden gebruikt om het succes van een interventie mee vast te stellen. Blackboard werd gebruikt om de diverse data op te slaan en te combineren. De data-analyses gebeurden in SPSS. Per meetinstrument werd via een pilotstudie gekeken of er geen storende onduidelijkheden in de vragen waren geslopen. De overall PGL-modus werd geïmplementeerd in de vorm van student-gestuurde projecten die aansloten op de arbeidssituaties in de praktijk.

In Experiment 1 werd een correlatie gevonden tussen de gradaties in studentattitudes en de verkregen cijfers bij de projectbeoordelingen. Er werd gevonden dat studenten die de PGL-methode volgden ook beter waren voorbereid op het zelfstandig doen van onderzoek. Ook leerden ze beter hoe in teams te werken en ontwikkelden ze meer zelfvertrouwen. Bovendien leerden ze beter hun kennis te benutten en waren meer gericht op het bereiken van leerdoelen, inschatten van taakprioriteiten, zelfredzaam en beter in staat zich in te stellen op het stadium

van de ontwerptaak middels zelfregulatie. Zij besteedden meer tijd aan reflectie, echter er werden geen hogere scores op de traditionele kennistoetsen en examens vastgesteld.

De attitude-, motivatie- en reflectiemeting toonden veel hogere warden in de PGL-conditie vergeleken met de conditie van colleges volgen.

2. Studenten die als eerste de PGL-aanpak volgden vonden het meer inspannend en warden zelfs negatief als ze daarna de collegevorm moesten volgen. PGL verbeterde duidelijk hun teamwork capaciteiten en communicatievaardigheden ook terwijl zij naar inhoudelijk kennis zochten om daarmee complexe technische ontwerpproblemen op te lossen.

Studenten scoorden meestal hoger op hun kennistoets als het ging over de kennis die ze als eerste projecteigenaar nodig hadden. Op het gebied waarin zij hun aanvankelijke project uitvoerden. Maar ook als zij slechts zijdelings in een later stadium bij het project van een ander team betrokken werden, zoals in Experiment 3. Alle teams waren in staat om de cijfers van project gerelateerde toetsitems in een follow-up toets te verbeteren. Er was een aanzienlijk effect van het plaatsvervangend leren op basis van voorafgaand teamwork te zien. Studenten die aan meerdere probleemtaken tegelijkertijd werken gaven betere presentaties; Blijkbaar draagt taakdiversiteit aanzienlijk bij tot attitude, motivatie en reflectie.

Deze studie laat diverse meerwaarden van het gebruik van PGL zien. Studenten hadden er zichtbaar plezier in en toonden meer vormend effect ten aanzien van attitude, motivatie en reflectie. Er werd in de benadering van PGL duidelijk meer kritisch nagedacht en met de teamleden gedeeld. Studenten met een gemiddeld hogere voorkennis die bij WSU binnenkomen zouden in elk geval aan de PGL-werkwijze moeten worden toegewezen. Curriculair gezien komt dit neer op een pleidooi voor een mix van traditionele en PGL-instructievarianten. Indien een student een mix van beide toegewezen krijgt, dan heeft de volgorde College-PGL de voorkeur. Een verdere differentiatiemaatregel is het divers maken van aan te bieden PGL-thema's, waardoor de meerwaarde voor ieders attitude, motivatie en reflectie nog verder te optimaliseren is.

De verdere implementatie van PGL heeft waarschijnlijk nog meer aanpassingen nodig. Bijvoorbeeld de faciliteiten per lokaal (Zie Hoofdstuk 8) en de te bezigen toetsmehoden (Zie APPENDIX BB). Dit alles om de essentie van PGL verder uit de verf te laten komen. Deze studie lanceert de verwachting dat het voor het hoger onderwijs lonend is om tenminste een deel van hun curricula met PGL uit te rusten. Nogmaals, dit om in de toekomst nog grotere fricties tussen studentcompetenties en eisen van de werkgevers te vermijden. Vooralsnog lijkt deze studie vooral uit te wijzen dat PGL een belangrijke schakel biedt tussen traditioneel aanbod gestuurd onderwijs en up-to-date probleemgerichte werkhouding die nodig is in de 21e eeuwse banen. Dit geldt dan natuurlijk in sterkste mate voor het beroepsgerichte onderwijs.

De meest waarschijnlijk succesvolle strategie om PGL te implementeren (in elk geval bevestigd binnen WSU) komt aan de orde in het slothoofdstuk. Daarin wordt tevens ingegaan op de toekomstvisie van de relatie scholing en werkloopbaan.

TABLE OF CONTENT

CHAPTER 1: PROBLEM STATEMENT

RESEARCH TOPIC, MOTIVATION AND PRAGMATIC PRIORITIES

Introduction

My career as a lecturer in the department of Electrical Engineering started in 1993 at the Walter Sisulu University in the Eastern Cape of South Africa. At the time, I had 14 years of industrial experience, but no teaching experience. I had to imitate the learning styles from my teachers and lecturers who were responsible for my education. As time went by, I realized that the students in my classes mainly relied on receptive rote- instead of active “constructivist-” learning just in order to pass the courses. Hence they were not able to apply their knowledge in a productive way.

During the late 90’s, I had an opportunity to write a text book for our Electronics I students “Introductory to Electronics”. Whilst writing the book, I also developed Computer Based Training material based on the content of the book. Normal figures were mostly replaced with animations. This helped a lot in explaining the basic concepts to the students.

I also developed a “Remote Lab” which enabled students to do transistor related practicalities via the internet. The slowness of the computers and network connectivity in the computer labs made it difficult to use the Remote Lab successfully at the time. (There was a reasonable improvement in the speed of the computers and network connectivity since then).

Some years later I realized that the Digital Systems III students need to learn more about the application of their knowledge, especially involving micro-controllers. Most of them use rote learning (to pass the subject), but they did not understand what they were doing. Almost all of my colleagues experience a similar situation, and feel that students are not well prepared to solve “real-world problems”. “Fischer Technik” offers design construction sets that are very close to reality to what is used in industry. They cover subjects such as mechanics, structural analysis, pneumatics, electrical engineering and regenerative energy.

Figure 1 shows some of the Fischer Technik systems.

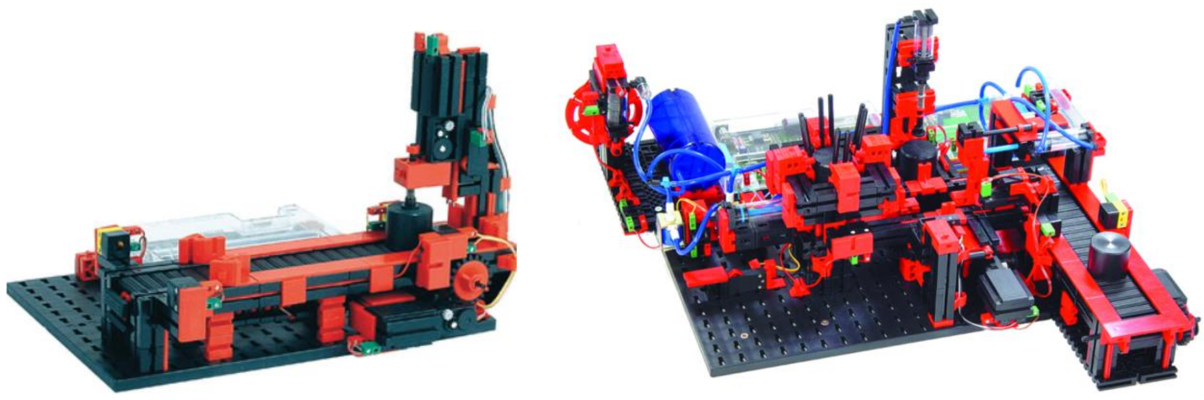


Figure 1. Typical Construction Sets available from Fischer Technik

I used one of these systems from Fisher Technik in a Problem-based Learning (PBL) way with the students some years ago. At the 1st day of the Digital Systems III class, I demonstrated the system to the students, explaining about the function of the inputs and outputs connected to the µController and gave them a flow chart. I then asked each group of 4-5 students to write their own software program for the system and to demonstrate it within 3 weeks. At the time I did not know anything about PBL or active learning, but as I look back today I realize that it was the first step towards a PBL approach. The students enjoyed the project, had a positive attitude and I observed a high level of motivation amongst them. One finding I found strange was that those students who repeated the subject actually did worse than some of the students who were new to the subject. Although these repeater students entered the problem with a much higher level of prior knowledge, they refuse to take the responsibility of playing a leading role in solving the problem and subsequently contributing very little towards their group.

During 2010 an opportunity arose to extend my studies. It related to e-learning and I immediately thought of the impact the Remote Lab could have in education. It was my desire not only to improve my own qualification, but to also to improve the quality of the education of the WSU students. The Nuffic (NPT ZAF 237/267) study grant was then awarded to me in order to undertake my PhD research. It was during this time that I was introduced to PBL. This PhD study demonstrates the typical adventure when trying to assimilate a new method in education. It seeks to determine the effect of Problem-based Learning (PBL) in the context of the Walter Sisulu University, and if beneficial, to distil its lessons and to derive it's more generic conclusions.

Experience from the "un-official" practice-based research with the Digital Systems III students were positive since results were experienced first-hand within the WSU environment. The practice-based research approach argues that effective educational research is deeply embedded in actual educational practice according to Furlong and Oancea (2005) and Martens, Kessels, de Laat, and Ros (2012). My position as a lecturer at WSU contributed towards the decision of using the practice-based research method during this research since it seeks to develop research from within practice and in dialogue with practice. Literature from other researchers who use the practice-based approach will get preference above those who got their data 2nd hand during this study.

Several effects related to the introduction of PBL are taken, described and explained. Its parameters are learning outcomes, sequential preferences when PBL is mixed with lecturing, and finally the potential of vicarious effects from one team to another. Also included is the recommended approach for transforming traditional- into PBL approaches and the creation of new processes as a result from the study and experimentation. It seems that the conventional, didactic teaching methods are not sufficiently stimulating to our tertiary students, particularly in the sector of vocational training. Many of today's students are only concerned on finishing their studies with the least possible effort. They do not always understand what they are learning and how it relates to their prior knowledge, intuition and their coming professional needs. This became evident when students in the electrical engineering department (at Walter Sisulu University) needed to use their knowledge and skills (from various subjects) to design and build a project of reasonable magnitude in their final year. Several students struggled to complete the project successfully for the first time because they were not able to apply their knowledge in a real-life situation. This is an indication that they were not well-prepared, probably due to the dominant learning by memorization" approach during conventional teaching and the lack of cross-disciplinary integration on actual cases. Grade 12 (also known as "matric") standards (at South African public schools) are low and marks are adjusted upwards for most subjects, with biased exams, rigged to make the weakest students passed (Jansen, 2017; Martens et al., 2012).

Under Apartheid South Africa, the 'white education system' was restructured whilst still under apartheid from the beginning of 1991. Most white schools at the time changed into "Model C" schools, a semi-private structure, with decreased funding from the state, and greatly increased autonomy for schools (" Model C' is the model to emulate," 2011). Although the form of "Model C" was abolished by the post-apartheid government, the term is still commonly used to describe former whites-only government schools, as of 2013.

Some of the reasons for the poor state of the South African education is: undue union influence and "critical educational factors", e.g. weak institutional functionality, uneducated teachers, and insufficient learning time (Masondo, 2016). South African is ranked 75 out of 76 in a ranking table of education systems drawn up by the Organisation for Economic Co-operation and Development in 2015 (News24 Correspondent, 2017).

Students who are capable of applying the basic mathematical knowledge range from 36.3% in the wealthiest 20% of South African schools compared to 0.6% to 4.3% in the remaining 80% of schools (Wilkinson, 2015). Results from international, standardised tests show that between 75% and 80% of South African schools are not able to teach the necessary skills to students (Wilkinson, 2015). The poor maths score of many South African students has led to the interim measure of lowering the standards for Grade 7, 8 and 9 mathematics during 2016 (Gontsana & Ntongana, 2016). It seems that students who passed all other subjects, but failed Mathematics with a minimum mark of 20%, were condoned and would thus pass Mathematics and pass the examination as a whole (Business Tech, 2017).

Traditional Lecturing

According to Michael (2006), lecturers tend to assume their expert knowledge of the discipline and accumulated experiences as a former student and novice teacher to be sufficient in order to be a competent teacher. The problem is that the majority of students retain and use little of what they memorize in the traditional classroom situations. (Vernon & Blake, 1993).

The traditional note taking during a lecture is usually referred to as 'receptive learning' and 'lecturing' (from the teacher role) whilst 'active learning' generally refers to a method of instruction that involves the active engagement of students as the main agent in the learning process of discovery (Adler, 1982).

"In the traditional approach to teaching, the professor lectures and assigned readings and well-defined convergent single-discipline problems, and the students listen, take notes, and solve problems individually" (Rugarcia, Felder, Woods, & Stice, 2000). Traditionally, engineering students need to do laboratory experiments as part of the curriculum and they should be able to apply their knowledge. Applying the knowledge seems to be problematic according to Case (2011) who asserted that students in the traditional lecturing mode graduate with a good knowledge of fundamental engineering science and computer literacy, but they do not know how to apply that in practice.

The three major causes of deficiencies and potential causes of failure according to Loji (2012) is poor reasoning abilities, lack of self-commitment or independence in the learning process and lack of self-confidence.

The receptive learning during an instruction session within the lecturing mode according to Prihatiningtyas (2012), causes:

- Students to take note of new principles instead of understanding them.
- Instructors to concentrate more on demonstrations with little time left for students to practice, resulting in no experience with experimentation and exploring new methods.
- Some students to fall behind due to the one-size-fits-all instructor's sessions.

Traditional lecturers focus too much on the presentation due to the limited time, ending up memorizing concepts and as a result, not producing generic problem solving skills/attitudes; just memorizing answers to the expected examination questions (Mirza, 2012). " …. The students' focus is set in the wrong direction: taking notes rather than understanding and absorbing new concepts (Mirza, 2012).

Students in the lecturing mode, find the traditional methods boring and irrelevant (Schmidt, Lipkin, de Vries, & Greep, 1989) and they tend to memorize new information instead of using it as a tool to solve problems when it is presented to them without meaning or relevance, and this leads to inert knowledge (Whitehead, 1929). These students depend on teachers and as a result, this lowers the opportunity to discover the creative side of their personality, depriving them from identifying their strengths (Essay Mania, 2017).

Traditional training focuses on basic skills and gradually builds to a whole and as a result, provides little context, which can disconnect students and Lacks Emphasis on Larger Concepts or Structures (Jaebi, 2018). Traditional training emphasizes the role of teachers as knowledge dispensers and students as repositories instead of encouraging critical thinking skills and developing deeper levels of understanding required for complex concepts and lifelong learning (Jaebi, 2018).

Students do not necessary get equal attention of their teachers during the lecturing mode (Essay Mania, 2017) and they work mostly as individuals, resulting in poor preparation for future professions, which are likely to include working on teams and collaborating with colleagues (Jaebi, 2018).

Employers expect more from local graduates (who followed the lecturing mode), especially when it comes to the application of knowledge (Griesel & Parker, 2009). According to Kitogo (2011), "today's graduates have attractive curricula vitae, but practically, their performance is insufficient; it doesn't match with what they claim to have studied". Students had to complete numerous standardized exams without putting most of what they have learned into practice (Zhiyu, 2012). They only act as passive audience, lacking active thinking with teachers who limit students' free thinking, imagination and supressing personality development (Zhiyu, 2012).

Table 1. Skills needed by the Employer for the Post of an Engineer, (Bakar, Mohamed, & Hanafi, 2007).

Skills	%
Effective communication skills	39.13
Interpersonal personality skills	36.96
Able to work independently	28.26
Able to plan manage organize a group (teamwork)	26.09
Computer Literacy	26.09
Logical and strong analytical Skills	26.09
Resourceful and knowledgeable	21.74
Strong leadership qualities	15.22
Problem-solving skills	15.22
Self-motivated	15.22
Dynamic enthusiasm aggressive and energetic	13.04
Proactive initiative and creative	10.87
Honesty integrity and commitment	10.87
Good presentation (report writing) skills	8.70
Able to work under pressure (tight schedule) with minimum supervision	8.70
Fast learner quick learner adaptability	8.70
Output or result oriented	8.70
Professionalism	8.70
Able to supervise a group	4.35
Responsibility	2.17
Discipline	2.17
Strategic thinking abilities	2.17

Young graduates may be without a job or have insufficient knowledge regarding entrepreneurship due to a lack of specialized skills (Erasmus, Loedolff, Mda, & Nel, 2006). Some of those skills are identified by Bethlehem (1997) as ‘communication skills’, ‘decision-making skills’, ‘analytical skills’, ‘teamwork skills’, ‘well-practiced leadership skills’ and ‘good interpersonal skills’. For instance, Table 1 ranks the importance of employability skills for engineers in Malaysia.

Many students at WSU struggle to design an electronic project of reasonable proportion in a final year program under the label ‘Design Projects 3’ due to a lack of application of knowledge. Design Projects 3 is a higher level subject, and students need to attend it during their last semester at university. They also need to do two semesters of appropriate in service experiential training before graduation. The first one can be sandwiched in-between their university studies, but the second can only be done after completion of all university-based classes. The practical experience gained from the experiential training cover the basic principles but very seldom problem solving and design skills. This is of great concern because their future employers need them for their ability to work in teams, problem-solving capacity, autonomous creative design and their sense for marketing and their customer-orientation.

Active Learning

“Problem-based Learning (PBL) is a student-centred pedagogy in which students learn about a subject through the experience of solving an open-ended problem found in trigger material” (Iswandari, Prayogo, & Cahyon, 2017). The essence of the approach is to arrange teaching material around case studies or scenarios rather than a particular academic discipline, with the aim of enabling “self-directed learners to engage with a self-determined process of enquiry” (McManus, 2008). Relevant complex open-ended problems which may have various correct answers are introduced to collaborative student groups at the beginning of the instructional cycle according to Prince (2004). PBL emphasizes putting learning into the realistic problem situation (Zhiyu, 2012). Students studying using the PBL method usually increase library use, textbook reading, class attendance and studying for meaning rather than simple recall (Albanese & Mitchell, 1993b; Gallagher, 1997; Major & Palmer, 2001; Vernon & Blake, 1993). Through PBL, students should be able to acquire knowledge and know how to apply this knowledge in real situations (Sockalingam & Schmidt, 2011).

According to Massialis (1985), active learning is a term that encompasses a wide range of pedagogic approaches. PBL, discovery-based or inquiry-based learning, collaborative learning, cooperative learning and work-based learning can all be classified as active learning. A study from Weltman and Whiteside (2010) shows an increase of test scores as active learning is introduced for students in the lower level grade point average group. This was particularly encouraging since most of the students at WSU belong to this group. Active learning also produces higher achievement test scores, more positive student attitudes and higher levels of student persistence with Engineering courses when compared to passive learning (Springer, Stanne, & Donovan, 1999). When engineering students are actively engaged, they are capable of recalling substantially more information and became more involved with the course and subject area (Prince, 2004).

The core elements of active learning involves the activity, engagement and reflection of the students, and the use of the higher order academic skills from Bloom’s taxonomy such as analysis, synthesis and evaluation (McManus, 2008). Active learning requires students to do meaningful learning activities and think about what they are doing (Bonwell & Eison, 1991). They are intellectually involved, and in some cases also physically during the learning process through activities that involve them in gathering information, think logically, and solving problems (Michael, 2006). Active learning is grounded on constructivism which requires active composition of understanding by the learner and places the student at the very centre of the learning process where they influence the content, activities, materials, and pace of learning (Michael, 2006).

Discovery-based or inquiry-based learning include persons who:

- Focus on meaningful ideas and concepts, instead of merely pieces of information that do not relate to each other;
- Exhibit a strong team involvement and demonstrate an active participation in a team of learners who are motivated to “learn by doing”;
- Have the mentality and courage to generate, test and implement hypotheses and ideas in and outside a certain domain of expertise;
- Perceive content and process as inseparable components of meaningful learning.

“Collaborative learning is a method of teaching and learning in which students’ team together to create a meaningful project and explore/test a vital question. A group of students discussing a lecture or students from different schools working together over the Internet on a shared assignment are both examples of the more prestigious interpretation of collaborative learning” (Szalavitz, 2004). Collaborative learning focuses on how collaboration influences learning outcomes; its emphasis is on student interactions rather than on learning as a solitary activity (Prince, 2004). Students in the collaborative learning mode; develop critical thinking skills, partake in the co-creation of knowledge and meaning and reflect on what they have learned (Palloff & Pratt, 2005). Many of the components within collaborative learning can also be found within PBL.

Cooperative learning relies on organised forms of group work where students pursue common goals while still being assessed individually (Millis & Cottell, 1998). ‘Individual assessment’ can also include a student’s capacity to learn/work within a team, as long as the total fan-out of the assessment criteria are a fair representation of students final required achievement. Students work face-to-face in small groups as a team on a structured activity during cooperative learning. They are both assessed for their own work and also as a group (McManus, 2008). Fundamentally, cooperative learning is based on the assumption that co-operation is more effective than competition among students for producing positive learning outcomes (Prince, 2004). The inbound co-operation may ideally be complemented by the outbound competition (Slavin, 1990).

Work-Based Learning or work-related learning enables students to learn from their working environment and include the traditional apprenticeships, sandwich year placements where students need to spend some time in industry, usually between their second and final year of the degree course (McManus, 2008).

Universities are a great national asset to any country. They lead in the discovery/creation of knowledge, transform people's lives and prepare their minds. Universities contribute to the health and wealth of a nation by being involved in the wider society and economy.

The vast majority of university students hope in getting a good job and making a success of their career upon completion of their studies. There is however a problem; various recent graduates found themselves on the unemployment line or they have to take on a job that do not require a degree of some sort. It seems that there is a wide gap between the graduate’s skills and what universities are producing. Most people is seeking to improve their economic situation, and one way of doing so is if universities do better at preparing students for the job market.

To do so, it may be necessary to do “fundamental changes to what happens in the classroom so that students better retain what they learn on the spot, and most important, are able to translate that learning for potential employers” (Selingo, 2015).

With PBL-based courses, students learn to work in teams and apply their knowledge to real-world problems as they’re learning. Students should rather learn for the sake of increasing their understanding instead of just trying to get "A’s" and graduating with their degree on time. We should ask ourselves if our educational system are doing justice to our students, employers, and the bigger society as a whole when we are still using passive-learning methods during these current times.

One always tends to think that high scoring students will be the most successful in the work place. We forgot that successful employees are usually those which are motivated and with a good attitude. The positive attitude and motivation usually cause them to be good workers and pleasant to communicate with. Successful employees are usually also able to think critically and solve problems. They reflect on what they were doing, and are able to learn and improve from that. To make students job-ready, educators need to imbed these qualities into students to acquaint them to become successful employees.

As a child, I had the opportunity to investigate various electrical, electronic and even mechanical items, to see how they are put together, what’s inside and try to figure out how they work. The knowledge I gained during that time helped me to be a hands-on person throughout my career. Engineers should be able to apply their knowledge in the real-world, for instance, the responsibilities of electronic engineering may include more than 60% fault finding. They should be problem solvers and critical thinkers and expect to work one day on yet to come invention e.g. engineers who studied in the 80's most probably do not have any training on networks and internet connectivity at the time. Students who worked on the Fischer Technik "scale-models", mentioned; "this is the first time that we feel we learn what we are supposed to learn, a taste of industry. Things are starting to make sense now". Most of these students never had an opportunity to disassemble and investigate any items during childhood, so using concrete component, if not real, then close to those in the real-world, and solving real-world problems, is highly valued for their education.

Engineers are problem solvers, and they need to learn that "less is more" during design. They should learn the concept that simplicity and clarity lead to good design. The less components there are, the less can go wrong. Their designs should also be sustainable, e.g. when designing physical objects, then the built environment and services should comply with the principles of social, economic, and ecological sustainability. Students should also learn that in these modern days, industry prefer to make use of a circular economy in which resources are kept in use for as long as possible. The maximum value is then extracted from them whilst in use. Products and materials are then recovered and regenerated at the end of each service life.

Recognising the value PBL could bring, I took it upon myself to investigate various arrangements of PBL by means of empirical research that builds further on available scientific evidence. Students should be transformed from passive to active learners who focuses on the application of knowledge instead of rote learning, so that they can be appreciated by their future employers. The department of Electrical Engineering at WSU is used as a testbed, and 'best practices' based on 'proven' and 'real' results from the practice-based research will be disseminated to my colleagues. The amount of attitude, motivation, reflection and learning outcomes is used as a measure to determine the success of an intervention. It is believed that the use of PBL will result in higher levels of these, and the higher the levels, the more successful the intervention. Lessons learned will be used to derive first-order rules that are more generic than the situation at WSU. This scientific exploration and experimental planning will be elaborated in Chapter 2.

CHAPTER 2: LITERATURE REVIEW

Introduction

The main aim of education is to gain knowledge in order to develop students' future potential. There is no sense for re-inventing the wheel, but it may not harm to improve on it, e.g. the radically new airless car tyre that has been designed and developed by Michelin shows potential (Holguin, 2005). The same applies to PBL. Various studies related to PBL have already been done. Existing literature assisted with the familiarization thereof and also helped to identify on how to build on it. It is therefore crucial to explore what was already found in existing literature.

PBL MODELS

Origin

Problem-based Learning (PBL) is currently seen as the most vital complements to traditional lecture-based education. It is built on the principle of constructivism in which students are usually challenged to solve a major real-life problem. PBL originated from the McMasters University in Canada in the late sixties, which uses a problem-based approach to educate students in the medicine field (Kolmos, de Graaff, & DU, 2009). Some European universities e.g. Aalborg in Denmark also put problem orientated, project organized PBL into operation (Kolmos, Fink, & Krogh, 2006). Problem analysis, participation in two or more fields of study and sharing of activities in group work is common amongst the McMasters and Aalborg models, but they differ in regard to the cycle assignments, assessment and group work (de Graaff & Kolmos, 2003).

Azer, Peterson, Guerrero, and Edgren (2012) indicated that good PBL scenarios should:

- Incorporate some fields.
- Promote conversation between different intellectual areas.
- Encourage collaboration.
- Promote self-directed learning.

According to Amoako-Sakyi and Amonoo-Kuofi (2015), the most effective PBL scenarios should:

- Deal with at least one objective in the syllabus.
- Triggers former knowledge and builds on current knowledge.
- Ensure problem matching with the level of the students.
- Ensure relevancy to the future profession of students.
- Stimulate critical thinking and encourage self-directed learning.

Students build on prior knowledge and learn in a context to resembling their future context in which they had to elaborate on (Bridges & Hallinger, 1991). Once the new knowledge to the problem was applied, students had to reflect on what they have learned and also on the effectiveness of the strategies employed (Hmelo-Silver, 2004). In PBL, the lecturer became a facilitator rather than a teacher and need to ensure that students stay on task by providing hints and resources for research to correct their reasoning when necessary (McManus, 2008).

The use of complex real-world problems as a vehicle to promote student learning of concepts and principles as opposed to direct presentation of facts and concepts make PBL an attractive choice as a teaching method (Duch, Groh, & Allen, 2001a). With PBL, students focus on how and what they will learn. The lecturer/tutor presents an unfamiliar problem, situation or task to a small student group, which they then need to solve by themselves. They need to utilise their prior knowledge in the topic area and identify the gaps in their knowledge as they attempt to solve the problem (Staff at Flinders University, 2018).

There is a lot of benefits when using PBL e.g. it promotes the development of critical thinking skills, analysis and synthesis to identify and solve complex problems, communication skills (verbal and written), and life-long learning whilst it provides opportunities for cooperatively working in groups and finding and evaluating research materials (Duch, Groh, & Allen, 2001b).

The students' academic achievements during examinations may not necessary improve during PBL according to Strobel and van Barneveld (2009), however, their long-term retention of knowledge may improve. Hmelo-Silver, Ravit, and Clark (2007) found that applying scaffolding, changed difficult and complex problems into accessible and manageable tasks within the learning capabilities of the student. This may cause the academic achievement of students in the PBL stream to be higher than those in the traditional lecturing mode according to Smith and Cook (2012).

Variants

Barrows identified the following varieties of PBL in 1986: Lecture-based cases, case-based lectures, case methods, modified case-base method, problem-based learning and closed loop problem-based learning (Kolmos et al., 2009). The following five different models were proposed by Savin-Baden (2007) as cited in Kolmos et al. 2009: Attainment of knowledge, PBL for professional work, PBL for interdisciplinary understanding, PBL for cross-discipline learning and PBL for critical competencies. When solving authentic PBL problems, students need to explore the concepts, find resources and apply the knowledge (Boud & Feletti, 1997; Ornstein & Hunkins, 1993).

Problem-based learning developed over a 20-year period and several variations exists. However, according to Bridges (1992), at its heart, PBL has six significant qualities:

1. It always starts with a problem.
2. The problem relates to a real-life situation.
3. The substance is organized around problems rather than the branch of learning.
4. Students take responsibility for their own teaching and learning.
5. The majority of learning occurs within small groups rather than in formal lectures.
6. The solution to the principal problem should not only include problem diagnosis and analysis, but also include implementation.

The conventional (Maastricht type) PBL consist of 7-steps according to Addae, Wilson, and Carrington (2012):

1. Clarify terms and concepts not readily comprehensible (1st meeting). Students:
    - Be confronted with a real-life problem.
    - Summarise the problem in their own words.
    - Identify relevant concepts and facts.
    - Have to understand and agree on the core issues and concepts.

- Make a working list in which they explicitly state what is known and what is unknown about the problem.

2. Define the problem (1st meeting).
    - Students construct a common understanding of the problem.
3. Analyse the problem (1st meeting).
    - Students activate their prior knowledge, and use their thinking and problem-solving skills to elaborate on the contents of the task.
    - Generate a list with a wide variety of facts, ideas and concepts.
    - Students explain and discuss the ideas, and ask critical questions to assess the quality of ideas.
4. Draw a systemic inventory of the explanations inferred from step 3 (1st meeting).
    - Develop a common understanding of the problem at individual and group level.
    - Different viewpoints and interpretations must be discussed, interrelated, and negotiated to attain shared conceptions and a shared mental model.
    - Provides a structure for the problem analysis that took place in the previous step
5. Formulate learning issues (1st meeting).
    - Identify knowledge deficiency.
    - Realise that the missing knowledge is relevant to or necessary for the eventual practice.
    - Reach consensus about the timelines of undertaking the study.
6. Collect additional information outside the group (in between meetings).
    - Search for relevant literature from a diversity of sources.
7. Synthesize and test the newly acquired information (2nd meeting).
    - Newly acquired knowledge is shared and discussed with the other group members. The students relate the acquired knowledge to the problem and evaluate what they have learnt from the problem, which helps them to apply their knowledge to other problems.

PBL finally became a curriculum concept, according to Barrows and Tamblyn (1980). Its implementation goes beyond the mere addition of “PBL-like” activities to a traditional curriculum (Amoako-Sakyi & Amonoo-Kuofi, 2015). In strict PBL a problem should be just that, not a mission statement or an instruction to do something, as one might find in a project (Raine & Symons, 2005). In some cases the variants of PBL are classified as “semi-problem-based courses, for instance:

- The PBL curriculum at Michigan State was modified to a “marriage of a traditional lecture -based curriculum and problem-based learning” on the basis of making basic science preparation a central goal (Doig & Werner, 2000).
- Harvard’s initial “hybrid” PBL curriculum (Armstrong, 1991) was developed on the basis of the faculty’s desire to make “the idea that adult students teach themselves” the “first principle” of their curriculum.
- In the medical course at the University of Queensland, the conception of self-directed learning in adult students held as a central principle by the leaders of change meant that didactic teaching was minimised in the PBL curriculum to the extent that students complained that they had to “teach themselves medicine” (Miflin & Price, 2000).

Defining a PBL problem is relatively easy when there is no pre-defined curriculum, and increasingly difficult the more one needs to cover stuff (Raine & Symons, 2005). In the light of this difficulty (to define a problem related to a curriculum), a number of variants of PBL have arisen which acknowledge that they are starting from a case (CBL) an enquiry (EBL), or subject to research (RBL) or a project according to Raine and Symons (2005).

Kwan and Tam (2009) referred to Hybrid PBL which can be divided into four subtypes:

1. Type I - Conventional curriculum with 2-3 PBL problems per year.
2. Type II – Incorporate PBL tutorials for supplementary knowledge.
3. Type III – Uses PBL problems for applying lecture-delivered information.
4. Type IV – PBL is main learning platform supplemented by unconventional interactive student-centred lectures. This is referred to as a standard PBL by some.

Bridges (1992) mentioned two versions of PBL that have been implemented in the classroom, problem-stimulated PBL and Student Centred PBL. Both uses role relevant problems in order to introduce and learn new knowledge and emphasizes three major goals:

1. Development of domain-specific skills.
2. Development of problem-solving skills.
3. Acquisition of domain-specific knowledge.

Student Centred PBL also includes a fourth goal:

4. Fostering life-long learning skills.

In Student Centred PBL, students have self-defined learning issues because they: identify the learning issues they wish to explore, the content to be mastered and determine and locate the resources to be used. With problem-stimulated PBL, students decide how to appropriately use the newly acquired information and knowledge in order to solve the problem at hand (Bridges, 1992; Edutech Wiki, 2014).Various Depths

PBL can be introduced to your teaching in various depths according to Bradbeer (2011). PBL can be used to do a:

1. Small period of PBL in a non PBL module.
2. Section in a non PBL module.
3. Complete module.
4. Combination of two or more modules.
5. Entire semester.
6. Entire year or level.
7. All-inclusive degree programme.

According to Elder (2015), brief PBL may be attractive as a focused, limited activity for instructors who can neither overhaul their existing curriculum nor reorganise their current course design, but are looking for ways to actively engage students in relevant and authentic course work. Brief PBL is semi-structured and resources are given compared to PBL which is ill-structured and where students need to seek and evaluate resources (Elder, 2015).

Johnson, Herd, Andrewartha, Jones, and Malc (2002) indicated that even small scale programs of PBL were rewarding for both staff and students when implemented. Continuous development and progress came from the will power to improve; and the willingness to test, evaluate, implement and change the directions for developing physicians for the coming decades (Talati, 2001).

Amoako-Sakyi and Amonoo-Kuofi (2015) gave the following warning; "Institutions planning to implement PBL should avoid the pitfall of a cosmetic PBL i.e. a curriculum that is essentially traditional with elements of PBL only as an auxiliary pedagogic tool. A hybrid or standard PBL-curriculum that thoughtfully uses instruction-like sessions in a non-redundant manner may be a more feasible approach in these settings".

A vital complement to PBL is Team-based learning (TBL), especially for beginners. TBL is not an overall curriculum approach (like PBL), but has been promoted as a cost-effective model for small group learning that can be integrated partially or fully in a course. In TBL, students still need to work in groups. They need to do prior reading to enable them to take tests and solve problems in group context with assistance from a content expert facilitator. One facilitator is sufficient for the whole TBL class. PBL's multidisciplinary open inquiry approach is more student centred and positioned to nurture self-directed and lifelong learning when compared to TBL (LIM, 2012). Providing a facilitator to each of the small groups in the PBL curriculum, implicates a large demand for teacher efforts which finally constitutes a huge increase in the cost of running a PBL curriculum as compared to lecture-based learning (Amoako-Sakyi & Amonoo-Kuofi, 2015).

Choosing a suitable PBL variant in a traditional instruction environment with a pre-defined curriculum such as at WSU, may require careful consideration. For instance, sufficient tutors, PBL-orientated facilities and sufficient components may not be available, whilst students may still be examined by means of traditional year-end exams. A hybrid aproach with the PBL method only covering selected portions may be a realistic starting point. Following the conventional (Maastricht type) seven steps as discussed earlier is achievable under the supervision of a wandering tutor.

PBL design and delivery

Lectures in PBL

When in the PBL mode, introductory lectures may be used to scaffold the students' capacity to thoroughly participate in solving the problem - introductory lectures may outline basic concepts, introduce technical jargon, guide with learning resources and include boundaries of learning (LIM, 2012). Appropriate education differ with age and background, and these variances may influence the way in which a PBL curriculum be implemented to achieve the best possible outcome (Bernstein, Tipping, Bercovitz, & Skinner, 1995b) for instance, the PBL at Maastricht is more structured in Year 1 to cater for school-leavers who are "less well-equipped with self-directed learning skills" than their graduate equivalents at McMaster (Schmidt & Moust, 2000). The limiting factor with younger students, especially those with a comparatively narrow academic background, is that, in general, they have not had the experience of assuming responsibility for their own learning (Taylor & Miflin, 2010).

There is no contradiction to the objective of having students take responsibility for their own learning when lectured since they remain self-directed in that they have to make sense of and apply what they hear in a lecture in terms of the problem on which they are working at any given time (Taylor & Miflin, 2010). Students in the PBL mode know why they are being given a lecture since it support the learning objectives, therefore students are keenly attuned to taking the best from the lecture to address their current learning objectives (Taylor & Miflin, 2010). Experience might be the most significant difference between novices and experts according to Qiao et al. (2014). Novices did not acquire the sufficient related knowledge when in the PBL mode and has to be supported. Experts must provide neither too much nor too little support to the novice to perform the task, but sometimes experts should demonstrate to students how to solve problems, using their domain knowledge and strategies (Pedersen & Liu, 2002). A growth mind-set helps students advance from novice to expert (Boss, 2014). Experts use more informal mechanisms including opinions from colleagues and other related experts and constructs a knowledge base for themselves in the context of their practice (Daley, 1998). Information from several sources are processed through peer-based discussion which results in a change of practices based on the revised meanings they created (Daley, 1998).

"Experts used an active process of creating their own knowledge base by seeking out information and assimilating that information with their current knowledge base. This process then changed the character and meaning of both the new information and the previous experience, because the expert would derive a deeper level of meaning and understanding in the process" (Daley, 1998).

The PBL Curriculum

The PBL curriculum may include problems that involve various disciplines. This may require major planning since it requires co-operation across departments. The successful creation and upkeep of a PBL curriculum according to LIM (2012) requires a number of policies in favour of PBL such as:

- Finance staff visits towards well-known PBL centres.
- Give credit and incentive to staff who are involved in PBL.
- Provide the necessary infrastructure such as equipped PBL rooms.
- Allow assessment methods which is compatible with PBL.

The sequencing of the content in a PBL-curriculum is crucial, and more complex because all domains of knowledge require appropriate sequencing. Because all domains of knowledge, skills and attributes are introduced in the horizontally integrated way in the PBL-curriculum, all domains also need to be vertically integrated, that is, they are presented for learning in all phases of the curriculum. The sequencing of problems should allow students to build upon their acquired knowledge in a structured and logical way (Taylor & Miflin, 2010).

Other Requirements

Facilities such as specially equipped tutorial rooms, recruitment of adequate numbers of qualified facilitators, periodic development activities, and numerous logistic requirements such as well-resourced libraries, consistent internet connectivity, and functional laboratories put at risk the implementation of PBL, especially resource-constrained universities, particularly those in third world countries where the budget for education is often inadequate (Amoako-Sakyi & Amonoo-Kuofi, 2015).

Talati (2001) suggested that Deans and principals be strongly involved in promoting organised set of undertakings, allowing experimentation with variants of PBL and alternative active learning models that would improve competence and conduct in practice.

Summary of PBL models

To summarise, various models could be used in PBL. It may differ in regard to the cycle assignments, assessment, group work and number of objectives. Hybrid PBL can range from a conventional curriculum with 2-3 PBL problems per year up to a main learning platform supplemented by unconventional interactive student-centred lectures. The depths of the PBL can vary from a small period of PBL in a non PBL module up to an all-inclusive degree programme which may include various disciplines. Brief PBL is semi-structured and resources are given compared to PBL which is ill-structured where students need to seek and evaluate resources.

When in the PBL mode, introductory lectures may be used to outline basic concepts, introduce technical jargon, guide with learning resources and include boundaries of learning. As a rule, all PBL triggers former knowledge and builds on current knowledge, stimulate critical thinking and encourage self-directed learning and the students' reflect on what they have learned.

When in the PBL mode, the lecturer usually portrays the role of a facilitator. The PBL always starts with a problem that preferably relates to a real-life situation with the substance organized around the problem/s. Students take responsibility for their own teaching and learning, with the majority of learning occurring within small groups rather than in formal lectures. The solution should preferably include the implementation.

Institutional leaders will have to constantly monitor and find practical solutions, that will work best for their institution, to ease the unavoidable problems associated with the implementation of PBL (Amoako-Sakyi & Amonoo-Kuofi, 2015). An existing syllabus, based on the traditional lecturing mode, was already in place at WSU. To accommodate this studies a hybrid PBL model had to be used which include "PBL problems for applying lecture-delivered information" as suggested by Kwan and Tam (2009).

ASSESSMENT

PBL learning processes differ from traditional instructional strategies like those that target the transfer of knowledge and skills. The testing of students' knowledge and competences is preferred beyond the testing of isolated factual knowledge (van der Vleuten, Norman, & de Graaff, 1991). The assessment should be aligned to the curricular objectives in order to encourage deeper learning (Biggs, 2003). It should focus on multiple skills and abilities, on processes as well as products (Shamsan & Syed, 2009). PBL assessment methods include laboratory journals, technical briefings, design reviews, technical reports, collaborative teamwork assessment, design portfolios, peer assessment, self-assessment (Maskell, 1999) as well as written examinations, practical examinations, oral examinations, triple-jump exams, oral presentations (both group- and individual ones) and written reports as well (MacDonald, 2005).

Davis and Harden (1999) pointed out that problems need to be consistent with the stage of the student's learning process. The complexity of a scenario should go with the prior knowledge of individuals in the PBL groups. A balance of comprehension, applications of knowledge and analytical or critical thinking during examinations for summative and annual assessment should be there in order to avoid a mismatch between learning and its assessment; It could undermine the essence of PBL and discourage students to invest in the PBL template; (Amoako-Sakyi & Amonoo-Kuofi, 2015). Various assessment methods could be used in PBL, e.g., formative-, summative-, self-, peer- and group assessment as discussed at APPENDIX BB.

SELECTING PBL PROBLEMS AND SKILLS DEVELOPMENT

PBL Problems

Conventional textbook problems may be well-constructed, challenging, and pedagogically useful, but they usually focus on a specific answer or a single concept drawn from the former chapter and therefore not good enough as a PBL problem (White, 2002). Appropriate PBL problems should be complex enough to require group effort, engage the interests of students and, involve students in rational decision making that is based on reliable information (Duch et al., 2001a). PBL problems should obviously addresses the content objectives of a course (White, 2002). White (2002) also indicated that the initial presentation of a PBL problem should be open-ended, based on previous knowledge, and perhaps controversial. An open-ended PBL design should allow multiple acceptable solution strategies and the instructor can guide each student group in developing solution strategies based on their situation (Steck, DiBiase, Wang, & Boukhtiarov, 2012).

When solving the PBL problems, the students have to solve genuine problems, as they happen in the real world. This gives them the opportunity to acquire "deeper and richer knowledge structures, leading to a higher likelihood of transfer to novel situations" (Albanese & Mitchell, 1993a, pp. 52-81). Savery and Duffy (1995) also recommend that authentic contexts like real-world problems be used in PBL. It is also better that the information is learnt in the very context where retention is trained, according to Brown, Collins, and Duguid (1989). Relevant problems engage students and contribute to the learning process. While participating in peer groups, student contributions may result in a difference of ideas and perspectives which may need some reasoning, thus leading to the refinement of their knowledge (Grabinger, Dunlap, & Duffield, 1995). Students who are working on practical and industry-relevant problems became more interested in the subject (Hammond, 2013). Zhiyu (2012) suggested to use many interesting and practical problems to encourage and direct students to actively learn the knowledge which make students acquire life-long efficient learning skills and improve their ability to solve problems. The design of the problem is of great importance with the trigger being complex, open-ended and relate to the prior knowledge of the students (Hammond, 2013). Essential understanding and skills may stay away if students are kept out from a real-size project with a large goal and concrete objectives (Dolmans, Gijselaers, & Schmidt, 1992).

Skill Development

Students acquire knowledge and skills through practice and reflection and not only by watching and listening to others telling them how to do something. PBL enhances skills development significantly, but the knowledge level remains more or less at the same level as with traditional learning according to Du, de Graaff, and Kolmos (2009). “To achieve the desired outcomes of expertise in content knowledge, positive attitudes and abilities in generic skills, student-centred teaching and learning techniques, especially PBL, are highly encouraged” (Yusof, Tasir, Harun, & Helmi, 2005, p. 175). PBL is a constructivist pedagogy in which students learn science and develop critical thinking skills by solving real-world problems in small groups (Ram, Ram, & Sprague, 2005). Students benefit from improved critical thinking and problem-solving skills according to Mergendoller, Maxwell, and Bellisimo (2006).

With PBL, students should be able to acquire and apply knowledge in real situations (Sockalingam & Schmidt, 2011). Reasoning ability and task value (the importance of attaining a goal) are factors that had a direct and indirect achievement according to Araz and Sungur (2007). Des Marchais (1999) found out that when students are confronted with a PBL problem, then it stimulates their thinking or reasoning which leads to self-directed learning.

The collaborative teams in PBL promoted student interaction and teamwork which enhanced students' interpersonal skills (Bernstein, Tipping, Bercovitz, & Skinner, 1995a) such as working in a group context, evaluated by fellow students, and how to present and defend their plans (Delafuente, Munyer, Angaran, & Doering, 1994). Many of these skills which are covered in PBL is required by employers and students will become more employable when in the PBL mode.

Knowledge

Knowledge is a very powerful, but abstract concept, without any reference to the physical, and no clear definition so far (Bolisani & Bratianu, 2018). Knowledge is defined variously by the Oxford Dictionary as:” a) Facts, information, and skills acquired through experience or education; the theoretical or practical understanding of a subject. b) Awareness or familiarity gained by experience of a fact or situation.” (Oxford English Dictionary, 2015).

Content knowledge refers to the body of knowledge and information that teachers teach and that students are expected to learn in a given subject or content area. (The Great Schools Partnership, 2016). Different types of knowledge exists in education. They are; a) *Procedural* - Information that is needed to accomplish certain tasks and participate in certain activities, b) *Conceptual* - based on concepts that drive factual pieces of information from the world around us, and c) *Implications* - express standards in terms of only factual knowledge (PLB, 2019). There are three broad types of knowledge that can be derived through experience or as a result of rational thought, or from a combination of both according to Biggam (2001). There is: a) “factual” knowledge; b) “practical” knowledge; and c) knowledge of people, places and things. Biggam (2001) differentiated between knowledge, blind belief and opinion. When something is true and the perceiver believe it is true and be in a position to know it is true, then it can be classified as knowledge. Knowledge outcomes are outcomes of the learning activities (University of Illinois and RMIT University, 2012).

Assistant Professor Luk (2019) suggested that more mature children need to be taught the critical thinking skills so that they do not assume everything imparted, but rather weigh that knowledge and start asking questions and be sceptical. “The fear of the LORD is the beginning of knowledge; Fools despise wisdom and instruction” (Solomon, 400 BC).

Vicarious Learning

Vicarious learning also labelled as observational learning occurred when an individual learns something simply through observation without direct reinforcement or punishment of the behaviour (Nicholle, Symmonds, & Dolan, 2011). The idea is that people can and will learn through being given access to the learning experiences of others (Cox et al., 1999).

Various factors can influence vicarious learning. Friedman and Schustack (2012) mentioned three; a) the internal attributes of the observer, b) external perceptions of the observed and c) perceptions of the behaviour itself relative to its simplicity or complexity. Creativity may be enhanced through vicarious learning according to Groenendijk, Janssen, Rijlaarsdam, and Van den Bergh (2013).

Munoz (2014) indicated that individuals with lower self-esteem and less confidence in their abilities (self-efficacy) were less likely to imitate modelled behaviours, especially complex behaviours. Students who observe others may identify relevant issues and learn from that (Cox & Pang, 2007).

Attitude

The students’ attitudes towards subject matter domains can be positively affected when using PBL (Bridges & Hallinger, 1991; Pincus, 1995). Dusick (1998, pp. 123-137) defined attitude as “an evaluative disposition based upon cognition, effective reactions, behaviour intentions, and past behaviours which can influence future cognitions, effective responses, intentions, and behaviours”. Students enjoy the learning process while in the PBL mode and they develop a positive attitude towards the instructional environment. Prince (2004) also experienced a more positive attitude, and also found a deeper approach to learning and a longer retention period with students in the PBL mode when compared to students in the conventional mode. The attitude towards learning improve when students enjoy a successful learning experience according to Hwang and Kim (2006).

Motivation

One of the advantages of PBL is its ability to improve student motivation (Hmelo-Silver, 2004) and Bartscher, Gould, and Nutter (2009). Vernon (1995) found an increase in student motivation, group atmosphere, student-directed learning, and student problem solving when PBL was applied. PBL appear to bring a more enjoyable, challenging and motivating approach to education and students become more actively involved and assume increased responsibility for their learning (Antepohl & Herzig, 1999); a skill that will help students to continue their learning practices once they leave school (Aspy, Aspy, & Quimby, 1993). There usually exist a positive correlation between attitudes and achievement according to Russell and Hollander

(1975) while the majority of classroom teachers regard student motivation as the most important factor in educational success in general (Dörnyei, 2001).

Reflection

Reflection can be seen as being intertwined with the process of learning and the representation of that learning. Reflection may involve a purpose, leading to a useful outcome (Ong, 2004). The different stages of reflection according to Brodie (2007) are : "retell (set the scene, summarise information, state the main ideas and identify key concepts); relate (make new connections, apply personal experience, compare and contrast, etc.) and reflect (draw conclusions, apply judgement, state opinions, new understandings, etc.)." When students reflect, they consciously looking at and thinking about their experiences, actions, feelings and responses (Boud, Keogh, & Walker, 1994).

Reflection bridges the gap between theory and practice (Schőn, 1983). Schőn (1983) also mentioned that when you reflect upon action, you need to think back on what you have done. This may help you to discover that what you have learned during the doing may have be part of an unexpected outcome.

The focal point of the PBL model is the usually "Open-ended" problem presented to the students. Shermis (1999) defined a problem as a situation where a student is 'curious, puzzled, confused or unable to resolve an issue'. Reflection requires you to think and learn from your experience on a daily basis. Giving students the opportunity to evaluate and reflect on their own learning is a key element in PBL and according to Brodie (2007), students should be able to analyse, synthesize and evaluate when applying knowledge in real world problems.

They learn from the interpretation or analyses thereof. Once students have finished a PBL problem, then they can establish if they have reached the initial goal set at the beginning of the project by reflecting on it. They take responsibility for their own learning and the process guides them towards the goal of becoming life-long learners (Waters & McCracken, 1997b).

Learning Outcomes

Learning outcomes refer to the knowledge, skills and the application of the knowledge and skills a person has acquired and is able to demonstrate as a result of learning (UNSW, 2017), whilst the learning effect refers to the impact, or outcomes for a person having learned new knowledge (Cooke, 2017).

Transfer of learning deals with transferring one's prior and recently-acquired knowledge and skills from one problem-solving case to another. One needs to distinguish between the transfer of learning in terms of near- versus far transfer. Near transfer involves an almost similar problem or task when compared to a previous one, which could easily be solved with little or no conscious thought (Perkins & Salomon, 1992). Far transfer often requires careful analysis and deep thinking. This relates to problems that are somewhat related to a previously known one, but in some sense relatively far removed from the known problem, with no obvious connection between the two (Perkins & Salomon, 1992). Near transfer refers to transfer between very similar contexts, e.g. doing fault finding on a newer model TV than the one you are used to. Far transfer refers to transfer that, on appearance seem remote and alien to one another, e.g. doing fault finding on an X-ray machine whilst you are only familiar with an analogue TV receiver. Lohman and Finkelstein (1999) had success with the near and far transfer skills. Their first-year dental education students improved significantly in their near transfer of problem-solving skills by an average of 31.3%, and their far transfer of problem-solving skills increased by an average of 23.1% within a 10-month PBL program.

The popularity of PBL is on the increase in higher education, with confirmation of a positive effect on the students' motivation, long-term retention of learned contents and on students' higher cognitive skills (Jones, Epler, & Mokri, 2013).

Gallagher and Stepien (1996) found no difference between PBL and traditional students in terms of short-term retention, but Dochy, Segers, Van den Bossche, and Gijbels (2003) found that although PBL students recalled slightly less during the short-term retention (when compared to traditional students), they consistently outperformed traditional students on long-term retention assessments. Likewise, Eisensteadt, Barry, and Glanz (1990) learned that PBL students retained less than traditional students in the immediate recall test, but their retention rate stayed rather consistent two years later, whereas the traditional students' retention had declined significantly. Mårtenson, Eriksson, and Ingelman-Sundberg (1985) also found no difference in the short-term retention of the content between PBL students and traditional students; however, the PBL students' long-term retention rate was 60% higher than that of traditional students two to four and a half years after the course was completed.

DISADVANTAGES OF PBL

There are also negatives related to PBL. Some of these are: the time required for assessment of student learning (Delafuente et al., 1994); additional preparation time for staff; creating suitable problem scenarios can be challenging; needs additional time from students which may reduce study time for other subjects; and students may learn less content knowledge (Weimer, 2009). Although PBL tends to reduce initial levels of gaining knowledge, it improves long-term retention (Dochy et al., 2003; Farnsworth, 1994). The hierarchical nature of engineering require students to learn material in a certain order (Mills & Treagust, 2003), and the fundamentals is crucial so that students do not miss the basics (Hammond, 2013). It may be necessary to progressive introduce PBL elements into the curricula for first year students (Hammond, 2013). For PBL to be successful, sufficient 'scaffolding' needs to be supplied by good facilitators (Hmelo-Silver et al., 2007; Kirschner, Sweller, & Clark, 2006).

The next Chapter will discuss the research questions, hypothesis, experimental setup and measuring instruments.

CHAPTER 3: METHODOLOGY

Introduction

South Africa's matric results are among the lowest in the world with only one in ten qualifying for university (Bloch, 2010). In South Africa, matriculation (or matric) is a term commonly used to refer to the final year of high school and the qualification received on graduating from high school, although strictly speaking, it refers to the minimum university entrance requirements (Department of Basic Education, 2018). Under-prepared students, usually with a score below the minimum entry requirement, may enter some universities in South Africa via the four year Extended Programme. One such program is meant to provide students at risk with a viable platform to successfully undertake Electrical Engineering studies at Walter Sisulu University (WSU) (*Walter Sisulu University prospectus*, 2012). These students need all the help they can get and it is important to determine if the PBL method can make a meaningful contribution towards their knowledge.

The core of this study consist of three related empirical studies with the aim of determining the effects of Problem-based Learning for various configurations. Details of these studies which include the description of the data collection and analysis methods are discussed in Chapters 4-6. Students who followed the Extended Programme participated in the 2nd and 3rd main experiments during this studies.

Research Questions

It was important to first investigate and become aware of the short-comings of receptive learning (such as the traditional being lectured), and then weigh up the benefits of switching to active learning. Various types of active learning exist and a well-informed decision should lead to choose the most suitable one for the conditions at WSU. In this case, PBL was chosen since it seemed to be a good candidate for enriching the learning, e.g. it helps students to think critically, enhancing problem-solving skills, and applying knowledge and make them self-directed learners.

PBL can be seen as a special type of active learning method which is highly regarded amongst educators world-wide, and capable to select and nurture students with qualities such as critical thinking and life-long learning. This study requires to determine the various qualities of PBL and it needs to be contextualized in the department of Electrical Engineering at WSU.

The experiments should instigate various formats of PBL and determine the optimal way of maximizing students' attitudes, motivation, reflection and learning outcomes within a limited range of experiments. "Positive learning attitudes and motivation are essential for enhancing students' academic achievement, and a successful learning experience can improve students' learning attitude" according to Hwang and Kim (2006, p. 320). Reflection, then again, contributes towards future continuing professional development and self-directed learning (MacDonald, 2005), whilst learning outcomes relate to the intellectual knowledge of the student.

The broad research question for this focus, therefore, concerns on the various aspects of optimizing PBL at WSU.

Three experiments were conducted as shown in Figure 2. In Experiment 1, PBL was compared with traditional learning. The independent variable for the research study was the instructional strategy. The second level of the independent variable is the traditional, lecture-based instructional strategy. The control group for this experiment consist of around 50% of the students. They followed traditional learning. The remaining students were in the PBL mode. This experiment will be discussed in Chapter 4.

Experiment 2 will be discussed in Chapter 5. It determines the best sequence when traditional learning is used to compliment PBL e.g. Traditional → PBL or vice versa? The independent variable for the research study was the instructional sequence. The first level of the independent variable is PBL followed by the lecturing mode strategy. The second level of the independent variable is the traditional lecturing mode followed by a PBL strategy. The class consisted of two almost equal halves, groups, G1 and G2. Students were divided into groups A, B and C during Experiment 3. This experiment investigates the promotion of vicarious learning when multiple problems are solved in parallel. The experiment was designed and conducted to use the same student groups as a target and control group, while having three different groups to compare results. This experiment will be discussed in Chapter 6.

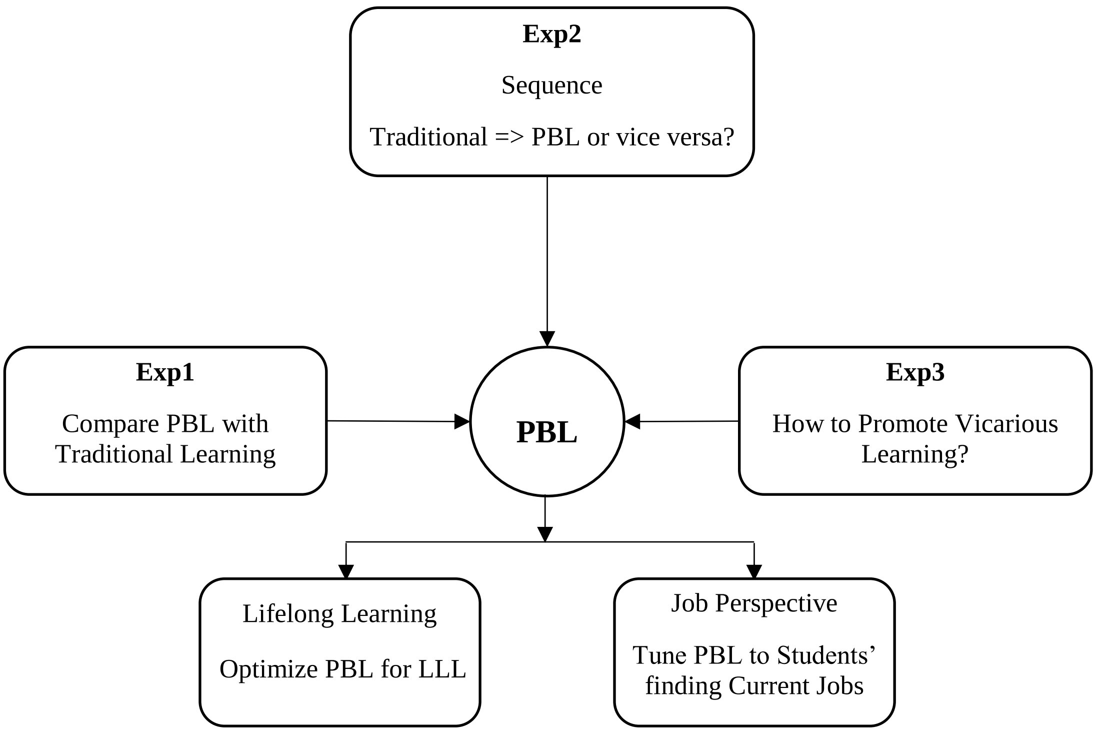


Figure 2. Pragmatic Experiments and Anticipated Outcome 2

Ultimately, it is anticipated that PBL will turn students into lifelong learners and to learn various other skills which will enhancing their chances of employment as illustrated in Figure 2.

The first experiment compared the lecturing mode with the PBL mode and evaluated three dependent variables: Students' attitudes, the amount of reflections by the students and its generated learning outcomes. The following three research questions were raised:

1. What attitudinal effects can be attributed to PBL compared to those raised in the lecturing mode?
2. Does PBL increase the amount of reflection by the students?
3. What learning outcomes can be attributed to PBL compared to those in the lecturing mode?

The second experiment targets determining the preferred sequence of supplementing PBL with traditional lectures. Its effect on students' attitude, motivation and reflection were used to determine the preferred sequence.

The following research questions was raised:

4. Would the transition lecturing-PBL produces better results than PBL-lecturing, as far as university students' positive attitudes towards the Electronics I Course, motivation and the amount of reflections is concerned?

The third experiment targets various items related to PBL and the following research questions' were raised:

5. Which type of PBL problems are most suitable for these students (closed versus open)?
6. What will be the amount of knowledge outcomes amongst students who solve a problem themselves versus those who inherit a project from another group versus vicarious learning amongst groups, when multiple PBL problems are being solved by other groups in parallel?
7. Does PBL improve students' attitude, motivation, and reflection?

Hypotheses

It can be hypothesized that the attitude, motivation and reflection of students will improve when applying the PBL mode. This assumption is based upon the review of literature now to date (see chapter 2 for a detail review of the literature). The traditional lecturing mode is often perceived as boring and most students struggle to concentrate for more than 20 minutes. In contrast: they are happy to "work" in the PBL mode for more than several hours. Earlier observations showed that students are more relaxed during the PBL instructional sessions when they participate actively and became involved in the problem solving process.

Students become active and involved whilst in the PBL mode; it motivates them. It is like a team session; for instance, if there are two students we assume they are equal. However if one of them plays soccer and the other not, which one will be more motivated to cut the grass? Most probably the soccer player has a richer understanding of how grass develops, since he depends on it during the soccer games. It is likely that students in the PBL mode are more motivated than students in the traditional mode due to their active involvement in the learning.

When in the PBL mode, students become actively involved within their groups. It is almost like a Formula 1 racing team; there is a great team spirit amongst the team members, with each member fulfilling its function to the best of its ability in an attempt to get their car to win. It's a team effort and after the race, they need to reflect on how they did it, so that they can prepare for the next race: Reflection improves students' learning from earlier attempts.

Learning outcomes should be retained for a longer time. However long-term retention may be more optimal in the PBL mode according to the literature (Strobel & van Barneveld, 2009). The amount of prior knowledge for students in the PBL mode may play a role in the learning outcomes. Students attending traditional lectures usually receive more theory than those in the PBL mode; who are least responsible to familiarize themselves with some part of the theory. Students in the lecturing mode may thus do slightly better in exam-based tests, especially if it relates to rote learning. Students in the PBL mode however may remember their experiences for a longer period, due to their more active approach in getting the information.

We have seen that the literature is not that clear on the best practices regarding the amount of prior knowledge required in the PBL mode, but it can be hypothesized that the extended-stream students at WSU may need more prior knowledge before solving a PBL problem due to their low entry level requirements.

The first experiment compared the lecturing mode with the PBL mode and evaluated three dependent variables: Students' attitudes, the amount of reflections by the students and its generated learning outcomes.

It is hypothesized that:

1. The overall attitude will be more positive among students who participate in PBL activities compared to those in the lecturing mode.
2. The amount of reflection will be higher among the students who participate in the PBL mode compared to those in the lecturing mode.
3. The level of near transfer skills and the retention of acquired knowledge will be higher among students who participate in PBL activities compared to those in the lecturing mode.

The second experiment targets determining the preferred sequence of supplementing PBL with traditional lectures. Previous groups of students at WSU who applied PBL with no or only little prior knowledge found it frustrating to familiarize themselves with the theory afterwards; this unexpected effect was obvious and clear. It is therefore hypothesized that:

4. The transition lecturing-PBL would produces better results than PBL-lecturing, as far as students' positive attitudes, motivation and the amount of reflections towards the course is concerned.

The third experiment targets various items related to PBL and the following three hypotheses were developed based on three research questions.

5. An achievable, yet challenging PBL problem that triggers students' curiosity will be more suitable in terms of learning effectiveness.
6. Students who solve a PBL problem by themselves will learn more than those who inherit a project from another group. Vicarious learning amongst onlookers will only transpire from striking projects.
7. PBL improves motivation, attitude, and reflection in students.

Experimental Setup

PBL setting at WSU during the experiments

Various PBL models were discussed during the literature review, but we had to choose a model that was suitable and pragmatic achievable at WSU. The environment were still geared towards the traditional lecturing mode and we had to find a way to do the practice-based experiments. The guidelines from Amoako-Sakyi and Amonoo-Kuofi (2015) were fully achievable at the time and we have decided to follow that. Their guidelines indicated that the most effective PBL scenarios should:

- Deal with at least one objective in the syllabus.
- Triggers former knowledge and builds on current knowledge.
- Ensure problem matching with the level of the students.
- Ensure relevancy to the future profession of students.
- Stimulate critical thinking and encourage self-directed learning.

and also include qualities as mentioned by Bridges (1992):

- The problem relates to a real-life situation.
- Students take responsibility for their own teaching and learning.
- The solution to the principal problem should not only include problem diagnosis and analysis, but also include implementation.

The lecturer always acted as a facilitator when in the PBL mode and make sure that students stay on task by providing hints and resources for research to correct their reasoning as suggested by (McManus, 2008). Students had to follow the guidelines in using PBL based on Moebs, Weibelzahl, Tomadaki, and Scott (2006) and the implementation of PBL in the medical curriculum of the University of Maastricht. Students have to explore the concepts, find resources and apply their knowledge when solving the authentic PBL problems. The syllabus already exist and a hybrid PBL had to be used at WSU, in this case Type III as defined by Kwan and Tam (2009) – “PBL problems for applying lecture-delivered information”. The depth of the PBL problems as defined earlier by Bradbeer (2011), usually involved a complete module.

One of the limitations during the experiments at WSU, was a lack of suitable facilitators/tutors, and the researcher had to facilitate all of the groups on a rotational basis, as if it was a Team-based learning (TBL) class. Other inadequacies include a lack of specially equipped tutorial rooms, a library that was not that well-resourced, and a rather sluggish internet connectivity. All of these can obviously be addressed once WSU decide to implement PBL on a larger scale.

Pilot tests

The researcher had to do pilot tests to familiarize himself with PBL since he was also inexperienced with the subject. The pilot tests were also used as a testbed to consider using Blackboard as an instrument of collecting data. The initial study was also meant to involve a “Remote Lab”, and an in-house Remote Lab was therefore prepared and made functional at Walter Sisulu University (WSU) as part of this study. It was then decided to also include Problem-based Learning (PBL) as part of the study. The first pilot test was done with a few students towards the end of 2010. The class was divided into two halves, with one half using the in-house Remote Lab whilst the other half had to use the conventional “Breadboard” to build various transistor related electronic circuits.

A breadboard also known as proto-board is a type of solderless electronic circuit construction, allowing the building of electronic circuit without any soldering (Shams, 2017). It is reusable and designed by Ronald J Portugal of EI Instruments Inc. in 1971 (Shams, 2017). Figure 35 in APPENDIX A shows a typical breadboard, connecting a small electronic circuit. The breadboard is meant to test the functionality of a circuit, allowing the user to do various measurements and quick changes to the circuit if necessary.

Computer-based simulation packages for electronic circuits has been available for years, and has proven to be accurate and effective (Matthews, 2017). The user drag and drop components onto the screen from a pop-down menu, wire them up, and runs the simulation (Matthews, 2017). Computer-generated oscilloscopes and voltmeters, probe any point in the circuit. Electronic circuit simulation uses mathematical models to replicate the behaviour of an actual electronic device or circuit. Simulation software allows for modelling of circuit operation and is an invaluable analysis tool. Figure 36 in APPENDIX B shows a typical electronic circuit when simulated with Multisim.

Remote Laboratories are created to enable a student or researcher to remotely conduct real experiments across the Internet (Stanford-University, 2017). The materials and operating equipment of the Remote Laboratory are contained in one geographical location, whilst the user is utilising the experiments from a different, sometimes very distant location (Stanford-University, 2017).

Figure 37 - Figure 39 in APPENDIX C show typical images from the graphical user interface when the in-house WSU Remote Lab was used. Students did the experiments in one of the computer labs whilst the actual hardware of the Remote Lab was located in one of the staff offices (see APPENDIX D).

Students had to work in groups of two and both the Remote Lab and “breadboard” groups had to use the PBL method during this pilot test. One of the main purposes of this test, was to test the WSU network to see if it had the capacity to accommodate a substantial amount of students to do transistor related practical experiments, using the Remote Lab at a given time. The pilot test confirmed sufficient speed of the WSU intranet and the Remote Lab was able to accommodate the need of the students to do the practical experiments in a specific time-slot. No major bottlenecks were experienced by the system.

Both the Remote Lab and “breadboard” groups used the PBL method, and they were monitored to identify any possible hiccups. APPENDIX E shows the detail of the actual problem to be solved. The average scores between the groups were almost identical as shown in APPENDIX E. No statistical analysis were done during these early stages.

The pilot tests shows that the students were unfamiliar with both the Remote Lab and PBL. This could result in unreliable measurements. It was thus decided that this study should rather focus on PBL versus Conventional Teaching Methods and not to use the Remote Lab from this point onwards. This leads to the three experiments as discussed in Chapters 4-6

Measuring Instruments

The three practice-based experiments had to be done in a hybrid way whilst the rest of the syllabus was covered in the traditional way. It was therefore not possible to assess the students in a way as discusses in ASSESSMENT, Page 21 and APPENDIX BB, due to the limited time, experimental and control groups for some experiments, and the compulsory traditional exams students had to write.

Traditional assessment methods were not ideal in testing students in the PBL mode, and instruments to measure dependant variables such as students' attitude, motivation and reflection were introduced. These were used during all of the main experiments for the various configurations (independent variables) as illustrates in Figure 3. Vicarious learning was also used as a dependant variable during Experiment 3 when multiple PBL problems were involved. In this section we focus on the variables used to measure and interpret the data.

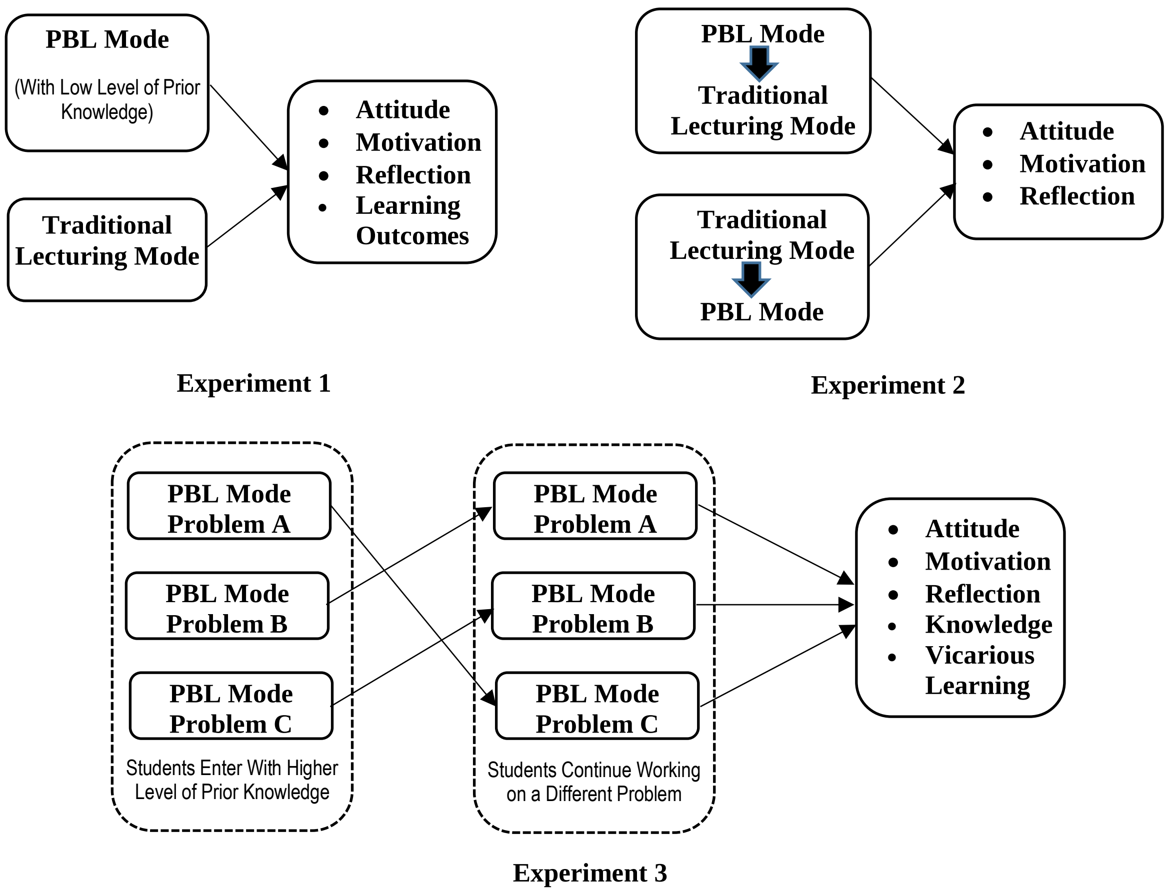


Figure 3. Illustration of the Independent and Dependant Variable for the Three Experiments 3

Attitude

Some of the categories of attitude are 'learning goal orientation', 'task-value', 'self-efficacy', and 'self-regulation'. Goal-orientated refers to how hard the students work in order to achieve good results in the tasks that they have been given (Cambridge Dictionary, 2018). Task-value refers to the efforts a specific piece of work requires to be done by the students (Collins Dictionary, 2018) whilst self-efficacy pretends to determine how the students feel, think, motivate themselves and behave (Bandura, 1994). Self-regulation in this case, refers to the controlling of a process or activity by the students themselves (Collins Dictionary, 2018). Using these mentioned categories one can measure the attitude of the students and gives some indication of students work ethics, feelings and behaviour. The difference in the attitude, whether it be more positive or negative, can give an indication on the influence of a specific treatment e.g. when a control group follows the traditional lecturing mode whilst the experimental group follows the PBL mode.

The ‘Adaptive Learning Engagement in Science’ questionnaire from Velayutham, Aldridge, and Fraser (2011), composed of 31 questions, was adapted in order to assess students’ attitudes toward the Electronics I course during the three main experiments (see APPENDIX M). It contains four *factors* of attitudes and perceptions; (1) Learning Goal Orientation, (2) Task Value, (3) Self-Efficacy and (4) Self-Regulation. A five-point Likert scale was used to measure the level of agreement of the student with the statement, with a score of (5) Strongly Agree, (4) Agree, (3) Neutral, (2) Disagree, and (1) Strongly Disagree.

Motivation

The level of learning motivation during the three main experiments was assessed by using a 36-item questionnaire that was modified from an Instructional Materials Motivation Survey (IMMS) of Keller (1993b), who applied the theory of ARCS (Relevance, Satisfaction, Attention and Confidence). With this questionnaire, a five-point Likert scale was also used to measure the level of agreement of the student with the statement, with a score of (5) Very True, (4) Mostly True, (3) Moderately True, (2) Slightly True, and (1) Not True. The detailed questionnaire is shown at APPENDIX N.

Reflection

The National Council for Curriculum and Assessment (NCCA) (2011) key skills student reflection sheet (as shown at APPENDIX O), composed of 54 reflection questions, was adapted to assess students’ reflection towards the Electronics I course during the five main experiments. It contains five *factors* of reflection; (1) Being Personally Effective, (2) Communicating, (3) Working with Others, (4) Critical and Creative Thinking and (5) Information Processing. A five-point Likert scale was used to measure the level of agreement of the student with the statement, with a score of (5) Strongly Agree, (4) Agree, (3) Neutral, (2) Disagree, and (1) Strongly Disagree.

Four additional qualitative questions were included. (1) Choose two of your favourite items above where you have chosen a high score like “Strongly Agree” and explain why you gave them a high score and describe in some detail what they did, (2) “What thing did you like the most?”, (3) “So what was the main thing that you learned?”, and (4) “Now what – what skill would you like to develop more?” These questions were included since it allow the researcher to gain an in-depth understanding of the participants’ experiences of the phenomenon according to Cohen, Manion, and Morison (2007). The qualitative questions gave voices to the participants in the study as pointed out by Gibson, Timlin, Curran, and Wattis (2004) and it were mainly used to gain a fuller understanding of the students’ experiences and to find out the way they think, feel, interact and behave. The data from the qualitative questions revealed additional information that could not have been obtained through quantitative data. This data assisted with the interpretation of the quantitative data, but it was not used as part of the data analysis.

Learning Outcomes

Strobel and van Barneveld (2009) found PBL significantly more effective as a training method for practitioners with an improvement in long-term retention of knowledge and skills when compared to traditional instruction. Students' test and exam scores were used to determine their learning outcome.

Knowledge

The definition of knowledge in the Collins dictionary is very similar to those of the Oxford English Dictionary. It says: "Knowledge is information and understanding[1] about a subject which a person has, or which all people have." (Collins English Dictionary, 2019). Students' test and exam scores were used to determine their knowledge.

Vicarious Learning

Vicarious Learning is learning that is derived from secondary sources such as hearing or observation of other students, rather than their direct, hands-on, learning experience (Alleydog.com's online glossary) e.g. learning via exposure to the learning experiences of others (Lee, 2009). It occurs when students see and/or hear a learning situation for instance when observing a learner in an instructional situation whilst not being predominantly addressed or interacted with, nor being instructed (Gholson & Craig, 2006). Examples of vicarious learning include; students watching another student at the front of the class interacting with the teacher (Pittsburgh Science of Learning Center, 2007) or passively watching our parents, friends and neighbours etc. do everyday tasks, pursue hobbies, interests, and physical skills (Alleydog.com's online glossary). Vicarious learning can also be learning by seeing what others experience in an area. e.g. when you see others getting burnt when they touch a hot vessel, you learn that you should not be touching a hot vessel as you will get burnt or when you see people getting cancer as a result of their smoking, you learn to stay away from cigarettes etc. (Tharad, 2010). Students' test and exam scores were used to determine the amount of vicarious learning that took place during the 3rd main experiment as discussed in Chapter 6.

Reliability and Validity

Reliability and validity in quantitative research are ensured through the experimental setup, control of co-variables, the chosen treatment, research tools, a sufficiently large sample sizes and random assignment to the conditions (Du Plooy-Cilliers, Davis, & Bezuidenhout, 2014). According to McMillan and Schumacher (2001), validity is the degree to which the interpretations and conclusions rest upon shared opinions between the participants and the teacher/researcher. Reliability, on the other hand, according to (Silverman, 2004), is the degree

[1] *https://www.collinsdictionary.com/dictionary/english/understanding*

to which the findings of the research are independent from accidental circumstances. Joppe (2000) defines reliability as the extent to which results are consistent over time, and are an accurate representation of the total population under study. If the results of a study can be reproduced under a consistent methodology, the instrument is considered to be reliable. Du Plooy-Cilliers et al. (2014) also agree that a research method or instrument becomes reliable when the same results are produced and if the research is led by a different researchers at different moments using the same method or instrument. A source of error could be anything that effects the data e.g. misinterpretation of a question (Du Plooy-Cilliers et al., 2014).

Welman, Kruger, and Mitchell (2006) suggest that the findings should reflect what was happening in the given situation. Validity is all about determining whether the research measured what it was supposed to measure and according to Du Plooy-Cilliers et al. (2014), it could include:

1. Content validity – Is the test representative?
2. Sampling validity – Does the measurement represent the specific content?
3. Face validity – Does the test look like what it is supposed to? Is it well designed?
4. Construct validity – Does it measure what it is meant to?
5. Internal validity – Refers to whether the research method or design will answer your research question.

Knowledge-related tests mostly came from previous exam and test questions. It was representative and measured the specific content. These questions were well designed and moderated by qualified colleagues from WSU, therefore ensuring the validity of the measurement tool. The other content that was used for the tests include the SALES, IMMS and NCCA questionnaires which were all developed in a professional way. The development of the 'Adaptive Learning Engagement in Science' (SALES) questionnaire involved identifying key determinants of students' motivation and self-regulation in science learning based on theoretical and research underpinnings (Velayutham, 2012). The developers used a comprehensive construct validity framework, which "ascertains content-, face-, convergent-, discriminant-, predictive- and concurrent validity" to establish the validity of the newly developed instrument (Velayutham, 2012). The development of the new questionnaire according to Velayutham (2012) followed a three - stage approach:

1. Identifying and defining prominent relevant scales in an effort to maximise content validity of the instrument by ensuring that the scales were based on a sound theoretical framework:
    - an extensive review of theories and research was carried out.
    - define concisely the scales identified in step one based on the analysis of literature.
2. Writing individual items within the scales:
    - Items from previously validated questionnaires were examined and, if appropriate, adopted.
    - Suitable items were written for each scale. Once the items for each scale had been adapted or written, ten experienced science teachers were asked to assess the comprehensibility, clarity, and accuracy of items for each scale e.g. is it representative, suitable and appropriate.

3. Conducted pilot study.

This new survey provides a reliable tool that teachers and researchers could utilise (Velayutham, 2012). The Instructional Materials Motivation Survey (IMMS) was designed by Keller, and it was also used during this study. It is a 36-item situational measure of people's reactions to instructional materials in the light of the ARCS model (Loorbach, Peters, Karreman, & Steehouder, 2015). The ARCS Model of Motivational Design is based on an extensive review of the motivational literature, which led to a clustering of motivational concepts into four constructs: **A**ttention, **R**elevance, **C**onfidence and **S**atisfaction (Keller, 2010).

The following goals have to be met for people to be motivated to learn according to Keller (2010):

> **A**ttention **-** People's curiosities and interests should be stimulated and maintained.
>
> **R**elevance **-** People need to feel connected to the setting and believe that the instruction is related to important personal goals or motives before they will be motivated to learn.
>
> **C**onfidence **-** Even if people believe that the content is relevant and they are curious to learn it, they still might not be appropriately motivated due to too little or too much confidence, or expectancy for success. Too little confidence due to well-established fears of the topic, skill, or situation may prevent someone from learning effectively. Too much confidence may cause someone to believe incorrectly that s/he already know it and overlook important details in the learning activities. Being successful in achieving these first three motivational goals (attention, relevance and confidence) results in people being motivated to learn (Keller, 2010).
>
> **S**atisfaction **-** People must have feelings of satisfaction with the process or results of the learning experience to enable them to have a continuing desire to learn.

Validity of the IMMS was established by Keller who prepared two sets of instructional materials, covering the concept of behavioural objectives. These materials were part of a unit of work on lesson planning and instructional design. Both lessons had the same objectives and technical content. The lesson for the control group was prepared according to standard principles of instructional design, but was not cosmetically enhanced in any way to make it interesting. The experimental lesson was enhanced with strategies to stimulate curiosity, illustrate the practical relevance of the content, build confidence, and provide satisfying outcomes. Students were randomly assigned to the two lessons that they completed during one class period, including testing. Scores on the experimental lesson were significantly higher than for the control lesson (Keller, 1993a). Keller also found the internal consistency estimates, based on Cronbach's alpha to be satisfactory.

A questionnaire is just a 'tool' that can be used to collect and record information about a particular issue of interest according to Harry (2013). The use of self-administered questionnaires, mostly done in Blackboard during this study, had several advantages. It can be completed by several participants in a short period, collecting a lot of information, and no cost incurred when computer based. It is also easy to export the data to SPSS.

The reliability of the surveys was evaluated by means of Cronbach's Alpha coefficient. Cronbach (1951) advises that the α value of 0.7 to 0.8 is regarded as satisfactory when comparing groups. The coefficient calculated from the data of the attitude, motivational and reflections surveys across all of the main experiments (1-3) was ≥ 0.7, showing the reliability of the surveys. It was only the coefficient from Learning Goal Orientation subscale within the attitude survey of main experiment 3 which had a smaller α value of .654. An independent t-test with a 95% confidence interval was used to compare the mean scores between the experimental and control groups for each of the individual items as well as for the different factors within the different surveys. Surveys are shown in APPENDIX M – APPENDIX O. More detail of the Cronbach values will be shown during the results.

Analysis

The quantitative approach was aimed at since the goal was to find out the answers to an inquiry through numerical evidence. Various hypothesis's had to be proven by mathematical and statistical means, hence the quantitative approach formed the basis around which all the experiments were designed. Creswell (2005) states that in quantitative research, "the researcher decides what to study, asks specific, narrow questions, collects numeric (numbered) data from participants, analyses the numbers using statistics, and conducts the inquiry in an unbiased, objectives manner". Quantitative research design is an excellent way confirming/refuting hypotheses. Besides the quantitative parameters, assessing the PBL effects needs the more direct observation of the situation in the classroom; often labelled as "evidence-based" research. However for the sake of objectifying and theorem building, the quantitative approach will be undertaken in the following experiments. After statistical analysis of the results, a comprehensive conclusion is targeted and its results can be formalized discussed and disseminated. The applied quantitative analyses are undertaken for filtering out external factors; if properly designed, its results can be seen as valid and unbiased (Shuttleworth, 2008).

The applied research method is based on the notion that experimental conditions need to be compliant to the educational practice as otherwise essential conventions in the interaction between teachers and students will be missed, and thus corroborate a proper investigation process. It was therefore decided to use experimental designs in which the basic intent of the experiments was to test the effect of an intervention on the outcome, such as with experiment 1 that includes an experimental- and control group. Experiment 2 also includes two groups, G1 and G2, but the nature of this experiment was such that none of the groups could have been classified as a control group. In this case, students of the two groups followed different sequences of learning, and the effect of that was tested. Experiment 3 entailed to three groups, G1, G2 and G3. There was also no control group as it would lead to an obviously inferior condition, seen the publicity that students gave amongst each other. The influence of different PBL project formats on the students as well as the effect of vicarious learning was tested.

The test-retest approach ("repeated measures") is a method with stability since the same participants were used, but the method, tool or instrument is administered at different times (Du Plooy-Cilliers et al., 2014). Various pre- and post-tests were done, and in some cases, in-between tests as well. Paired sample T-tests were used to determine whether there was statistical evidence that the mean difference between paired observations on a particular outcome within a group was significantly different from zero. The Paired Samples t-Test (also known as the Dependent t-Test, Paired-t Test or Repeated Measures t-Test), compares two means that are from the same individual, object, or related units (Kent State University, 2017b). The two means according to Kent State University (2017b) typically represent two different times (e.g., pre-test and post-test with an intervention between the two time points) or two different but related conditions or units.

Independent Samples t-Tests were used to test the statistical differences between the means of two groups. This was done in order to determine whether there was statistical evidence that the associated population means were significantly different between two groups (Kent State University, 2017a). A One-Way ANOVA ("analysis of variance") was used to compare the means of the three independent groups during Experiment 3. This was to determine whether there was statistical evidence of significantly different means between the groups.

The statistical analyses of this study were performed by using statistical package program for social sciences (SPSS).

Experimental Condition

All of the experiments involved 1st year tertiary students in the department of Electrical Engineering who were enrolled in the Electronics 1 Course. This course covers: Instruments, Semiconductor theory, and the theory, characteristics and applications of Diodes and Bipolar junction transistors (BJT). The PBL problems were founded from the Diode and BJT applications.

The three main experiments that were conducted include various configurations of PBL as discussed in Chapters 4-6. When in the PBL groups, students had to follow the following guidelines:

- 1st Small group meeting - PBL students met in their respective groups and discussed the problem. Each student in the group had to use his/her prior knowledge and experience and assume that they were personally asked to solve the problem/s. They need to explore the issue, state what is known, define the issues and come up with a small number of hypotheses that were likely to explain and solve the problem and then divide the work to be done amongst the group members.
- Individuals – They worked separately over the next 2 days to allow each member to independently carry out the research on how to design, develop, and test a suitable electronic circuit e.g. a power supply.
- 2nd Small meeting - The pairs met again and drew conclusions on the nature of the problem and the best fit solutions given the information known.
- Finally, each student group had to implement the solutions, demonstrated the operation of the project, and submit a report as to the solution and its consequences.

CHAPTER 4: EXPERIMENT 1

MIXING PROBLEM BASED LEARNING AND CONVENTIONAL TEACHING METHODS IN A COURSE ON ANALOGUE ELECTRONICS

Summary

This study, undertaken at the Walter Sisulu University of Technology (WSU) in South Africa, describes how problem-based learning (PBL) affects the first year 'analogue electronics course', when PBL and the lecturing mode was compared in terms of attitudinal effect, the amount of reflection and learning outcome effects. Problems were designed to match real-life situations. A strong correlation was found between the students' attitudes and project marks for those who underwent the problem-based learning method. It was found that students who followed the PBL method learned to do research, learned better how to work in groups and developed greater confidence. Also, what they learned was more of a practical value and they had more positive attitudes towards learning goal orientation, task value, self-efficacy and self-regulation. They also reflect more, but there were no significant improvements in their short term learning. This research targets the generally-perceived gap between employer expectations and higher education outcomes in South Africa.

Introduction

It was decided towards the end of the pilot study to abandon the Remote Lab and rather focus on PBL. This was done for various reasons as mentioned in Chapter 1. It was also necessary to use suitable measuring instruments in addition to the tests and exams that normally favours traditional lectures. The lessons learned from the pilot study steered the researchers towards the path to be taken during the first main experiment.

In this chapter, the influence of PBL on a first year analogue electronics course is analysed. Its main objective is to determine how the learning process of students is affected when both traditional teaching methods (as defined on page 9) and PBL teaching methods (page 15) is used in a mixed way. It undertakes to answer sub problems 1-3 as shown in the objectives.

Research Questions

1. What attitudinal effects can be attributed to PBL compared to those raised in the lecturing mode?
2. Does PBL increase the amount of reflection by the student?
3. What learning outcomes can be attributed to PBL compared to those in the lecturing mode?

A version of this chapter is published in the *American Journal of Engineering Education* (Podges et al., 2014).

Independent variable

The independent variable for the research study was the instructional strategy. The controlled condition used the traditional, lecture-based instructional strategy whilst the experimental condition used the PBL strategy.

Hypotheses

It is anticipated that well-motivated students have an optimal attitude towards the design of electrical circuits and are therefore expected to be more successful if they follow a systematic approach compared to non-motivated students. Students' curiosity will be satisfied with a higher self-esteem and increase in concentration. Students also benefit from reflection since they think deeply about a subject or question over a period of time. This triggers prior knowledge and earlier experience and helps them to gain a fresh insight into a new knowledge- or skill domain and also a higher involvement in terms of presentation and collaboration. In other words: Reflection helps the students to 'learn to learn'. So the expectation is that there will be a positive correlation between the amount of reflection and the size of learning outcome, both in the instructional and the PBL condition.

The need for near transfer of learning focusses on tasks in the same context; When a nearly similar problem or task is encountered, it should be automatically solved or accomplished with little or no cognitive load (Chandler & Sweller, 1991).

The research questions address the effect of PBL on the attitude, reflection and academic performance in the two groups of students in this study: the group of students that received traditional instruction (CG) versus the group that received PBL instruction (EG). The following three hypotheses were developed based on the three research questions.

It is hypothesized that:

1. The overall attitude will be more positive among students who participate in PBL activities compared to those in the lecturing mode.
2. The amount of reflection will be higher among the students who participate in the PBL mode compared to those in the lecturing mode.
3. The level of near transfer skills and the retention of acquired knowledge will be higher among students who participate in PBL activities compared to those in the lecturing mode.

Experimental Setup

The process and purpose of the research study was explained to the students, for instance, that the class will consist of two 'halves' and that each will follow a different learning mode. They were also told about the group-work, questionnaires and pre/post tests and the benefits when successful lessons learned be implemented, but no detail was given about the two learning modes. All of the 44 students in the Electronics 1 semester-based class of 2011 at WSU, College Street campus agreed to participate. They were allocated randomly to one of the two conditions: EG: Experimental Group (with the PBL instruction) and the CG: Control Group (in the traditional lecturing mode). In both conditions, the students were randomly grouped in dyads (pairs) instead of larger groups by the lecturer due to the low student numbers and simplicity of the PBL problem. All students were satisfied from the start with the allocations made and no one requested to change groups or partners. One student left the course early in the semester, leaving the EG group with only 21 students. According to Yusof, Hassan, and Tasir (2007, p. 115): " …. most students who enter the university come from a traditional, plenary educational system and many of them are not ready for the change to university life, much less for PBL". PBL, which was only part of this particular course, required from students to work much harder since they had to figure out how to do difficult work by themselves.

This research focuses on the selection of a special type of project-based lab activity suitable for students in their first year, given the lack of technical knowledge, and which would still offer students the opportunity to work on real-life engineering projects and gain and practise skills in wiring and testing electrical circuits, the proper use of electronic instruments and the interface of various components, similar to those of Nedic, Nafalski, and Machotka (2010). The PBL classes were based on the traditional Aalborg model which is founded on problem-based project work according to Kolmos et al. (2006), and which means to solve real-life problems that students may face in their future jobs.

Table 2 shows the activities around the experiment. The EG participated in the PBL activities during weeks 9-13 of the mixed semester course.

Table 2. Activities during Semester

Week	**Activities**	
	EG (Experimental Group)	**CG (Control Group)**
9	Pre-Test 1 (paper test)	Pre-Test 1 (paper test)
9	Traditional theory (portion of module 5)	Traditional theory (portion of module 5)
9-10	Experiment: PBL and Lab instruments	Traditional theory (remainder of module 5)
11-13	Experiment: PBL and Lab instruments	Experiment: Traditional way and Lab instruments
12-13	Traditional theory (modules 6,7 and portion of 8)	Traditional theory (modules 6,7 and portion of 8)
14	Post-Test 1, Attitude 1, Reflection 1 Surveys	Post-Test 1, Attitude 1, Reflection 1 Surveys

PBL related to electrical engineering usually includes a large complex design component that could only be executed in a lab. The magnitude of the PBL project is usually much larger than the traditional 'step-wise' instructions that students need to follow during discrete lab sessions. Students need to meet regularly in the lab until the PBL problem complies with the given specification(s) (Nedic et al., 2010). Resources were limited, but we had the privilege of having both a computer lab and an electronics lab available to us for most of the required allocated 8 sessions of 45 minutes per week. The computer lab was used for most of the time during normal lecturing, for instance all those activities excluding the one's with the grey background as shown in Table 2. Whenever the PBL method was used, each pair in the group had to do research in the library, another computer lab or work in the electronics lab. Due to a lack of small venues the 11 student pairs were spread evenly during PBL sessions across the electronics lab with a capacity of 30 workstations. There was a sufficient space between the different student pairs with no interference between them. When students had to use the computer lab during practical classes the 22 students in the CG used the computers placed in the front rows while the 21 students in the EG used those at the back half. The researcher had to fulfil both the role as a facilitator to one group and a lecturer/lab-technician to the other. The evaluation between the CG (which entails 'step-wise' instructions) and EG groups (which entails PBL problems) had to be different due to the vast difference between the two. Theoretical tests and the examination still favoured the traditional lecturing mode and had to be in common.

Both groups completed various pre- and post-tests, attitude- and reflection surveys, semester tests and an examination during the course. Some of these were done electronically, using Blackboard. The data were compared at the end of the course and the differences were analysed.

The pre-test was done on paper during Week 9, but in order to ease the workload, all tests and surveys were done via Blackboard. All students, excluding those who were absent for the day, participated, resulting in a high response rate. The surveys related to the experiment were done in Week 14.

The 'Adaptive Learning Engagement in Science' questionnaire from (Velayutham et al., 2011) as shown in APPENDIX M, composed of 31 attitude questions, was adapted to assess students' attitudes toward the Electronics I course. It contains three factors of attitudes and perceptions; (1) learning goal orientation, (2) task value, and (3) self-regulation. A five-point Likert scale was used to measure the level of agreement of the student with the statement, with a score of 5-Strongly Agree, 4-Agree, 3-Neutral, 2-Disagree, and 1-Strongly Disagree.

The National Council for Curriculum and Assessment (NCCA) (2011) key skills student reflection sheet, composed of 54 reflection questions was adapted to assess students' reflection toward the Electronics I course. It contains six factors of reflection; (1) information processing, (2) critical and creative thinking, (3) communicating, (4) working with others, (5) being personally effective, and (6) class experience. A five-point Likert scale was used to measure the level of agreement of the student with the statement, with a score of 5-Strongly Agree, 4-Agree, 3-Neutral, 2-Disagree, and 1-Strongly Disagree. Four additional qualitative activities were included. (1) "Choose two of your favorite items above, where you have chosen a high score like 'Strongly Agree' and explain why you gave them a high score and describe in some detail what you did", (2) "What thing did you like the most?", (3) "So what was the main thing that you learned?", and (4) "Now what – what skill would you like to develop more?"

The reliability of the surveys was evaluated by means of Cronbach's Alpha coefficient. The coefficient calculated from the data of all surveys was ≥ 0.8, showing the reliability of the surveys. An independent t-test with a 95% confidence interval was used to compare the mean scores between the EG and CG for each of the individual items as well as for the different factors within the attitude and reflection surveys of the experiment. Surveys are shown in APPENDIX O and APPENDIX M.

Experimental Condition – Mixed Approach of the Electronics 1 Course

Electronics 1 (ETRO1) covers the following topics/modules:

1. Instruments	5. Diode applications
2. Semiconductor theory	6. Bipolar junction transistor (BJT) theory
3. Diode theory	7. BJT characteristics
4. Diode characteristics	8. BJT applications

Most of the 1st year students had very little or no prior knowledge about instruments, such as oscilloscopes, multi-meters, bench power supplies, frequency generators and analogue/digital trainers. Their theory and practical uses were covered in the electronic lab using a hands-on approach where possible.

The content of the semiconductor and diode theory is theoretically oriented and at the time of the research the traditional lecturing methods were used. Students were also introduced to Multisim, an electronic schematic capture- and simulation program. Students had to work within their pre-allocated groups/pairs during the experiment. A prior experiment was done in a traditional way with all the instructions given to the students. They were required to compare simulated and real measurements via hand plotted graphs before plotting it using Excel. Most of them needed assistance with Excel. It was also the first time that the students had used the electronic ‘Breadboard’ (BB) to construct a circuit – a big learning experience for most of them. Figure 4 shows an example of an ‘Electronic trainer unit’ with a (white) BB.

Figure 4. Electronic Trainer Unit with a Breadboard

The content of 'Diode Applications' lends itself towards problem-based project work, but all students had to participate in a pre-test to test the prior knowledge before continuing with the experiment. This and various other steps that followed are shown in Figure 5. Students from the EG were excluded from the lectures that related to 'full-wave bridge rectifiers', 'voltage regulators' and 'filters' since it was part of the experiment.

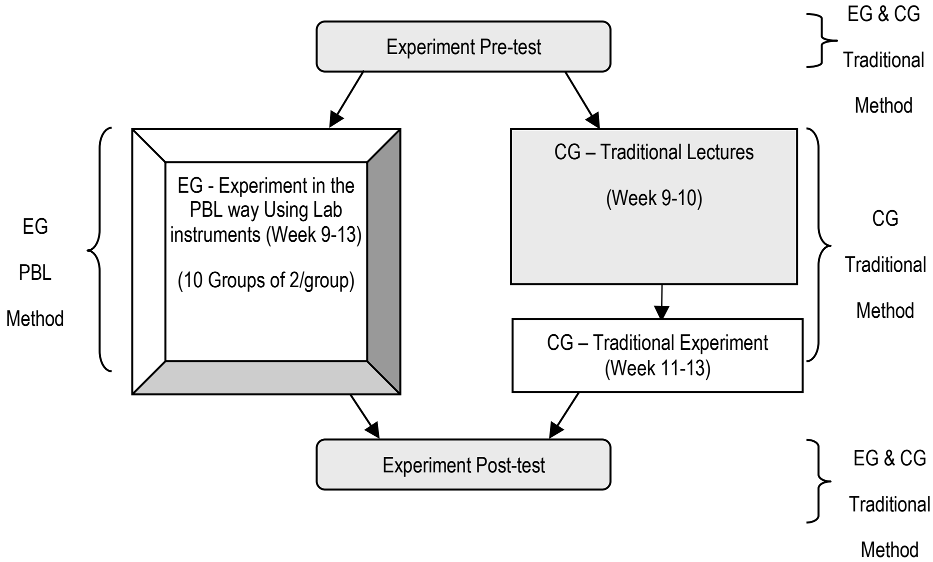


Figure 5. Illustration of how the Experiment was Conducted

After being introduces to the PBL procedure students had to solve a real-life problem, in this case a power supply that needs to fulfil a certain function as shown in APPENDIX Q whilst the CG had to do the traditional experiment as shown in APPENDIX R. Collaborative learning was embedded in the PBL-model with the students being the primary focus of instruction, interacting with each other and working in groups on a real-world problem.

Students in the EG condition were requested to solve the problem, following the operational definition of PBL according to Barrett, Mac Labhrainn, and Fallon (2005) – see APPENDIX P.

The PBL procedure was as follows:

- 1st Small group meeting - PBL students met in their respective pairs and discussed the problem. Each student in the group had to use his/her prior knowledge and experience and assume that they were personally asked to solve the problem/s. They need to explore the issue, state what is known, define the issues and come up with a small number of hypotheses that were likely to explain and solve the problem and then divide the work to be done amongst the group members.
- Individuals – They worked separately over the next 2 days to allow each member to independently carry out the research on how to design, develop, and test a suitable power supply.
- 2nd Small meeting - The pairs met again and drew conclusions on the nature of the problem and the best fit solutions given the information known.
- Finally, each pair of students implemented the solutions, demonstrated the operation of the power supply, and submitted a report as to the solution and its consequences.

The EG was working on their problem while, the CG had to finish the theory classes before continuing with their traditional experiment. This caused the time-on-task to be similar for both groups during the experiment as indicated in Figure 5, but with a difference in the overall time spent on the theory and experiment as shown in Table 3. All students had to do a post-test after the experiment.

Table 3. Overall Time spent on the various Activities

	Time Spent	
Activity	**EG**	**CG**
Theory	61%	66%
Experiment	31%	26%
Tests and Surveys	8%	8%

Power supply – Experiment for the PBL group

Students in the PBL group had to solve a real-life problem while assuming that they were working for a real company. They had to develop a power supply that needed to comply with certain requirements, including supplying a regulated voltage to a variable load while the incoming supply from the electricity provider was unstable. Details of the problem are shown in APPENDIX Q.

The appropriate outcome based on the subject level, should be a power supply, using preferably a 16 V transformer with a full-wave bridge rectifier, a Zener diode voltage regulator circuit and a capacitor as a filter. Most students followed this route, but some of them started with more advanced circuits, containing transistors and voltage regulators. Eventually they switched to the more basic circuits. Initially, students had problems in identifying the primary and secondary windings of a transformer and needed assistance. A variac was used to adjust the 'supply voltage' between 180 VAC and 240 VAC during the testing phase. The project was challenging to the students as it required them to regulate the output voltage for various loads and input voltages.

Results

The Cronbach's Alpha coefficient, calculated from the overall data for all post-surveys, was ≥ 0.7, showing acceptable to good reliability for all. (See Table 4).

Table 4. Cronbach's Alphas for the overall Attitude, Motivation and Reflection Survey

	Cronbach's Alpha (α)
Subscale	**Post-survey**
Attitude	.967
Reflection	.893

The study sought to establish whether there was a significant difference in students' attitude, and amount of reflection between in the traditional and PBL learning modes. The combined mean values for each of the post surveys were nearly similar as shown in Figure 6. However, some individual items differ significantly in favour of the EG condition.

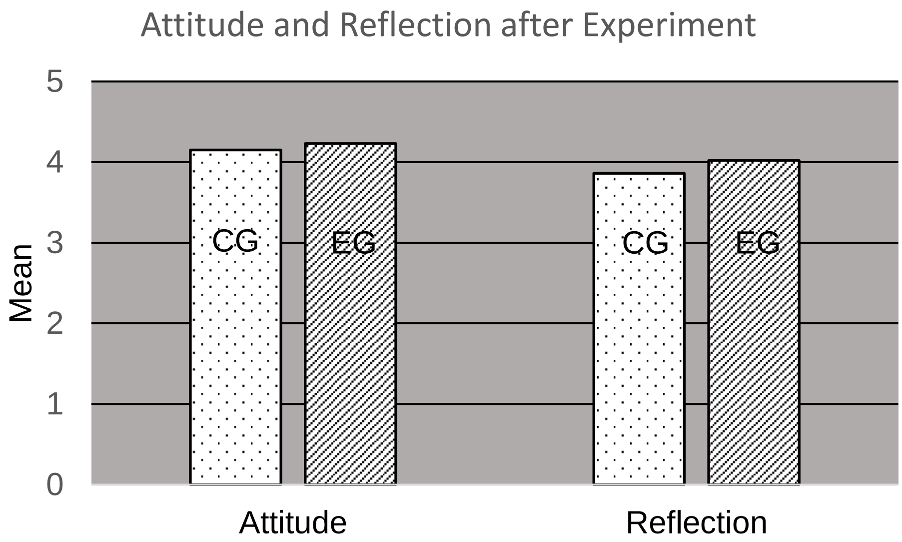
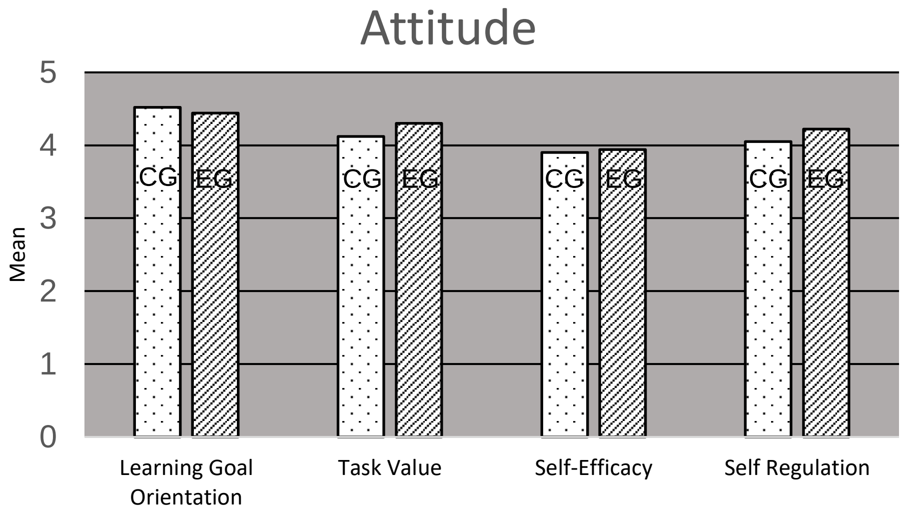


Figure 6. Overall Attitude and Reflection after the experiment

Normal probability plots were generated on the attitude and reflection survey subscale variables, confirming the normal distribution of all data. The reliability of the surveys was evaluated in terms of Cronbach's Alpha coefficient.

Comparison of the Attitude and Reflection Sub-groups after the Experiment



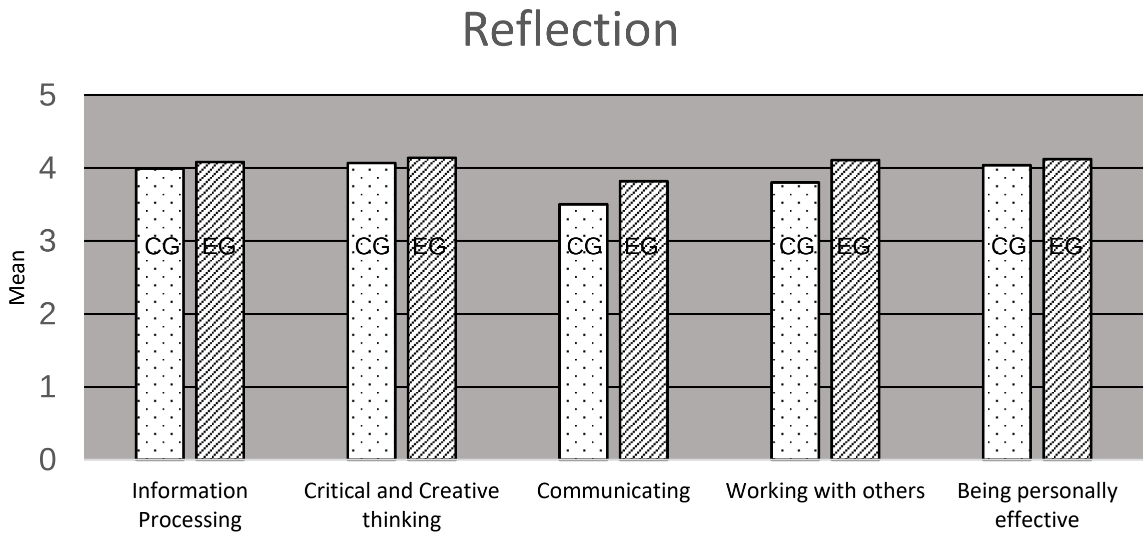


Figure 7. Comparison of the Attitude and Reflection Sub-groups after the Experiment between CG and EG

Preliminary analysis of the data involved; statistically significant interaction between treatment and control, and Levene's test for violation of the assumption of equality of variance amongst CG and EG.

Figure 7 shows a higher mean score for all of the subscales for the attitude and reflection besides 'Learning Goal Orientation'.

On completion of the experiment the presence of any significant difference between the EG and CG student's attitudes and reflections were checked using appropriate surveys (as discussed on page 32). The pre- and post-test scores were also used to check the learning outcomes.

Attitude

The Cronbach's Alpha coefficient calculated from the data was ≥ 0.7 for all subscales, showing acceptable to good reliability for all during the Survey (see Table 5).

Table 5. Cronbach's Alphas for the various Subscales of the Attitude Surveys

Cronbach's Alpha (α)	
Subscale	**Post-survey**
Learning Goal Orientation (8 items)	0.912
Task Value (7 items)	0.872
Self-efficacy (9 items)	0.890
Self-Regulation (7 items)	0.917

None of the factors, 'learning goal orientation', 'task value', and 'self-regulation' appeared 'significantly different' with an independent-samples t-test. However, three of the thirty-one individual items differed significantly as shown in Table 6. See APPENDIX M for all items related to attitude.

Table 6. Items related to Attitude

	EG			**CG**				
Individual items	***M***	***SD***	***n***	***M***	***SD***	***n***	***p***	***t***
In this Electronics 1 class, What I learn satisfies my curiosity.	4.06	.998	18	3.45	1.191	20	.050	1.688
In this Electronics 1 class, I am good at this subject.	3.61	.778	18	3.05	1.026	19	.036	1.858
In this Electronics 1 class, I concentrate so that I will not miss important points	4.61	.502	18	4.30	.470	20	.028	1.973

The 'sum scores' for the various factors as well as all factors combined, were also very similar as shown in Table 7. These results, may not overwhelmingly support Hypothesis 1: that the overall attitude is more positive among students who participate in PBL activities compared to those in the lecturing mode. However, the three items who stick out of the noise in favour of the PBL condition may be an indication that students' attitude may be a valuable measuring instrument during future experiments.

Table 7. Compound Scores related to Attitude

Individual items	EG *M*	EG *SD*	EG *n*	CG *M*	CG *SD*	CG *n*	*p*	*t*
Learning Goal Orientation	35.56	5.544	18	36.14	3.732	21	.697	-.393
Task Value	34.39	4.203	18	32.95	4.873	21	.335	.977
Self-Efficacy	31.500	5.783	18	31.191	5.115	21	.860	.177
Self-Regulation	33.78	6.558	18	32.38	6.241	21	.500	.681
Overall Attitude	135.22	20.429	18	132.67	17.033	21	.672	.426

The overall attitude for the students in the EG were 135.22 compared to 132.67 for the students in the CG. This is almost the same and far from significant, even so, the attitudes of the students in the PBL mode were still more than those in the traditional lecturing mode.

Reflection

The Cronbach's Alpha coefficient calculated from the data was ≥ 0.7 for most subscales, showing acceptable to good reliability (see Table 8).

Table 8. Cronbach's Alphas for the various Subscales of the Reflection Survey

Cronbach's Alpha (α) Subscale	Post-survey
Personally Effective (12 Items)	.742
Communicating (10 Items)	.702
Working with Others (10 Items)	.729
Critical and Creative Thinking (11 Items)	.829
Information Processing (6 Items)	.541

An independent-samples t-test was not significant for Factors 1, 2, 5 and 6 (information processing, critical and creative thinking, being personally effective and class experience – see APPENDIX O), but the mean values for the EG were still higher in all cases. Factors 3 and 4 (communicating and working with others) as well as various individual items related to the Likert-type scale questions of the reflection survey (significant $p < .05$) differed significantly during an independent-samples t-test with a preference towards PBL (EG) as shown in Table 9.

Table 9. Significant Individual and Categorized Items related to Reflection during the Experiment

Individual questions	**EG** (*n*=18)		**CG** (*n*=22)			
	M	***SD***	***M***	***SD***	***p***	***t***
I got information from different sources.	4.61	.502	3.77	1.1378	.010	*2.448*
I checked the reliability and credibility of different sources.	4.17	.707	3.68	.945	.040	*1.801*
I expressed myself in a written Presentation.	4.39	.608	3.73	.935	.007	*2.585*
I worked in pairs.	4.78	.548	4.18	1.097	.022	*2.097*
I worked in small groups.	3.17	1.581	2.09	1.231	.010	*2.420*
Factors						
Communication (in speech and writing).	3.82	.485	3.50	.481	.045	*2.072*
Working with others.	4.11	.465	3.80	.380	.036	*2.178*

Table 9 shows that students had to consult various sources and seriously thought and ponder about its content within their groups. The significant items as reflected in Table 9 include five from fifty-three individual items as well as two from six factors. This may arguably support/not support Hypothesis 2: that the amount of reflection is considered greater among the students who participated in PBL activities compared to those of the lecturing mode". The most obvious is that there is not an overwhelming majority of preferences for PBL in the specific group of involved students. It is valuable though to articulate that various items and factors steak out of the noise in favour of the PBL condition. Instead of taking them as proof of PBL preference at large, it is better to take them as agenda for later analyses during future experiments.

Learning Outcomes

Both the EG- and CG students did theory and a prior experiment in the traditional way. They had to do a pre-test before proceeding with the experiment itself. This pre-test was common for both groups and it contained both questions related to work already covered and also questions related to work that was covered during the experiment. An independent t-test revealed a significant difference in the means of pre-test marks, EG (M = 30.5%, SD = 16.05) and CG (M = 40.0%, SD = 15.81), t (39) = -1.909, p < .032. The 9.5% mean difference between the pre-test scores is significant at the level of 3.2%; an indication that the EG entered the experiment with a lower prior knowledge. However, students were not selected based upon prior knowledge and it is not surprising that they were different in this respect. Selective examination questions were used 2 weeks after the post-test as a retention test. The analysis focuses on the differential effect due to the difference between the EG and CG.

Table 10. Learning outcomes related to the Experiment

Item	EG			CG				
	M	***SD***	***n***	***M***	***SD***	***n***	***p***	***t***
Short-term Learning-Effect (Post-test – Pre-Test)	33.0%	36.8%	17	28.2%	29.0%	18	.336	*.428*
Long-term Learning-Effect (Retention Test – Post-Test)	-2.7%	36.0%	17	-4.0%	42.3%	19	.461	*.097*

Independent t-tests were used to determine the initial level of both groups during the pre-test, and the outcome of each of the types of instructional strategies on students' performance in the post-test, containing relevant near-transfer problems. Similar t-tests were also used to determine the learning outcome. With EG (M = 33.032, SD = 36.840) and CG (M = 28.248, SD = 29.032) the learning outcome did not differ significantly, t (33) = .428, p = .336. This is in line with the results from a repeated measures ANOVA test of between-subjects outcomes that were additionally done, indicating no significant effect between the groups on learning outcomes (F(1,32) = 2.135, p = .154). Table 10 shows that in terms of absolute values (33.032 vs. 28.248) the EG scored a higher learning outcome and a lower decay (2.744 vs. 4.028). However, as its differences did not reach the 5% level (α = .05), it cannot be concluded that the posed hypotheses were confirmed. It might be better with future experiments to match students based on prior knowledge so that a more uncontrived comparison of the post-tests might be gained.

Conclusions

A brief overview of the main findings from the research, in relation to the stated hypotheses for the research study, is presented below.

The overall attitude towards Electronics I will be more positive among students who participate in PBL activities compared to those in the lecturing mode.

The statistical analysis of students' attitude levels may not overwhelmingly supports Hypothesis 1: that the overall attitudes are more positive among students who participate in PBL activities compared to those in the lecturing mode (Table 6). However, these results suggest that EG students appreciate the PBL mode more because it had a positive effect on their attitude, which includes learning goal orientation, task value, self-efficacy and self-regulation. This gave them more self-confidence and making the topic more appealing. As their curiosity was satisfied, they had more confidence in themselves and they did not want to miss any important points. They believe they could master the skills taught, master difficult work and be good with Electronics I. PBL obliges students to become more actively involved since it is based on an active learning system which requires them to find solutions to (usually) real life problems by means of research, prior knowledge and critical thinking.

The amount of reflection is higher among students who participate in PBL activities compared to those in the lecturing mode.

The analysis of the data on reflection (Table 9) were not that overwhelming and it may arguably whether it is sufficient to support Hypothesis 2: that the amount of reflection is higher among the students who participate in PBL activities compared to those of the lecturing mode. It is valuable though to observe the various items and factors related to reflection in favour of the PBL condition. Reflection is very important since it allows students to step back from their learning experience so that they can develop critical thinking skills and improve on future performance by analysing their experience. Reflection helps students to move knowledge from short-term to long-term memory. The results suggest that the students in the EG condition (the PBL mode), triggered the skills on how to search for information, make decisions and co-operate with their partners. All items as shown in Table 9, suggest that the students in the EG condition experienced a richer learning experience and subsequently a higher involvement in terms of presentation and collaboration.

Items 4-7 in Table 9 shows that in the EG condition, students worked more in pairs and small groups although both the EG and CG were grouped in groups of two. The PBL method stipulates that each student in a group should explore a certain area and make a specific contribution towards solving the PBL problem. In contrast, students who do experiments in a traditional way usually work together in a group, and there is a less-articulated role for each individual. This might cause some group members not to participate but to rely on the partner to do the experiment instead. The CG students had to complete various tables and graphs on the hand-out material. They needed more teacher assistance at this point as expected since they adhere to the teacher-centred lecturing mode pedagogy.

Retention and near transfer skills will be higher among students who participate in PBL activities compared to those in the lecturing mode.

The pre-test, post-test and retention tests reported in this research study were focused on solving near-transfer problems. The short-term learning outcome for the EG was 4.78% higher than the CG. The EG also outscored the CG by 1.28% during the long-term learning outcome (see Table 10). These results suggest that the PBL method increased near transfer skills more than the traditional lecturing method. However, it does not exceed the level of significance and thus it does not formally support Hypothesis 3. The trend is obvious however and demands for a research approach that observes a more articulate contrast in time balance between the PBL episode (EG) and the more common phase of practicality (CG).

Discussion

PBL requires students to activate prior knowledge and problem-solving skills and thus anticipates real-life situations once they are employed. One should, therefore, ask if it is fair to evaluate the outcomes from PBL through traditional examination methods. It can be expected that students in the PBL condition will achieve substantially higher results should they be given a practical examination where a real-life problem needs to be solved. An outcome-based evaluation of skills rather than knowledge-based might be more suitable to evaluate the gained PBL outcomes and the Aalborg model of individual judgement in a team-based exam instead of traditional exams is suggested. In the Aalborg situation, all group members are present for an examination involving the group's supervisor(s) as well as an external examiner. The students are assessed individually.

Implications and further Research

Students in the PBL condition felt remarkably more responsible in making a success of their studies. For instance, they took responsibility for their own learning and develop various skills for instance on how to apply their knowledge. Students are usually eager to investigate and learn on how to solve a new PBL problem. This curiosity is usually satisfied once they completed the problem successfully. The PBL also made them to think more and what they had learnt was of practical value to them. It is encouraging to note that the students remained motivated during the PBL activities with some showing an improvement in their self-confidence and sincerity towards their studies due to the active involvement required by PBL. Electronic engineers need to work in teams in many cases, e.g. during large installations such as equipment in cell phone towers, control equipment in factories, the development of various electronic hardware and software systems etc. The commissioning and fault-finding of these larger systems are usually also team-based.

Working in teams of two or more people increases collaboration and allows brainstorming and creative thinking, for instance, more ideas are developed which results in an improvement of productivity. The uniqueness of each team member which may include different skills, backgrounds and experiences help you see things from a different angle (Cubukcu, 2016). It is expected that students who followed the PBL method should work easier in a team when employed, similar to the graduates from the Aalborg University as reported by Dahms and Stentoft (2008).

Students indicate the following from the qualitative data of the reflection survey:

- PBL group - They enjoyed the ‘practical’ part the most and indicated that they predominantly learnt how to ‘design’ an electronic circuit in most of the cases.
- The traditional group - enjoyed building a circuit practically; they learnt from the mistakes they made. They have mostly learnt about the electronic components used within the given circuit but not any design principles.

The traditional group merely followed the instructions from the hand-outs during their experimentation. It was therefore no surprise to find that the attitude of the PBL group was substantially more positive according to the statistical analysis. The PBL mode usually requires that a tutor be allocated to each group. These PBL tutors should facilitate the PBL process by keeping the group focused on tasks, and guiding them to achieve their goals according to Nesargikar (2010). Finding suitable tutors during the study was problematic, but it was possible for the experimenter to act as a lecturer, lab technician and facilitator and vice versa as required within the existing facilities of WSU, mainly because of the low student numbers and because of the students working in pairs. The PBL method seems to be more time consuming, in particular when it was done for the very first time. This can be problematic, because the lecturer usually determines the pace during the lecturing mode based on available time. The student-centred classroom strategy of the PBL mode makes it difficult to alter the pace and one should ensure that sufficient time be available to deal with problem-solving and project work (Sahin, 2010)

Recommendations

The students’ mind-set in terms of interest (curiosity), attitude and learning approach should be improved and the retention of fundamental technical skills should be prolonged. All of these are highly valued by employers, resulting in better job opportunities for students, especially in technical sectors with a short life cycle as in electronics.

The advantage of PBL compared to being lectured has shown to lead to a significant improvement in the development of student skills without sacrificing knowledge attainment according to Dochy et al. (2003). This study proofed to be a step in that direction and it was felt that the effect of PBL also emerged in the group of low-achieving students who are typically ‘underprepared’ already in the stage of Secondary Education. Those are the students who usually enter the university in the so-called ‘extended stream’. These students have a full year, instead of a semester, to complete a subject such as Electronics 1.

Hybrid Context

PBL could either be used before or after the lecture mode. This sequential difference is supposed to be crucial for the contribution of PBL. In case PBL is applied in (A) the start of the course, it may work stronger; to be compared with what David Ausubel calls an “advance organiser”. We may expect a deeper attitudinal effect, however the risk of drop-out is higher as well. PBL as (B) appendix to the traditional teaching mode has the nature of achieving some extra goals; it is soon seen as an optional feature, while in fact it is the crux. This is the crucial dilemma for sequencing and pacing PBL in a hybrid context. Additional to finding the summative effects of A versus B we might argue that both have its preferred effect and it might be best to apply both of them at various moments in the overall curriculum. In the case of this research, the choice was made to give priority to the more direct comparison of A with B, striving at complementary effects to the traditional lecturing mode: the urgency to let students improve their collaborative skills, critical thinking and attitudes. Experiment 2 was used to investigate the effect of using PBL as a supplement to the normal lecturing mode, versus just sticking to the normal lecturing mode as introduction for activating prior knowledge before they enter PBL.

CHAPTER 5: EXPERIMENT 2

DIFFERENTIAL EFFECTS OF VARIATIONS IN PROBLEM-BASED AND LECTURING SEQUENCES

Summary

This study describes how PBL (problem-based learning) can best be used as supplementary to the lecturing mode. In this Experiment 2, the lecturing mode has been followed by PBL in contrast to PBL followed by the lecturing mode. The PBL mode was organized as student-driven project and integrates various concepts, in order to match a real-life situation. The attitudinal effects, motivational effects and the amount of aroused reflection were much higher for those students who were in the lecturing mode followed by PBL. Students who did PBL first found it more strenuous and they became negative once confronted with the lecturing mode. The PBL mode proves to improve the students' teamwork and communication skills whilst they still learn to apply their prior knowledge to solve complex engineering problems. In South Africa, there is a real need to overcome gaps between employer expectations and the outcomes from traditional vocational education formats. The source of this academic thesis is the expectation that it might be worth for universities to move at least a part of their curricula into the PBL format.

Introduction

South Africa's matric (Secondary School) results are among the worst in the world with only one in ten qualifying for university (Bloch, 2010). Under-prepared students, usually with a score below the minimum entry requirement, may enter some universities in South Africa via the four-year Extended Programme. One of these programs is meant to provide students at risk with a viable platform to successfully undertake Electrical Engineering studies at Walter Sisulu University (WSU) (*Walter Sisulu University prospectus*, 2012). These students need all the help they can get and it is important to determine if the PBL method can make a meaningful contribution towards their knowledge and life-long learning skills.

Graduates today might not be as successful in the work place as expected and we can agree with Mantri (2009) who mentioned that it so happens that merely memorising the facts and concepts of the basic courses does make the students pass the theory and practical semester end examinations. Dale (1969), in his Cone of Learning model, suggests that people learn and retain 20% of what they hear, 30% of what they see, 50% of what they see and hear, 70% of what they say, and 90% of what they experience directly or practise doing.

From the previous research at WSU (during experiment 1), it appears that the overall attitude was more positive whilst the amount of reflection, retention and near transfer skills were also higher towards Electronics I amongst the students who participated in the PBL activities compared to those in the lecturing mode. The results were not that overwhelming, but it encouraged the further exploitation of PBL which leads to this experiment. This study investigates the effect of using PBL as a supplement to the normal lecturing mode and vice versa. It followed a hybrid approach and the idea originated from the recommendations of the previous experiment as shown under "Hybrid Context" on page 55. The extra work is meant to

A version of this chapter is published in the *Int. J. Cont. Engineering Education and Life-Long Learning* (Podges & Kommers., 2016).

provide an additional foundation to students to facilitate them in the understanding of the course material.

Costa and Kallick (2008) indicated that reflection enhances the meaning of work and encourages insight and complex learning from experiences. This inspires the decision to compare students who were in the PBL instruction followed by the lecturing mode (G1) versus those who were in the lecturing mode followed by PBL (G2) in terms of both their attitude, motivation and reflection. It urges us to answer Sub-problem 4 as shown in the list of objectives.

Research Questions

Would the transition lecturing-PBL produces better results than PBL-lecturing, as far as university students' positive attitudes towards the Electronics I Course, motivation and the amount of reflections is concerned?

It is important to determine the difference between the PBL-Lecture versus Lecture-PBL sequence. Its answer is relevant for improving future classes. Using the correct sequence may produce students with a sound theoretical knowledge and be able to solve problems in a critical way.

Hypotheses

Previous research at WSU shows that with the PBL method, students learn to do research, learned better on how to work/learn in groups, developed greater confidence, had more positive attitudes and reflected more (Podges, Kommers, Winnips, & van Joolingen, 2014). The positive effect of PBL during the prior research was clear. However, the risk of overlooking proven effects from literature should be avoided. All existing potentially-relevant theories needed to be taken into account in order to optimize sequential effects between PBL and the more receptive moments in the instruction; the sequence of its ingredients might influence the students' attitude, motivation and reflection. It's direct and more indirect effects needed to be tested.

Previous groups of students at WSU who applied PBL with no or only little prior knowledge found it frustrating to familiarize themselves with the theory afterwards; this unexpected effect was obvious and clear. It is therefore hypothesized that:

The transition lecturing-PBL would produces better results than PBL-lecturing, as far as students' positive attitudes, motivation and the amount of reflections towards the course is concerned.

Experimental Setup

The class of twenty-nine students was divided into Group One (G1) and Group Two (G2). The groups were balanced, in terms of their matric results. Students were then allowed to group themselves in dyads (pairs) according to their preference within each group. The PBL classes were organised as a small project-based PBL activity where students had to solve a real-life problem. They had to develop and demonstrate the operation of a voltage-regulated power supply, capable of accommodating fluctuations in supply voltage and variable loads. The students were not familiar with components such as variable transformers, high power loads and they were also not used to the integration of various modules like rectification, regulating and filtering. Table 11 shows the activities around the experiment.

Table 11. Activities during Semester (related to a portion of Module 5)

Week	Activities	
9	Pre-survey: Attitude, Motivation, Reflection Surveys (G1 & G2).	
10-14	PBL and Laboratory instruments (G1).	Traditional theory and practical (G2).
15-16	Traditional theory and practical (G1).	PBL and Lab instruments (G2).
16	Post-survey: Attitude, Motivation, Reflection Surveys (G1 & G2).	

The first observation was that students took the choice of the PBL topic much more serious than during the selection of traditional 'problem sets' and it costed more time during the various laboratory meetings. These students accomplished a working device, similar to the experience of Nedic et al. (2010). Students in the PBL mode used both a computer and electronics laboratory or library instead of a lecturing venue. A wandering tutor scenario, as described by Northwood, Northwood, and Northwood (2003), was deployed. Blackboard was used to complete all surveys and the response rate was high since it was done during class time with attendance usually close to 100%.

Measuring Instruments

The 'Adaptive Learning Engagement in Science' questionnaire from Velayutham et al. (2011), composed of 31 questions, was adapted in order to assess students' attitudes toward the Electronics I course (see APPENDIX M). It contains four *factors* of attitudes and perceptions; (1) Learning Goal Orientation, (2) Task Value, (3) Self-Efficacy and (4) Self-Regulation. A five-point Likert scale was used to measure the level of agreement of the student with the statement, with a score of (5) Strongly Agree, (4) Agree, (3) Neutral, (2) Disagree, and (1) Strongly Disagree.

The level of learning motivation was assessed by using a 36-item questionnaire that was modified from an Instructional Materials Motivation Survey (IMMS) of Keller (1993b), who applied the theory of ARCS (Relevance, Satisfaction, Attention and Confidence). With this questionnaire, a five-point Likert scale was also used to measure the level of agreement of the student with the statement, with a score of (5) Very True, (4) Mostly True, (3) Moderately True, (2) Slightly True, and (1) Not True. The detailed questionnaire is shown at APPENDIX N.

The National Council for Curriculum and Assessment (NCCA) (2011) key skills student reflection sheet (as shown at APPENDIX O), composed of 54 reflection questions, was adapted to assess students' reflection towards the Electronics I course. It contains five *factors* of reflection; (1) Being Personally Effective, (2) Communicating, (3) Working with Others, (4) Critical and Creative Thinking and (5) Information Processing. A five-point Likert scale was used to measure the level of agreement of the student with the statement, with a score of (5) Strongly Agree, (4) Agree, (3) Neutral, (2) Disagree, and (1) Strongly Disagree. Four additional qualitative questions were included. (1) Choose two of your favourite items above where you have chosen a high score like "Strongly Agree" and explain why you gave them a high score and describe in some detail what they did, (2) "What thing did you like the most?", (3) "So what was the main thing that you learned?", and (4) "Now what – what skill would you like to develop more?"

The statistical analyses of this study were performed by using statistical package program for social sciences (SPSS).

Experimental Condition –Electronics 1 Extended

The independent variable for the research study was the instructional sequence. The first level of the independent variable is PBL followed by the lecturing mode strategy. The second level of the independent variable is the traditional lecturing mode followed by a PBL strategy. The 'Electronics 1 Extended' class covered four modules in the lecturing mode, but the fifth module, 'Diode applications' lends itself towards a mini-project and was therefore used during the research. Students from G1 were excluded from any lectures and were immediately confronted with a PBL problem while G2 continued in the lecturing mode during Phase 1 as shown in Figure 8.

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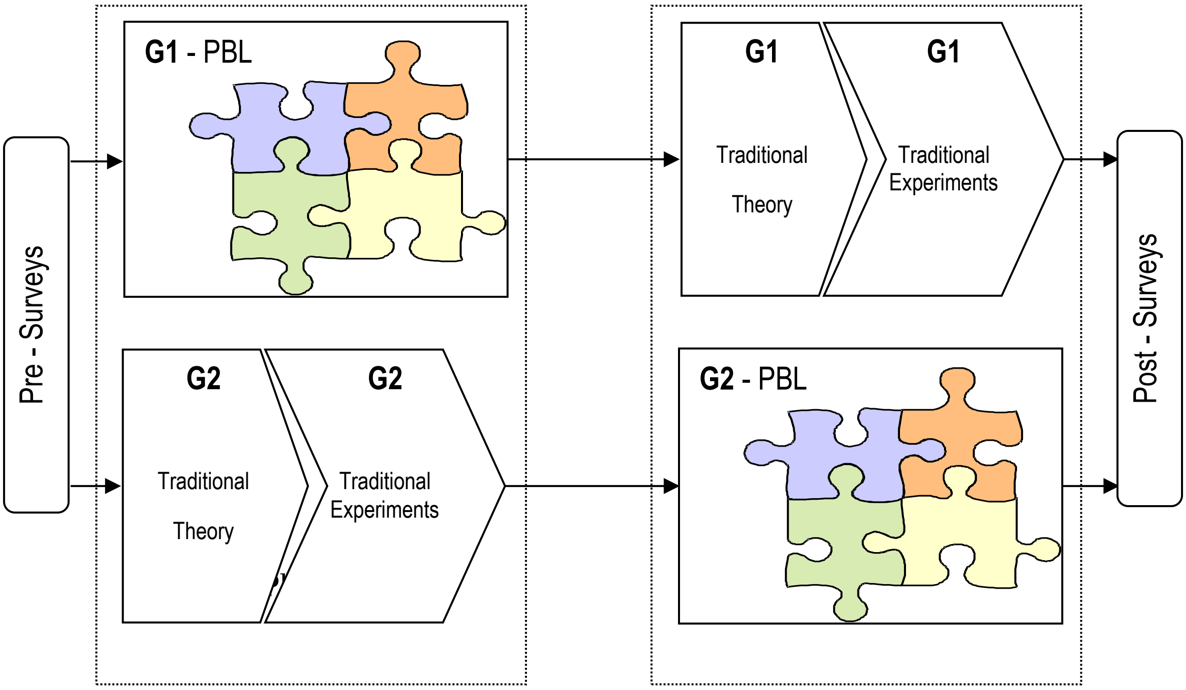


Figure 8. Illustration of how Experiment 2 was conducted

The groups exchanged roles during Phase 2, with G1 repeating all the relevant theory in the lecturing mode, followed by a traditional experiment, while G2 was confronted with a PBL problem. Attitude, motivation and reflection surveys were done as shown in Table 11.

Results

The Cronbach's Alpha coefficient, calculated from the overall data for all pre- and post-surveys, was ≥ 0.7, showing acceptable to good reliability for all (see Table 12).

Table 12. Cronbach's Alphas for the overall Attitude, Motivation and Reflection Survey

	Cronbach's Alpha (α)	
Subscale	**Pre-survey**	**Post-survey**
Attitude	.923	.930
Motivation	.920	.923
Reflection	.953	.969

The study sought to establish whether there was a significant difference in students' attitude, motivation and amount of reflection due to the sequential position of PBL. The combined mean values for each of the pre – surveys were nearly similar before the experiment started. However, Figure 9 shows that the attitude, motivation and reflection were higher for G2 after the 2nd phase.

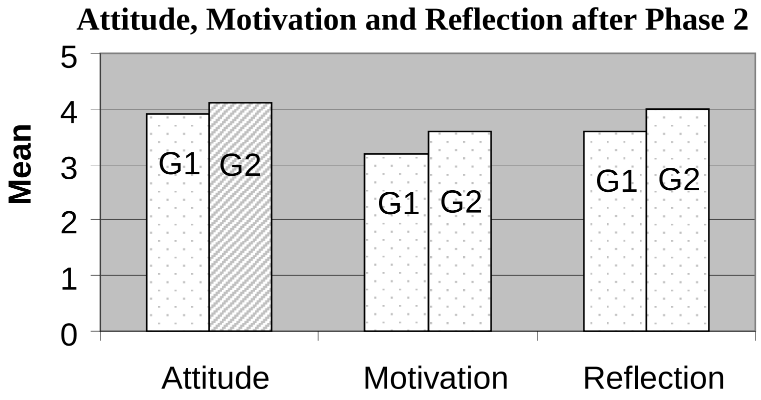


Figure 9. Overall Attitude, Motivation and Reflection after Phase 2

The students who participated in PBL activities during Phase 2 (G2), used the work they did during Phase 1 as prior knowledge. Normal probability plots were generated on the attitude, motivation and reflection survey subscale variables, confirming the normal distribution of all data. The reliability of the surveys was evaluated in terms of Cronbach's Alpha coefficient.

Comparison of the Attitude, Motivation and Reflection Sub-groups after Phase 2

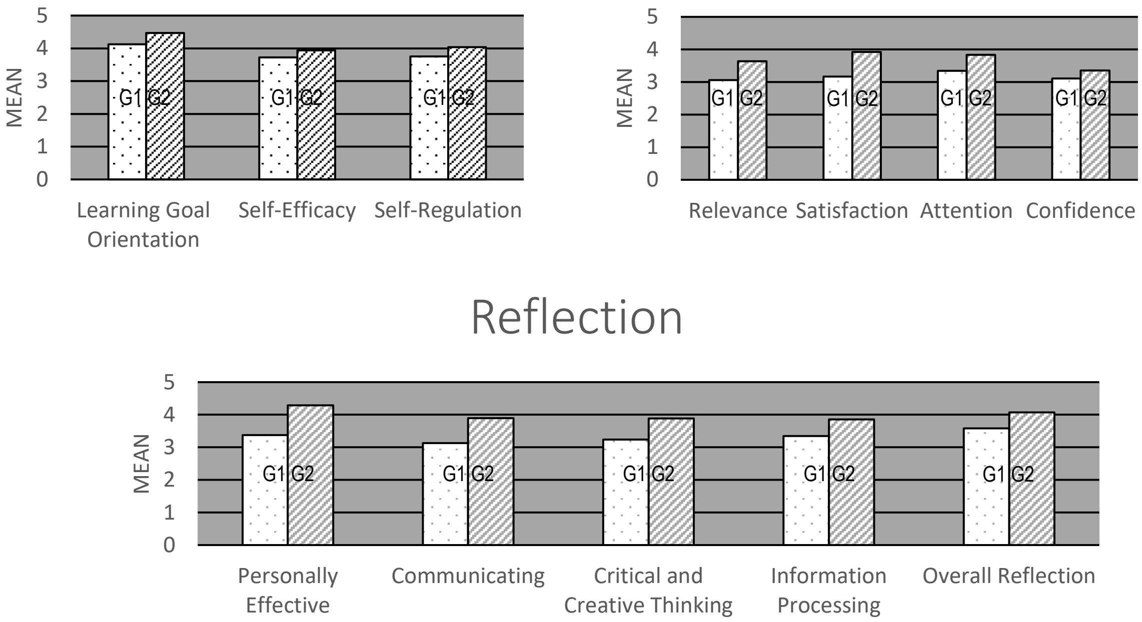


Figure 10. Comparison of the Attitude, Motivation and Reflection Sub-groups after Phase 2 between G1 and G2 when the ANCOVA Method was used

The differences in the attitude, motivation and reflection between G1 and G2 at Phase 2 were also tested, using the analyses of covariance (ANCOVA) method. Preliminary analysis of the data involved; inspection of scatter plot graphs to check linearity between the covariant and outcome, statistically significant interaction between treatment and covariate, and Levene's test for violation of the assumption of equality of variance amongst G1 and G2. Most assumptions for the analysis of each of the sub-groups were met and those who did not, were excluded from the results. Figure 10 shows a higher mean score for G2 in all of the subgroups for the attitude, motivation and reflection. Many of these reached significant levels as shown in the detailed results – see Table 15, Table 19 and Table 22.

The results for the various surveys will now be discussed in more detail.

Attitude

The Cronbach's Alpha coefficient calculated from the data was ≥ 0.7 for most subscales, showing acceptable to good reliability for all but 'Learning Goal Orientation' during the Pre-survey (see Table 13).

Table 13. Cronbach's Alphas for the various Subscales of the Attitude Surveys

	Cronbach's Alpha (α)	
Subscale	**Pre-survey**	**Post-survey**
Learning Goal Orientation (8 items)	.654	.894
Task Value (7 items)	.846	.903
Self-efficacy (9 items)	.856	.855
Self-Regulation (7 items)	.850	.818

Figure 11 shows a sharp decline in the attitudes based upon G1. The students became more negative since they received the relevant theory after the PBL. They strongly preferred to have entered the PBL after being submitted to the theory already, similar to what the students under G2 had received.

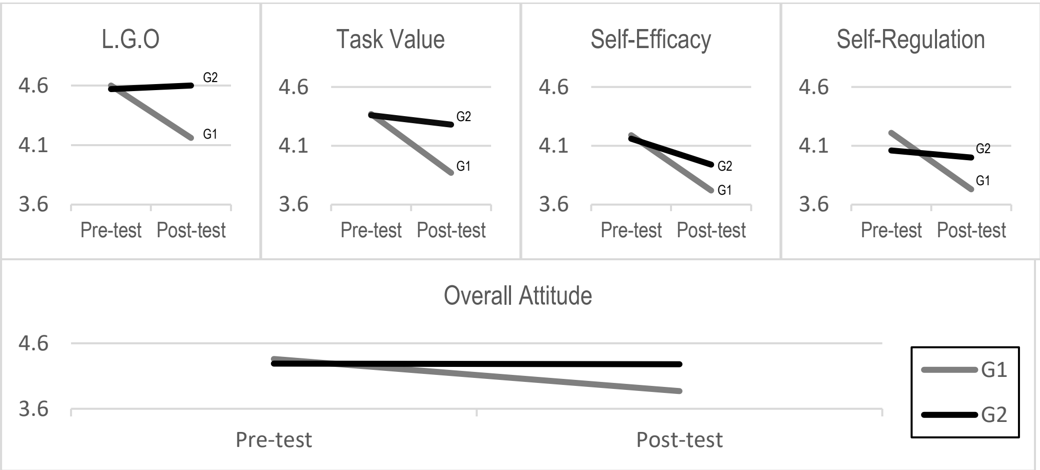


Figure 11. Multiple Comparison between the Least Square Means of Pre-survey and Post-survey Results related to Attitude for G1 and G2. Includes the Least Square Means of Learning Goal Orientation (L.G.O), Task Value, Self-Efficacy and Self-Regulation as well as the Overall Attitude

Post hoc comparisons using the Fisher LSD test revealed that G1, who entered the PBL mode with almost no prior knowledge and then replicated similar content in the lecturing mode, showed a significantly greater reduction in their attitude than G2 who entered PBL with a much higher level of prior knowledge. The drop in the attitude of G1 reached significant levels in all of the subgroup categories (and overall) between the Pre- and Post-survey's as shown in Table 14.

Table 14. A Comparison between Pre- and Post-survey Results Related to Attitude for Both Groups

Subgroup		Pre- survey *M*	*SD*	*n*	Post-survey *M*	*SD*	*n*	*p*
Learning Goal Orientation – goal to learn, understand and master content and skills	G1	4.60	.320	16	4.16	.431	14	.002*
	G2	4.57	.403	14	4.60	.389	13	.947
Task Value - useful, interesting, relevant and of practical value	G1	4.37	.560	14	3.87	.470	14	.009*
	G2	4.36	.415	14	4.28	.647	14	.657
Self-Efficacy – students self-belief in producing a desired effect	G1	4.19	.508	16	3.72	.457	14	.000*
	G2	4.16	.408	14	3.94	.561	14	.091
Self-Regulation – work ethics	G1	4.21	.559	16	3.73	.426	14	.000*
	G2	4.06	.686	14	4.00	.657	13	.685
Overall – includes all subgroups	G1	4.36	.392	14	3.87	.278	14	.000*
	G2	4.29	.402	14	4.28	.374	12	.696

*p<.05.

Table 15 also shows that after controlling for pre-test scores, the average ‘Learning Goal Orientation’ and ‘Self-Regulation’ attitude subgroups post-test scores for G2 were statistically significantly higher than the average post-test scores for G1.

Table 15. A Comparison between G1 and G2 at the Post-survey Results Related to Attitude

Subgroup	G1 *M*	*n*	G2 *M*	*n*	*f(1,26)*	*p*
Learning Goal Orientation – goal to learn, understand and master content and skills	4.12	15	4.47	14	6.215	.019*
Self-Efficacy – students self-belief in producing a desired effect	3.72	15	3.94	14	1.429	.243
Self-Regulation – work ethics	3.75	15	4.04	14	4.261	.049*

*p<.05.

The sequence, lecture-PBL versus PBL-lecture resulted in a considerable contrast, and the overall in-between difference in the attitude between the two groups reached a significant 5% level as shown in Table 16.

Table 16. Comparison in-between G1 and G2 at the Post-survey related to Attitude

	G1			G2			
Subgroup	***M***	***SD***	***n***	***M***	***SD***	***n***	***p***
Overall – includes all subgroups	3.87	.278	11	4.28	.374	14	.028*

*p<.05.

The G1 students appreciated the development of problem solving skills and critical thinking while doing PBL, but it took them some time to adapt and found it very challenging and time consuming to find the information themselves. When G1 moved back to the lecturing mode their way of thinking was still PBL orientated, and their longing to further develop their critical thinking and problem-solving skills was not satisfied. Students preferred to enter PBL with a higher level of prior knowledge so that they are more equipped to solve the challenging problem/s. These results support the first part of the Hypothesis; the sequence, lecturing-PBL produces better results than PBL-lecturing as far as university students' positive attitudes towards the Electronics I course are concerned.

Motivation

The Cronbach's Alpha coefficient calculated from the data was ≥ 0.7 for most subscales, showing acceptable to good reliability for all but 'Relevance' (see Table 17).

Table 17. Cronbach's Alphas for the various Subscales of the Motivation Surveys

	Cronbach's Alpha (α)	
Subscale	**Pre- survey**	**Post- survey**
Relevance (9 Items)	.652	.657
Satisfaction (6 Items)	.848	.895
Attention (12 Items)	.666	.716
Confidence (9 Items)	.719	.770

The Least Square (LS) Means show a similar tendency for all motivational subgroups as well as for the total (overall) as shown in Figure 12. It decreased from the Pre-survey to the Post-survey for both groups, with all of G1 reaching significant levels. Students in G2 were slightly more motivated.

Figure 12. Comparison between Pre-survey and Post-survey Results related to Motivation for G1 and G2. Includes the Least Square Means of the Relevance, Satisfaction, Attention and Confidence as well as the Overall Motivation

Post hoc comparisons using the Fisher LSD test revealed that the students in G1, who entered the PBL mode with almost no prior knowledge and then replicated similar content in the lecturing mode, showed a significantly greater reduction in their motivation (for some subgroups) when compared to G2 who entered PBL with a much higher level of prior knowledge. The drop in the motivation of G1 reached significant levels in all of the subgroup categories between the Pre-survey and Post-survey as shown in Table 18.

Table 18. A Comparison between Pre-survey and Post-survey Results Related to Motivation for Both Groups

Subgroup		Pre- survey			Post- survey			
		M	***SD***	***n***	***M***	***SD***	***n***	***p***
Relevance – relevant knowledge, important, worth knowing, relate to it and useful	G1	3.74	.684	16	3.13	.541	14	.000*
	G2	4.20	.378	14	3.69	.554	12	.005*
Satisfaction – accomplishment, enjoyment, curiosity, reward and achievement	G1	3.89	.980	15	3.17	.915	16	.006*
	G2	4.19	.694	14	3.94	.776	12	.521
Attention – interesting, variety and appearance	G1	4.01	.553	14	3.39	.573	15	.000*
	G2	4.17	.419	13	3.83	.551	13	.064
Confidence – be able to learn and understand	G1	3.73	.675	16	3.13	.816	15	.001*
	G2	3.94	.516	14	3.35	.475	13	.002*
Overall Motivation – includes all subgroups	G1	3.82	.644	13	3.24	.692	12	.001*
	G2	4.14	.438	13	3.71	.505	11	.036*

*p<.05.

There was, however, still a significant reduction in the ‘Relevance’ and ‘Confidence’ subgroups for G2, but at least not for the ‘Satisfaction’ and ‘Attention’ subgroups. Table 19Table 18 shows that after controlling for pre-test scores, the average ‘Relevance’, ‘Satisfaction’ and ‘Attention’ of the motivation subgroups post-test scores for G2 reached statistically higher levels than the average post-test scores for G1 although it did not reached the significant level.

Table 19. A Comparison between G1 and G2 at the Post-survey Results Related to Motivation

Subgroup	G1		G2			
	M	***n***	***M***	***n***	***f(1,26)***	***p***
Relevance – relevant knowledge, important, worth knowing, relate to it and useful	3.06	16	3.64	13	3.266	.082
Satisfaction – accomplishment, enjoyment, curiosity, reward and achievement	3.17	16	3.92	13	4.163	.052
Attention – interesting, variety and appearance	3.34	16	3.83	13	3.983	.057
Confidence – be able to learn and understand	3.11	16	3.35	13	.388	.539

$*p<.05$.

Students preferred to enter PBL with a high level of prior knowledge and these results support the second part of the Hypothesis; the sequence, lecturing => PBL produces better results than PBL => lecturing as far as university students' motivation is concerned.

Reflection

The Cronbach's Alpha coefficient calculated from the data was ≥ 0.7 for most subscales, showing acceptable to good reliability (see Table 20).

Table 20. Cronbach's Alphas for the various Subscales of the Reflection Surveys

Subscale	Cronbach's Alpha (α)	
	Pre- survey	**Post- survey**
Personally Effective (12 Items)	.899	.905
Communicating (10 Items)	.842	.818
Working with Others (10 Items)	.698	.836
Critical and Creative Thinking (11 Items)	.855	.864
Information Processing (6 Items)	.802	.803
Overall Reflection (6 Items)	.866	.934

The difference between the amount of reflections for G1 and G2 widens from the pre-survey to the post-survey for all subgroups excluding 'Information Processing' as shown in Figure 13. The reflection of G2 students increased in most of these subgroups whilst it was the other way around for G1.

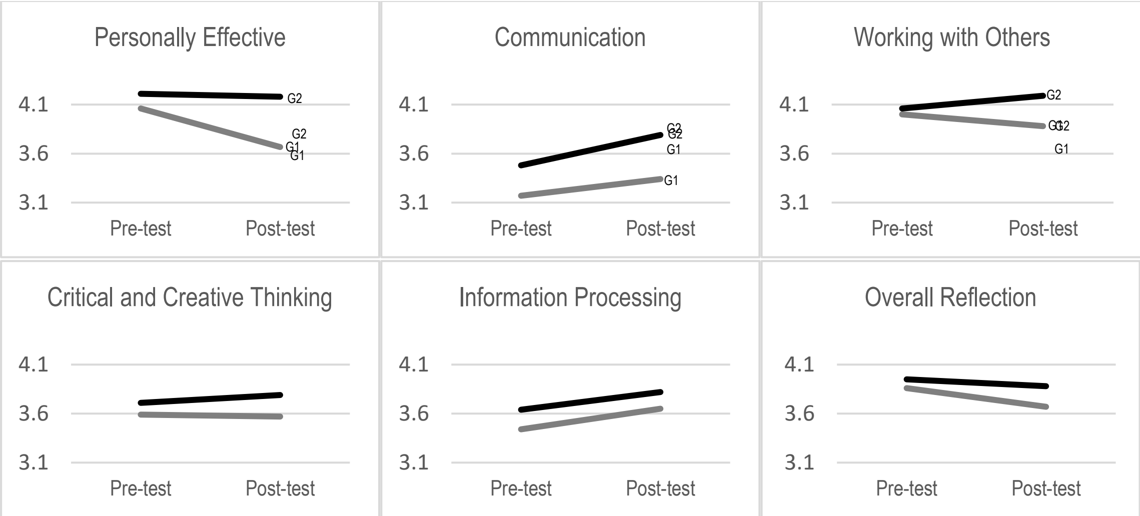


Figure 13. Multiple Comparisons between Pre-survey and Post-survey Results related to Reflection for G1 and G2. Includes the Least Square Means of the Personally Effective, Communication, Working with Others, Critical and Creative Thinking and Information Process

Post hoc comparisons using the Fisher LSD test revealed that G1, who entered the PBL mode with almost no prior knowledge and then replicated similar content in the lecturing mode, showed a significantly greater reduction in their reflection than G2 who entered PBL with a much higher level of prior knowledge. The drop in the reflection of G1 reached significant levels in the 'Personally Effective' subgroup category between the Pre-survey Post-survey time periods as shown in Table 21.

Table 21. A Comparison between Pre-survey and Post-survey Results Related to Reflection for Both Groups

Subgroup		**Pre- survey** *M*	*SD*	*n*	**Post- survey** *M*	*SD*	*n*	*p*
Personally Effective - feel worthy and able to accomplish a purpose, set objectives, reach target, use resources, help from others, plan forward, meet requirements, use different solutions, meet deadline, satisfaction and enjoyment	G1	4.06	.749	14	3.67	.426	13	.032*
	G2	4.21	.564	11	4.18	.658	14	.703
Communicating - the activity of conveying information, investigate, validate sources, give opinion, listen, express	G1	3.17	.824	16	3.34	.575	15	.252
	G2	3.48	.648	11	3.79	.559	14	.089
Working with Others – small groups, listen, participate, cooperate, responsibility, suggest, resolve conflict	G1	4.00	.514	16	3.88	.408	14	.593
	G2	4.06	.450	12	4.19	.617	14	.191
Critical and Creative Thinking – find information, solving problems, make conclusions, reflect	G1	3.59	.736	16	3.57	.390	13	.775
	G2	3.71	.666	12	3.79	.615	14	.510
Information Processing – consult different sources, make notes, present, summarise, use ICT	G1	3.44	1.061	15	3.65	.426	14	.253
	G2	3.64	.692	12	3.82	.824	12	.268
Overall Reflection – includes all 51 questions	G1	3.86	.564	13	3.67	.343	9	.214
	G2	3.95	.517	10	3.88	.660	12	.610

*p<.05.

Table 22 also shows that after controlling for pre-test scores, the average ‘Personally Effective’ and ‘Communicating’ subgroups as well as the ’Overall’ reflective post-test scores for G2 were statistically significantly higher than the average post-test scores for G1.

Table 22. A Comparison between G1 and G2 at the Post-survey Results Related to Reflection

	G1		G2			
Subgroup	***M***	***n***	***M***	***n***	***f(1,25)***	***p***
Personally Effective – feel worthy and able to accomplish a purpose, set objectives, reach target, use resources, help from others, plan forward, meet requirements, use different solutions, meet deadline, satisfaction and enjoyment	3.38	16	4.29	12	7.284	.012*
Communicating - the activity of conveying information, investigate, validate sources, give opinion, listen, express	3.13	16	3.90	12	6.120	.021*
Critical and Creative Thinking – find information, solving problems, make conclusions, reflect	3.24	16	3.89	12	3.928	.059
Information Processing – consult different sources, make notes, present, summarise, use ICT	3.35	16	3.86	12	1.871	.184
Overall Reflection – includes all 51 questions	3.58	15	4.07	12	6.601	.017*

*$p<.05$.

Students preferred to enter PBL with a high level of prior knowledge and these results support the last part of the Hypothesis; the sequence, lecturing-PBL produces better results than PBL-lecturing as far as university students’ reflection is concerned.

Conclusions

Many of the graphs (see Figure 11 - Figure 13) give the impression that there is a decline in the attitude, motivation and reflection of the students of both groups during Experiment 2. Intermediate surveys were also given after Phase 1, but it was omitted for the sake of simplifying the contrast. Figure 14 shows the difference during the pre-, mid- and post-surveys. It is in particular the decline in the attitude, motivation and reflection of G2 during Phase 1 which is remarkable, as the students continued with the traditional learning method during this phase and one would rather expect minor variations in their attitude, motivation and reflection. The class was taught by the course lecturer before the research and by the researcher thereafter. According to Rosenthal (1998), slight differences in instructions such as vocal intonations, subtle actions and changes in posture, may influence the subjects given to control and experimental groups. The switch of lecturers could have affected the outcome of the experiment. It might have been a possible reason why the attitude, motivation and reflection of both groups declined during the first phase. No retention tests were done during this experiment.

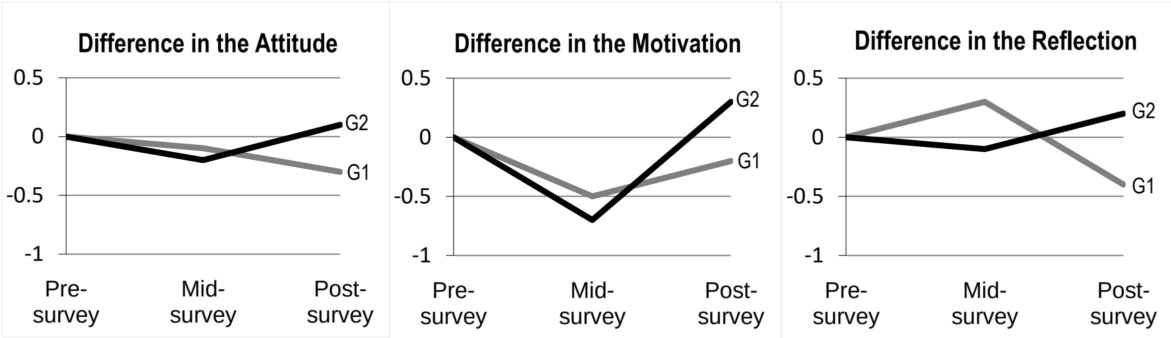


Figure 14. Comparison of the Attitude, Motivation and Reflection before and after the Study

Both groups managed to complete the second phase in substantially less time (see Table 11). The G1 students obtained substantial knowledge during PBL which made it possible to cover the basic theory swiftly while spending a bit more time on the unclear areas during the second phase. Figure 14 suggested that the sequence followed by G2, had a positive overall effect in terms of attitude, motivation and reflection. The effect for G1 was negative because its sequence was the other way around.

It is important for students to find the content of their studies useful, interesting and relevant and of practical value. They should also be eager to learn as much as they can, master new skills, understand the work and what is taught to them so that they can turn into fine engineers. These values were more prominent amongst the students in G2 (lecture-PBL) method as shown in Figure 11, for instance, the 'Task Value' and 'Learning Goal Orientation' (L.G.O) were much higher for G2 at the post-survey (when compared to G1). Students in the G2 group were also more 'satisfied' according to Figure 12, an indication that they enjoyed the learning and believed that they have accomplish something. This is supported by the 'Personally Effective' graph as shown in Figure 13, a strong indication that G2 students felt that they have reached their targets and meet the requirements.

Table 23. Possible Reasons for the difference in Attitude, Motivation and Reflection between the Groups

G1 – PBL activities followed by the lecturing mode.	**G2 – Lecturing mode followed by PBL activities.**
Student's attitude, motivation and reflection were negatively affected when they moved from PBL to lecturing mode during the 2nd phase. Probably because: • They had already gained most of the theoretical knowledge during the PBL activities. • They had to repeat similar work in the lecturing mode. • They prefer practical's, working in groups and applying skills to theory. • The theory seems to be the least attractive to them. • Students who do experiments in a traditional way usually work together in a group, and there is a less-articulated role for an individual. This might cause some group members not to participate, but to rely on the partner to do the experiment instead.	Student's attitude, motivation and reflection were positively affected when they moved from lecturing mode to PBL during the 2nd phase. Probably because: • They entered PBL with a higher prior knowledge. • They were challenged to put their knowledge to the test during PBL and solve a related, challenging problem instead of just doing a pre-arranged practical experiment. • Their increased confidence helps to solve the PBL problem by means of calculation and critical thinking. • PBL is student-centred and they had to take responsibility of their own learning. • They were busy with PBL activities

A summary of possible reasons for the difference in results between the groups are shown in Table 23). These students were 'underprepared' from the schooling system, the reason for ending up in the 'extended-stream. PBL has the goal to make students more active thinkers and these students prefer to entering PBL with a higher prior knowledge instead of suffering to find the knowledge that essentially is on the shelves. They prefer to apply PBL based upon common sense and prior knowledge.

Discussion

In a previous study it was found that the PBL was time-consuming, especially when done for the very first time. Brodeur, Young, and Blair (2002) and de Camargo Ribeiro and da Graça Mizukami (2005) had similar experiences with PBL and found it different to the traditional method where the teacher lectures and takes away the real challenge for the student to organize him/herself. Also, while lecturing it is not always visible to the teacher if the student is really committed to the topic. In most of the cases the student is mainly concerned on providing the "right answers" during the test to come. So most commonly, students "follow" the teacher and avoid an active role. In the lecturing mode, it is easy to differentiate the pace of presentation. However, in the PBL mode, students decide on how to approach a topic and its solution. This may influence the pace. Therefore, PBL can be seen as an ultimate way to instigate student-centred learning. Students who enter PBL with a lower level of prior knowledge run the risk in the PBL approach of not being confronted with the full repertoire of topics. PBL supposes that through the in-depth confrontation with the problem-relevant topics, the student can easily master the remaining topics by him/herself. In this way PBL is the ultimate upbeat for self-sustained life-long learning.

It is a good starting point for students to enter PBL activities with a high prior knowledge (like in G2), so that they can focus on solving the problem instead of having to study the basic theory first. Less confident students can still revise and strengthen some theoretical aspects if the need arises during the PBL problem solving process.

Students of both groups appeared to be more active and involved while busy with PBL activities, but students in G1 (PBL-lecturing) became negative when they had to repeat the work that was covered during the PBL activities (Phase 1) in the lecturing mode (Phase 2). These students entered PBL with very little prior knowledge, and they had to work hard to master the theory before solving the PBL problem. There is also the possibility that they may have missed some of the theory, especially the theories that were not required for solving the PBL problem. It seems that the theory that followed during Phase 2 were mostly known to G1 and there was not much participation during the lessons. These students did not enjoy the traditional practical experiments after the theory. Perhaps because of the specific instructions that they had to follow from the hand-outs which became more of a routine instead of a learning experience.

Most of these students from both groups enjoy practical's and experiments especially PBL more than theory and many of them indicated in the prior reflection survey that they would like to improve their practical, reasoning and, most of all, their problem-solving skills. The students in G1, who repeated the theory after the PBL may be more satisfied if the theory was done in a more compact way, so that it rather serves as a reflection and a revision on what they did during the PBL so that it enhances their long-term memory.

The following came from the qualitative data in the reflection survey:

G1 – Students who did PBL activity followed by traditional lecturing:

In case the students underwent 'PBL First'. – They enjoyed the practical component and preferred to work in groups most of the time. They felt satisfied in solving the posed problems but were not completely confident with the extensive content of the theory. Many of them found it tiring to search and find the information themselves. This supports the findings of this experiment, that these students rather need to enter PBL with a higher level of prior knowledge.

G2 – Students who did traditional lecturing followed by PBL activity:

Those who started in the traditional lecturing mode: – They enjoyed experiments and felt that they had learned most from their mistakes. They enjoy verifying the theory by comparing the calculated and measured values but failed to develop problem-solving skills.

When in the PBL mode: - They found the problem-solving in PBL challenging but enjoyable. They felt that they had learned how to solve problems and develop skills for critical thinking and found the problem-solving less tiring than those in the G1 condition.

Both groups concluded that PBL was more enjoyable and at the same time more time-consuming and difficult. As positive side effects, they reported to have improved problem-solving skills with a longer-term retention effect. This is in accordance with the outcomes of earlier meta-studies from Dochy et al. (2003) and Perrenet, Bouhuijs, and Smits (2000).

Mathematics, physics and much of electronic engineering rest upon a hierarchical knowledge structure. Students need to know basic concepts before learning the more complex concepts or else it will be hard for them to compensate or to correct. This is according to Mills and Treagust (2003) who also indicated that students probably would not be able to repair the missing concepts, even if they get used to the PBL method. Students in the G2 condition do not meet such a problem since they have covered the necessary theory first before attempting to solve a problem, using the PBL method. G2 students still find the problems challenging since these problems require the integration of various concepts. The fundamental basic concepts are very important in the field of engineering and it would be advisable for these students to enter PBL with at least that as part of their prior knowledge. This may not be the case for students in the medical field.

This study focusses on the two modes, PBL-lecturing (G1) and lecturing-PBL (G2). The overall results show that students prefer the lecturing-PBL mode, however, Figure 14 shows that the attitude, motivation and reflection of the PBL-lecturing group was higher during the mid-survey. This was the time when G1 completed the PBL problem and G2 completed the lecturing mode. This points towards a possible improvement towards a more optimal method.

It may be that G1 students received too much theory (during phase 2) after solving the PBL problem during phase 1. It also shows that G1 enjoyed the PBL, even with the limited prior knowledge. Students in G2 did not really enjoy the lecturing mode during the 1st phase, but their higher prior knowledge helped them to excel when in the PBL mode. The two groups can be compared with a radio that is almost tuned to the desired frequency. One might be slightly below and the other slightly above the desired frequency, with G2 slightly more in tune than G1.

Various more compact lectures, with the first one before the PBL problem and others spread within the PBL problem as required may even be more beneficial to the students, especially students who are new to PBL. Likewise, allowing students to solve PBL problems with little prior knowledge and then strengthening their newly acquired knowledge with short lecturing "revisions" from time to time may also be beneficial, but all of these need to be tested during future research.

Implications and further Research

WSU is situated in the Eastern Cape and the overall matric pass-rate for this province was 58.3% during 2010 (Soobrayan, 2012). The Eastern Cape had the lowest pass rate at 58.1% during 2011, and only 24.3% of all grade 12 students in South Africa qualify for Bachelor's studies (Motshekga, 2012). Many of these will only qualify for the extended programme in engineering, and universities need to ensure that these candidates also graduate as outstanding engineers. Northwood et al. (2003) indicated that the skills and knowledge base that engineering students of a PBL curriculum acquire, directly affects and enhances their ability to be more successful engineers upon graduation. This study has shown that students prefer the sequence lecture-PBL instead of PBL-lecture. Students which are more motivated and with a more positive attitude and higher reflection will most probably become better engineers.

Recommendations

The following items might be considered during further research:

- Students should receive sufficient prior knowledge before attempting a PBL problem that integrates various concepts.
- A variety of PBL problems which incorporate rotation and reverse-engineering amongst the different groups may widen the learning experience of the students.
- Assessment methods should be adjusted to include the testing of the application of knowledge and skills in a practical way.
- Intensify the use of PBL by means of incorporating it to subjects other than Electronics I. PBL problems can also be expanded to combine various subjects.
- Upgrading instrument laboratories so that they also contain internet-enabled computers.
- Find the optimal combination between lecturing and PBL.

CHAPTER 6: EXPERIMENT 3

VICARIOUS LEARNING IN PBL VARIANTS FOR LEARNING ELECTRONICS

Summary
Three different groups in a class of first-year tertiary engineering students had to solve a problem based on a project by applying the distinctive problem-based learning (PBL) approach. Each group's project (PBL project) was then studied by the other two groups after successful completion and demonstration. Each group then had to study the 'new – already made' project, inherited from one of the other groups before presenting it to the class. Students scored mostly higher during a knowledge test on the project they initially worked on and also those projects (from the other groups) that they found interesting. All groups managed to improve their scores during a follow-up knowledge test for those questions related to the project they initially worked on. A great deal of vicarious learning took place in most cases between the different student groups. Students are getting much more exposure when doing several PBL problems (as by the different groups) simultaneously and data confirms that this improves their attitude, motivation and reflection significantly.

Introduction
Students with school exemption results slightly below the minimum acceptance requirement may enter the extended course stream at the Walter Sisulu University (WSU). These students usually have an average to low verbal ability and a little prior content knowledge of the subject they plan to study. However, according to Mergendoller et al. (2006), low-verbal students may learn more in PBL classes than in traditional classes. Additionally, PBL develops collaborative skills such as understanding multiple perspectives (ChanLin, 2008).

Previous research at WSU shows that the overall attitude, motivation, and the amount of reflection were much higher when students were confronted with a PBL problem after all the relevant theories were covered first, instead of doing a PBL problem first and then the relevant theory thereafter. This is perhaps the best illustrated in Figure 14 within the previous chapter. Various other studies also supported the view that prior knowledge strongly influences learning (Mamede, Schmidt, & Norman, 2006; Soppe, Schmidt, & Bruysten, 2005). Inexperienced first-year students prefer to receive appropriate lectures first and they rely much more heavily on the details of the PBL problem to identify the challenging aspects of the learning objective when compared to senior students (Mauffette, Kandlbinder, & Soucisse, 2004).

Based on these research findings, it was decided that students should enter PBL with sufficient prior knowledge by means of appropriate relevant lectures. There was no need to further investigate students in the traditional lecturing mode versus the PBL mode, but to rather focus on variants of PBL.

In the real-life, Electrical engineers design, develop, test, and supervise the manufacturing of various electrical equipment whilst Electronics engineers design and develop electronic equipment. These can include electric motors, radar and navigation systems, communications systems, power generation equipment broadcast and communications systems and areas

A version of this chapter is published in the *Journal of Education and Practice* (Podges & Kommers., 2017).

closely related to computer hardware (Owens, 2017). Engineers are usually involved in various projects, and they do not necessary work on a particular project from day one. In many instances, engineers need to improve or further develop existing machinery and equipment. It is not uncommon for engineers who are involved with distinct projects, to exchange ideas, especially when they work for the same company.

The real-world environment influenced the way in how the third experiment was designed, for instance, to confront the WSU first-year extended stream students with multiple PBL problems at once. This allowed for the inclusion of vicarious learning. Vicarious learning is learning that is derived from secondary sources such as hearing or observation of other students - see pages 24 and 35.

One of the PBL problems could be solved in various ways. This problem is a more open-ended PBL design according to Steck et al. (2012), since it allows multiple acceptable solution strategies where the instructor can guide each student group in developing solution strategies based on their situation.

Most of the theoretical aspects were covered in the lecturing beforehand but the solutions to the PBL problems were obviously not covered during lecturing. Students had to be aware of known information, additional information required, and strategies to use to solve the problems (Gijselaers, 1996).

Based on the previous experiments and literature review, it is anticipated that the PBL orientation of this experiment to continue improve students' attitude, motivation, and reflection. The multiple problems, meant to imitate a real-world situation, should also result in some form of vicarious learning through observation and it is hoped to identify the more effective problems. This experiment seeks to answer sub problems 5-7 as shown as shown in the list of objectives.

Research Questions

The extended programme engineering students are 'under-prepared' for tertiary education by the South African schooling system. This is usually a result of an underperforming school within the South African system, due to current and a history of poverty and deprivation. These students are not that familiar with the PBL concept. The following questions are posed.

1. Which type of PBL problems are most suitable for these students (closed versus open)?
2. What will be the amount of knowledge outcomes amongst students who solve a problem themselves versus those who inherit a project from another group versus vicarious learning amongst groups, when multiple PBL problems are being solved by other groups in parallel?
3. Does PBL improve students' attitude, motivation, and reflection?

Hypotheses

The following three hypotheses were developed based on three research questions.

1. An achievable, yet challenging PBL problem that triggers students' curiosity will be more suitable in terms of learning effectiveness.
2. Students who solve a PBL problem by themselves will learn more than those who inherit a project from another group. Vicarious learning amongst onlookers will only transpire from striking projects.

3. PBL improves motivation, attitude, and reflection in students.

Method

The sample used in this study consists of 29 first-year engineering students who were enrolled in the Electronics 1 extended stream class at WSU. They were divided into three groups (A, B and C), as shown in Figure 15. Each group was then then further divided into three smaller groups (say C1, C2 and C3) as shown in Figure 15. Groups were balanced according to their academic capability which was based on their school exemption results for the subjects; English, Mathematics and Science. No other reliable information was available yet for this group of students.

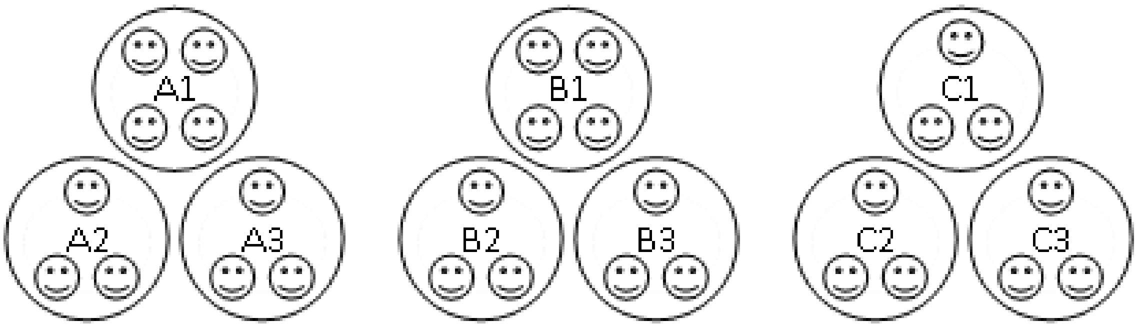


Figure 15. Twenty-nine Students were Divided into Nine Groups, with Three or Four Students in each Group

The experiment was designed and conducted (Figure 16 illustrates how the experiment was conducted) to use the same student group as a target and control group, while having three different groups to compare results. The experimental steps were:

- Students had to complete an Attitude, Motivation and Reflection survey before they were initially confronted with the PBL problems. See APPENDIX M to APPENDIX O in the Appendices for more detail about the surveys.
- Students in the A1, A2, and A3 groups had to solve a Score Board (SB) problem.
- Students in the B1, B2, and B3 groups had to solve a Table Number Display (TND) problem, while
- Groups C1, C2, and C3 had to solve a LED Fader (LF) problem.
- Each group had to 'hand over' their PBL project to another group after successful completion and demonstration in the laboratory. As an example, the students in group A1 handed their SB to C1 while receiving a TND from B1 (but A1 will never be involved with the LF) as shown in Figure 16.
- Students were not informed about the 'hand over' beforehand to ensure their utmost dedication towards their own original projects. None of the students expected a 'hand over' and it took all of them by surprise.
- Each group now had to study (reverse-engineer) the 'new – already made' project, inherited from one of the other groups before presenting it to the whole class a fortnight later.
- Students had the opportunity to study the solutions of the other groups and were 'peer-reviewed' by fellow students as well as scored by two lecturers during the presentation.

- A 30-point multiple choice test containing a few common, relevant questions as well as questions specifically related to the SB, TND, and LF were used to determine each student's knowledge for each of the specific PBL problems.
- Students had to complete an Attitude, Motivation and Reflection survey after completion of the PBL problems. See APPENDIX M to APPENDIX O in the Appendices for more detail about the surveys.

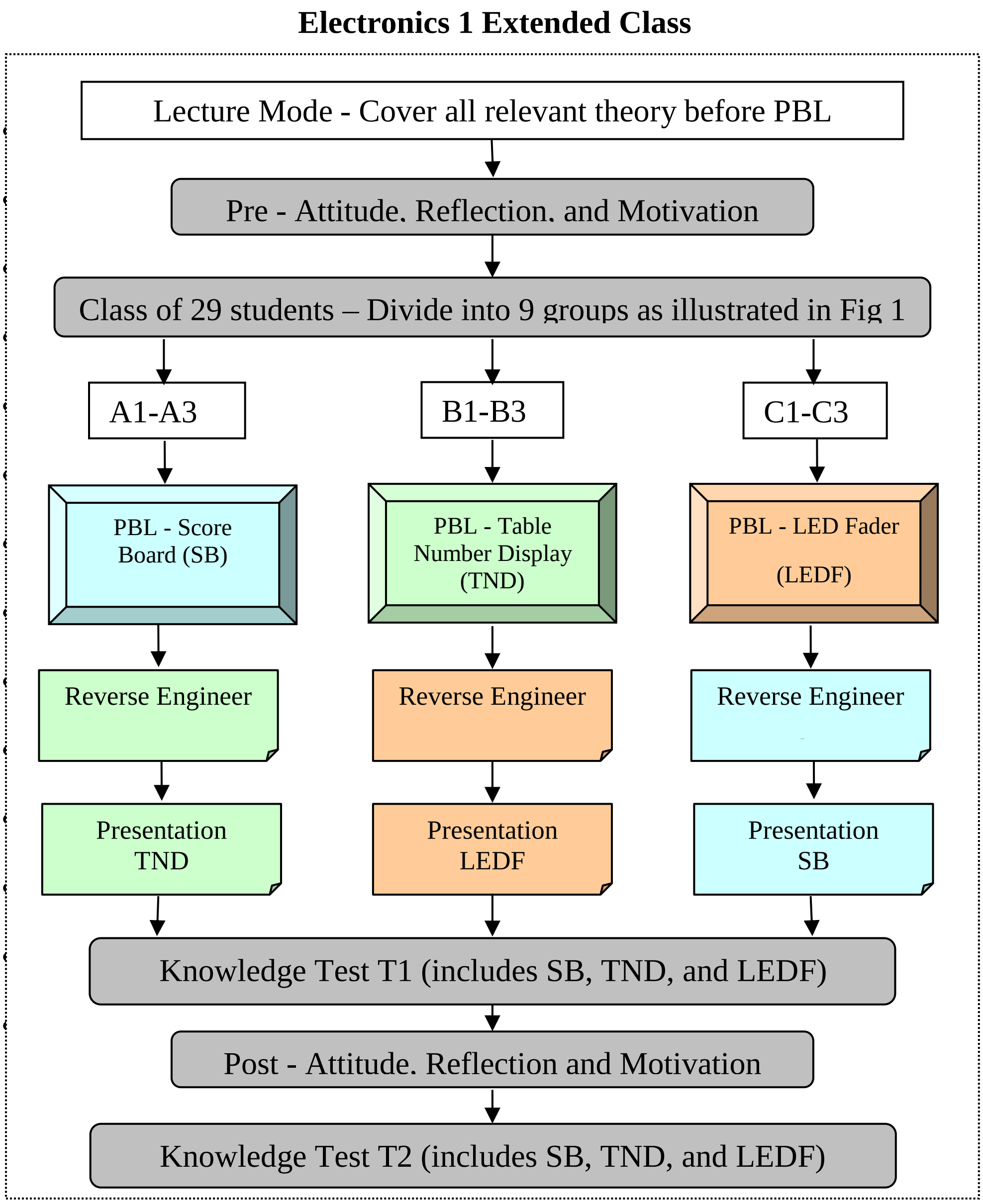


Figure 16. Illustration of how Experiment 3 was conducted

The PBL problems

According to Mauffette et al. (2004, pp. 13,15), students may find PBL problems that contain substances they can relate with, more interesting, especially if it provides more choices and ensure the tasks are optimally challenging. Students also appreciate problems that deal with realistic or actual situations. In Electronics 1 students should have covered at least the use of instruments, rectifier diodes, Zener diodes, basic power supplies, and LED's during the 1st semester. This knowledge is still very limited and one should be creative to present challenging, extraordinary PBL problems within such a limited scope. The following three problems were derived:

1. *Score Board (SB)*
   The SB display of a numerical number between 0 and 9 and is suitable to be used at a football stadium. A rotary switch would change the displayed value.
2. *Table Number Display (TND)*
   The TND displays the number of a table at a restaurant, adjustable to a required value. It should include an 'auto dim' feature during low-light intensity levels.
3. *LED Fader (LF)*
   The LF should indicate the position of a potentiometer, using six LED's. The two center LED's (no's 3 and 4) are the brightest when the setting is at the 50% resistivity position. The brightness intensity of the LED's on either side (no's 2 and 5) should be about half that of the center. Those LED's at either of the ends (no's 1 and 6) should be the least bright but when compared with the LED intensity as at the 50% resistivity position. Turning the potentiometer one way or the other should shift the brightness of the LED's to one side or the other.

Results

Knowledge

The knowledge of the students (related to all the three PBL tasks) was tested twice:

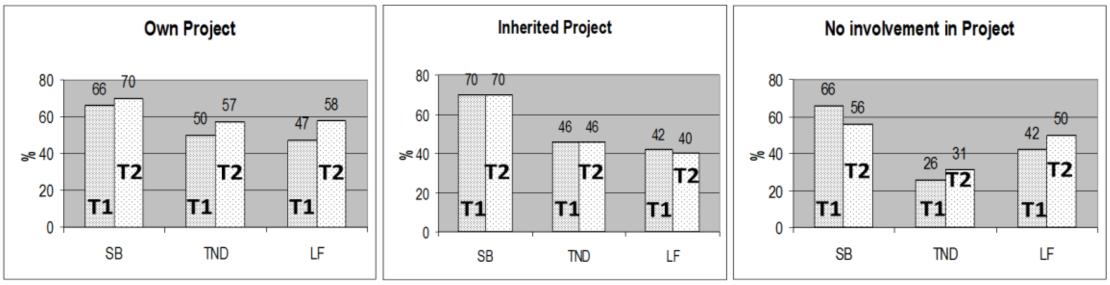
1. The first test (T1) was after they presented on both their own and the inherited project from another group: "Post Test" and
2. The second test (T2) about three-and-a-half weeks later: "Retention Test"

The test marks of the students improved between 4% and 11% for T1 and T2 on those questions related to the project they originally started with, as shown in Figure 17a. This was not the case for those questions related to the inherited projects from other groups as shown in Figure 17b.

The students in group C3 did not do that well during this course because two of them were not allowed in the exams while the 3rd student failed the exams. It was therefore decided to omit the marks of C3, since the group was considered as an outlier.

The following can also be concluded from Figure 17a - Figure 17c:

- Students obtained better marks on questions related to the SB project, regardless if it was their own, inherited or even a project that they were not-involved in. Those students not involved in the SB were most probably curios about its operation and sneak a quick look at the circuit diagram.
- Higher marks (in most cases) were obtained by students on those questions related to the project they originally worked on (own project).
- Students learnt more during the interval T1 and T2 on the projects they originally were involved in ('Own project').
- Students not-involved in the TND project scored badly on related questions. The academic level of the TND is very similar to the SB and LF, but students not involved most probably did not show any interest since the 7-segment it uses is extensively used amongst various electronic devices.



a) b) c)

Figure 17. Student's performance during the 1st and 2nd Knowledge Tests (T1 and T2) for those Questions related to their Own, Inherited and Project not-involved in.

The results indicate that the marks obtained by students for those projects in which they were not involved (although they observed it) are more dependent on the type of project. It can be seen from Figure 17c that students scored the highest on the SB and lowest on the TND. However, students had some time to elaborate on those projects in which they were not-involved, and improved their scores for the TND and LF during T2.

Although the LF project was deemed to be the easiest (based on the school knowledge of students as well), it was surprising that the students obtained the worst marks for this project when inherited (Figure 17b), even when it was an own project (Figure 17a). A possible explanation for this result is the poor level of science education that students receive in the stage of South African Secondary Education. Another reason may be that students need to think out of the box to solve this problem and they couldn't. They received almost all of their education in the traditional mode, using rote learning. This leads to students with underdeveloped critical thinking skills.

Students obtained good marks for the SB project, regardless if they were the originators, inheritors or not even involved as shown in Figure 17. The SB project was achievable and challenging plus it turned into a spectacular final product (which triggers students' curiosity), therefore it was perhaps the most suitable in terms of the learning experience, hence supporting Hypothesis 1.
Students scored the highest on their own projects as shown in Figure 17a. This supports Hypothesis 2.

Marks related to one's own, the inherited and the not-involved-projects, are generally close to each other (for each individual project) except for those marks related to the students who were not at all involved with the TND project (see Figure 18a-b). Most of the concepts used in the TND were obvious, but two of them, although basic, were not that obvious, and students may not know these unless intentionally shown. This knowledge was most probably not transferred during vicarious learning.

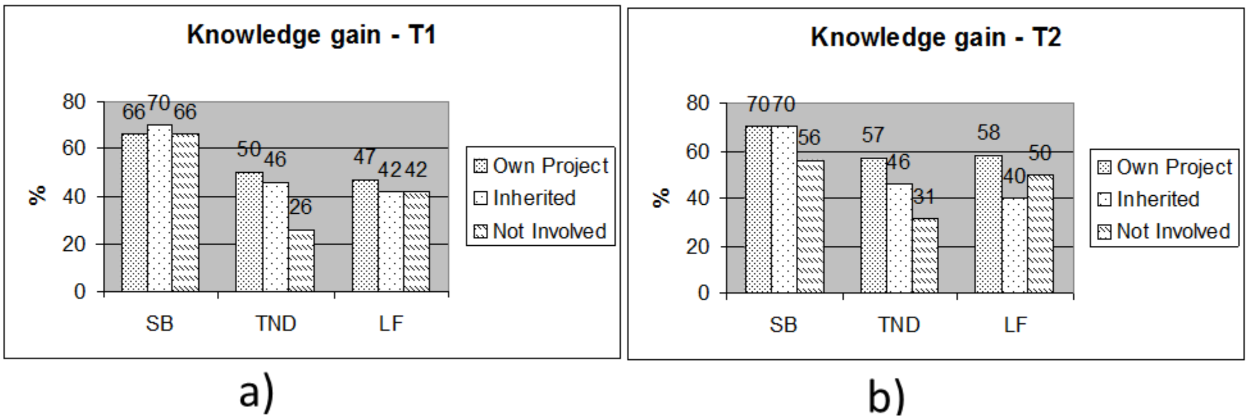


Figure 18. Comparison of Knowledge transfer between Students Own, Inherited- and Not-involved Projects

The compound score of all students drops with a modest 2% between T1 and T2 for the SB. On the contrary, the score for the TND increased by 4% and almost 6% for the LF between T1 and T2. Both the scores of the students who originally worked on the TND and LF as well as those who were not involved at all increased (see Figure 18a-b). This is an indication that vicarious learning related to the more challenging projects took place even after the projects were completed.

The only significant difference in results between the three groups was found for those questions related to the TND. This was the case for both tests as shown in Table 24. Groups C1 and C2 were not-involved with this project and scored significantly lower than the other groups.

Table 24. Knowledge related to TND – Significant difference in Results between Groups (One Way ANOVA)

		T1					T2				
Project	Group	*M*	*SD*	*n*	*p*	*F*	*M*	*SD*	*n*	*p*	*F*
	A1-A3	66.00	18.974	10			70.00	32.071	8		
SB	B1-B3	66.00	25.033	10	.915	.090	56.00	22.706	10	.397	.965
	C1-C2	70.00	10.954	6			70.00	10.954	6		
	A1-A3	45.71	16.218	10			46.43	14.787	8		
TND	B1-B3	50.00	15.430	10	.030*	4.114	57.14	21.296	10	.037*	3.861
	C1-C2	26.19	18.988	6			30.95	16.701	6		
	A1-A3	42.00	11.353	10			50.00	32.733	8		
LF	B1-B3	42.00	14.757	10	.774	.260	40.00	12.910	10	.309	1.243
	C1-C2	46.67	16.330	6			58.33	20.412	6		

*p<.05.

The significantly lower marks obtained by those students not-involved with the TND as shown in Table 24 confirms the limited amount of vicarious learning for this group. Non-obvious concepts may need to be emphasized more during the presentation of less interesting projects to make them suitable for vicarious learning.

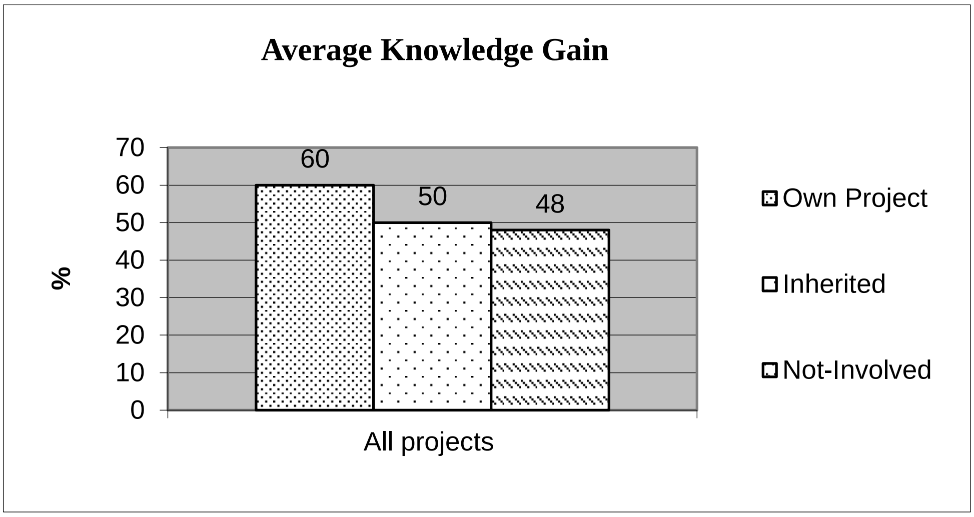


Figure 19. Average Knowledge gained on Own-, Inherited and Not-involved with Project

Figure 19 shows the average scores (of T1 and T2) for the knowledge gained by students for the own, inherited and project not-involved in. There was a significant effect on project involvement and knowledge gained at p<.05 level for the three conditions [f (2,146) = 4.45, p = .013]. Post hoc comparisons using the Tukey HSD test indicated that the mean score for the 'own-project' condition (M = 59.62, SD = 20.31) was significantly different to the 'project not-involved in' condition (M = 47.66, SD = 25.15). However, the 'inherited-project' did not significantly differ from the 'own-project' and 'project not-involved in' conditions.

It also supports Hypothesis 2 that students, who solve a PBL problem first-hand, like those indicated by 'Own Project', learned the most from that specific problem, followed by the students who inherited the project from another group. Students not-involved with a specific PBL problem will only learn from striking projects that caught their attention, like the SB and LF as shown (Figure 18). Students were familiar with the TND and found it unexciting due to its widespread use.

There was a high amount of vicarious learning between the different projects since students had the opportunity to move around in the venue and observe each other's projects. It was especially the SB that attracted a lot of attention once operational. Students also had to investigate their 'inherited' project first-hand in more detail since they had to build up on what the previous group has done. They were able to share lessons learned from both good and adverse experiences of the other groups. Students had to spend far less time on their 'inherited-project' since it was already designed and constructed by a previous group. They saved much time by building upon co-student's PBL outcomes. No official time was allocated to the projects that the students were 'not-involved' in.

Attitude, Motivation, and Reflection

The Cronbach's Alpha coefficient, calculated from the overall data for all pre- and post-surveys, was ≥ 0.7, showing acceptable to good reliability for all (see Table 25).

Table 25. Cronbach's Alphas for the overall Attitude, Motivation and Reflection Survey

	Cronbach's Alpha (α)	
Subscale	**Pre-survey**	**Post-survey**
Attitude	.923	.938
Motivation	.919	.938
Reflection	.964	.951

The study also sought to establish whether there was a significant difference in students' attitude, motivation and amount of reflection when confronted with multiple PBL problems at once. Normal probability plots were generated on the attitude, motivation and reflection survey subscale variables, confirming the normal distribution of all data. The reliability of the surveys was evaluated in terms of Cronbach's Alpha coefficient. Figure 20 shows a higher mean score after students completed the multiple problems in all of the subgroups for the attitude, motivation and reflection. Many of these reached significant levels as shown in the detailed results – see Table 26.

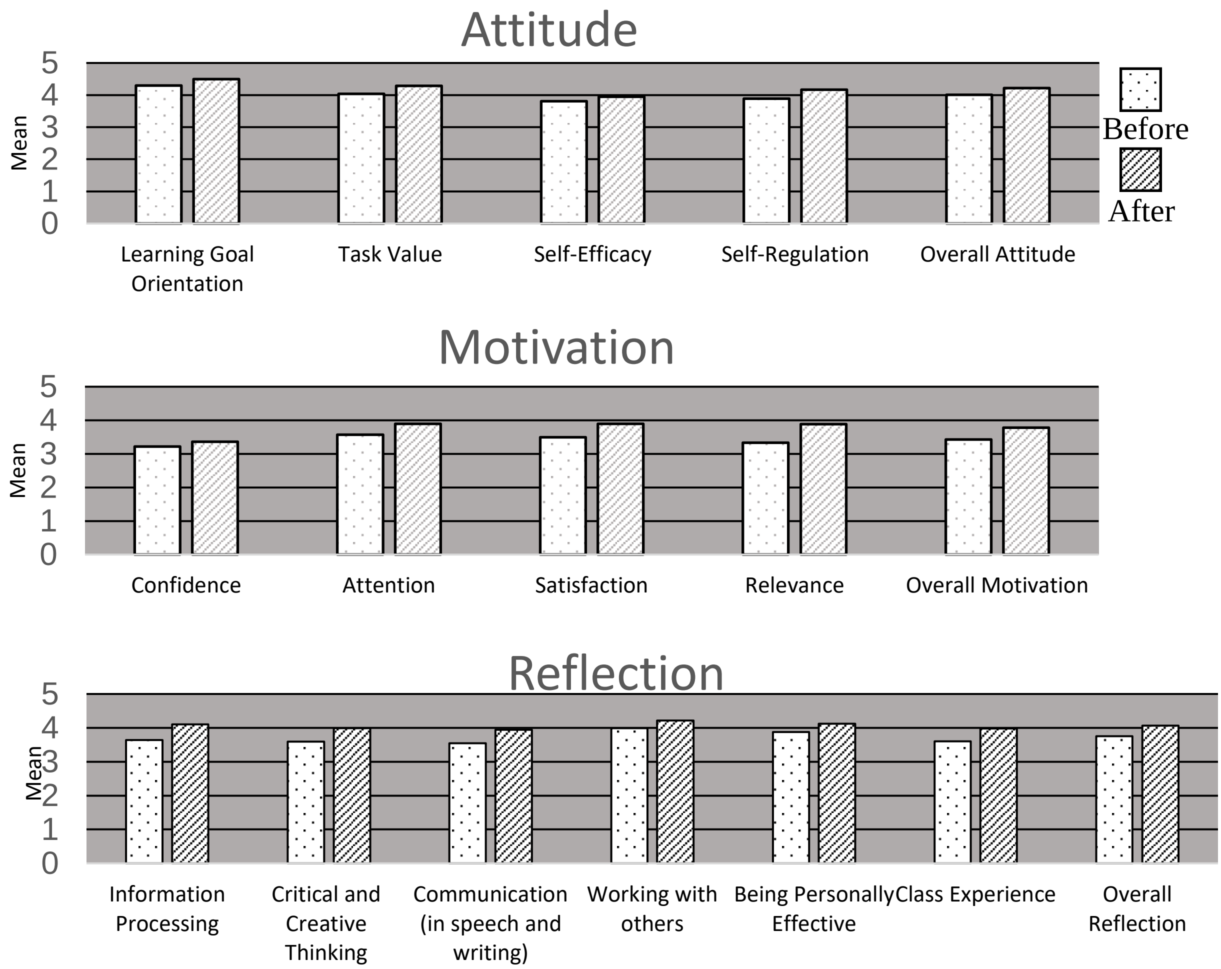


Figure 20. A Comparison of the Attitude, Motivation, and Reflection before and after the Three LED Problems

There was a significant improvement in the attitude, motivation, and reflection of the students as shown in Table 26. The data collected were analyzed for underlying factors. The mean score was higher for all subscales excluding the self-efficacy and confidence subscales. Although students' self-efficacy and confidence levels improved, the PBL most probably helped them to realize that they still have a lot more to learn, something that usually comes with time and more experience.

Table 26. A Comparison of the Attitude, Motivation, and Reflection before and after the Three LED Problems. (Paired Sample T-test)

		Before three PBL's			***After three PBL's***				
	Subscale	***M***	***SD***	***n***	***M***	***SD***	***n***	***p***	***t***
Attitude	Learning Goal Orientation	4.302	.5629	27	4.50	.411	27	.049*	-2.070
	Task Value	4.043	.6287	27	4.29	.478	27	.013*	-2.656
	Self-Efficacy	3.810	.5193	27	3.95	.541	27	.136	-1.537
	Self-Regulation	3.892	.5566	27	4.17	.567	27	.012*	-2.703
	Overall Attitude	4.008	.4649	27	4.22	.410	27	.006*	-2.993
Motivation	Confidence	3.214	.6842	26	3.363	.6686	26	.159	-1.453
	Attention	3.567	.6276	26	3.897	.5458	26	.004*	-3.158
	Satisfaction	3.494	.9469	26	3.891	.9030	26	.008*	-2.878
	Relevance	3.333	.6540	26	3.889	.7647	26	.000*	-4.917
	Overall Motivation	3.425	.6069	26	3.778	.6260	26	.001*	-3.960
Reflection	Information Processing	3.637	.6637	28	4.10	.498	28	.000*	-4.251
	Critical and Creative Thinking	3.597	.5535	28	3.99	.484	28	.000*	-5.685
	Communication (in speech and writing)	3.546	.6107	28	3.94	.433	28	.000*	-4.501
	Working with others	3.993	.5709	28	4.22	.490	28	.035*	-2.217
	Being Personally Effective	3.872	.6238	28	4.12	.455	28	.013*	-2.666
	Class Experience	3.607	.7741	28	3.98	.751	28	.006*	-3.000
	Overall Reflection	3.755	.5188	28	4.07	.400	28	.000*	-4.683

*p<.05

The top 50% achievers in the class (based on the T1 scores), show a significant improvement in factors such as: 'Self-Efficacy', 'Self-Regulation', 'Attention', 'Satisfaction', 'Relevance', 'Information Processing', 'Critical and Creative Thinking', 'Communication', 'Working with others' and 'Class Experience'. The bottom half of low-achievers only show significant improvements for: 'Relevance', 'Critical and Creative Thinking' and 'Communication'. There was no significant difference between 'low' and 'high' achievers' based upon their matriculation results (English, Math's and Science), but it is interesting to note that the matric results of the 'low' achievers were actually 5% higher than those of the 'high' achievers during matric (as shown in Table 27).

Table 27. A Comparison between the higher/lower Achievers. The 50% top Achievers versus the 50% Low-achievers based upon their PBL Knowledge Test T1. (Paired Sample T-test)

Subscale	***Low achievers*** *M*	*SD*	*n*	***High achievers*** *M*	*SD*	*n*	*p*	*t*
Matric	47.83	4.823	14	43.19	12.672	15	.251	.305
T1	43.88	7.077	14	64.29	4.269	15	.000	-8.503
Theory test1	40.44	15.387	14	53.74	9.532	15	.009	-2.821
Year mark	45.74	12.845	14	59.38	6.067	15	.002	-3.615
Exam mark	48.39	8.391	10	58.00	8.556	15	.012	-2.782

The university environment is different from the schooling system and students should endeavor to exercise their freedom with maturity and responsibility. It seems that those students who had more positive attitudes, motivation, and reflected more, became the 'higher achievers' in the university environment, despite their lower matric results.

Table 27 shows that these students scored significantly better during the course, especially during T1, which was PBL related. Nevertheless, Table 26 supports Hypothesis 3 that PBL improves student motivation, attitude, and reflection of the entire class. The through-put rate of this class was 72%, the highest in a four-year cycle.

Conclusions

Sockalingam and Schmidt (2011) identified eleven problem characteristics of PBL (see Table 28).

Table 28. Problem Characteristic of PBL

Criteria	Characteristics
1	The extent to which the problem leads to the intended learning issues.
2	Interest triggered by the problem.
3	Format of the problem.
4	The extent to which the problem stimulated critical reasoning.
5	The extent to which the problem promoted self-directed learning.
6	Clarity of the problem.
7	Difficulty of the problem.
8	The extent to which the problem is relevant; that is applicable and useful.
9	The extent to which the problem relates to the students' prior knowledge.
10	The extent to which the problem stimulates elaboration.
11	The extent to which the problem promotes teamwork.

A brief overview of the main findings from the research, in relation to the stated hypotheses for the research study, is presented below.

An achievable, yet challenging PBL problem that triggers students' curiosity will be more suitable in terms of learning effectiveness. The SB with its large dimensions was the most visible and impressive project and it received the highest attention from all the students in the class once the first group achieved success with this project. Many of these students developed a strong interest in sportive activities, especially soccer and rugby, and this may have triggered the motivation and enthusiasm of the initial developers. Once operational, the SB caused extraordinary excitement and its visual presence inspired most students to become more interested in the detail operation of this project. The technical orientation of these engineering students most probably contributed to the success of the SB. Students scored well on the SB project, regardless if they were the originators, inheritors or not even involved (as shown in Figure 18). The SB project could therefore be seen as the most suitable PBL trigger from the three projects and met, at least criteria 1, 2, 4, 5 and 8, as shown in Table 28. All of the criteria as shown in Table 28 is important and an attempt should be made to incorporate as much as possible of those during the problem design. It is especially item 2; '*Interest triggered by the problem*' that led to more vicarious transfer in learning. Hence, the focus should thus be more on the aspect of a topic's affordance of encouraging vicarious learning or not. The type of knowledge to be learnt needs a special PBL scenario in terms of organization, group composition, allotted time, assessment timing.

The TND was perhaps the most ordinary of the three projects. It was not that difficult to design, but it had a few stumbling blocks to overcome. The display was the usual 7-segment display that is very often used in ordinary electronic appliances. It did not elicit that much attention among other students since they thought they knew it, but those not-involved in the TND scored badly during the knowledge tests since they missed some important basic principles (see Figure 18). Criteria items 2, 4 and 7 as shown in Table 28 were most probably lacking in this project. Those who were involved with the project found it easy and they didn't have to think a lot to make it work. However, all groups made a common fundamental design error which they rectified after some guidance from the tutor. Students from other groups did not show much interest in the TND's during class time, hence they didn't learn about the fundamental design principle for these types of circuits.

The LF was the most difficult project for the students to solve and the following might be true for these students as mentioned by Mauffette et al. (2004, p. 19); "When it becomes clear to students that they are unable to meet the problem's challenge, their performance dips once again and they give up". The LF required from students to think 'out of the box' and they (eventually) needed a vast amount of guidance from the supervisor to steer them in the right direction. Once they overcome their 'stumbling block', the project turned out to be more understandable and the originators, inheritors and those not-involved turn out to have very similar marks (as shown in Figure 18). These students initially struggled with Criteria 6, 7 and 9 as shown in Table 28.

Students who solve a PBL problem by themselves will learn more than those who inherit a project from another group. Vicarious learning amongst onlookers will only transpire from striking projects.

The scores of the SB were almost the same for the originators, inheritors and those not-involved during the 1st test (as shown in Figure 18a). There was a great amount of vicarious learning for this project since it was extraordinary and it attracted a high attention.

The scores of the TND and LF were slightly higher for the originators when compared to the inheritors during the 1st test, and the scores of those not-involved in the LF, matched the score of the inheritors (see Figure 18a). A great deal of vicarious learning took place between the originators and inheritors, but the low scores of those not-involved in the TND shows that vicarious learning might not take place if students find a project that they are not-involved in as ‘uninteresting’.

The scores related to the student’s original projects increased during T2 (see Figure 17a), most probably because those who were left behind had about 6 weeks to catch-up, even if they had moved on to a different project that they had inherited. It may also be that the students’ took ownership of their original projects and they were triggered to learn from them. The scores related to students who inherited projects remained almost the same along T1 and T2 as shown in Figure 17b. This is an indication that the students learned from it, but perhaps no trigger that encouraged them to learn more. Figure 19 confirms that the students learned the most from their original, own project and the least from the project that they were not-involved in. The three project types; ‘original project’, ‘inherited project’ and ‘project not involved in’ can in some way be compared with a family where a child fits in as; ‘own child’, ‘step child’ or ‘child of a friend’.

PBL improves students’ motivation, attitude and reflection.

Students benefited from working on the three PBL problems, resulting in a significant improvement in their attitude, motivation, and reflection as shown in Table 26. Mauffette et al. (2004) cite Paris and Turner (1994) who argue that the freedom to choose among alternatives, challenges that are moderately difficult, control over the task and collaboration through peer commitment are motivational for students. The students experienced most of these factors and enjoyed solving the PBL problems. This was perhaps the reason of the improvement of their attitude, motivation, and reflection.

Discussion

Students get a wider exposure to various types of electronic circuits when multiple PBL problems are done in parallel. A great deal of vicarious learning took place in most cases between the various student groups (see Figure 19); groups who do similar projects usually tend to copy from each other, typically from the group who progresses the most. Having a variety of projects reduces the amount of copying but it can be challenging to generate interesting problems that differ and still remain more or less within the scope of a specific subject.

Students were confronted with various concepts during the three PBL problems. They covered the theory of most of the individual components as well as example circuits, but the apprehension of the underlying concepts of the PBL problems were not covered. There was a vast difference between the three projects, even though they all relate to opto-electronics and specifically LED's. The ratios in attractiveness and domain influenced the amount of vicarious learning that took place, and some were of a more technical/conceptual challenge to resolve than others. Teachers need to get sensitive for promoting the "right" application domains in order to vitalize PBL for technical students. It would be beneficial to choose problems closely related to students interests and to involve as much as possible of the criteria as shown in Table 28.

Once students are confronted with the PBL problem, they had to find a solution to the problem by integrating various components, including some unknown ones. Tutors or teachers fulfilling the role as tutors should facilitate the PBL process supporting and keeping the group focused on tasks, ensures learning objectives are achievable, comprehensive, and appropriate and guiding them to achieve their goals. To do so, they need to understand and have reasonable insight and knowledge into the problem/s to be solved.

Experiences with problems

SB - Students who worked on the SB had to find a way to display individual numbers on a 7-segment display without the use of sophisticated digital components. This was expected to be the most difficult part of all the PBL problems, but the various diode configurations required to solve the problem was well thought-out by some of the students after some initial struggling. The rotary switch and LED strip were also components that they hadn't dealt with before. The SB was about 1m in height with a high light intensity. It was impressive to look at, and reasonably visible for over 100m in day-light. The interest triggered by the SB caught the attention of most students and this is perhaps the reason why many students became familiar with its operation.

TND – This project was more common, but students had to be aware of using separate resistors for each segment instead of one common resistor for all. They also had to find a method to reduce the supply voltage to dim the display, instead of adding a series resistor in the supply line. All of B1-B3 originally made these mistakes and they learned from that. Students not-involved with this project (C1-C2) were not that interested in this project and it appeared that most of them never learned these important principles. (It might also be that they were so caught-up with trying so solve the LF which they found difficult, that they never made the time to observe what the TND groups did).

LF – This project was supposed to be the easiest since it contained the smallest circuit, yet it was the one that students struggled with the most on the whole. Students are used to providing power to a circuit in a certain way, but it was different for this circuit. They also did not realise that the amount of current through a LED will directly influence its brightness. None of the students involved manage to overcome these hurdles and they only made progress after a series of interventions by the supervisor. This is an indication that the students are not used to thinking 'outside of the box'. This project required some critical thinking to solve it. Problems such as this can be good, especially if it is not the only PBL problem. It shows the shortcomings of the lecturing mode, develops students' critical thinking skills and eventually transfers the solution to the whole class.

Students who completed the theory in the lecturing mode were initially very insecure in applying their knowledge in the PBL mode and it seemed that they could not bring the two together. That improved with time and student became more comfortable in applying their knowledge. From observation, it appeared that students developed various skills while doing

PBL, e.g. application of knowledge, critical thinking, communication, working in groups, reverse engineering and vicarious learning.

The higher through-put rate for this class was respectable. The PBL most probably assisted the students in better understanding what they had learned since they scored high (72%) on the exam question most closely related to the PBL projects. This may also be an indication that their long-term learning outcome was good.

Previous PBL studies at WSU also showed some significant improvement in the attitude, motivation and reflection of the students, but it was more intense during this study, most probably because of the three problems that were done at once. This made the learning experience more intense and students felt that they had achieved more.

One should attempt to design multiple PBL problems in such a way so that they are at the same level of complexity. This may avoid the situation where one group may spend excessive time and energy to get their original project functional and as a result miss out on the potential transfer of knowledge from the other projects.

Recommendations

From prior experiments with extended stream students, it appears that it is better to do all the relevant theory first followed by a relevant PBL problem. It may be though that a compact theory lesson before a PBL problem and then again at regular intervals within the PBL may even optimize the learning further, but that should be tested during further research.

It is also better to do multiple PBL problems in parallel with different groups, and exciting problems should get preference. Stronger teams typically find the solutions to the problems first, but weaker teams usually benefit more from the problem's attractiveness since they also had to do a lot of research and critical thinking in solving the problem. Once the stronger team found the solution, the weaker team manage to leap-frog on how to solve the problem to some extent, but they still need to work hard to achieve the desired results. This may compensate in a way to the asymmetric attraction amongst the teams.

The 'more interesting' PBL problems may serve as an 'ice breaker' to get the students' interested and going. This will boost their self-esteem and confidence, which could be valuable when more 'conceptually complex' problems need to be solved later on.

It might also be beneficial to increase the variety of PBL problems even further. The course should also include some smaller PBL problems in order to emphasize important concepts. Small PBL-like problems should replace the tradition-like experiments as far as possible.

The PBL should be structured in such a way to strengthen the students' growing capacity for self-regulation, for instance, they should take control of their own behavior without external control or monitoring. Ideally, students should get used to; also working hard and with good concentration on uninteresting tasks that they may not like, be dedicated and finish on time. Perhaps a small scale higher order curriculum can be used where students should start on a feasible and socially visible topic like the SB and gradually be introduced to problems with a higher level of schematic complexity as they are getting more confidence. Teachers who uses the PBL method in the time to come need to develop the rationales and intuition on how to balance between these two. Teachers should provide more support and guidance towards students when learning new concepts or skills in the early stages to protect them from too complex concepts. These scaffolding can gradually be reduced so that students' are encouraged to take more autonomy and self-regulation if complexity runs out of hand. They learn to think about thinking and develop self-awareness and the ability to self-assess. This will prepare them for their career path since it steer them towards life-long learning and higher-order thinking. PBL is both problem- and content driven. This becomes wider as students develop in knowledge, skills and efficacy. This is more completely discussed on Page 99 with the aid of a spiral as shown in Figure 23.

The amount of time taken by students to execute these PBL problems is still of a concern and additional sophistication should be found to balance time dissipation and increasing students' ambition as well.

More research and empirical evidence is needed to determine the optimal amount of prior knowledge required before students should attempt a PBL problem, and the type of problems to use at the various stages. The same applies to solving multiple PBL problems by different groups and the amount of vicarious learning that may took place in such a case.

CHAPTER 7: OVERALL CONCLUSIONS

ANALYTIC OUTCOMES

The core of this study focuses on the various aspects of optimizing PBL for students at WSU. Most of the participants entered the University with a minimum academic entry-level requirement.

The three central experiments in this study are:

- Experiment 1 - Comparison of students who enter the PBL mode with only very little prior knowledge with students in the traditional lecturing mode.
- Experiment 2 - Comparison of students who enter the PBL mode with only very little prior knowledge with those who enter PBL with a high level of prior knowledge. Sequence PBL→ Traditional versus Traditional →PBL.
- Experiment 3 - Vicarious learning in PBL variants when all participants have a higher level of prior knowledge.

Statistical data from the experiment as discussed in CHAPTER 4: EXPERIMENT 1, show a marginal improvement among students who participated in PBL activities compared to those in the traditional lecturing mode in terms of:

- The overall attitude towards the learning required to design electronic circuits.
- The amount of reflection was higher.
- The level of near transfer skills and the retention knowledge was higher.

This was an indication that PBL should get preference above being lectured in the traditional mode. The students in the PBL condition had very little prior knowledge, nevertheless they improved as indicated above, but only a few items reached significant levels. The lessons learned from Experiment 1 were transferred to Experiment 2 as illustrated in Figure 21.

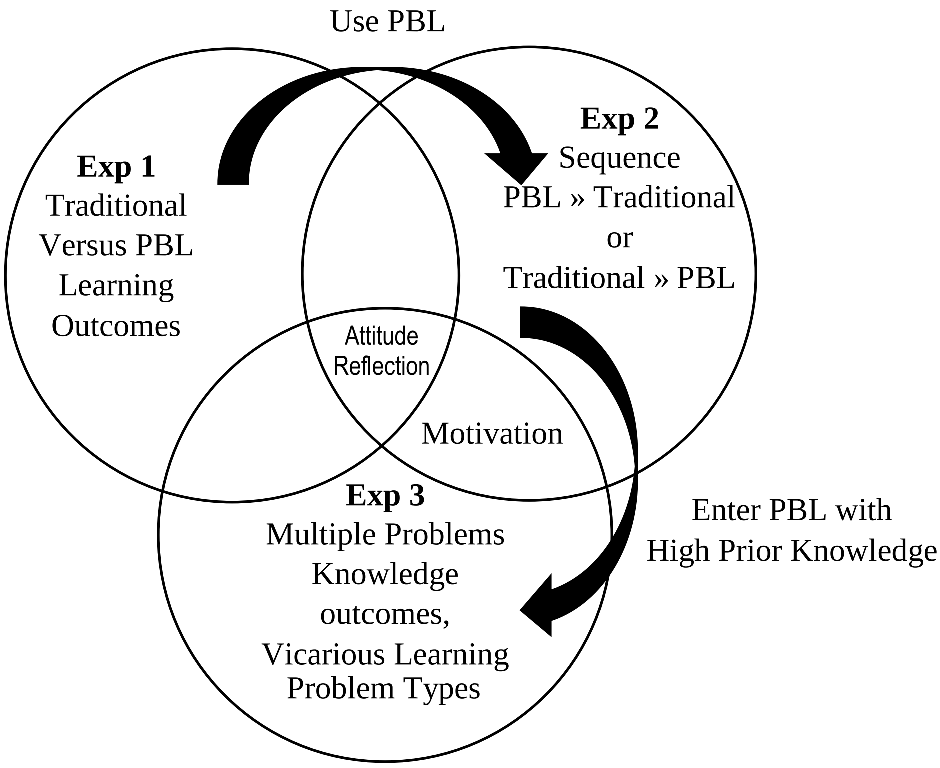


Figure 21. Transfer of "Good practices" between Experiments

The choice to focus on the variables in the intersections between Exp2, Exp3 and Exp1 was made based upon the literature review at that time. The lessons learnt from Experiment 1 were transferred to Experiment 2 as illustrated in Figure 21. Based on the outcomes of Experiment 1, it was decided to use PBL during Experiment 2, but then again, also to supplement it with traditional lectures. The sequence PBL→Traditional lectures were compared with Traditional lectures→PBL during this experiment as discussed in Chapter 5. It was very similar to Experiment 1 during the 1st phase for G1. These students also entered PBL with very little prior knowledge. G2 was in the traditional lecturing mode during the 1st phase resulting in accumulating a high level of prior knowledge. The combined attitude, motivation and reflection of G1 (in the PBL mode) was much higher during Phase 1. These results mimic and strengthen the results from Experiment 1.

The 2nd phase however revealed a remarkable increase in the attitude, motivation and reflection for G2 who entered PBL with a high level of prior knowledge. Their attitude, motivation and reflection were lower during the beginning of Phase 2 (when compared to G1), but it was much higher after the second phase.

Data in Table 14, Table 18 and Table 21 clearly show that students who entered PBL with low prior knowledge (G1), should not be supplemented with traditional lecturing methods afterwards. On the other hand, those students who were in the traditional lecturing mode during Phase 1 (G2), entered the PBL mode with a high level of prior knowledge, resulting in a significant difference for several of the attitude, motivation and reflection sub-groups as shown in Table 15, Table 19 and Table 22. The most important lesson learned from Experiment 2 is that students prefer to enter PBL if they have a higher level of prior knowledge; mostly gained from earlier traditional lectures.

This lesson was applied in Experiment 3 as illustrated in Figure 21. Experiment 3, as discussed in Chapter 6. All students received theory via traditional lectures before they had to solve one of three project-orientated PBL problems. Once they reached a certain milestone, groups had to rotate projects, and each group ended up with another group's project which they had to continue with.

The results show that students learned most from the projects they originally started with, but also from the project they inherited and also, to some extent, from the project they were not involved in. It appears that the knowledge transfer was higher for the more interesting project; e.g. the Score Board (SB). On the contrary, students found the Table Number Display (TND) trivial and dull. The final score for the students who were not involved, was significantly lower than the others.

There was a significant improvement in the students' attitude, motivation and reflection in almost all of the subscales. The reason might be that in all of the students entering PBL with a high level of prior knowledge, the factor of "ownership" of a certain posed problem goal played a crucial role. They also found it challenging (but enjoyable though) to work on different projects, which may also have contributed to the total knowledge outcome after all.

Limitations

This study was limited to three main experiments. From that we learnt that students prefer PBL, especially when entering with a certain minimum level of prior knowledge. Students also prefer a variety of problems to be distributed amongst groups instead of just one common problem for all of the teams. The type of problem may also have had an influence on the amount of vicarious learning that took place amongst groups with different problems; both the very easy and the very complex problems at the other project teams may inhibit a swift transfer to the learning of the receiving team. More research needs to be invested at this point.

Secondly: Chances are good that optimal PBL needs to be implemented in a hybrid- rather than in a monolithic mode of PBL. Seen the results in the Chapters 4 and 5, we can estimate that this may well lead to a more overall conclusion/recommendation.

Thirdly: We can only base our conclusions on the findings at the WSU Engineering Departments. In this way, students' learning will systematically cover the wider range of basic principles. We found that the (vicarious) learning between teams caused beneficial effects. An additional experiment on the ratio between the knowledge outcomes during vicarious learning within- versus between the teams needs to be undertaken in the future. Important finding so far was that the explicit agenda for exploiting the vicarious learning between teams was beneficial anyway.

SUMMARY OF RESULTS

This study has focused on the various aspects of optimizing PBL at WSU. Overall, the following was found to be relevant:

- PBL seems to be more effective when students enter PBL with a higher level of prior knowledge. This causes a significant increase in the students' attitude, motivation and reflection.
- Using various problems during PBL, may contribute even further to this and also results in vicarious learning taken place.

The above may be a good starting point for future implementation of PBL at WSU. However, in order to optimize the learning process, the optimal balance should be based upon the amount of prior knowledge students get from traditional lectures and upon the type and size of PBL problems and upon how many PBL problems can be carry out in parallel. This balance may not be an issue of "one size fits all". Also, the situational factors may affect the amount of emerged vicarious learning and thus affect the students' confidence, flow and courage; (Csikszentmihalyi & Schneider, 2000).

The next chapter will focus on discussions, recommendations for future research and suggest a possible strategy on how to implement PBL, especially at the engineering departments of WSU. A possible future perspective of what the future hold for education will also be discussed.

CHAPTER 8: SUMMARY AND RECOMMENDATIONS FOR FURTHER STUDY AND PRACTICE IMPLICATIONS

INTRODUCTION

In this chapter we will focus on discussions, recommendations towards future research and practical implications, future possibilities of PBL in South Africa and conclude on the lessons learned from the experiments.

DISCUSSION

Overview of the Study

Students in the PBL condition had difficulty to demonstrate PBL's value in terms of higher learning outcomes during the 1st experiment as discussed in Chapter 4. However, the results show a slightly higher effect on skills for problem-solving and longer-term retention compared to traditional lecturing. PBL requires students to activate prior knowledge and problem-solving skills and thus anticipate real-life situations once they are employed.

It became clear that the more unique PBL learning outcomes could not be evaluated through traditional examination methods. Assessment methods when using PBL are not necessarily similar to those used during traditional lectures. For instance, formative assessment is meant to monitor student learning and it works well to establishing what students do or do not grasp or understand about a topic. Instructors can use formative feedback outcomes in order to improve their teaching whilst the students can use it to improve their learning by taking control of it. Formative assessment may be time consuming, but it improves self-reflection and it develops self-confidence in the classroom. Students evaluate their own work during self-assessment whilst peer assessment like PBL, focus on group collaboration and share key objectives and philosophies where students need to make judgement about other students work. PBL students achieve substantially higher results when evaluated using methods they utilized during PBL e.g. using a practical examination where a real-life problem needs to be solved. An outcome-based evaluation of skills rather than knowledge-based might be more suitable to evaluate the gained PBL learning outcomes. Assessment methods are also discussed at APPENDIX BB, (Page 195).

WSU students found the project-oriented PBL problems more enjoyable and challenging than traditional practicalities and at the same time they found it more time-consuming. PBL may be time-consuming, especially when done for the very first time. This can be problematic since it is not possible for the teacher to lecture on, and continue with the course due to the student-centred teaching strategy. At WSU, PBL is more suitable to be used with extended stream students who have more time available to complete the syllabus.

We've learned from the 2nd experiment as discussed in Chapter 5, that students who entered PBL with little prior knowledge, should not be strengthened afterwards with traditional lectures. Nevertheless, the students prefer to enter PBL activities with a higher level of prior knowledge, so that they can focus on solving the problem instead of having to study the basic theory first. This is perhaps a good thing since mathematics, physics and large parts of electronic engineering rest upon a hierarchical knowledge structure and these students need to know the basic concepts perhaps in the lecturing mode before learning the more complex concepts whilst in the PBL mode. A hybrid approach of traditional lectures which serves as the scaffolding, followed by a project-based PBL problem seems to work well in the department of Electrical Engineering at WSU. In this way, all basics could at least be covered during lectures. The less confident students can still revise and strengthen some theoretical aspects if its need arises during the PBL problem solving process.

Students get a wider exposure to various types of electronic circuits when multiple PBL problems are done in parallel and a great deal of vicarious learning took place in most cases between these different student groups (as learned from experiment 3). There was a big improvement in the students' attitude, motivation and reflection when students participated in PBL activities, especially once they enter the PBL activity with a higher level of prior knowledge.

Discussion of the Findings

This study reveals various benefits in the use of PBL. Students enjoy it and their attitude, motivation and reflection were enhanced. Students need to think more critically, learn to communicate and work in groups. It is important for students to enter PBL with a higher level of prior knowledge, and thus pleads for a hybrid approach of traditional lectures followed by a project-based PBL problem. This seems to work well in engineering at WSU. Using different problems for the various groups encourages vicarious learning and enhances students' attitude, motivation and reflection even further.

The implementation of PBL requires some adjustments e.g. it would be beneficial if facilities are adjusted to accommodate group work. (APPENDIX AA on page 194 shows one of the venues at WSU that was changed into a more PBL orientated Laboratory after these experiments were done). At WSU, most graduates and post-graduate students are working, and traditional staff is usually fully loaded with their own work-load. Finding suitable tutors may thus be problematic, but a lecturer operating as a wandering tutor seems to be sufficient when only project-based PBL problems are done in the PBL way. Assessment methods should be adjusted to PBL so that it fit to the key values as targeted by the PBL method.

PBL even when used in a hybrid way, adds a lot of value to students' learning and skills. For instance, during this study, students in the PBL-mode learned how to work in groups and solve problems. They learned how to design and test circuits and use equipment earlier not known to them. In one case, there was a serious conflict in one of the groups, most probably due to personality clashes, but it was easily resolved when the individual understood that one of the goals of PBL is to prepare students to work in groups since future employers will expect the same from them.

The recommended implementation method is focused at engineering departments at WSU, but it may also be valid for other departments and institutions. The three Experiments understandably didn't test all the transformations caused by PBL and there may be a lot of secondary side effects e.g. cognitive long term ability, conflict resolution skills, improve time studying and impact of socio-economic status.

Lessons from this study may be a good starting point when training staff and transforming facilities to best meet the PBL conditions. Staff should also be allowed to experiment with various variants of PBL, and in doing so, being part of a team, doing practice-based research. Quantitative and/or qualitative data could be used to further optimize the implementation of PBL. The involvement of one or more dedicated researchers may be required to do so.

RECOMMENDATIONS TOWARDS FUTURE RESEARCH AND PRACTICAL IMPLICATIONS

PBL is mostly used in isolated cases within South Africa and Africa in general. Those who use PBL, mostly do so using a hybrid approach between PBL and traditional lecturing. So far at WSU, we learnt that a blend of lecturing and PBL can be seen as a scaffolding method: the traditional mode like providing lectures serves as a stage of scaffolding, to be followed by a project-orientated PBL phase. It proved to work well in the department of Electrical Engineering at WSU, however if it can be generalized a wider set of contexts has not been proven. Figure 22 suggests a hybrid approach that includes traditional lectures and PBL. The speed of crossfading the lecturing into PBL needs to be adapted to the actual learning processes at the involved students.

The "extended stream students" preferred a higher amount of prior knowledge before solving a PBL problem. It is not clear what may happen if prior knowledge be reduced to let's say the basic principles only. It may be that the students' relative intelligence and level of education play a part in the amount of prior learning required. Students with higher levels of knowledge and trust are likely to rely to a lesser degree on prior lecturing. There is also the possibility of "last minute" slotting in a traditional lecture within a PBL problem e.g. a "just in time" lecture to educate students when they need it most. Providing lectures after the PBL phase did not show good results during Experiment 2; tutoring a compact version of the theory might even be more adequate.

Various degrees of PBL models can be discerned; the lightest version may be a conventional curriculum with 2 or 3 PBL problems per year. But also it can go as far as embodying PBL as the main learning mode, supplemented by unconventional interactive student-centred lectures.

The way in which the PBL problems are designed is of great importance. It should be relevant and the complexity such that all group members get involved. Problems should be interesting in order to maximize commitment and it should require prior and new knowledge to solve the problem. The problem should be challenging, have many solutions and require logical decision making based on reliable information. The type of chosen PBL problem also plays a role. E.g. can it be solved in a day, week, month, or does it require a whole semester to be solved? Results obtained from Experiment 3 were quite promising when different student groups had to solve different problems. In this case, there were three problems to be solved and some vicarious learning took place. Students were very much interested in investigating what others achieved, e.g. when one group in the class got their scoreboard to work, many of them rushed towards them to see what was going on. There was also an increase in the amount of positive attitude, intrinsic motivation and reflection (meaning-making activities) for these students. Adding a bigger variety of problems may increase the amount of vicarious learning, but it may also be that an even larger number of PBL exemplars have the opposite effect.

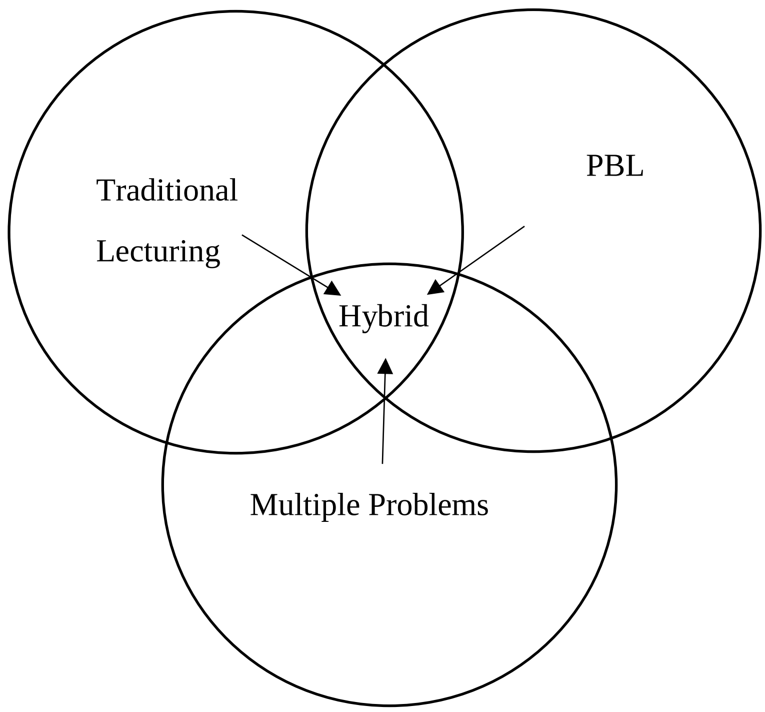


Figure 22. Optimization of Learning when using PBL in a Hybrid Mode

Jerome Bruner's notion of "spiral curriculum" might be helpful to imagine how investing in PBL fragments finally fan out into larger societal- and economic effects as the students learn to take a more active approach and are less scrupulous in starting their own enterprise. Bruner conceived that students need a more active support when they start understanding new concepts at a stage of "guidance" and "constraint complexity"; e.g. to be seen at point "A" in Figure 23. As the students become more mature and equipped with knowledge, they become more independent in their thinking, acquire higher levels of skills and strategies. Gradually the teacher's support can be faded away, e.g. like in point 'B' of the figure below; (Wood, Bruner, & Ross, 1976).

The spiral illustrates that PBL is both problem- and content driven and becomes wider as students develop in knowledge, skills and efficacy (Donohoe et al., 2016).

University curricula usually start implementing PBL on a small scale and increase its scope only once they sense the added value of PBL. Finding the optimal combination will lead to: a) preparing students with the correct amount of prior- and other knowledge requirements, b) choosing the correct type- and level of PBL problem/s and c) choosing the correct amount of problems to be solved in parallel. This may require various iterations in order to find the best possible combination; the teamed students' relative intelligence, their level of education and maturity may also play a role.

When changing towards student-centred learning, Biggs (1999) suggests that the differences in learning experiences are due to 'the students' level of engagement, the degree of learning-related activity that a teaching methods is likely to stimulate and the academic orientation of the students. For instance, the learning of non-academic students entails to a lower order of learning activities such as brittle rote knowledge, unconnected facts and 'memorizing' subject matter when in the traditional passive lecturing mode (see Figure 24).

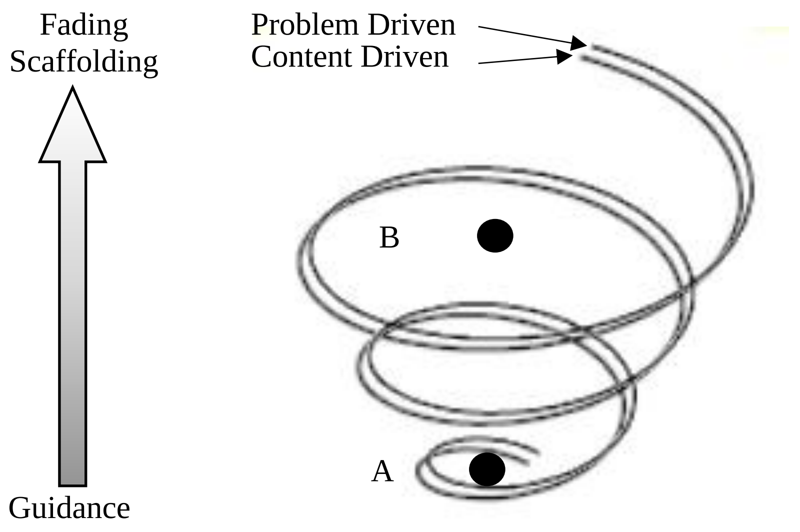


Figure 23. Spiral Curriculum

Academically-orientated students learn by trying to understand the topic and use higher order learning activities like reflection and analysis, regardless if passive- or active learning is used. However, active learning such as PBL will challenge the non-academic students to learn more intensely. This decreases the gap between the academic and non-academic students as illustrated in Figure 24 (see the difference between A and B). PBL confront students' to use the higher order of thinking in education, such as analysing and evaluating concepts, processes, procedures and principles, instead of just memorizing, note taking and describing.

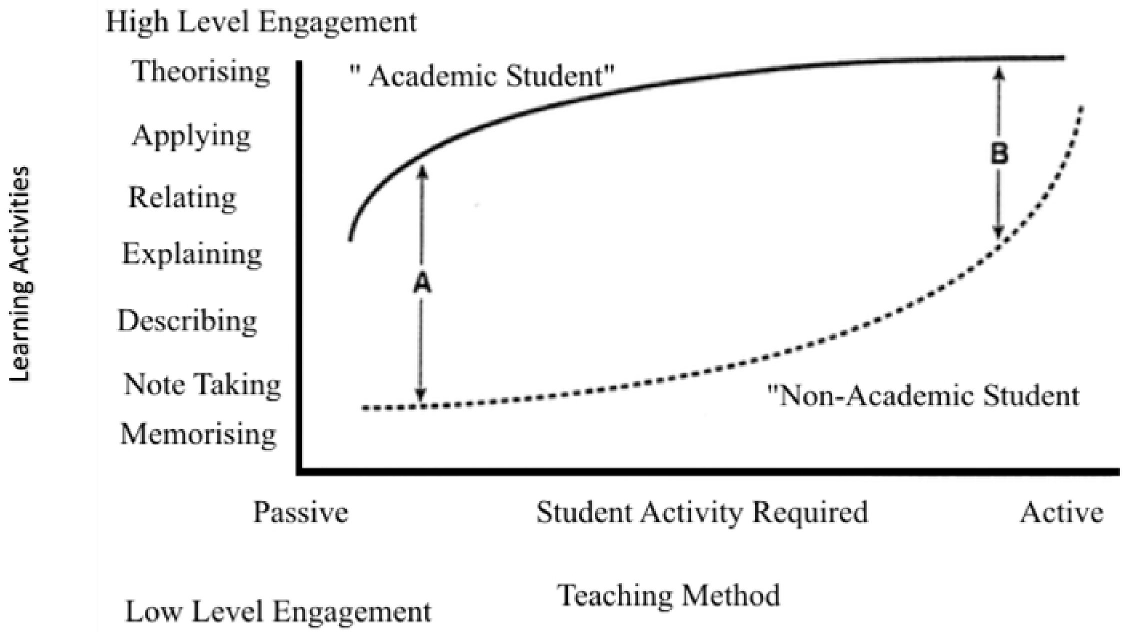


Figure 24. Biggs' Factors influencing Student learning. Student Orientation, Teaching Method, and level of Engagement (McNaught, 2003)

The top 50% versus the lower 50% achievers (based on the PBL knowledge test T1), were compared during Experiment 3 as shown in Figure 25. The difference was significant for all marks besides the matric mark (see Table 27). The interesting part is that the lower achievers entered the university with a higher matric result, 47.83% compared to 43.19% for the higher achievers. Nevertheless, matric results for both groups were still relatively low, the reason why these students were placed in the 'extended stream' instead of in the main stream. The "non-academic" students excelled during T1 and all other tests/exams that followed, since they were required to use the higher-order learning activities during PBL that followed.

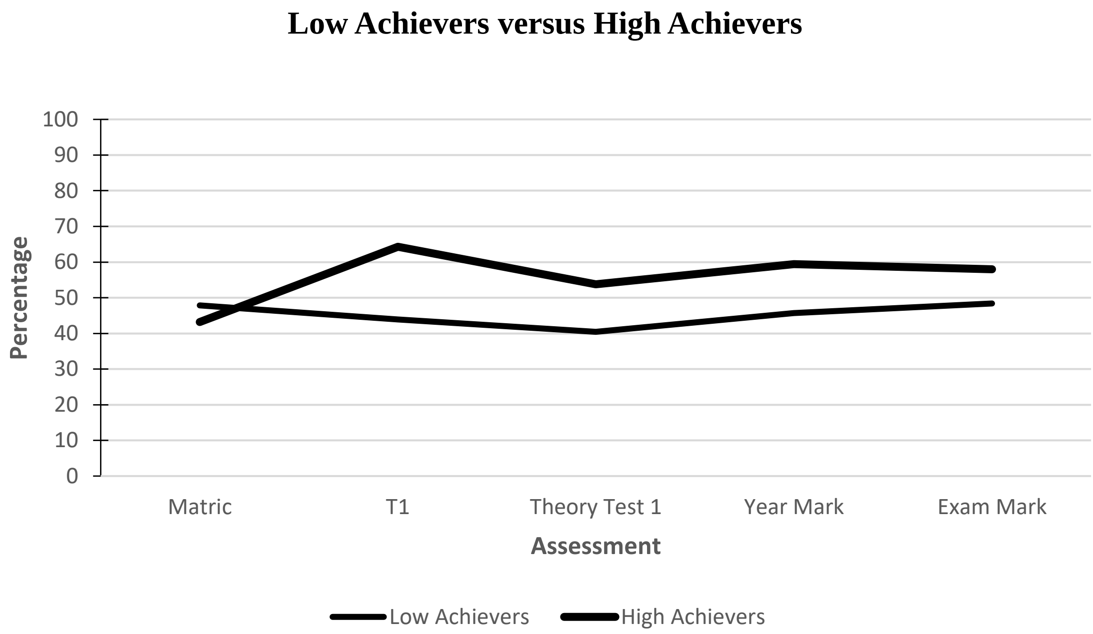


Figure 25. High versus Low Achievers based on the PBL Knowledge Test "T1"

PBL is used both in South Africa and a few other African Higher Education Institutions (HEI's), but mostly in isolated cases. It seems that most of them who use PBL, have very similar experiences which is in line with what was shown during this study. Most of these African-based institutions use a hybrid approach between the PBL- and the traditional lecturing mode where students had to solve one specific PBL problem instead of multiple problems at any given time, therefore no experience with vicarious learning in PBL variants.

IMPLICATIONS FOR PRACTICE

The implementation of PBL at WSU has been focusing on the situation where students develop their new knowledge, understanding and design skills in electronic circuit design. It targets the fit on labor demand and students' readiness to start their own enterprise.

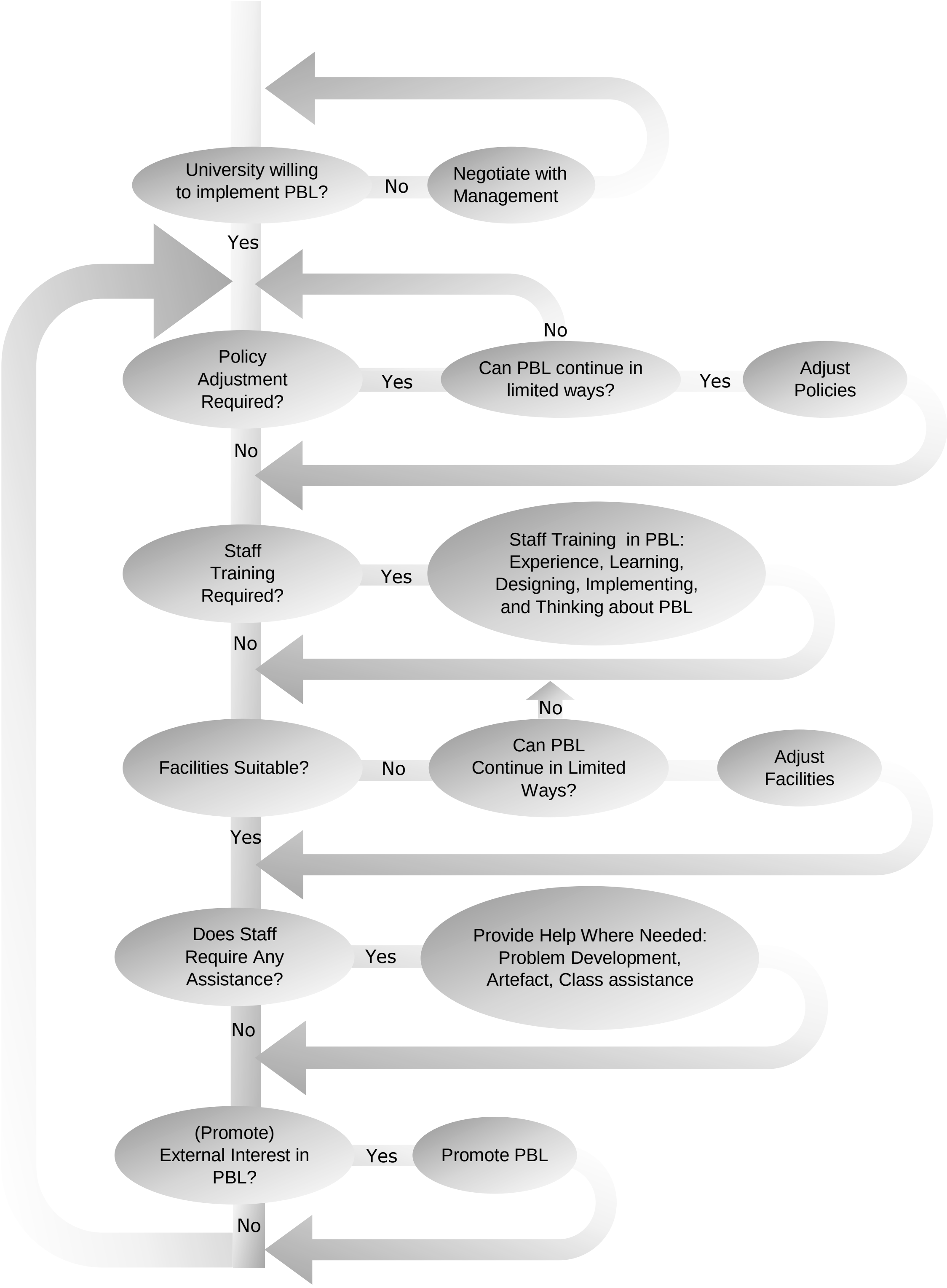


Figure 26. Recommended Method of implementing PBL at WSU

In all of these functions PBL has served a catalytic role for South Africa's societal development at the moment. PBL is a step in the right direction and is beneficial for students, the university and industry when implemented.

Seen the indications from the analytic outcomes in the Chapters 4 and 5 during the practice-based research, it is recommended to initially implement PBL in a hybrid way across all engineering subjects, or at least all electrical engineering subjects. It should be an on-going process, starting with at least one PBL problem in each "main stream" subject, and perhaps two or more PBL problems in the "extended stream" subjects. It is anticipated that those staff members who put PBL into practice, may "un-officially" become involved in practice-based research, similar to what was experienced during Digital Systems III (as discussed during the 1st Chapter), by observing the added values that PBL brings. This may encourage staff to increase the use of PBL. It also provides an opportunity for one or more researchers to collect quantitative and/or qualitative data from the various practice-based PBL-orientated classes, which could be used to find a more effective way in the implementation of PBL. It should be an on-going process until it is reasonably optimized. Most practical experiments should be replaced with project-based PBL problems after a few semesters. Assessment methods should also be adjusted in order to facilitate the PBL component.

Figure 26 shows a preferential way of implementing PBL at WSU. This method should also work at other traditional lecturing-orientated Universities. Staff who would like to implement PBL should first negotiate with the university management if their university opposes the use of PBL. It may be required that the university adjusts or implement additional policies for supporting the implementation of PBL. For instance, most traditionally-lectured courses require a uniform exam at the end, whilst PBL should encourage assessment methods that include the outcomes of formative tests and especially the unique project outcomes, later called "authentic learning outcomes".

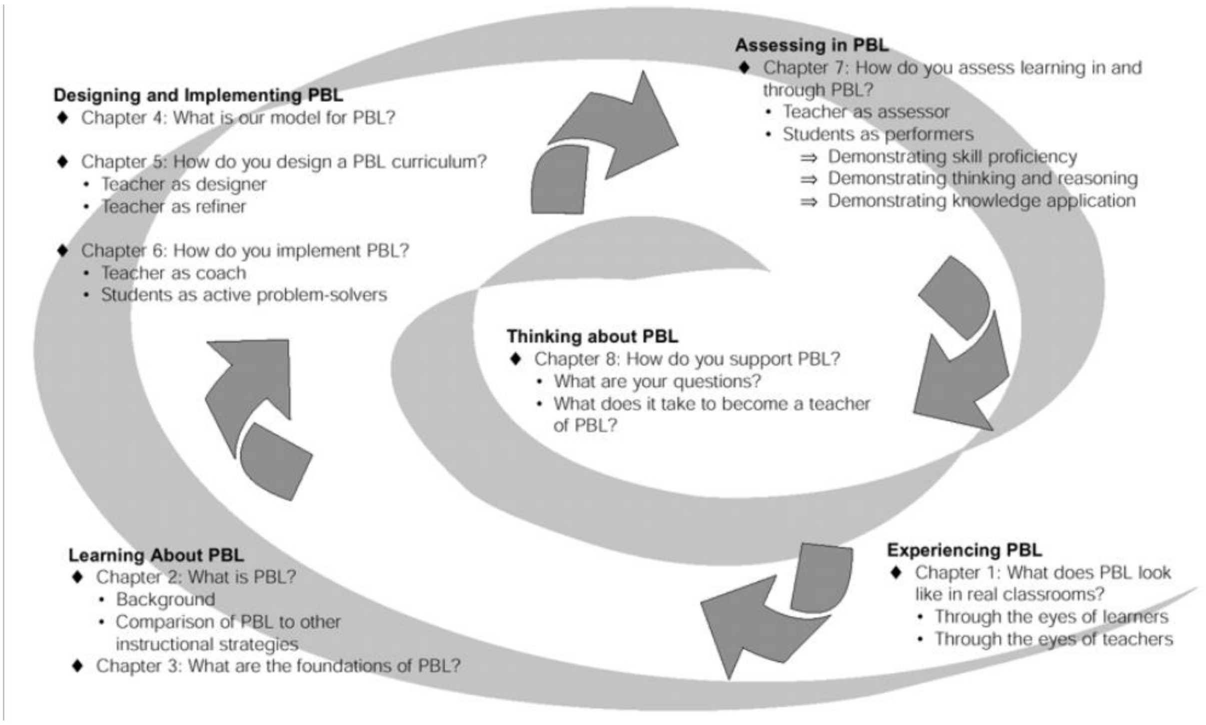


Figure 27. Overview of Problems as Possibilities (Torp & Sage, 2002)

At WSU, the implementation of PBL is encouraged, and it is possible to use it in a hybrid way, but many of the subjects still require a 3-hour examination at the end of the semester. This can be changed, but it needs to follow a process of approvals from various bodies' e.g. departmental, faculty and finally the senate.

It is important that staff be adequately trained before they start using PBL. The book of Torp and Sage (2002), cover various aspects of PBL such as Experiencing PBL, Learning About PBL, Designing and Implementing PBL, Assessing in PBL and Thinking about PBL (see Figure 27 for more detail). Many of these aspects can be covered during the training.

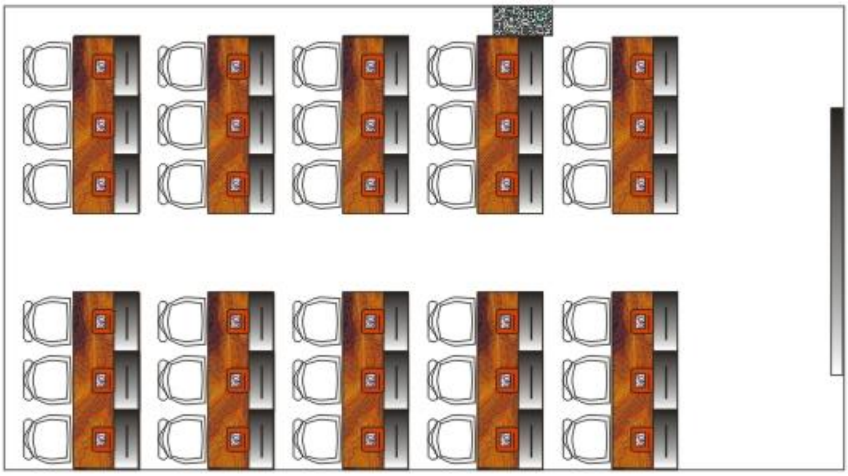


Figure 28. Typical Layout of a Traditional Lab used to do Electrical Engineering Experiments

Most universities are not ready for adopting the full-blown mode of PBL. Students need to work in groups when in the PBL mode, and at WSU, it seems that the ideal groups should contain 3-5 students when in the department of electrical engineering. The traditional benches/tables that are placed in straight rows, make it difficult for all group members to interconnect. For instance, Figure 28 shows a layout of a very compact 30-seater lab, usually used during traditional practical experiments for various subjects in the field of electrical engineering. Each student uses its own set of equipment during traditional practical experiments, which includes; an Oscilloscope, Digital Multi-Meter, Function Generator, Power Supply, Trainer and Breadboard. Figure 29 shows a typical layout for a work bench which contain three sets of equipment. This workbench can be used during PBL, but there should not be more than three students in a group. All three students should be able to participate when the middle set of equipment is used, but it will be awkward for them to have meetings in this configuration. Student should be in good view of each other as well as the equipment. Another problem is the lack of computers with these benches. Adding an All-In-One (AIO) computer above the benches will obscure the view during lectures. Ideally, the AIO computers should be part of the equipment. AIO's are chosen due to its compactness. When in the PBL mode, students are active, so as a rule, they need to use the internet to do research, find data sheets, use Excel and simulation packages, do software development, and write reports and so on. In many cases they need to crisscross between the instruments and computers. The lab can be more PBL accessible by mounting the equipment against the walls and arrange the seating as shown in Figure 30. The table-on-wheels could move underneath the wall mounted equipment when needed. This allows for groups of up to four sharing a single "workstation". The "half-moon" or "half octal" type shape of the tables (see Figure 30) make it possible for group members to have face-to-face conversations and it is anticipated that both the communication skills as well as the participation of the students will improve because of that. The equipment should also be reachable for all group members in this configuration. Floor-space at WSU is limited, but this design allows the transformation of existing venues into multi-purpose venues that could be used as a lecture room, conducting PBL meetings and allowing students to solve their PBL project-based problems within a group as illustrated lower down. It is also easy for a wandering tutor to move between the various groups. This configuration allows for the optimal use of the available space in a very economical way.

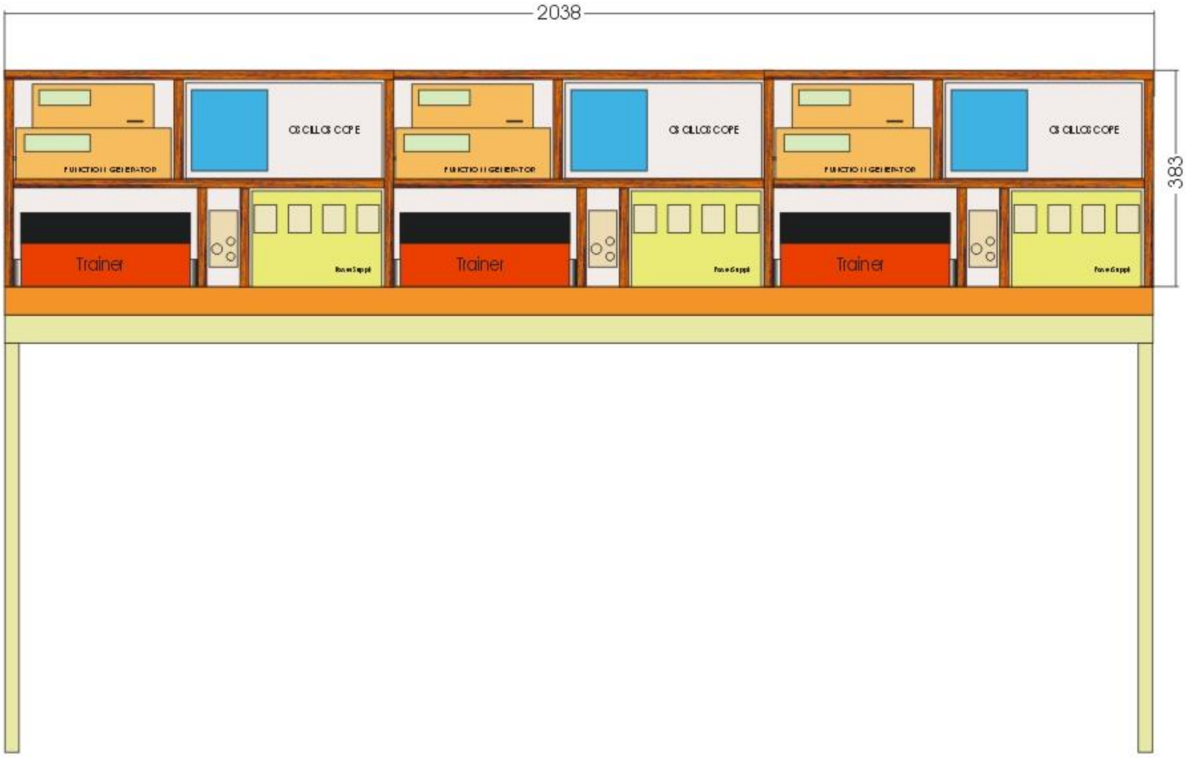


Figure 29. Workbench containing Three Sets of Equipment

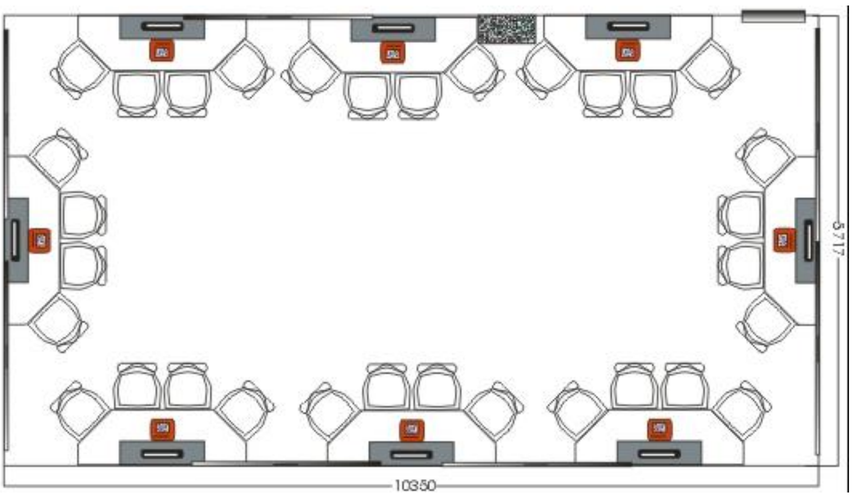


Figure 30. Suggested Layout of PBL Facility for Groups up to Four

Instruments can be placed in a configuration as shown in Figure 31, with whiteboards mounted nearby to enable participation of all group members during group discussions.

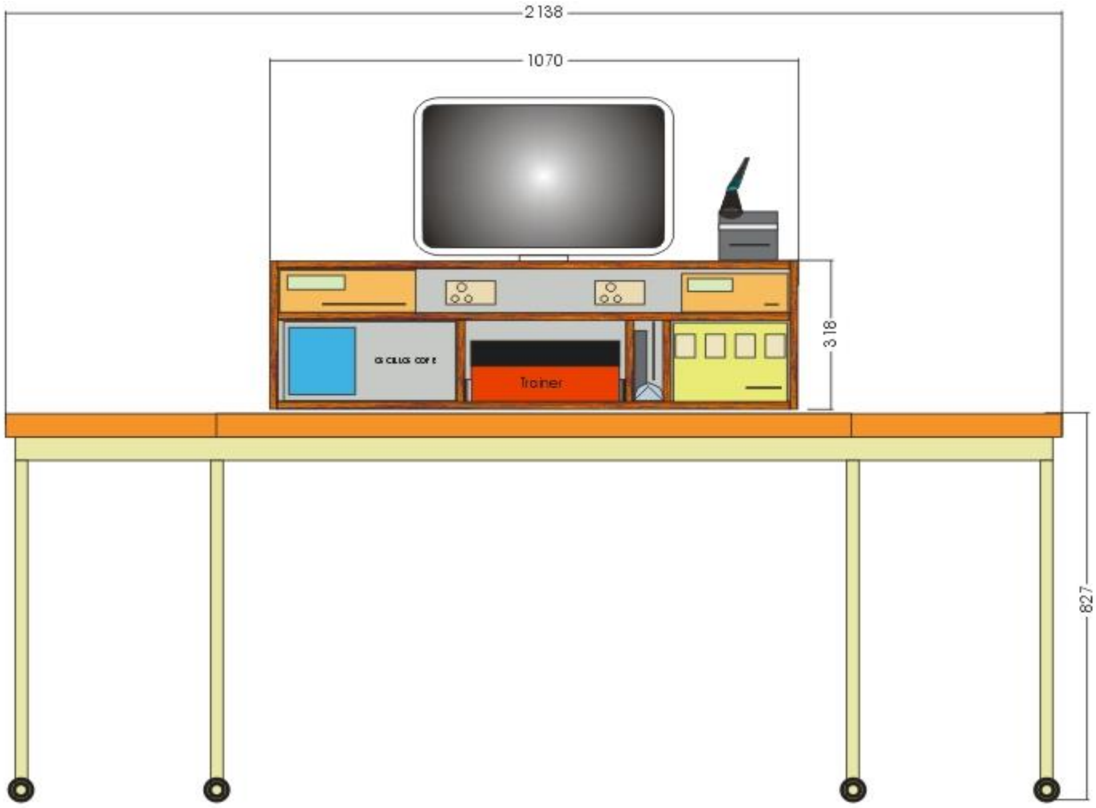


Figure 31. Workbench containing One Set of Equipment – Wall Mounted

The venue can quickly be turned into a lecturing room when required by re-arranging the tables and chairs as shown in Figure 32. Whiteboard placements should be on both sides of one workstation for lecturing purpose.

Minimal usable whiteboard space may be lost due to the AIO computer in front of it, but extra-large whiteboards may compensate for that. Alternatively, reducing the workstations from 8 to 7 which results in a 28-seater instead of a 32-seater.

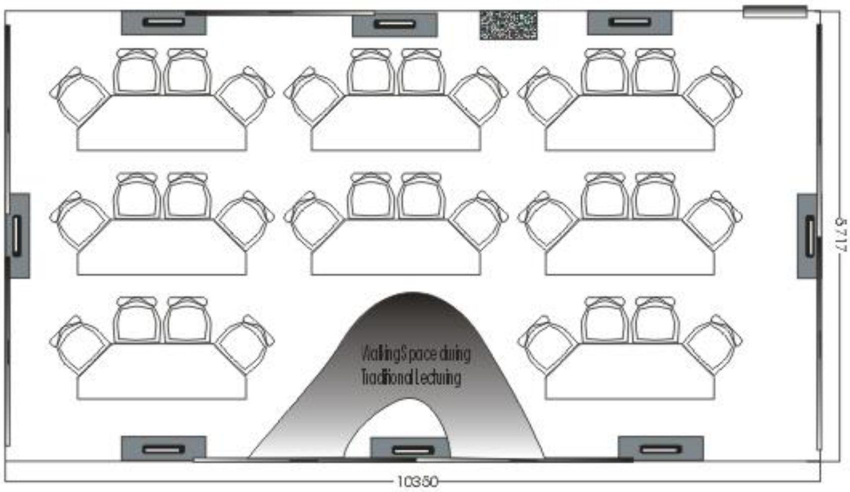


Figure 32. Placement of Benches during Lecturing

Another solution is to mount the workstation in front of the whiteboard on a sliding system so that it could be moved out of the way during lectures.

Tables can be placed as shown in Figure 33 when students need to meet in larger groups for instance when two groups of four meet during a group evaluation. One of the laboratories at WSU was actually converted during the time of writing this thesis based on the guidelines as discussed in this Chapter. Various photos of the laboratory is shown in APPENDIX AA.

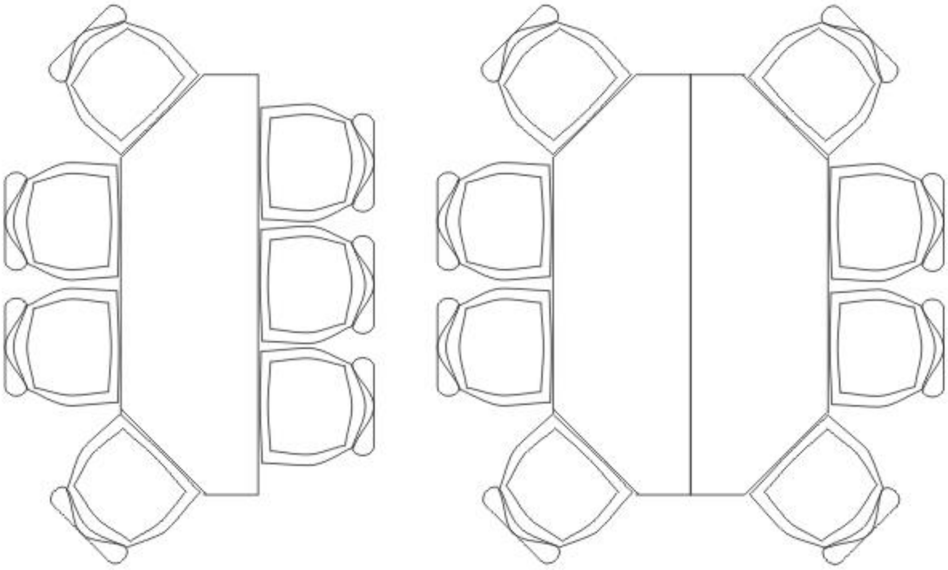


Figure 33. Larger Group Meetings without Instruments etc.

A partnership project between WSU, Stellenbosch University and Coventry University (United Kingdom) were formed during 2018. This project focuses on knowledge exchange for the enhancement of the engineering education programs at WSU and cover the following objectives:

1. Enhancing communication skills of engineering graduates;
2. Enhancing staff capacity towards teaching for the "world of work";
3. Enhancing capacity to implement project and problem based learning.
4. Enhancing staff capacity to undertake postgraduate supervision;
5. Developing curriculum mapping as a tool for curriculum analysis

It is especially objective 3; “Enhancing capacity to implement project and problem based learning” that may link up with this research.

FUTURE POSSIBILITIES OF PBL IN SOUTH AFRICA

Future education in South Africa may include several rural based well equipped “mini-satellite venues” to accommodate poor students in those areas. Each venue should have a tutor, and may be equipped to accommodate students from various fields. The group-based, active learning PBL-method will strengthen students learning. Many of these activities may later on shift from the “mini-satellite venues” to homes, and groups may then interact on-line. This is perhaps a far-fetched theory, but it may be a good solution for various reasons.

In South Africa, more than 90% of households can be considered as poor or belonging to the working class (Masutha, 2018). The "fees must fall" campaign started in 2015, where students demand free education (Wikepedia, 2017). In 2018, President Zuma announced free higher education for poor students, something South Africa may not be able to afford in the long run (Muller, 2018). The area of South Africa is 1,219,912 km^2 and extends 1,821 km north-east to south-west and 1,066 km south-east to north-west (Nations Encyclopedia, 2018). Some of the South African students may live very far from any university – See Figure 34 for the university locations according to Eton (2017). These students need to travel extensively and find alternative accommodation close to a university of their choice to study. This can be costly, and the free education may not cover all of these.

A possible solution towards reducing the cost of education in South Africa for students living in rural areas can be as follow:

- Find suitable venues within rural areas for instance spare class room/s at a school.
- Equip them as required based on the concept as discussed before in Figure 30 - Figure 33. The demand in a specific area should guide the capacity for instance, one workstation for every student group of up to four should be sufficient.
- Work stations should be specific towards the field for instance, some will be for Electrical engineering, others for Mechanical engineering and some for Civil engineering and so on. All of these can be in one venue.
- The PBL method can be followed in these venues. One (wandering) tutor with the relevant background should be sufficient to assist up to eight groups in one venue whilst students are busy solving the problems.

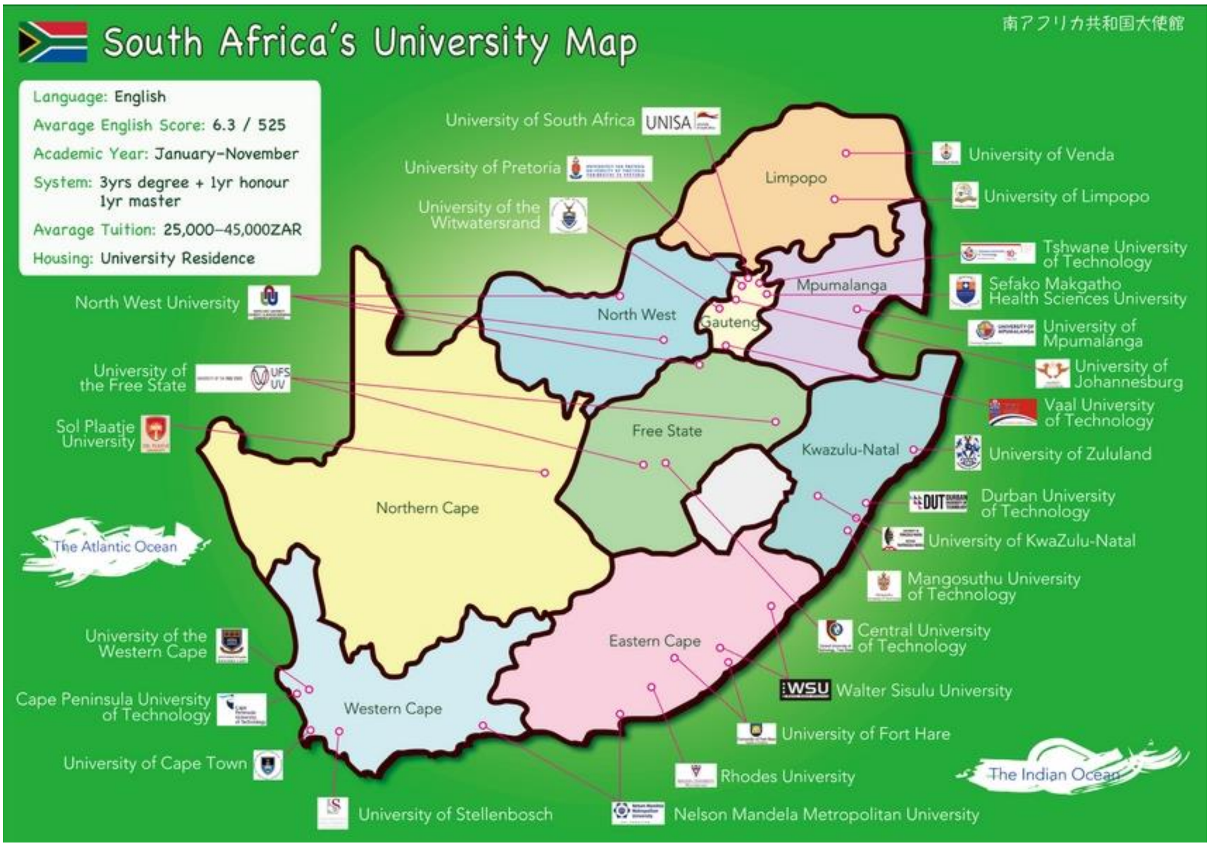


Figure 34. Location of South African Universities (Eton, 2017)

- Classes can be online with the instructor teaches 'live' and takes questions, possibly by streaming video. Each group can use the microphone equipped computer at their workstation to participate in the discussions. The use of headphones may possibly minimize interference with other groups. Another option is the use of self-paced online classes where a course is designed to allow students to proceed at their own pace and on their own schedules. Internet resources, like video- or audio-recorded lectures, are available all the time. Students communicate with instructors via Blackboard or similar (Powell & Jurling, 2018).

- The tutor should have excess to a well-equipped store to provide students with components and advanced instruments when required.
- In some cases, it may be required from students to gather on the campus from time to time.

The Internet has had a revolutionary impact on culture, commerce, and technology, including the rise of near-instant communication by electronic mail, instant messaging, voice over Internet Protocol (VoIP) telephone calls, two-way interactive video calls, and the World Wide Web with its discussion forums, blogs, social networking, and online shopping sites (Hilbert & López, 2011).

It was not too long ago that the library was almost always required to do research. Those days, you had to meet classmates and teachers at schools and offices to work together. Today, students can access information with just a few clicks and collaborate online. The Internet has changed virtually every aspect of education as students attend classes on the Web and find more opportunities to learn than ever before (Delzotto, 2018a). The Internet was already used as an essential study aid outside the classroom during 2001, and at the time, Simon, Graziano, and Lenhart (2001) predicted the use of the internet inside the classroom. These days, the effects of computer technology can be readily observed in classrooms full of students texting away on their smartphones with substantial amounts of information literally available at their fingertips (Delzotto, 2018b). Distance communication technologies such as blogs, wikis and Webinars are becoming more and more useful in the field of higher education, allow groups to interact with each other while being hundreds, if not thousands of kilometers apart (Cotter, 2017). Some classrooms take place entirely on the Web making it possible for the geographically-isolated and the underprivileged to connect to broader learning communities (Delzotto, 2018b). It is possible today to connect with the world outside homes, classrooms, and Internet cafes and plug into the Library of Congress, make virtual visits to famous museums in the world, write to celebrities, and even send questions to heads of states (Nuer, 2013).

So, how may the education of tomorrow look like? Is the "dying off" of the shopping malls in Northern America some indication of what the future of education may hold? Analysts estimate that 1 out of every 4 malls in the U.S. could be out of business by 2022. They may be victims of changing tastes, a widening wealth gap and the embrace of online shopping for everything from socks to swing sets according to Sanburn (2017).

If online shopping became so popular, the same may apply to education. Socio-economic factors such as poverty and the ongoing strikes may just as well be the trigger point in South Africa. Most students prefer to study and finish their studies in the shortest possible time so that they can become independent.

The possible future of education may be PBL orientated. Students may still work in groups within the PBL mode, but the meetings may be mostly online, using blogs, wikis, LinkedIn, Twitter, Facebook, podcasts and Webinars (provided the internet speed is sufficient). They may only meet in-person when it is required to construct some sort of an artefact or during assessments that can't be done otherwise. When the artefact consist of various individuals modules, then students may also do their part at home where possible and combine the various parts when they meet.

Further evolution in education may omit the traditional semester and year courses. It may happen that students start a module whenever they are ready and join a national or international PBL group at the time. Students should collaborate during the design phase of an artefact, for instance when an electronic circuit such as a power supply is required. At least one student in the group then needs to construct the artefact and demonstrate it on-line perhaps via video to the other group members. Everybody then needs to familiarize themselves with the artefact. The course should be designed in such a way so that each student needs to construct a certain minimum amount of artefacts. A central computerized system can be used to control the process e.g. check if student meet pre-requisites requirements, allocate student to a group, arrange assessment etc.

CONCLUSIONS

The traditional approach to teaching is good, however not sufficient anymore; Lectures and well-defined, closed mono-disciplinary problems together with laboratory experiments help students mostly to graduate with satisfactory knowledge of fundamental engineering science and computer literacy, but they do not know how to apply that in practice. Students tend to memorize new information instead of using it as a tool to solve problems. The PBL learning style on the other hand, influence students to examine resources more frequently, and this develop patterns that define the proactive lifelong learning during the transition from a novice to an expert learner (Benner, Tanner, & Chesla, 1996; Boss, 2014).

Students' performance who followed the traditional lecturing mode is insufficient; it doesn't match with needs in their coming jobs. Employers expect more from graduates, especially when it comes to the 'application of knowledge', 'communication skills', 'decision-making skills', 'analytical skills', 'teamwork skills', 'well-practiced leadership skills' and 'good interpersonal skills' and 'entrepreneurial skills'. PBL can address these problems and develops the skills required by employers when implemented at a reasonably realistic scale.

The impact of a hybrid between PBL and traditional learning in a reasonable large scale e.g. for Electrical Engineering, should be researched. The skill needed by the employer (as mentioned in Table 1) is especially important and an attempt should be made to measure at least the improvement of the higher ranked ones. Practice-based research can then be taken to the next level by replacing even more of the traditional delivery modes with PBL methods. Results from the research should guide the university to identify the best practices finally.

In order to perform successfully in the future, WSU will require a team effort. Management should be actively engaged, strengthened by the needed policies and corresponding facility support systems. Staff directly involved should be trained in the implementation of PBL by means of workshops and online courses, for instance see the web-site of Dahms, Kolmos, and Velmurugan (2018). Staff can also attend one of the different types of educational and consultancies for instance at the Aalborg University (2018). Facilities may also be adjusted to ensure that it support the PBL processes and -experience.

Results from this study go along with those from the literature e.g. PBL causes an increase in the students' attitude, motivation and reflection. It also shows that PBL is more effective when students enter PBL with a higher level of prior knowledge. This may be further enhanced by utilizing various problems in parallel which may also result in vicarious learning taken place.

This study shows how students and future employees may benefit when PBL be implemented at WSU. It also recommends a process and methods to follow, that will suit WSU engineering departments the best.

With this study, my desire is not only to improve my own qualification, but to also contribute towards and to improve the quality of the education of the WSU students and beyond. It is my wish that the staff and university will buy into this, and PBL be implemented as suggested so that our graduates became better engineers who are able to apply what they have learned and became problem-solvers.

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APPENDICES

APPENDIX A

Example of an Electronic circuit Build on a Breadboard.

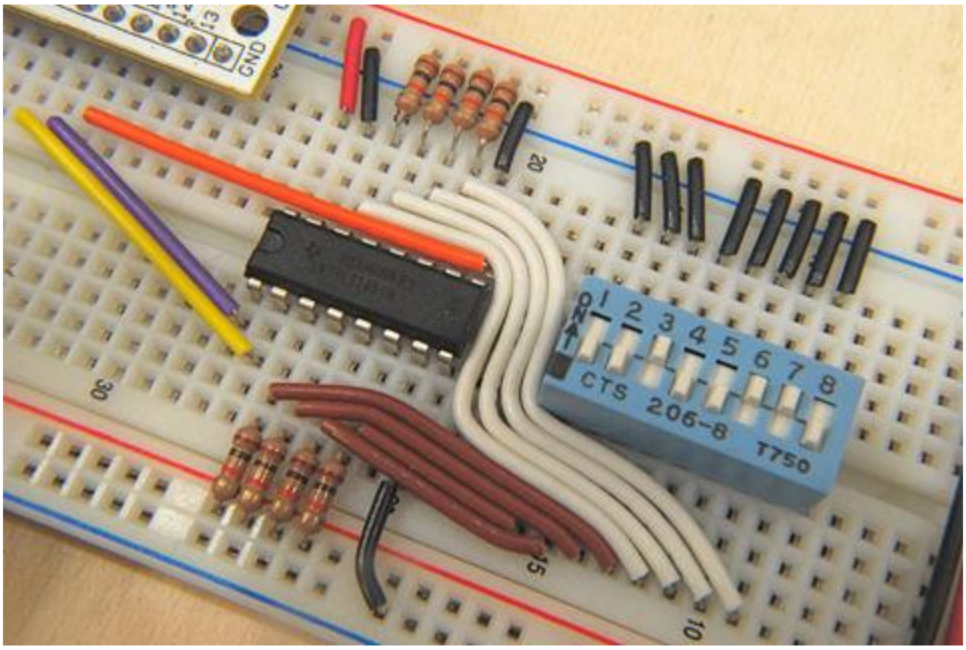


Figure 35. Example of an Electronic Circuit constructed on a typical Breadboard. Image from (Shams, 2017)

APPENDIX B

Typical Simulation of a basic transistor circuit

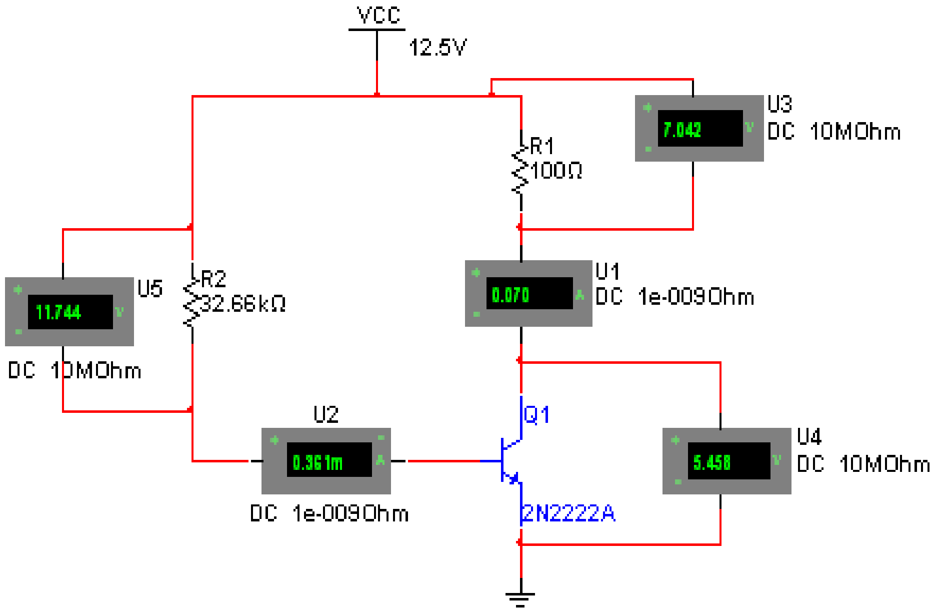


Figure 36. Simulation - Example of a typical Transistor Circuit, showing various Simulated Values

APPENDIX C

Remote Lab indicating various measured and calculated values

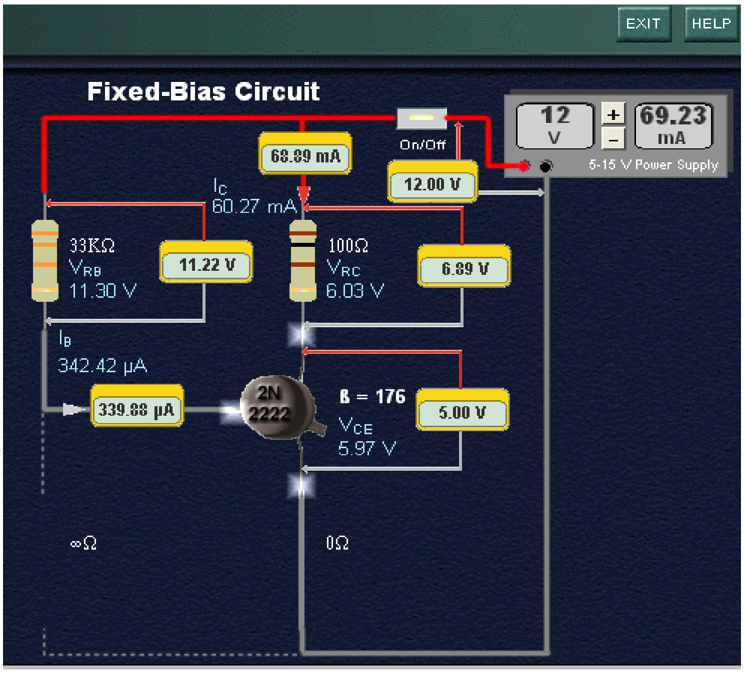


Figure 37. Remote Lab - Example of a typical Transistor Circuit, showing various calculated and measured Values

Changing various components and parameters with the Remote Lab is effortless

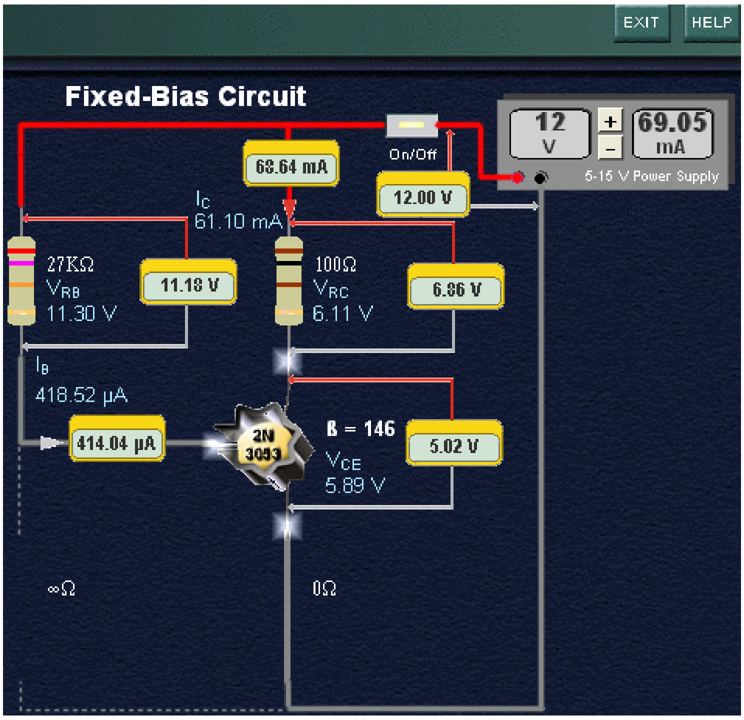


Figure 38. Remote Lab - Example of another Transistor Circuit, showing various calculated and measured Values

The Remote Lab is also capable of introducing various faults within the circuit and shows measured versus calculated values

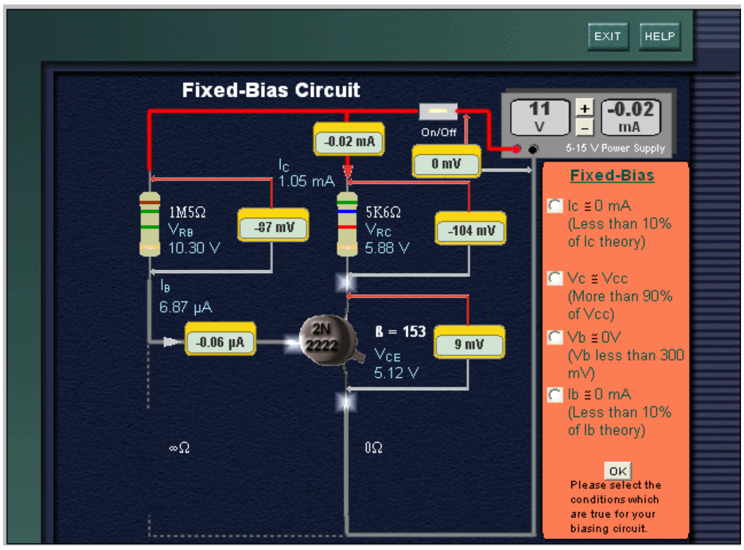


Figure 39. Remote Lab - Example of another Transistor Circuit, showing various calculated and measured Values

APPENDIX D

Remote Lab Hardware

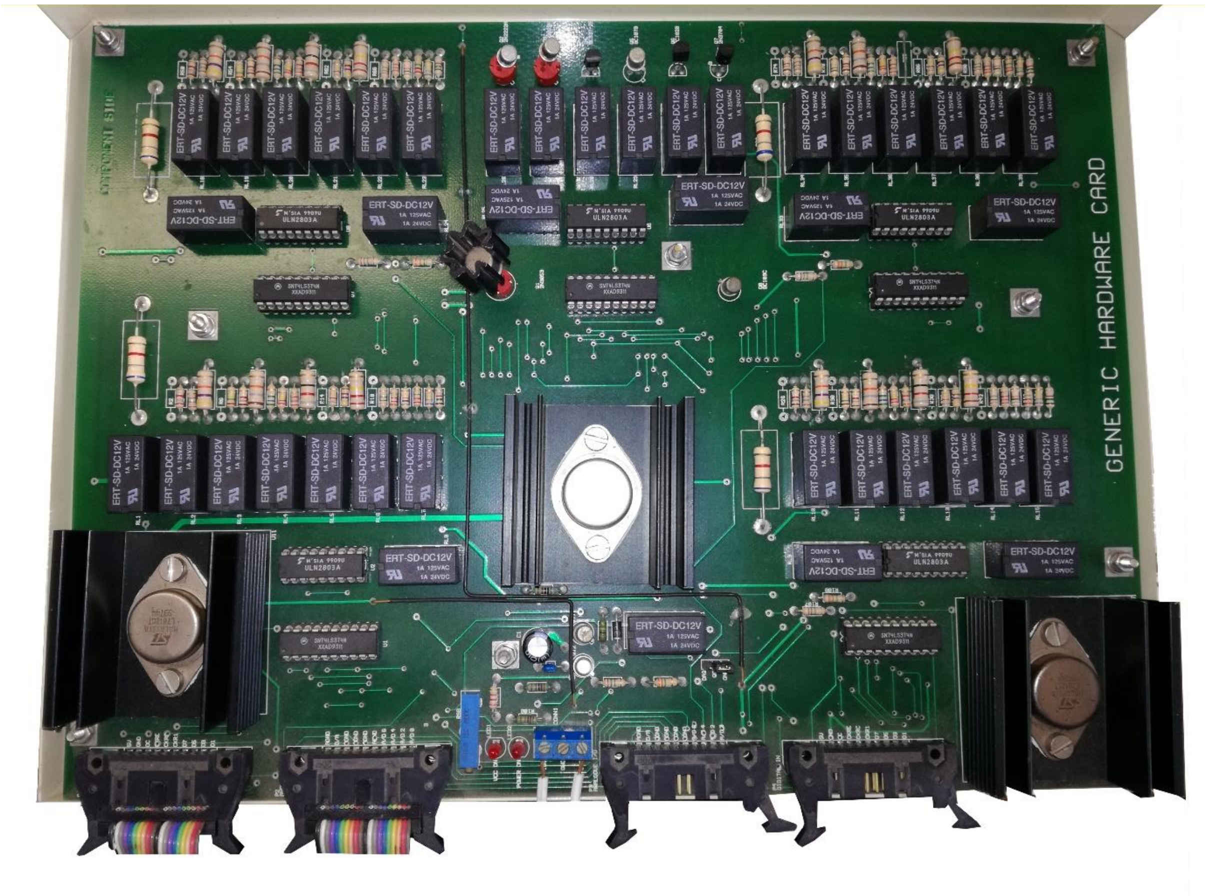


Figure 40. Internet Enabled Remote Lab capable of doing selective Transistor Experiments

APPENDIX E

Problem to be solved during 1st Remote Lab – Pilot study

1.1 FIXED BIAS TRANSISTOR CIRCUITS

This experiment will introduce the learner to transistor dc-biasing.

1.2 Learning Objectives

After completing this experiment, the student must be able to:

- Design and build various fixed bias transistor circuits
- Measure all relevant voltage and current values and compare it with theoretical values
- Predict the changes in voltage and current values with a change in selected circuit components
- Determine the circuit response for all possible faults

1.3 Components and EQUIPMENT required:

The following will be required to successfully complete this practical:

Group A

- Internet enabled PC
- Calculator
- RCAnalysis software (Remote Lab)

Group B

- A wide range of standard resistors with a power rating of at least 0.5 W (or as required)
- A selection of transistors such as a 2N3053, 2N222A, BC337, BC107B, BC182 and 2N3704 (or other available Transistor's)
- DC Power supply
- Digital Multimeter
- Breadboard and appropriate wires
- Calculator

1.4 STUDENT INDUCTION

Many students do not have adequate skills to be able to absorb knowledge and an understanding through independent (traditional) learning. In addition, this approach does not foster the development of the key skills, in particular creativity, critical thinking, communication and interpersonal skills, nor does it allow for the level of deep learning that you can achieve through interaction and discussion.

Problem-based Learning (PBL) on the contrary is group-based and the learning is problem or project driven. It develops key skills and shows to be more effective in facilitating meaningful learning, fostering critical thinking skills and self-directed learning.

A strong emphasis has been put on the need for an actual shift from teacher-centered to student-centered systems, in which the development of interpersonal and professional capabilities (e.g. working in groups, leadership, making presentations, writing technical reports, tackling a problem) gains relevance, the demand being that the opportunities for their development should be made explicit in the learning experience. Problem-based Learning (PBL) and Project Led Education (PLE) seem to achieve these goals, providing a framework in which students "learn by doing", in a dialectic relationship between academic theory and professional practice. *(Dialectic means: Any formal system of reasoning that arrives at the truth by the exchange of logical arguments)*

We will make use of the PBL method when doing this experiment. Students should be aware that the learning is facilitated through guidance, experience, discussion, making mistakes, exploration, reflection and in context. Students will be placed in groups of 2 and each member of the group must operate effectively for the group learning process to be positive and productive.

This experiment forms part of a research project that tests the contribution of Remote Labs towards PBL. One half of all the groups will therefore doing their experiments, using Remote Labs, while the remaining groups need to do experiments in the traditional way. Students should stick to the method that they are supposed to use and not be involved in the other method in any way to ensure reliable results.

1.5 Pre-required KNOWLEDGE

Students should have covered:

- Transistor theory and transistor characteristics
  The following elements of transistor applications:
  - DC Biasing principles
  - DC Load line
  - Operating point
- Fixed bias (base bias) circuits

Students should study the above topics on their own and can use the following resources:

- The computer based training material "*Etro1 800X600 R2*"
- Prescribed text book
- Material available from library
- Material available on the internet
- Any other source of material

Students should work in the pre-allocated groups (of 3) and use the PBL method to solve the following problem:

1.6 THE PROBLEM

Assume that you are working for a large international electronic company called "World Wide Electronics" (WWE). They have tasked you to design and test a simple transistor circuit that will operate in such a way so that VCE is close to half of the supply voltage when no external signal is injected. This circuit will eventually be part of a larger electronic circuit for a newly Hybrid car currently under development.

WWE is not sure of the current requirements for the circuit at this stage, but they do know that the supply voltage will vary between 11V (when the battery bank is flat) and 14V (during charging). They also want to keep the cost down and have requested that the absolute minimum number of components be used. Another strategy of WWE is to try and use similar components as far as possible for the various electronic circuits in an attempt to limit the overall variety of components on the parts list. The following transistors are already in use in some of the other circuits: 2N3053, 2N222A, BC337, BC107B, BC182 and 2N3704.
Your boss at WWE expects you to be an expert on this circuit. He has requested you to investigate at least the following:

- A comparison between calculated and measured values for various conditions
- The effect on the current and voltage values when the resistor values are changed
- The effect on the current and voltage values for at least 3 of the available transistors
- The influence of a change of the supply voltage

WWE would also like to include this circuit and "Fault finding procedure" in the Service Manual of the car. They are concerned that not all "service staff" around the world would be able to fix this circuit once it is faulty. You are thus expected to document all possible faults and indicate the symptoms for each. Your boss wants to be sure that no mistakes are made and expect you to actually verify the response of the circuit when the faults are introduced in a real circuit.

1.7 Procedure

Groups

1. The tutor divides the class in groups of 2 (based on previous test results). Each group of 2 students will be called a "small group".
2. All evenly numbered groups will do Remote labs instead of the traditional labs (Group A).
3. All odd numbered groups will do the traditional labs instead of the Remote Labs (Group B).

1st Small group meeting

1. Students should meet in their respective small groups and discuss the problem situation as mentioned in 1.6 above. Each student in the group should use his/her own knowledge and experience and presume that they are personally asked to solve the problem/s.
2. The group should now come up with a small number of hypotheses that are likely to explain and solve the problem/s. *(Hypotheses means: A message expressing an opinion based on incomplete evidence)*
3. Once these hypotheses have been established the group negotiates an area of exploration for each member.

Individuals

4. The group now separate for a sufficient time to allow each group member to independently carry out the research which should include the experiments.
    - Evenly numbered groups will use "Remote labs" (use RCAnalysisR1)

- Odd numbered groups will use the traditional labs

2nd Small group meeting

5. The group will meet again and draw conclusions as to the nature of the problem/s and the best fit solutions, given the information known.
6. Finally, the group makes a professional presentation as to the solution and its consequences.

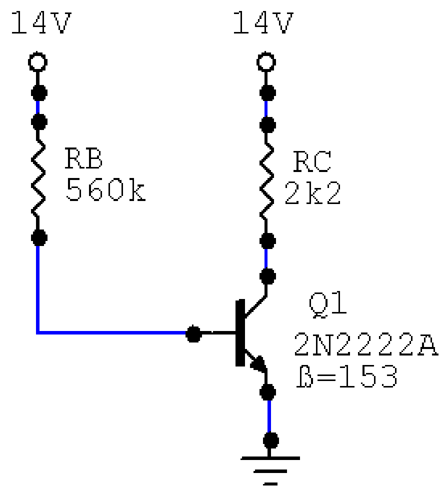
1.8 ASSESSMENT

Students will have a formative and summative assessment. Students will write a small individual test in the beginning to determine their prior knowledge.
On completion, each small group needs to submit a written report and making a public presentation before a three-member jury. The presentation is followed by a discussion period, in which students may be individually asked different questions. Complementarily, self and peer assessment will also be included. Students will also be required to write a small individual test.

1.9 FORMATIVE TEST

STUDENT NUMBER:________________________________

Consider the drawing below when answering the following multiple choice questions. (Circle the correct answer)



1. When R_C is changed from 2.2kΩ to 220kΩ then:
   a) I_C will increase
   b) I_C will decrease
   c) I_C will remain the same
   d) None of the above

2. When ß is changed from 153 to 170 then:
   a) I_B will increase and I_C will increase
   b) I_B will increase and I_C will decrease
   c) I_B will decrease and I_C will increase
   d) I_B will remain the same and I_C will increase
   e) None of the above

3. When R_B is changed from 560kΩ to 470kΩ then:
   a) I_B will increase, V_{CE} will increase and I_C will increase
   b) I_B will decrease, V_{CE} will decrease and I_C will decrease
   c) I_B will increase, V_{CE} will decrease and I_C will increase
   d) I_B will decrease, V_{CE} will increase and I_C will decrease
   e) None of the above

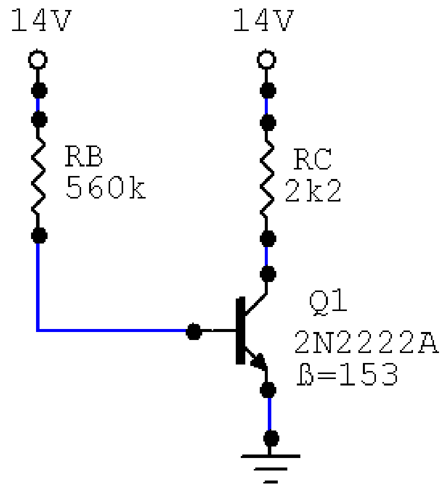
4. When R_B is faulty and open circuit then:
   a) I_C will be zero or near zero
   b) I_C will be very high
   c) V_C will be close to V_{CC}

d) None of the above

5. For the above circuit with values as shown:
   a) V_{CE} should be the closest to 3V
   b) V_{CE} should be the closest to 6V
   c) V_{CE} should be the closest to 9V
   d) V_{CE} should be the closest to 12V
   e) None of the above

2.0 Summative TEST

Consider the drawing below when answering the following multiple choice questions. (Circle the correct answer)



1. When R_C is changed from 2.2kΩ to 220kΩ then:
   a) I_C will increase
   b) I_C will remain the same
   c) I_C will decrease
   d) None of the above

2. When ß is changed from 153 to 170 then:
   a) I_B will remain the same and I_C will increase
   b) I_B will increase and I_C will decrease
   c) I_B will decrease and I_C will increase
   d) I_B will increase and I_C will increase
   e) None of the above

3. When R_B is changed from 560kΩ to 470kΩ then:
   a) I_B will increase, V_{CE} will increase and I_C will increase
   b) I_B will increase, V_{CE} will decrease and I_C will increase
   c) I_B will decrease, V_{CE} will decrease and I_C will decrease
   d) I_B will decrease, V_{CE} will increase and I_C will decrease
   e) None of the above

4. When R_B is faulty and open circuit then:
   a) V_C will be close to V_{CC}
   b) I_C will be very high
   c) I_C will be zero or near zero
   d) None of the above

5. For the above circuit with values as shown:
   a) V_{CE} should be the closest to 3V
   b) V_{CE} should be the closest to 6V
   c) V_{CE} should be the closest to 9V
   d) V_{CE} should be the closest to 12V
   e) None of the above

Student Number _______________ Surname ___________________ Initials ____
Small Group ______
Method used: **Remote Lab** or **Traditional Lab** (Please circle one)

APPENDIX F

Scores - Remote Lab versus Breadboard using PBL.

Table 29. Score for Problem to be solved during 1st Remote Lab versus Breadboard in PBL Mode

Group	Small Group	Name	Student Number	%
Breadboard	1	Sonaba S	210163011	4
Breadboard	1	Mancoba	209120231	62
Breadboard	3	Mbenyer A	210163070	8
Breadboard	3	Rasi J S	209188480	56
Breadboard	5	Mhbali	210162864	20
Breadboard	5	Madikizela N.P	210099100	42
Breadboard	7	Mxokozeli T.G	210163062	22
Breadboard	7	Sentse O	201050072	38
Breadboard	9	Matoti N.F	210009403	32
Breadboard	9	Booi L.M	210163003	34
			Average	**32**
Remote Lab	2	Mpika G.L	210163178	8
Remote Lab	2	Skotha S	201096625	60
Remote Lab	4	Zaboluna Z	204018963	18
Remote Lab	4	Matoss N	210085605	56
Remote Lab	6	Mlunsu Z	210163127	20
Remote Lab	6	Maya L	201062224	40
Remote Lab	8	Rubuluma Z	210013893	32
Remote Lab	8	Kebe N	201082845	36
Remote Lab	10	Ndlebe Q.S	210162499	32
Remote Lab	10	Mqele A.A	210162813	34
			Average	**34**

APPENDIX G

Results from Test 1 and Test 1B

There were various disruptions (strikes) during the semester 1, 2011 and the 1st class with a significant number of students was on the 10th of February. The students had their 1st theoretical test before any experiments were done and the results were generally very poor, ranging from 8% to 71% overall, with an average of 30% for each group. Figure 41 shows the results for each of the groups. (One of the R-Group students quit the course and the marks for that student will not be shown in any of the graphs).

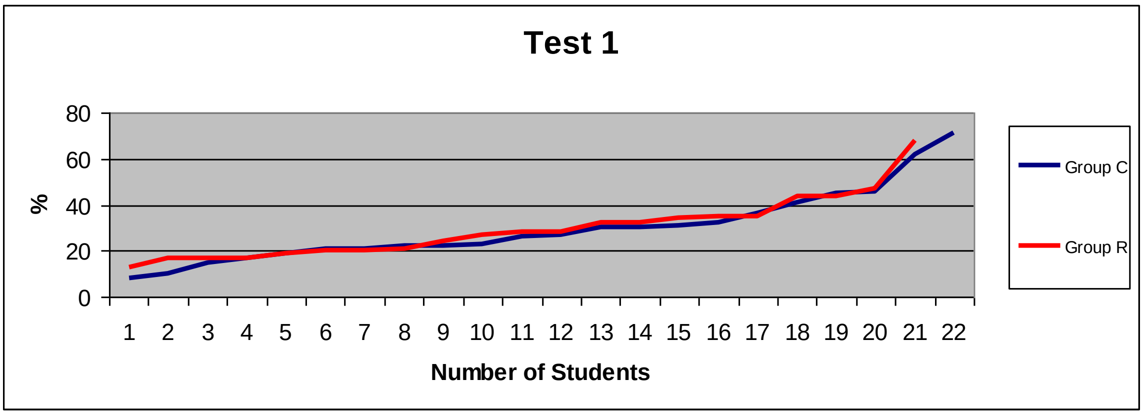


Figure 41. Results of the 1st Test for both Groups

Students were then given the opportunity to improve their results during Test 1B. It includes additional work since it was only done on the 16th of May. At that stage, students were almost done with the 2nd experiment (as discussed in the chapter "Mixing Problem-based Learning and Conventional Teaching Methods in an Analog Electronics Course"). This test was done in the Black Board environment, using many of the available options such as True/False, Multiple Choice, Hot Spots, Calculated Formula, Calculated Numeric, Multiple Answers and Fill in the Blank. The test includes questions from various old exam papers and was very comprehensive (it consists of 85 questions). There was a big improvement in the student marks, ranging from 22% to 85% with an average of 50% overall, an average improvement of 20%. Figure 42 shows the improvement in marks between test 1 and test 1B.

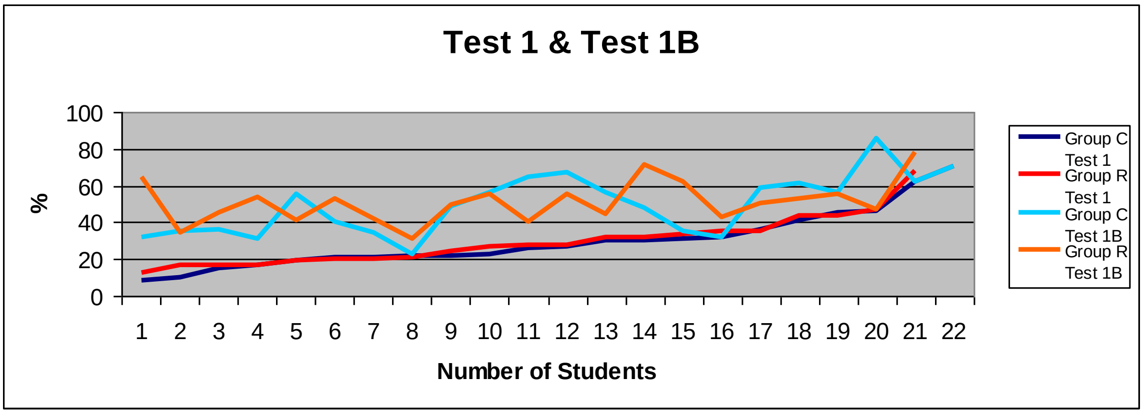


Figure 42. Results for Test 1 and Test 1B for both Groups

It appears as if the lower part (student 1-9) of the R-group students did slightly better than the C-group students while it were the other way round for students 11-13 and 17-20. (*Test1B was a voluntary test to allow students to improve their marks and students 8, 16 and 21 of Group C chooses not to participate and therefore received the same mark as what they achieved during Test 1*)

APPENDIX H

Electronics I – Practical Experiment – Traditional Method

Most of the electrical engineering students at tertiary institutions in South Africa experience difficulty in graduating within the minimum required time. This is caused due to the high failure rate within some of the major subjects. These days, students are also limited on the number of times that they are allowed to re-register for any of the 21 or so subjects required to complete their diploma, causing many of them to "drop-out". Employee's also complained about the lack of skills from graduates in the work environment. It also seems that most students at WSU struggle to complete the subject "Design Projects 3". In this subject, students are required to use their knowledge and skills from various subjects to design, develop, construct and present a project of a certain minimum required level.
It is clear that we are dealing with a real problem and that something should be done about it. In an attempt to improve the situation, we will start implementing changes to the Electronics I mainstream class at College Street. We will use Action-based Research when we do the experiments/lab's in this class and all the students will be co-researchers. Action-based Research includes; planning, acting, observing and reflecting as shown in Figure 43. Lessons learned will then be transferred to the next experiment.

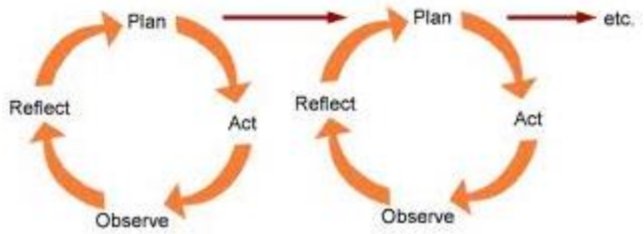


Figure 43. Lessons learned during the planning, acting, observing and reflecting need to be transferred to the next Experiment

Problem
The problem that we need to solve is to improve the pass-rate of students, and also to turn students into engineers that are more capable and usable to industry.
The students are part of this problem and they will be involved in all the phases. Electronics I will be used as a test bed.

Planning
Individual views, understanding, perceptions and assumptions will be shared during the planning phase and alternatives will also be considered. These alternatives will include Problem-based Learning (PBL) and Remote Labs (RL).

Action
The Lab's/experiments will be done in the light of new insight. This will begin to change the situation. Students will be working in groups of two and will be randomly selected. Students should remain in these groups for the entire semester.

Observe
Look at the experience gained from the Lab/experiment done and decide what worked and what not and why.

Reflections
Discuss progress, lessons learned, and next steps. Students will be required to submit a report and selective students might be asked to present their reflections.

Experiment 1 – Diode Biasing

This is the 1st experiment of Electronics I and will be the starting point of the Action-based learning. The experiment is still designed in the traditional way and students should carefully observe and reflect the strong and weak points of this method to allow for improvements during the planning of the next experiment in an attempt to solve the problem mentioned before.

Software needed
Multisim
Microsoft Excel

Components needed
68Ω Resistor ($\geq$ 1W)
1 x 1N4001 – 1N4007 diode (or equivalent)
1 x Breadboard

Instruments needed
DC power supply
Digital multimeter (DMM)

1. **The forward and reverse bias current and voltages in a series diode circuit.**

   (Use the Answer sheet at the back)

   Aim: To prove that a diode is a one way conductor.

   A. Use Multisim

   Steps:

   1. Build the circuit as shown in Figure 44.
   2. Adjust the power supply voltage (E) to 10 V
   3. Record I_F, V_F and $V_{RESISTOR}$ in Table 30.
   4. Change the polarities of the power supply around so that the circuit is reverse biased.
   5. Record I_R, V_R and $V_{RESISTOR}$ in Table 30.

   B. Use a Breadboard and instruments and repeat steps 1-4 above

2. **Plotting the forward operating region V-I characteristic curve of a diode.**

Aim: To sketch the voltage – current characteristic curve of a real silicon diode when forward biased, and to prove that it starts to conduct at approximately 0.7 V.

(Use the Answer sheet at the back)

A. Use Multisim

Steps:

1. Build the circuit as shown in Figure 44.
2. Adjust the power supply voltage (E) to 0 V and record V_D, V_R and I_D in Table 31.
3. Adjust the power supply voltage to 0.1 V and record V_D, V_R and I_D in Table 31.
4. Complete the remaining part of Table 31 in a similar way.

B. Use a Breadboard and instruments and repeat steps 1-4 above

(Tip: Choose the most accurate selection on your DMM)

C. Plot Graph

a. Plot the data and complete the graph with the aid of Figure 45
b. Use Excel to plot the graph of the data and compare it with Figure 45 (the hand graph).

D. Answer the remaining questions on the answer sheet

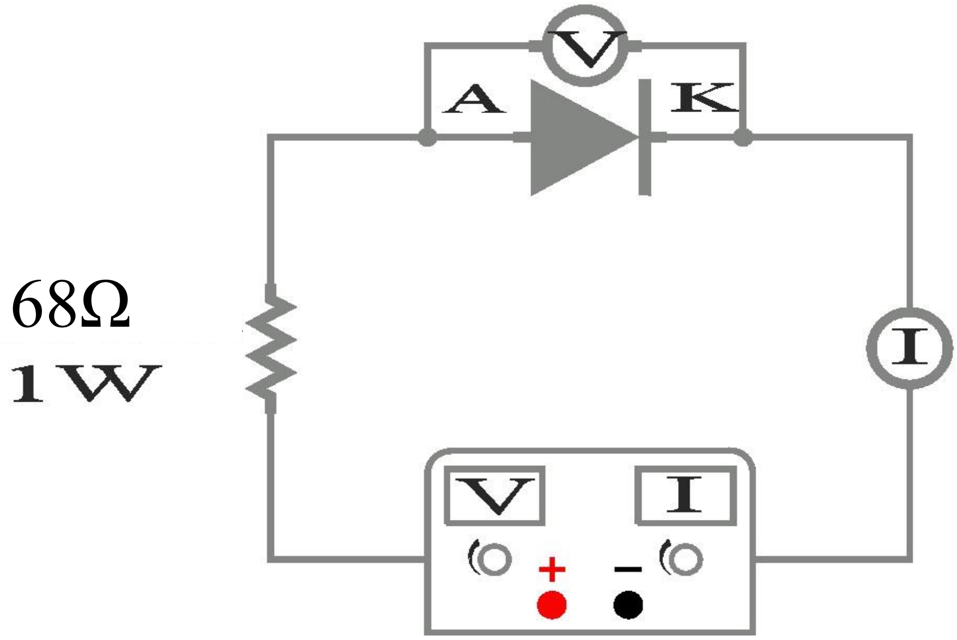


Figure 44. Plotting the Forward Biased V-I Characteristics of a Silicon Diode

Answer Sheet for ETRO1 Unit/Objective 3 Practical Experiment

Student Number: ___________________ Date: ________________

Student Number: ___________________

1. **Measure the forward and reverse bias current and voltage.**

Table 30. Current and Voltages in a Diode Circuit

Biasing	Unit	Simulation	Breadboard Circuit
Forward	I_F		
	V_F		
	$V_{RESISTOR}$		
Reverse	I_R		
	V_R		
	$V_{RESISTOR}$		

(6)

Can we assume that a diode is a one way conductor from the above measurements? Why? (2)

____
____
____
____
____
____

Discuss $V_{RESISTOR}$ (2)

____
____
____
____
____
____

2. Plotting the forward operating region V-I characteristic curve of a diode.

Table 31. V-I Characteristic Data of a Silicon Diode

	Simulation			Breadboard Circuit		
E	**V_D (V)**	**V_R (V)**	**I_D (mA)**	**V_D (V)**	**V_R (V)**	**I_D (mA)**
0.0						
0.1						
0.2						
0.3						
0.4						
0.5						
0.6						
0.7						
0.8						
0.9						
1.0						
1.2						
1.5						
5						
10						
20						
30						

(5)

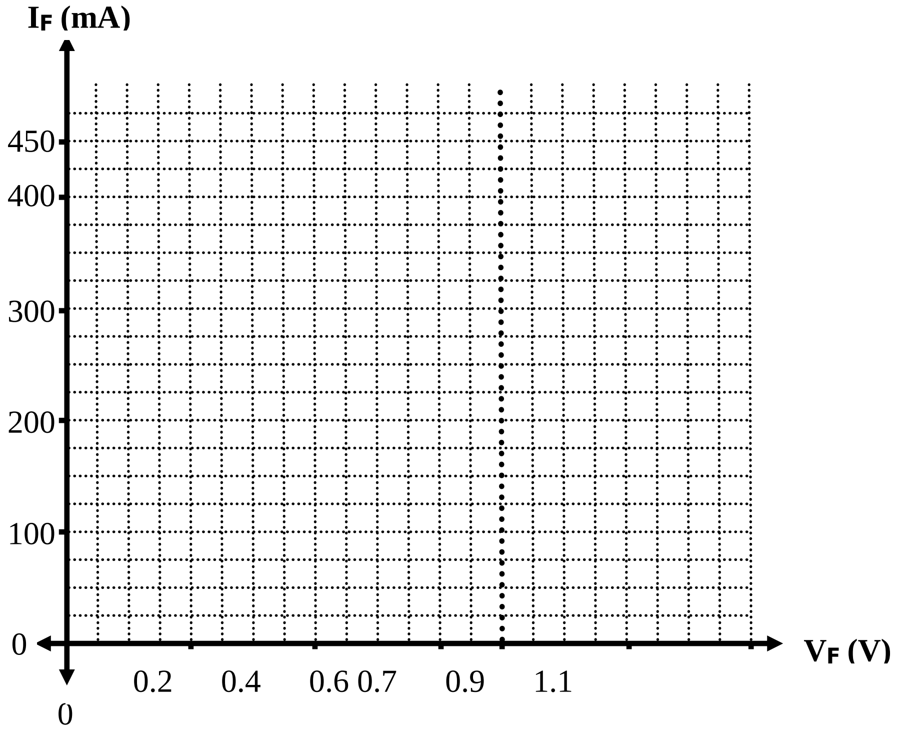


Figure 45. Characteristic Curve of 1N4007

This graph (5)

Excel graph (5)

Analyse and discuss your results (10)

TOTAL [35]

APPENDIX I

Electronics I – Practical Experiment – Traditional Method – Additional information.

The instructions as shown in APPENDIX H were given to the students and they had to work in their pre-assigned pairs. This experiment went well and it actually prepared the students and set the standard for the experiments to follow. From the Reflection survey it can be seen that most of the students enjoyed working in pairs. It was also emphasized to them that it is ok to make mistakes because they will learn a lot from that (which they strongly agreed upon during the reflection surveys later). They have learned that different ways could be used to get information and that different ways could be used to present data e.g. tables and graphs. They also learned that they can conclude on the results. The students have also enjoyed comparing simulated and measured results, and they have learned that it is good to do both. The have learned that results should be closely related but not necessary exactly similar.

Most of the student did not have any previous experience with Excel and they did not cover that in the Computer skills class at the time. These had to be demonstrate to them. Most students got the Excel calculations and graphs right but they were very uncertain in what they were doing nevertheless positive from the experience. They admitted afterwards that they have learned a lot from it.

The experiment were identical for both groups and one would expect similar results, but the C-group did better with an average mark of 81% compared to 75% for the R-Group. It also seems that there is no real correlation between the test results and the results of experiment 1 as shown in Figure 46.

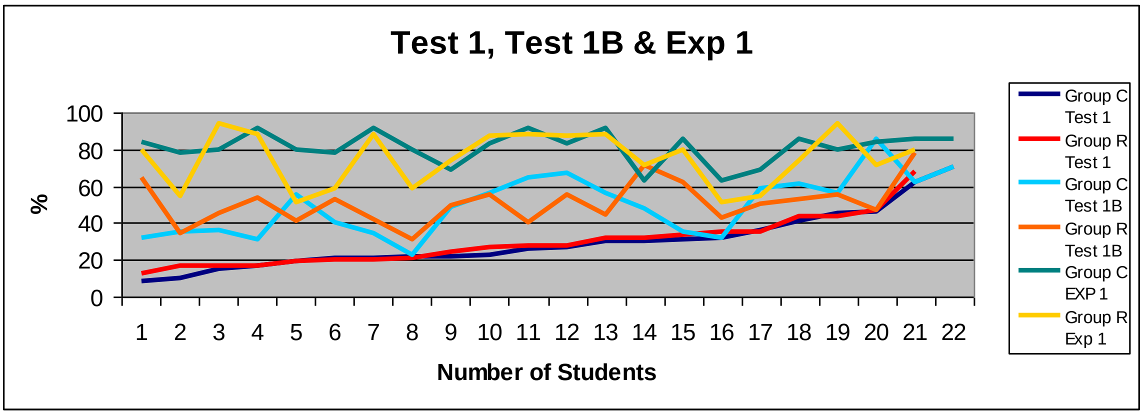


Figure 46. Relationship between Test and Experiment Results

It is interesting to see that 14 students from the R-group did worse in experiment 1 as shown in Figure 47. Also, some of the students who did not fair that well in the tests did very well in experiment 1.

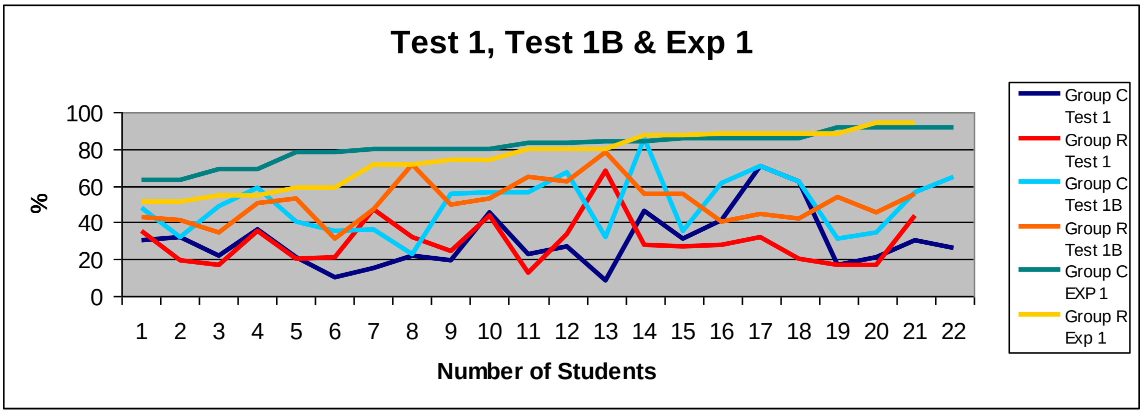


Figure 47. Test and Experiment Results

A few questions not related to the experiments and the research were included in the reflection survey e.g. Q49 "*I like it when we are doing the activities in the class*" and Q50 "*I like it when we use the drawings and animations in the class*". The purpose was to see how the students experienced the activities and animations because a few weeks into the semester, some activities were added on Blackboard and students allowed to individually answer these after each lesson. The students enjoyed this because it gave them some indication on how well they understood the work just covered. Activities were open-book since it includes new formulas in many cases and it also helps the students to determine where to find the answers. The activities also serves as an indication if students need additional help with some parts of the lesson.

Animations (via a data projector) were used to explain the lessons and feedback from the reflection survey indicated a positive and pleasant experience by the students. Most theory classes were in a computer Lab and the students were able to play these animations during class time or afterwards in their own time. Students were also allowed to do simulations from time to time and it seems that students were very positive about this since it helped them to understand the theory better.

APPENDIX J

Conventional Teaching Methods versus PBL - additional information

Students were required to build a DC Power Supply with the C-group still using the traditional method while the R-group had to use the PBL method. Both groups did the same pre-test to test their prior knowledge. Certain theoretical lessons related to experiment 2 were then deliberately not covered with the R-group and they had to solve a typical industrial related problem. The R-group was allowed to continue with their group meetings, research etc. while the remaining theory was covered with the C-group. This helped to balance the time-on-task for both groups. The C-group had to calculate, simulate and measure various values of a pre-determined circuit. The experiment took much longer than expected to complete but both groups finished around the same time.

Most R-group pairs worked well without help from the beginning. They found literature from the internet, library, text books and the animation software. Some students also discovered some more advanced circuits not appropriate for the level but they were allowed to continue with that since they would also learn from the experience. They later switched to more appropriate circuits. Two of the groups were initially lost at the beginning of the experiment and some guidance were given to them so that they were able to move on. They were probably lost because it was the 1st time that they had to use the PBL method. Most of the R-group students also simulated their circuits first once they had a circuit to work with. They were lacking the skill of doing the calculations first and need to be guide in that direction. They were also introduce to variable transformers (variacs), since that was completely new to them and they had to use that during the testing and demonstration part of the experiment. Although the power supply project was actually called an experiment, it could rather be classified as a mini project which is more suitable in the PBL environment. The R-group students enjoyed the PBL method and they developed their creativity, critical thinking, communication and interpersonal skills much more than the C-group.

The C-group was enthusiastic to do their experiment and followed the procedure as given to them. Many of them did not understood some of the terms (like V-rectifier out or V_{sec} DC). Most of them manage to simulate and monitor the waveforms with an oscilloscope on the simulator but some needed some help with the settings (like the V/Div. and time-base). It seems that this control group (C-group) asked more questions compared to the PBL group. Many of the C-group students also struggled to build the circuit on the Breadboard. One of the biggest lessons that they have learned is that calculated, simulated and measured values should be closely related. This showed in the reflection survey.

From the reflection survey (EXP 1_2_3 Reflection results.xls), the following is also evident:

The R-group students felt stronger that they need to look at different ways to solve problems. They also had to forward their opinions and ideas much stronger. The R-group also felt much stronger about working in small groups but students in the C-group helped others in doing their work much more.

It seems that the C-group students were feeling more confident after Experiment 2 (see Exp2 ReflectionV2.xls). The R-group enjoyed “building the circuit practically” more, probably because it is their own design and they might be curious to see if it works. The R-group also enjoyed the research involved, (required when using the PBL method). The C-group indicated that they enjoyed comparing the calculated, simulated and measured values. This might be an indication that some of these methods were lacking with the PBL group.

The R-group rate the Simulations higher while the C-group enjoyed Simulations more. This might be an indication that Simulations are popular amongst both groups. The R-group felt that they have learned on "*how to build a power supply*" while the C-group felt that they have learned to *"build a circuit practically"*. The reason might be that the PBL group had to design a specific power supply while the control group were given a circuit. It seems that **the R-group achieved more because they had to design** a circuit and not just building it, something that might help them later on in industry. Both groups learned a lot regarding electronic components.

More members of the R-group, (44% compared to 31% of the C-group) felt that they need to gain more knowledge when the question; "*What skills would you like to develop more*?" were asked. This might be because of the lack of theory covered officially in the class. One of the R-group members wanted to develop his design skills more, an indication that he was not confident at the time, but curious to do more designs.

More students from the **R-group** felt that what they have learned in experiment 2 was of practical value, satisfies their curiosity and encourages them to think (see Exp 2_3 Attitude.xls). More of them also felt "*good*" about the subject, concentrate more, meet deadlines and are more determined not to give up. All these are signs of students with a **better attitude**.

Students from the R-group were more interested in the experiment. They also indicated that the material (PBL method) was more difficult to them than expected (see Exp 2_3 Motivation.xls). They also felt stronger that they had **accomplished more**. The R-group felt slightly **more confident** that they could learn the content and that it is relevant to them. They also **enjoyed** it **more** and felt stronger that it is "*worth knowing*". They could also **relate** the content better to **real life situations**. All of these indicated that R-group students were **more motivated**.

The marks for experiment 2 were allocated in different ways due to the differences that exist between the Traditional and PBL methods, but the averages for each group were within 1% from each other (R-group (PBL) = 56% and C-group = 57%). Figure 48 below shows the individual results across the spectrum for each group.

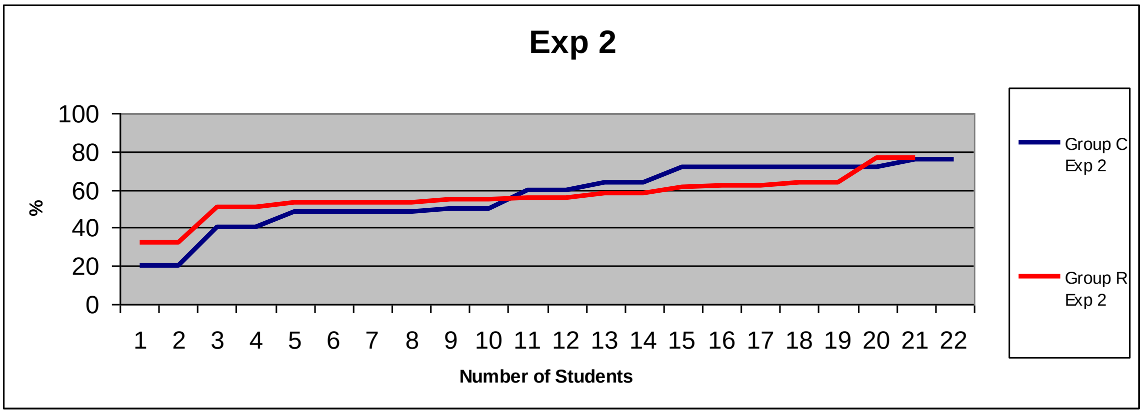


Figure 48. Students Score during Experiment 2 for both Groups

The marks for the pre and post-tests related to experiment 2 are shown in Table 32.

Students did poorly in the pre-test but at least notably better for those questions where they had prior knowledge. The C-group did slightly better for the question where both groups were supposed to answer questions due to prior knowledge within the Post-test. This question was not directly related to experiment. Both groups got 66% for those questions where the theory was only covered by the C-group. This means that the R-group gained the knowledge during the PBL experiment. The R-group did quite a bit worse in the last category where they covered only portions of the theory compared to the C-group who covered all of the theory. Some of the PBL (R-group) students did not follow the route of calculating the component values during the design phase of the experiment while it was required from the C-group to calculate the values of a given circuit. This might be the reason for the big difference in the marks.

Table 32. Students Score related to Experiment 2 for both Groups

Experiment 2 - Pre-test		
Item	**Both groups (%)**	
Students should be able to answer questions due to prior knowledge	42	
Students did not cover these work yet at the time	31	
Average	**35**	
Experiment 2 - Post-test		
	C-group (%)	**R-group (%)**
Students should be able to answer questions due to prior knowledge but not directly related to experiment	55	50
R-group students did not cover the theory but the C-group did	66	66
R-group students cover the theory only partially, but the C-group covered all	65	56
Average	**65**	**61**
Exam results for those questions that relates to Experiment 2		
Q3.3	66	64
Q3.4	56	46
Average	**61**	**55**

Table 32 shows a substantial improvement in the knowledge of the students (for both groups) after they have completed the experiments (from 35% to around 63%). The exam marks for those questions that related to experiment 2 also reflects a similar trend in the results when compared with the results of the pre and post-test.

APPENDIX K

Remote Lab versus Breadboard using the PBL method.

Introduction

The students had to design various transistor biasing circuits during Experiment 3. Both groups had to use the PBL method during this experiment. The C-group had to use the traditional Lab, using Breadboards to build the circuits and instruments to do the measurements while the R-group used the Remote Lab. Transistors were introduced to the students and only the basic principles of transistors were covered during the theory, but no biasing circuits. The problem was introduced to the students and the PBL concept was explained to the C-group, since it was their first time to use the PBL method. The hardware of the Remote Lab was shown to both groups so that students can better understand how real measurements were done with this equipment. A demonstration of the operation and use of the Remote Lab was also done so that students became familiar on how to conduct an experiment remotely.

Method

The students were then left to work in their respective pairs and they soon realized that they had to familiarize themselves with the different biasing circuits first. Most of them used the animation program and text books for this. They have also learned how to do the calculations to determine the values for the different components (for the various biasing circuits). No guidelines were given to the students on the value of the supply voltage or what typical current to use and they had to choose their own.

It was then realized that many of the students choose resistors with very low resistance values which will result in very high currents and powers that may exceed the maximum ratings of the transistors. The simulations did not show this problem during simulation and it was also not possible to select such low resistance values with the Remote Lab. Intervention was thus required at this stage due to the limited time available for this experiment. (It was later discovered that Secondary schools in South Africa actually use these very low resistor values like 0.1Ω in some of the examples e.g. from their grade 12 science notes – perhaps the reason why the students opt for similar values). They also violated one of the design principles, probably because they only covered the theory related to transistor biasing but no theory on design. They had to be guided in the right direction.

The students also had to find the β (hfe) of the transistors from the data sheets. This created a problem since it is not given as a single value (like in conventional methods), but rather as a min, typical and max value which are usually also influenced by the ambient temperature and amount of current. The students were thus confronted with a real life problem and realized that the simulated and real values for the β might differ substantially.

The Remote Lab always showed the calculated values before the real measurement were done and act thus as a simulator as well. Most of the R-group students choose to use the Remote Lab directly after they designed a circuit and did not bother to use the simulator program first. The Remote Lab also indicated to them whenever any of the maximum ratings will be exceeded and it won't allow a real measurement in such a case. A total of 263 measurements were done with the Remote Lab, about 24 measurements/group. One measurement took approximately 5 seconds and no bottlenecks were experienced. It was also easy for the students to change the value of one of the components at a time and to observe the effect. One of the problems that students initially experienced was the fact that the Remote Lab did not cover resistors less than 82Ω and some students had to redesign their circuits because of that.

Students from the C-group had to build the circuits in the lab using breadboards. Many of them struggled to identify the various transistor terminals correctly. The component store was also limited in stock and it was not always possible to give the students the exact components that they asked for. It took a long time to build the circuit and to do the measurements and students from the C-group hardly had the time to build three different circuits.

Student experiences

From the reflection survey (EXP 1_2_3 Reflection results.xls), the following is evident:

The R-group worked more in **pairs** compared to the C-group. More C-group students **helped other students**. Both of these were also evident in experiment 2. The R-group made more use of **feedback** to help them **plan** their **next action** and progress further and they also **enjoyed the experiment** more and won't give up that easily. The Remote Lab gave them feedback by showing both the calculated and measured value's simultaneously and it also shows a warning message, should there be a problem. It is thus easier for the students to respond on the feedback. Students probably enjoyed the Remote Lab more because it is so easy to use, using only a computer. There is no physical effort involved and it is also very fast.

It seems that the favourite items for the R-group students were that they could make **mistakes** and **learn from** that (see Exp3 ReflectionV2.xls). The reason might be that the Remote Lab will indicate to the student when something seriously is wrong with the circuit, and it won't be possible to damage the hardware in such a case due to the build-in protection. R-group students also favour **working in pairs** and the ability to forward their **opinions and ideas** more than the C-group. The C-group favours using **simulations** the most. The Remote Lab fulfils the work of the simulator for the R-group students.

It look as if that the **Remote Lab** was more popular than **building** a circuit in the Lab. 31% of the R-group students indicated that they liked the Remote Lab most compared to the 22% of the C-group students who indicated that they like building a circuit in the lab. Both groups indicated that they like doing **simulation** and **calculations** a lot. The fact that 33% of the C-group students indicated that they like simulations the most (compared to only 22% of the same student indicating that they like building a circuit in the lab) might be an indication that students rather prefer working on computers.

It transpires that the Remote Lab is very effective in learning students on how a **transistor functions** because the majority (63%) of R-group students felt that way. Only 25% of the C-group felt the same way, but 21% of them agreed that they have learned about **transistor design**, something that is absent from the Remote Lab group. It is so easy to use the Remote Lab and students who use it might design the 1st initial circuit and thereafter just change the components selectively. This might explain why they learned a lot on the function of the transistor but no mentioning of the design.

The R-group students indicated that they want to develop more skills around the Remote Lab while the same amount of students (23%) from the C-group indicated that they want to develop more skills around the building of circuits on breadboard. This is an indication that some of the students felt that they did not reached their full potential yet for those. The R-group has a slightly greater need to improve their **calculation skills** (23%), compared to the 14% of the C-group. This may be because of the effortless way in which the Remote Lab works, allowing the user to make changes without any calculations and instantly seeing the outcome.

The attitude of both groups was very positive and it is difficult to draw attention to any specific cases that hold opposing views (see Exp 2_3 Attitude.xls). The R-group felt that they have **accomplished more** during experiment 3 (see Exp 2_3 Motivation.xls). They also felt stronger that the material was eye-catching and important to people. The C-group struggled more to understood some of the material, perhaps because it was the first time that they were using the PBL method, but they felt stronger that the content were well organized which helped them to be confident in learning the material.

Results

The score for experiment 3 were based on a report that the students of both groups submitted. There was a big improvement in these reports compared to those of experiment 2 (PBL group only). The score were allocated in a similar way. The Remote Lab group included screen shots taken from the Remote Lab while the C-group used screen shots from the simulation program. The averages for each group were within 4% from each other (R-group (Remote Lab) = 58% and C-group (PBL and traditional lab) = 62%). Figure 49 below shows the individual results across the spectrum for each group.

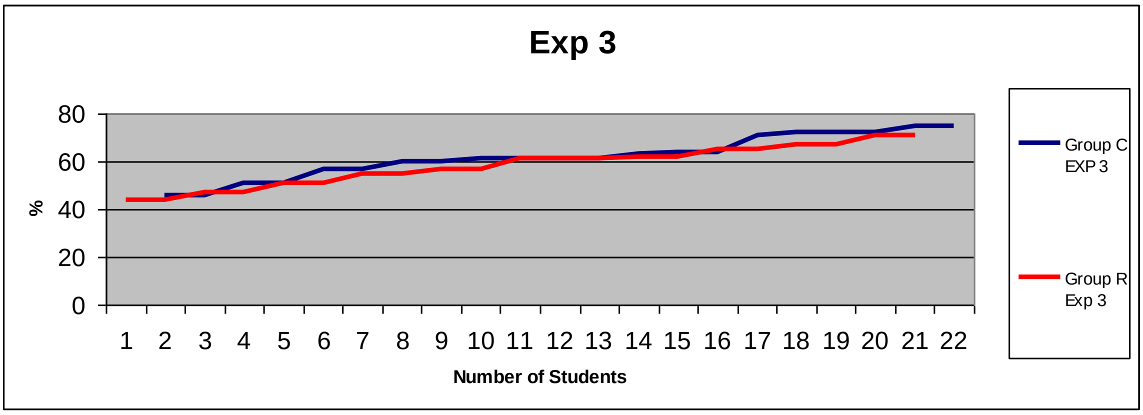


Figure 49. Student Scores for Experiment 3 based on their Reports

The score for the pre and post-tests related to experiment 3 are shown in Table 33.

Table 33. Score for the Pre and Post-tests related to Experiment 3

Experiment 3 - Pre-test		
	C-group (%)	**R-group (%)**
Students should be able to answer questions due to prior knowledge	81	82
Both groups did not cover the theory	69	68
Average	**75**	**75**
Experiment 3 - Post-test		
Students should be able to answer questions due to prior knowledge but not directly related to experiment	74	70
Both groups did not cover the theory	64	58
Average	**66**	**61**
Exam results for those questions that relates to Experiment 3		
Q5.1	45	37
Q5.2	17	26
Q5.3	35	44
Q5.4	52	56
Average for above two questions	**41**	**44**
Overall results		
Average Year Mark	**56**	**55**
Average Exam Mark	**50**	**50**
Average Final Mark	**52**	**52**
Students who passed the course	**55**	**62**

The students did unexpectedly well during the pre-test and therefore investigated. It was found that those questions related to prior knowledge were actually very easy and the high marks achieved for those could be accepted. It was also possible for them to determine the answers for some of the other questions in which they scored well but there was a concern with one specific question in particular. Students had to choose between various complicated formula's not known to them at the time in which 71% answered correctly. Blackboard indicated 38 marked attempts (the amount of students that participated on the day), but 52 attempts. This means that up to 14 students might have more than one attempt which allowed them to improve on their original results. (*"force completion"* and *"disabled multiple attempts"* are usually selected, but those conditions had to be abandon on the day due to an unknown error in Black Board e.g. attempts of various individual students had to be clear manually since some of students were not allowed excess to the test or survey, even without any questions answered yet).

The final results for the pre-test of experiment 3 were similar for both groups, but the R-group did slightly worse during the post test. It cannot be assumed that the Remote Lab be responsible for the lower results of the R-group since the results of the post test of experiment 2 were also lower for the R-group (with a similar margin). The R-group did better during the exams for those questions related to experiment 3, which is quite noteworthy.

Conclusion

Students enjoyed using the Remote Lab and it seems very effective (when used in a PBL environment) in learning the students on how a transistor functions but not on transistor design. It also seems that those students who used the Remote Lab achieve higher results for relevant questions during the exam.

When the PBL method is used to do experiments with real instrument and a breadboard, then student learn how to design and they could also relate the content better to real life situations.

It seems that the PBL method indeed developed creativity, critical thinking, communication and interpersonal skills amongst the students at WSU. More information mostly related to scores between the R-group and C-group is available in APPENDIX L.

APPENDIX L

The average year mark for the R-group was 1% less than that of the C-group (55% versus 56%) and the average exam mark for both groups are similar (50%), but it is interesting to note that more students from the R-group passed overall as shown in Table 33. The overall pass-rate for the R-group students was 62% compared to the 55% of the C-group.

The final overall mark for these students were determined as follow:

- Exam 60%
- Year mark 40%

The Year marks are made up as follow:

- Test 1 5%
- Test 1B 40%
- Test 2 25%
- Experiment 1 10%
- Experiment 2 20%
- Experiment 3 0% (Could not meet deadline as determined by exams)

Test 1B, Test 2 and Experiment 2 contributed the most to the year mark of these students. Experiment 3 was included in the graphs that follow to determine if there is any correlation between the final mark of the students and the various items.

C-group

Figure 50 shows that those students who did poorly overall in the C-Group did so because of low test and exam marks and not because of the experiments (follow the line where Exp3 and Test1B meet).

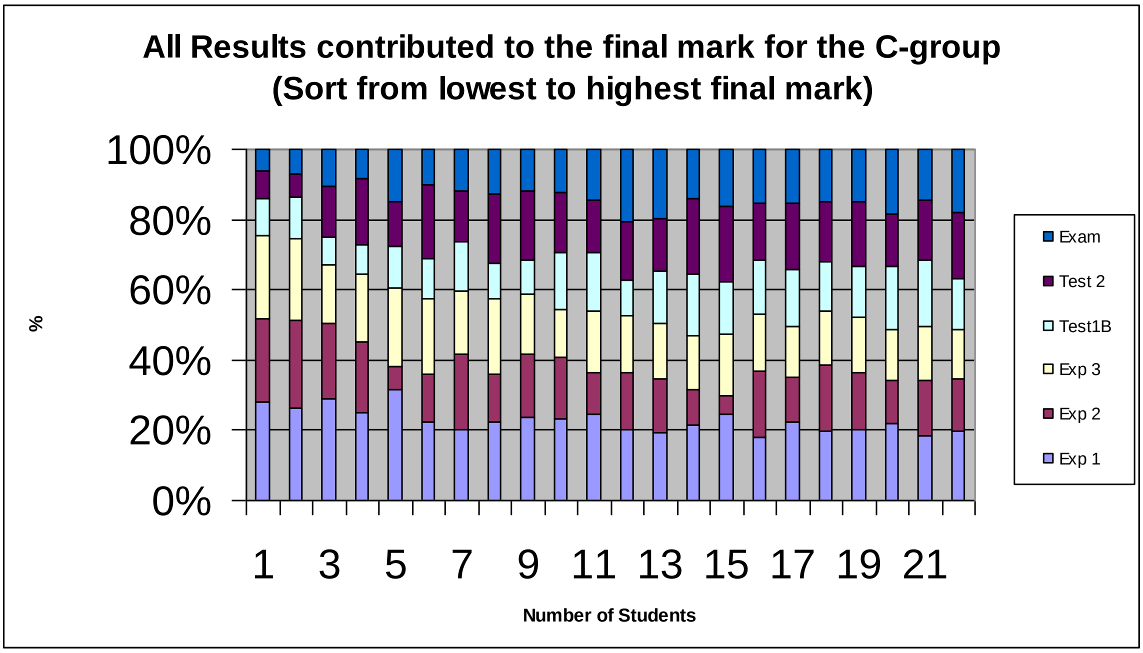


Figure 50. Students with lower final Marks scored lower during the Tests and Exams

Figure 51 actually shows that most of the students with lower final marks did actually well during the experiments.

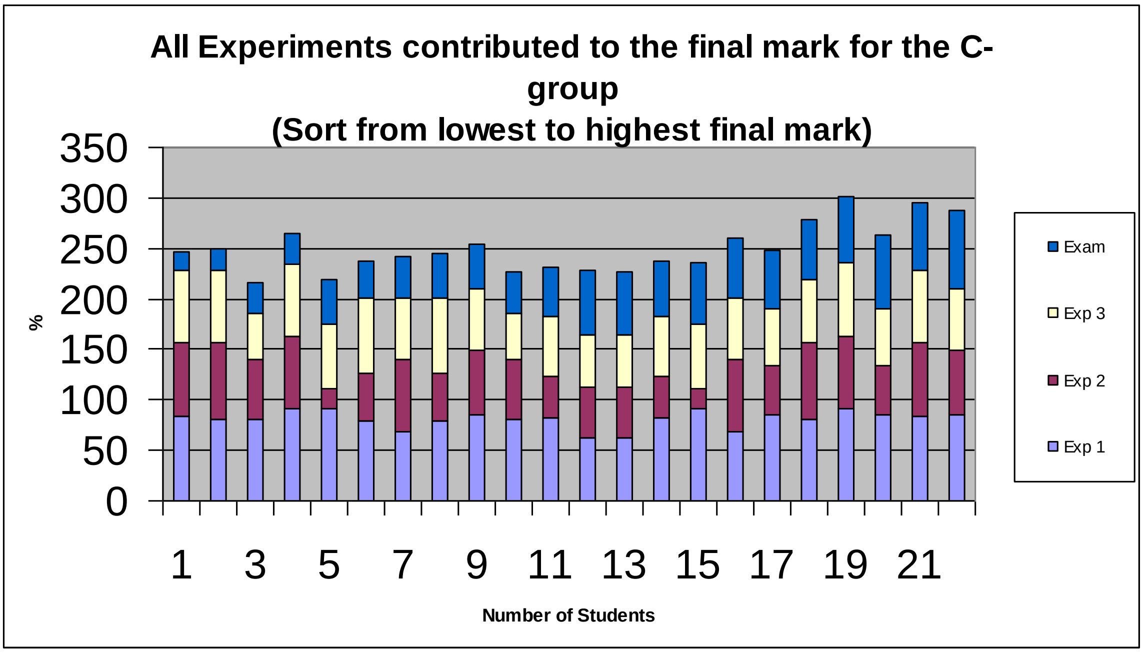


Figure 51. The Scores of the Experiments does not relate to the final Mark

The marks for experiment 1 were very similar across the spectrum as shown in Figure 52.

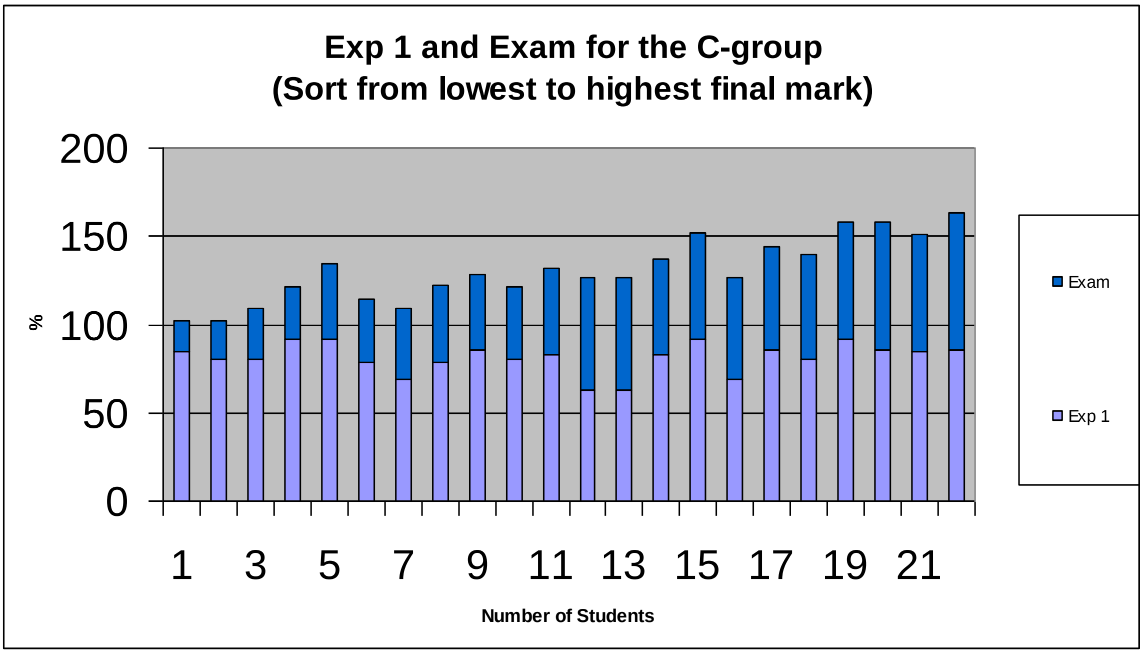


Figure 52. The Score for Experiment 1, which was done in the Traditional Way, was high for most Students

There is also no correlation between the marks of experiment 2 and the final overall mark as shown in Figure 53.

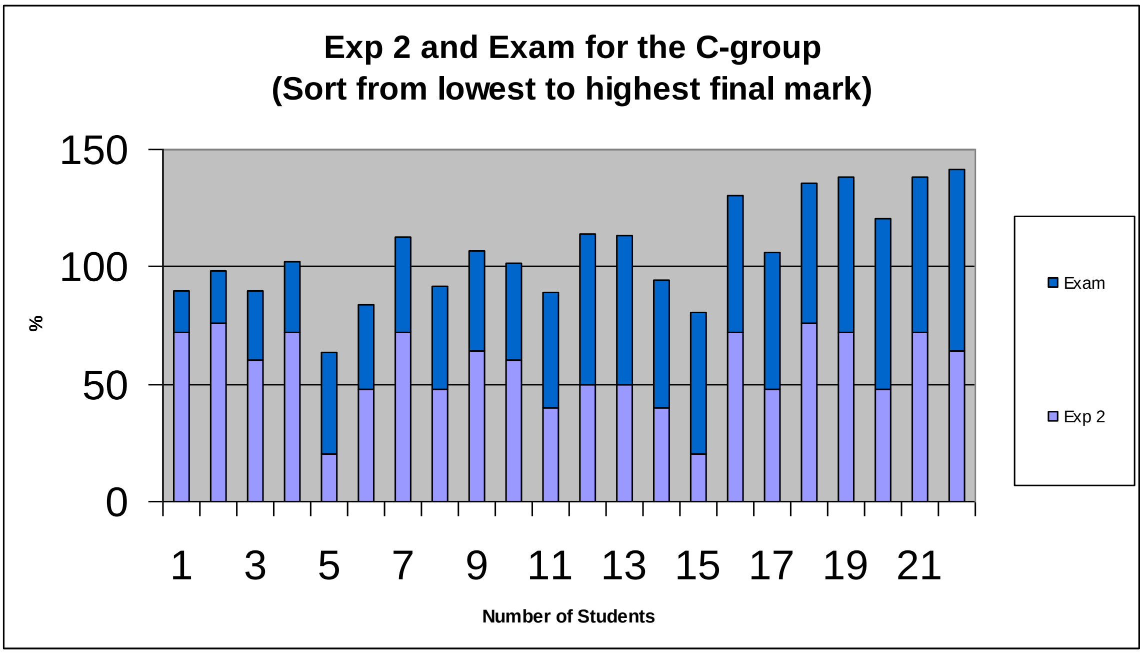


Figure 53. The Score for Experiment 2, which was done in the Traditional Way for the C-Group, did not relate with the Exam Marks

The C-group used the PBL method to do experiment 3 and it seems that the low overall achievers actually did better than the rest with this experiment if we look at the first 8 students (excluding student 3) as shown in Figure 54.

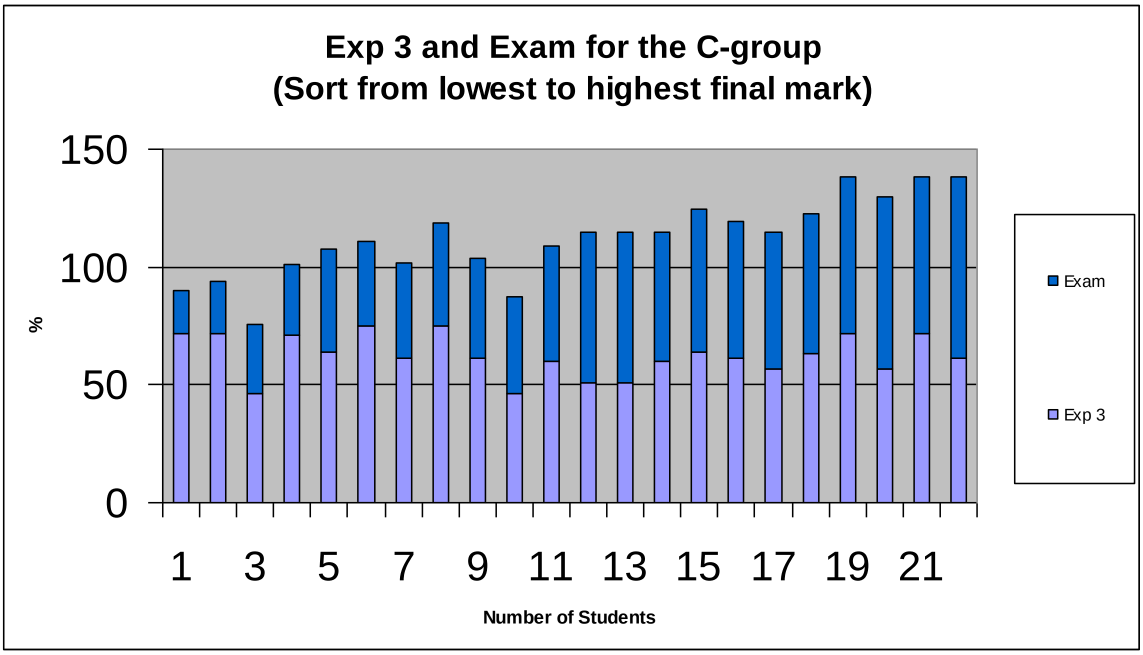


Figure 54. It seems that the lower Achievers benefitted more from the PBL Method

Those low achievers did badly in most tests including test 2 and the exams as shown in Figure 55. Both Test 2 and experiment 3 were about transistors but only 13% of test 2 relates to experiment 3. Test 1 already shows an indication of who the higher achievers would be (student 16 upwards). It should be noted that all tests and the exam were done in the traditional way.

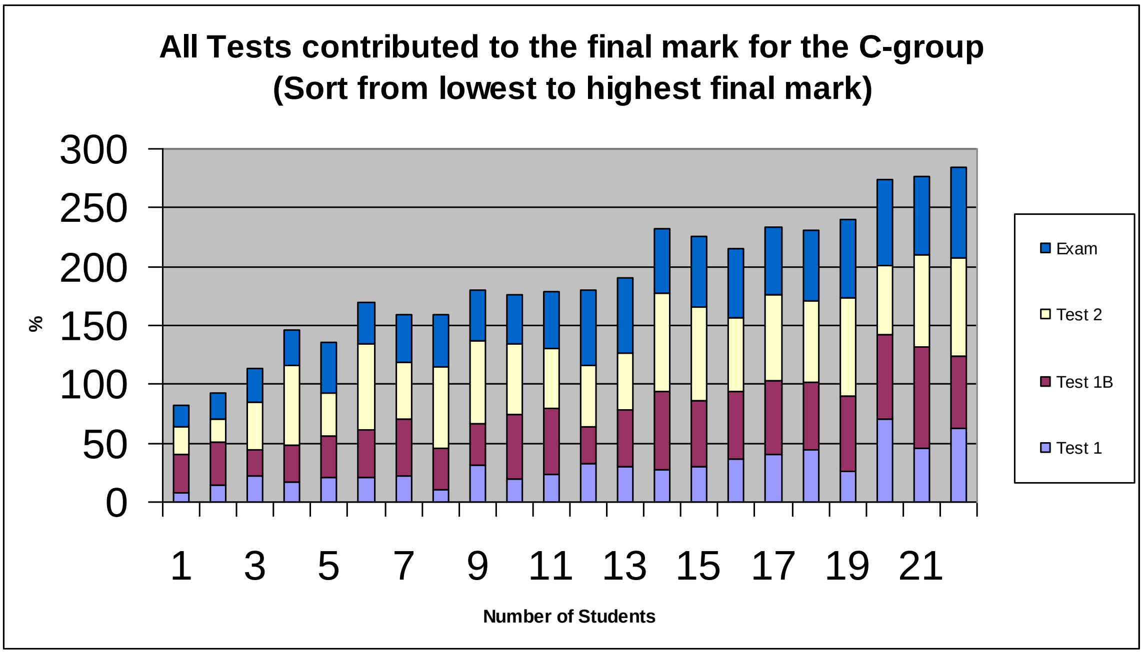


Figure 55. There is a strong Correlation between Test and Exam Marks

The low achievers also did extremely badly in the exams for those questions related to transistors (Question 5). These exam questions are either directly or indirectly related to experiment 3, who was done, using the PBL method. The low achievers did not benefit from the PBL method (used during experiment 3) whilst participating in a traditional orientated exam see Figure 56.

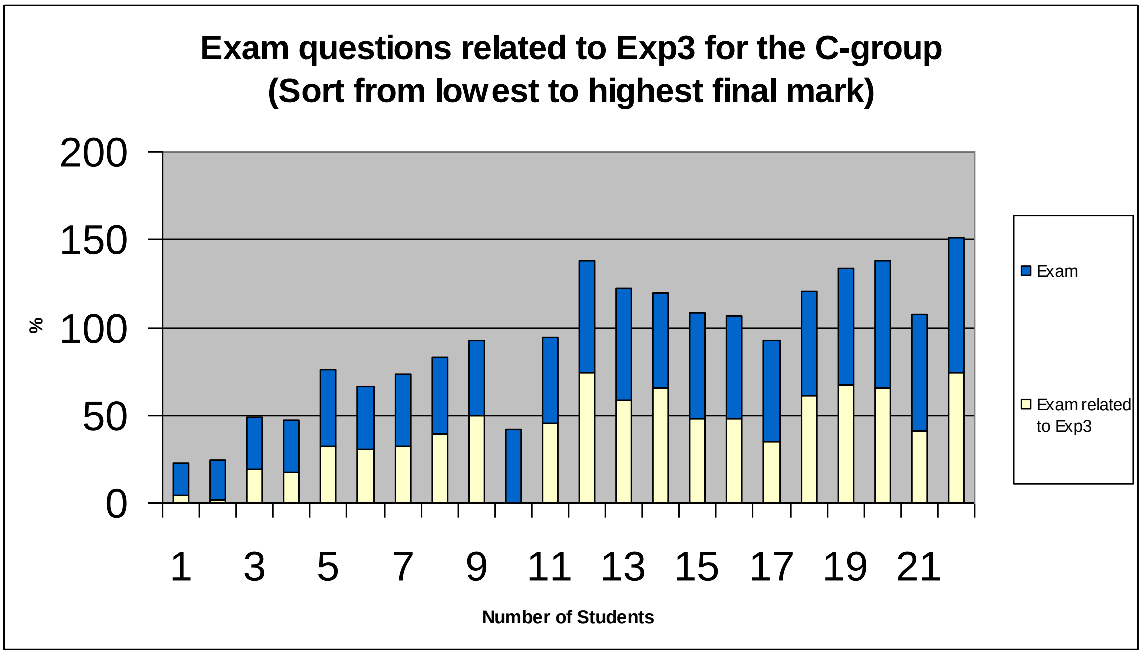


Figure 56. Low Achievers did not benefit from the PBL Method when accessed using a Traditional Exam

R-group

The R-group, (who used PBL during experiment 2 and PBL with the Remote Lab during experiment 3), seems to be different because most of those students on the left (who achieved a low final mark), actually performed well in the tests but slightly lower in the exam (see Figure 57).

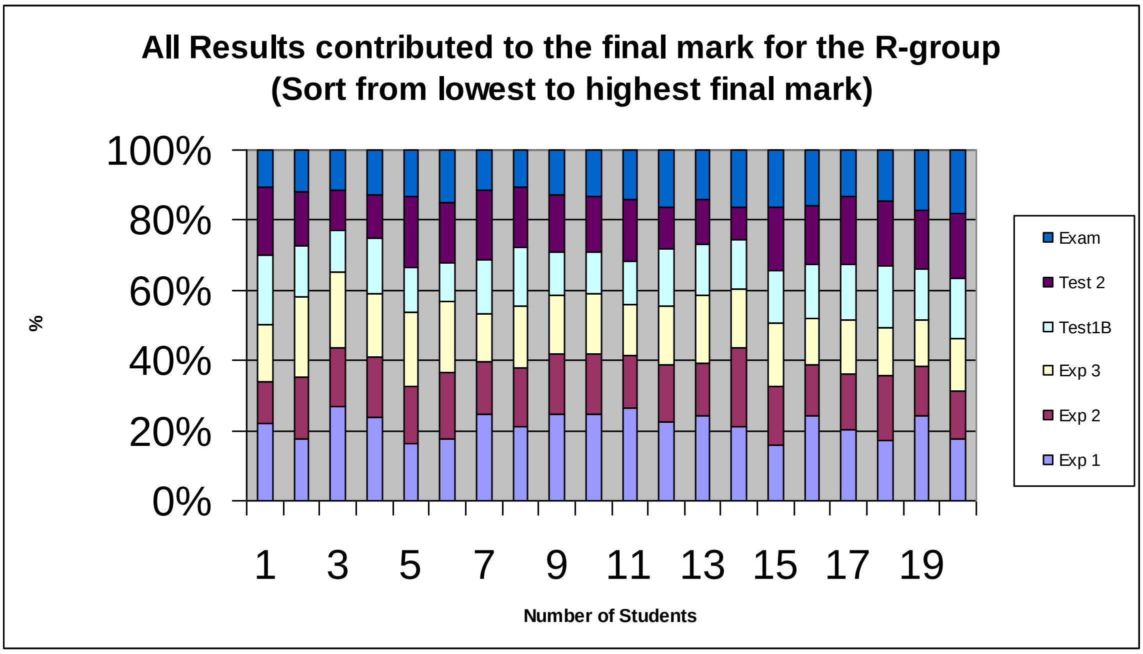


Figure 57. Test and Experiment Marks for low and high Achievers are very similar

Most of the low achievers did slightly worse in experiment 1 compared to the rest of the group as shown in Figure 58.

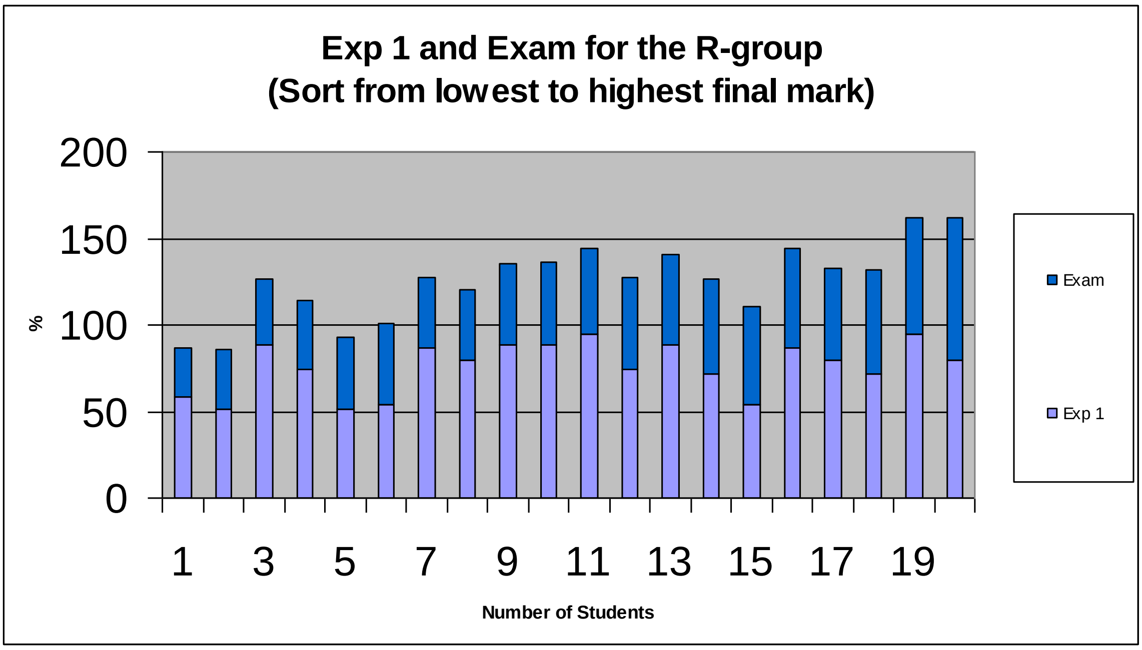


Figure 58. There was some Correlation between Test 1 and Exam Marks for the low Achievers

The R-group used the PBL method during experiment 2 and the marks of the low achievers were not that obvious lower when compared to many of the other students (that is if we ignore the 1st student on the left (see Figure 59).

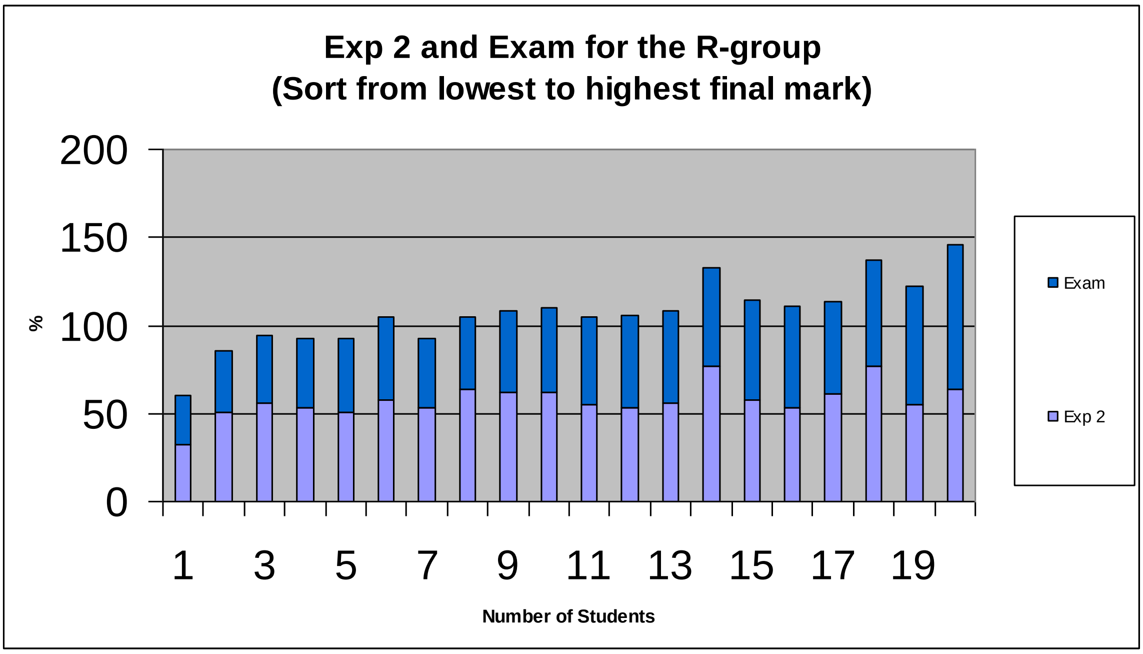


Figure 59. The Marks for the lower Achievers is on par with the rest when the PBL Method was used during Experiment 2

If we ignore the student on the left again, then it seems that all of the students did very similar with experiment 3 when they used the Remote Lab in a PBL environment as shown in Figure 60.

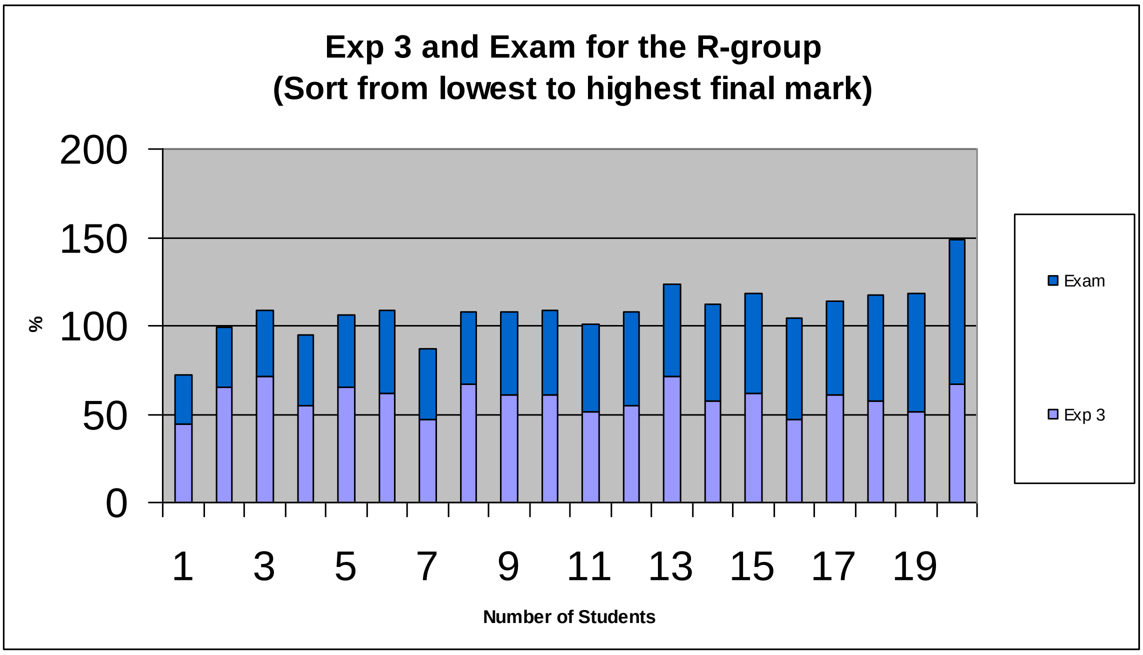


Figure 60. The Marks for the lower Achievers was also on par with the rest when the PBL Method was used during Experiment 3.

Figure 61 shows that there may be some relation between the experiments and the final marks for the R-group of students although not that significant. The exam mark seems to have the biggest influence on the final mark.

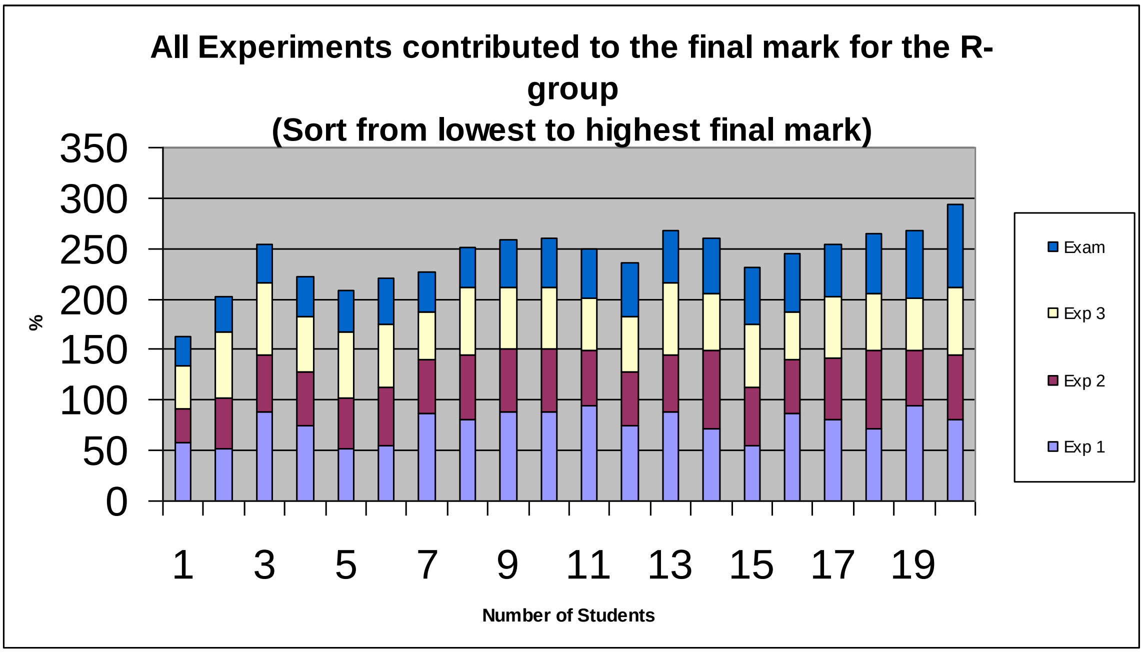


Figure 61. Exam Mark had the biggest influence on the final Mark

It is interesting to note from Figure 62 that the middle group of students did actually the worst during the 1st test as shown below. PBL was not used at that stage, hence they improved a lot at the end. This pattern is not visible for the C-group (see Figure 55). This may be some indication that the lower achievers may benefit more from PBL. There was also already an indication who some of the higher achievers would be (from student 14 onwards – based on the Test1 scores).

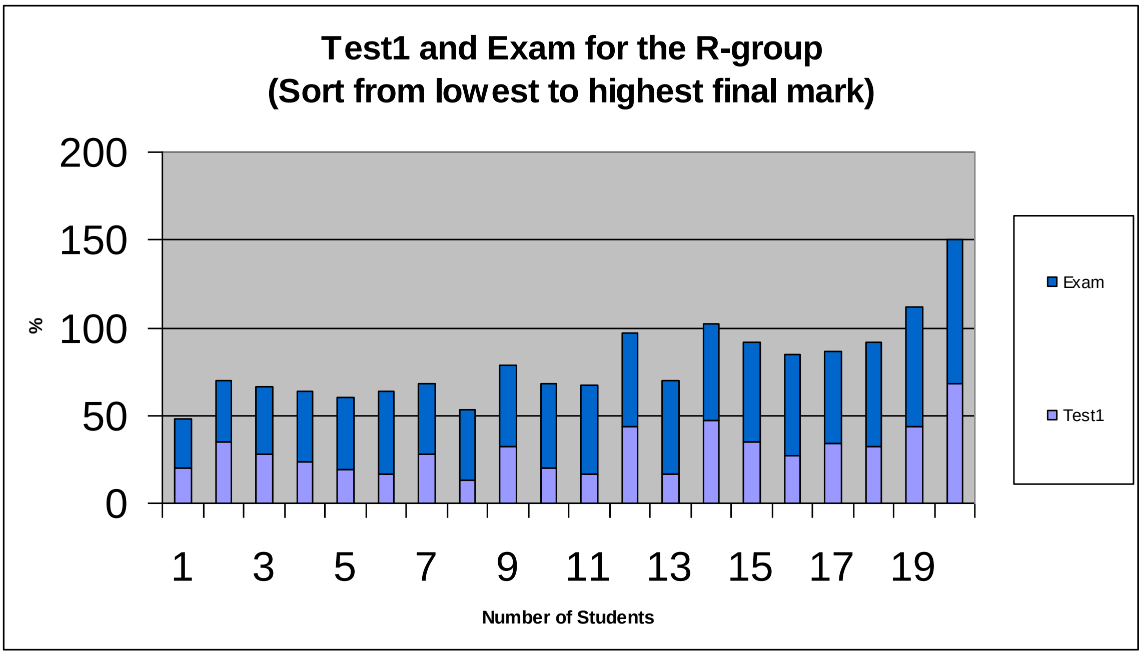


Figure 62. Most of the Students from 5-13 were the low Achievers at the time of Test1

The first 17 students also achieved very similar results during test1B as shown in Figure 63.

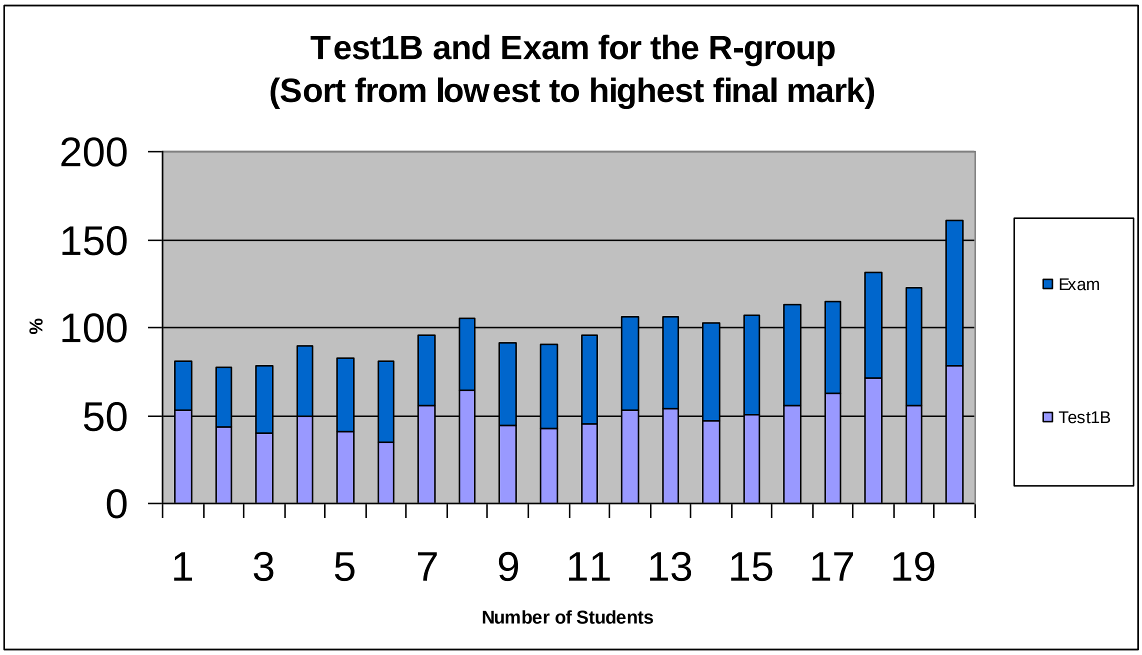


Figure 63. Score of the 17 lower Achievers were very similar during Test 1B

Figure 64 shows that students 5-11 seems to improve on their marks quite a bit during test 3 when compared to the previous 2 tests. In fact, it seems that their marks were from the lowest during test 1 (see Figure 62).

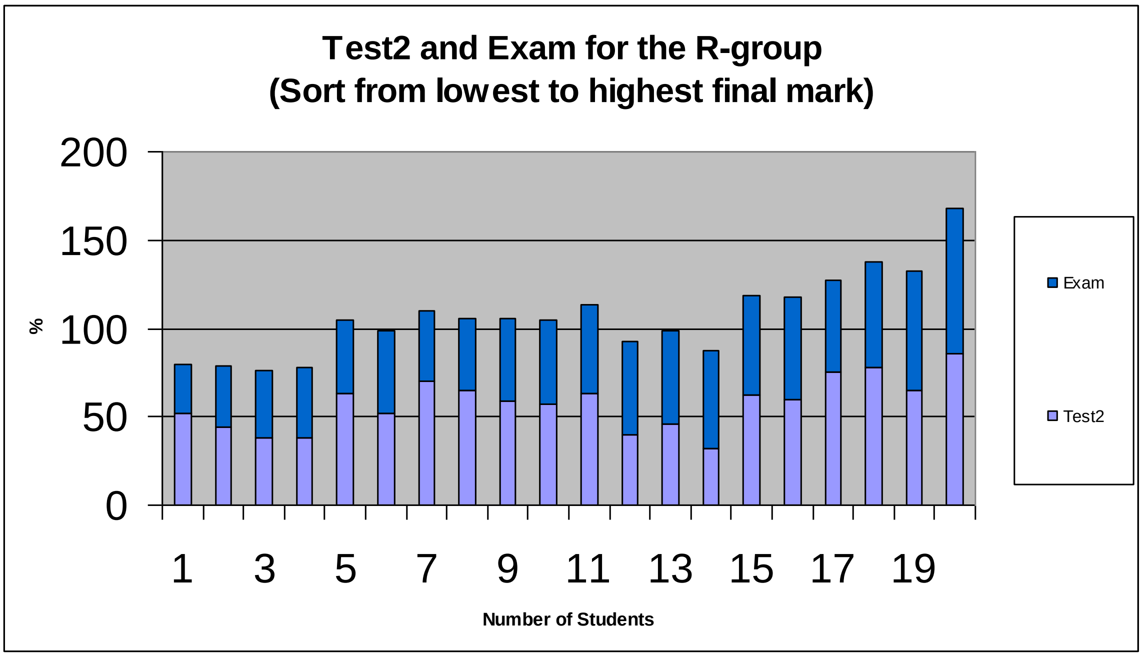


Figure 64. The Score of Students 5-11 improved during Test 2

It seems that the final results of the R-group students were mainly influenced by the exam marks although the cumulative test marks of the first 6 students is slightly lower than most of the others – see Figure 65.

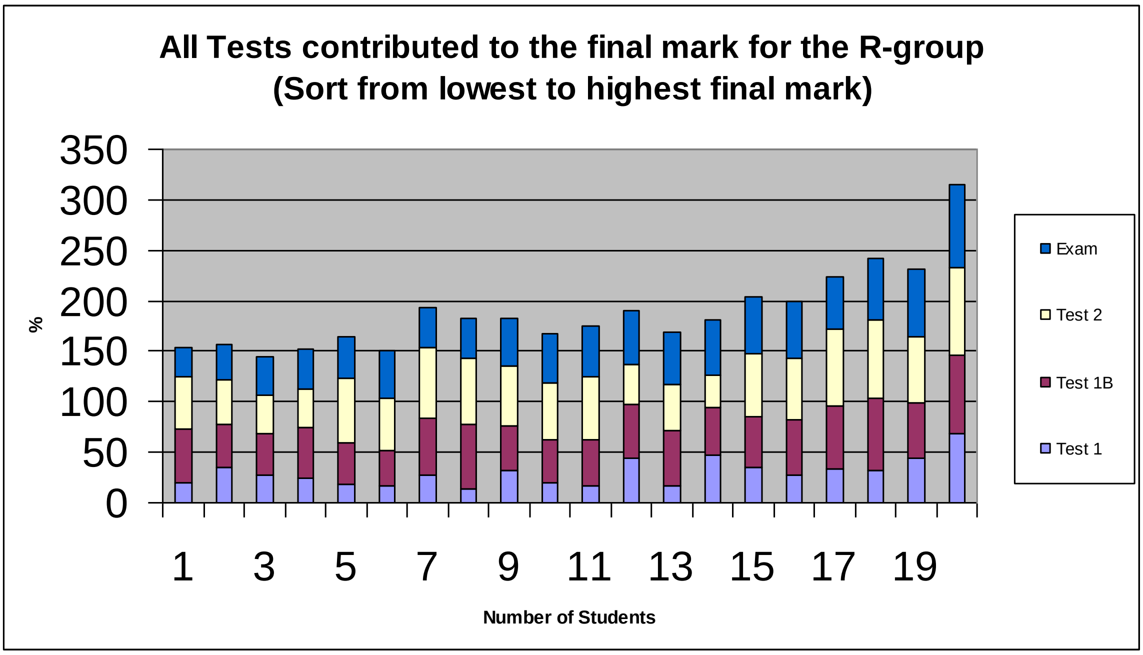


Figure 65. The Six lower Achievers also scored the least during the Tests

It seems that the poor achievers from the R-group benefited from the Remote Lab. See the "exam related to EXP3" at Figure 66 (ignore the first two students on the left). Poor achievers from the C-Group scored less for the same questions in the exam – see Figure 56.

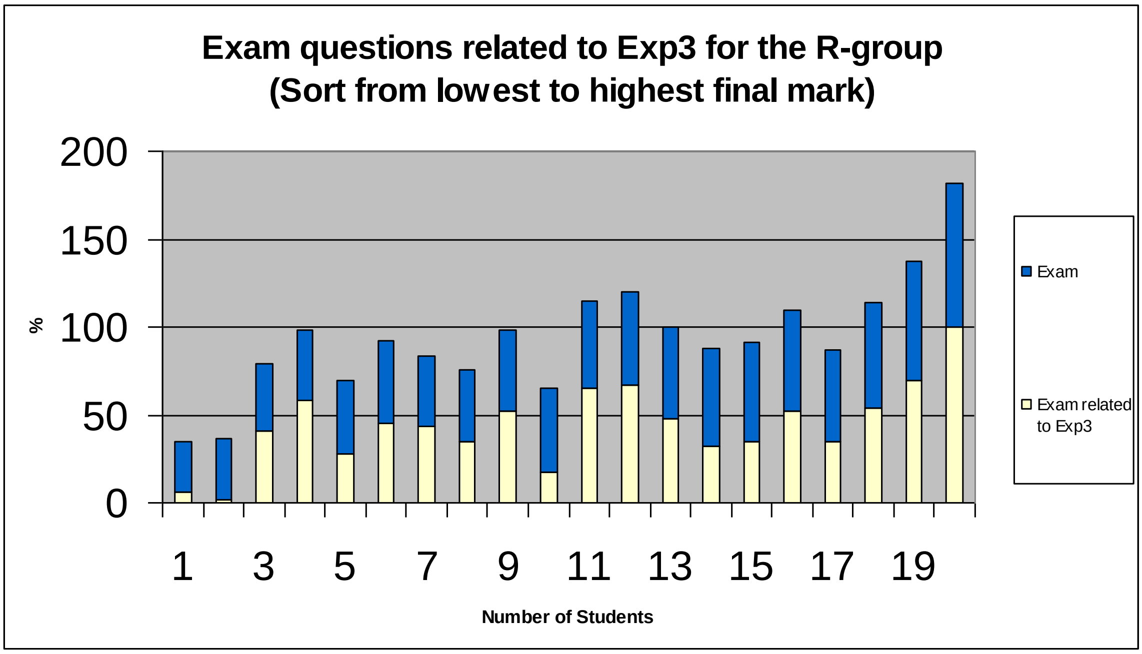


Figure 66. Lower Achiever Students benefitted from the Remote Lab

Correlation between Tests and Final Result

The C-group students did experiment 1 and 2 in the traditional way and there seems to be a strong correlation between the results of Test 1, Test 1B and the final mark as shown in Figure 67 and Figure 68.

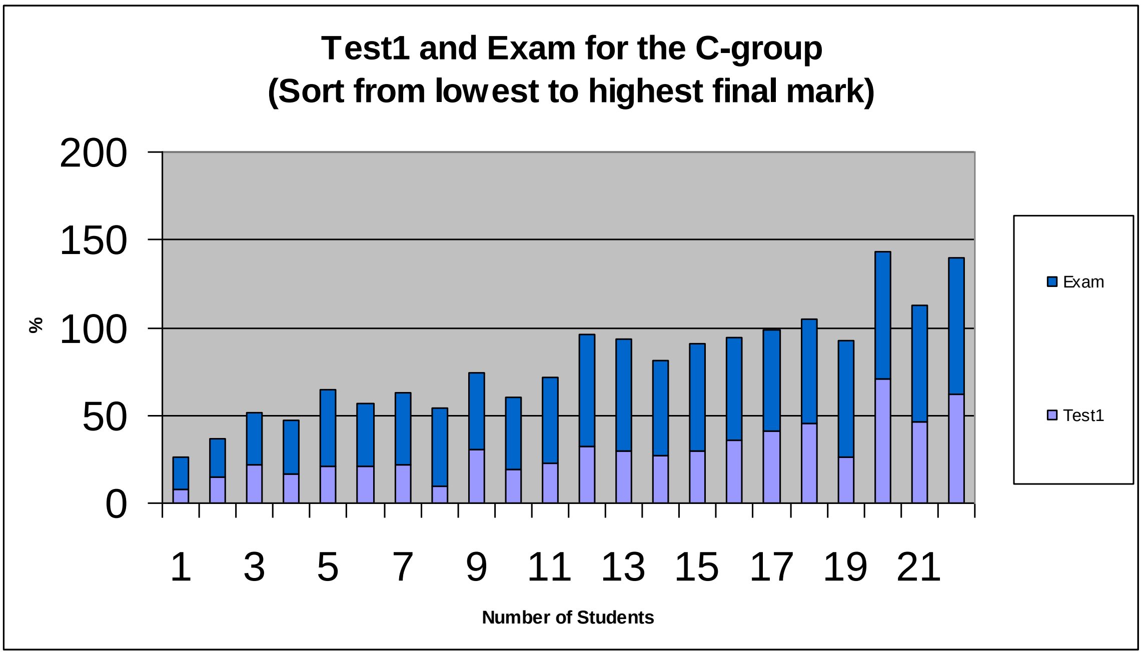


Figure 67. Results of Test 1 and the Final Mark

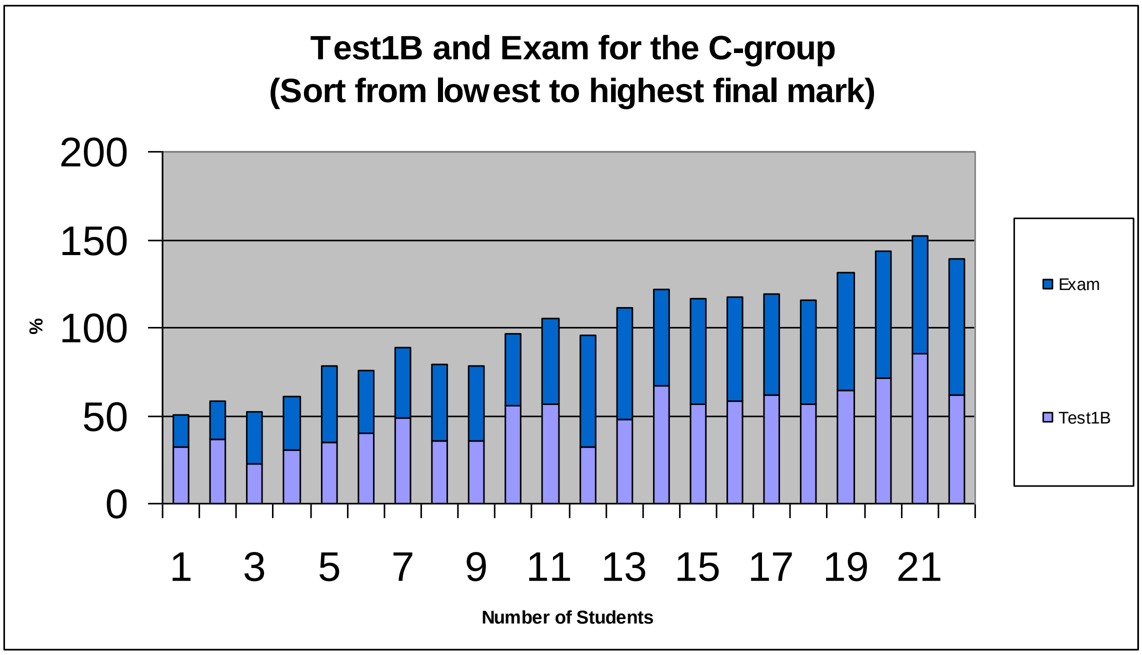


Figure 68. Results of Test 1B and the final Mark

The C-group students used the PBL method during experiment 3 and it is clear that the correlation was less evident between Test 2 and the final mark as shown in Figure 69.

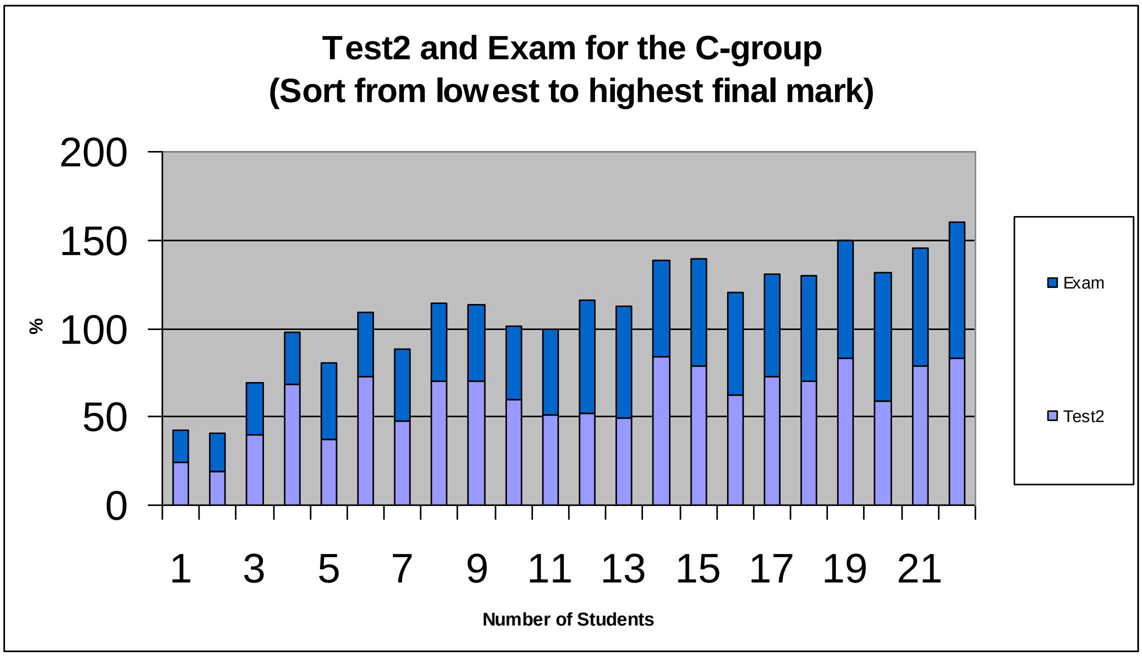


Figure 69. Test 2 and the final Mark

The R-group students did experiment 2, using the PBL method. Experiment 3 was also done, using the PBL method with the Remote Lab. One would also expect a strong correlation between the results of Test 1, Test 1B and the final mark like we did with the C-group, but this is not the case as shown in Figure 70 and Figure 71. Those students that achieved higher results, let's say from student 15 upwards were not really affected with the methods used in the R-group, and they would have achieved most probably similar results if they were placed in the C-Group. It seems that student 5 – 13 benefited the most from the methods used by the R-group since their initial marks during Test 1 were the lowest. That trend was still visible in Test 1B although not that obvious but there was a reasonable improvement during Test 2 for students 5-11 as shown in Figure 72.

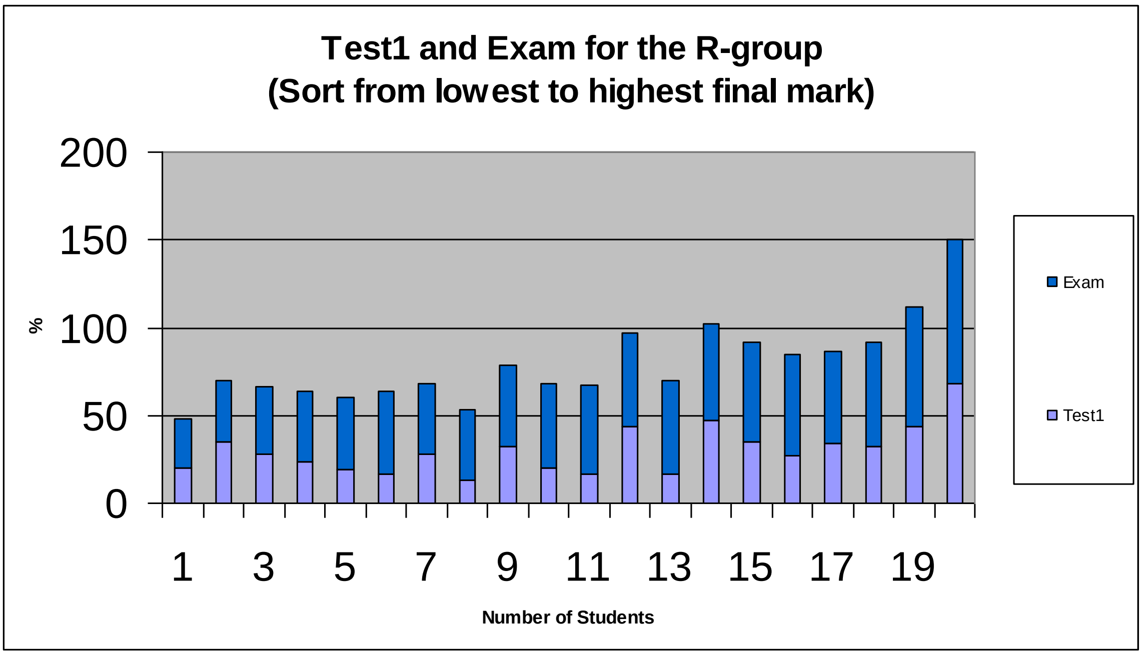


Figure 70. Results of Test 1 and the final Mark

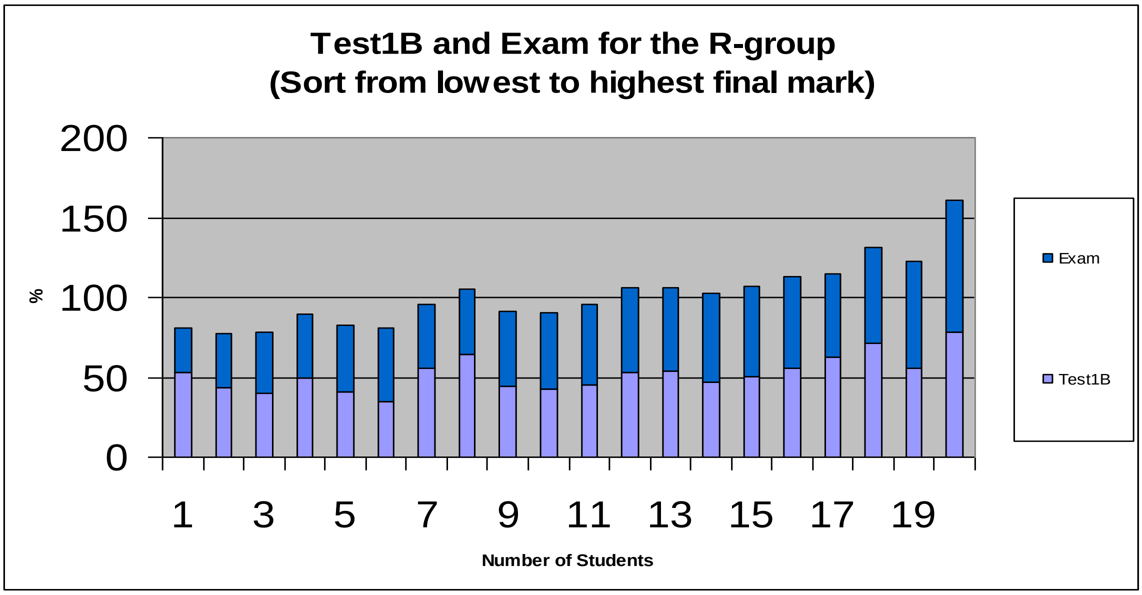


Figure 71. Results of Test 1B and the final Mark

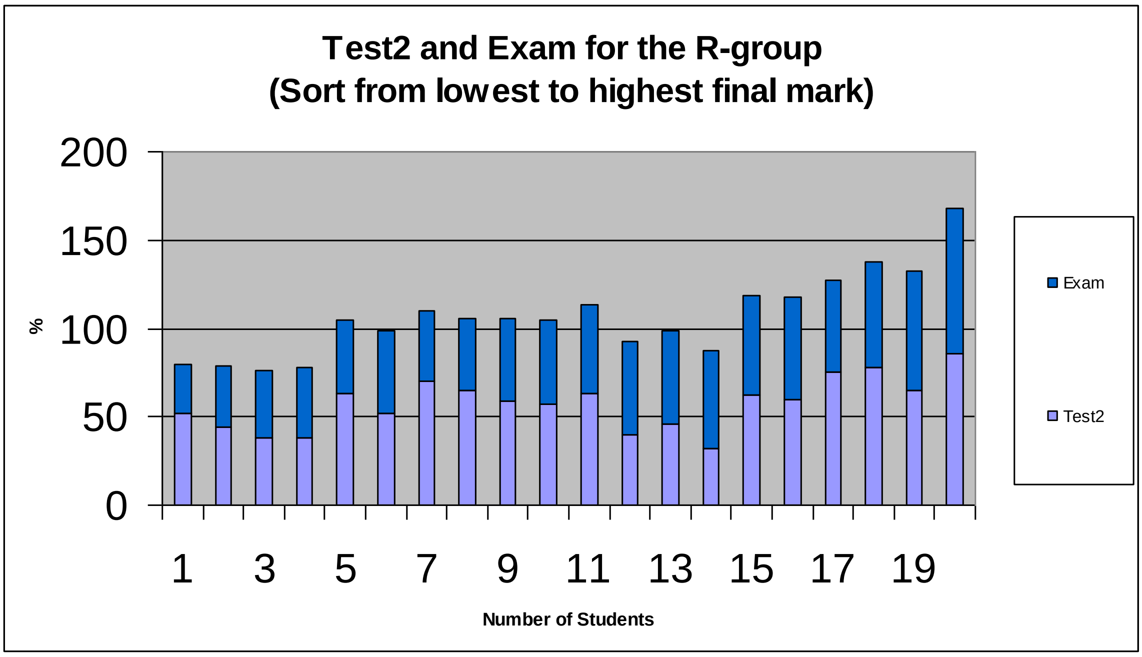


Figure 72. Results of Test 2 and Exam

<u>All of the graphs to follow are sorted from low to high based on the Test 1 marks</u>

When sorted on Test 1

There is a strong correlation between Test 1 and the Exam mark for the C-group as shown in Figure 73. Both of these were set by Mr. Ndondo. (The first 9 students remained sort-off the lowest)

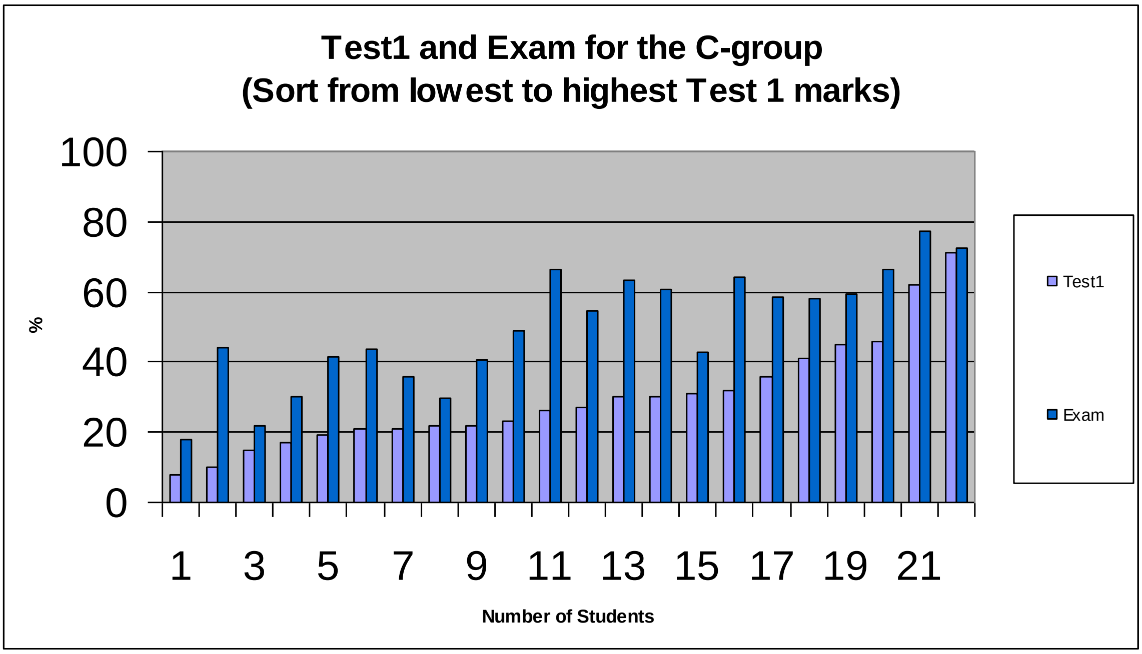


Figure 73. Test 1 and the Exam Mark for the C-group

There was also some correlation between Test 1 and Test 1B, but perhaps a bit less between Test1 and Test 2. Students 2, 4, 5 and 7 improved a lot during Test 2, but there is no obvious correlation between those marks and the exam – see Figure 74 (These students used the PBL method within experiment 3 before test 2 was written).

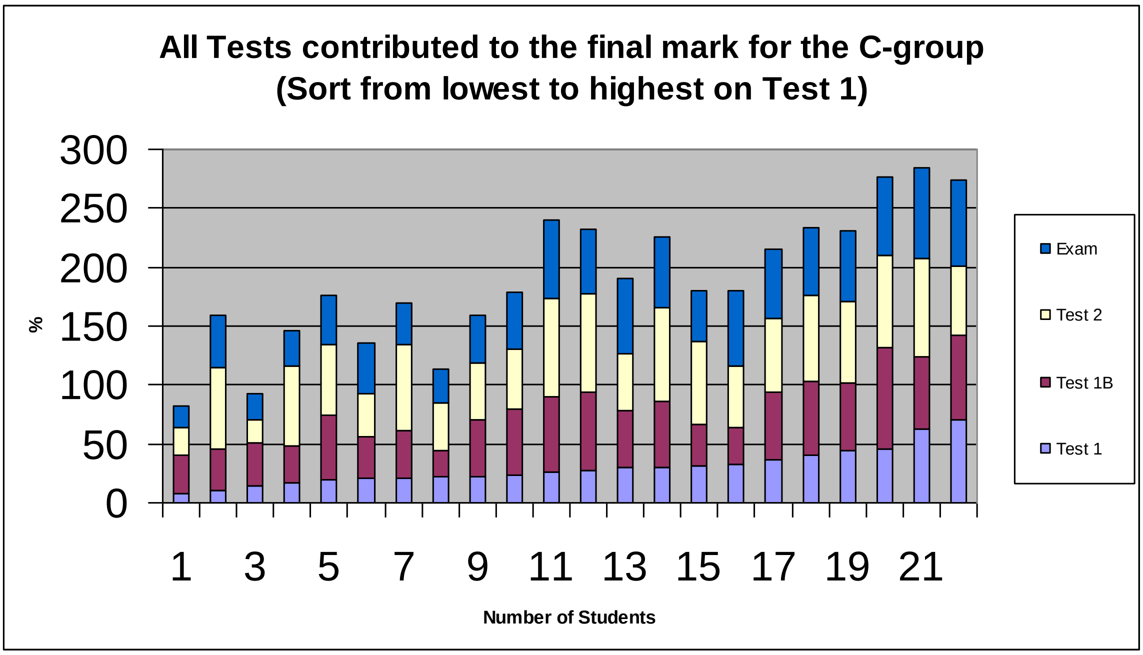


Figure 74. All Tests contributed to the final Mark for the C-group

There seems to be no correlation between any of the experiments and Test 1 or the exam - Figure 75.

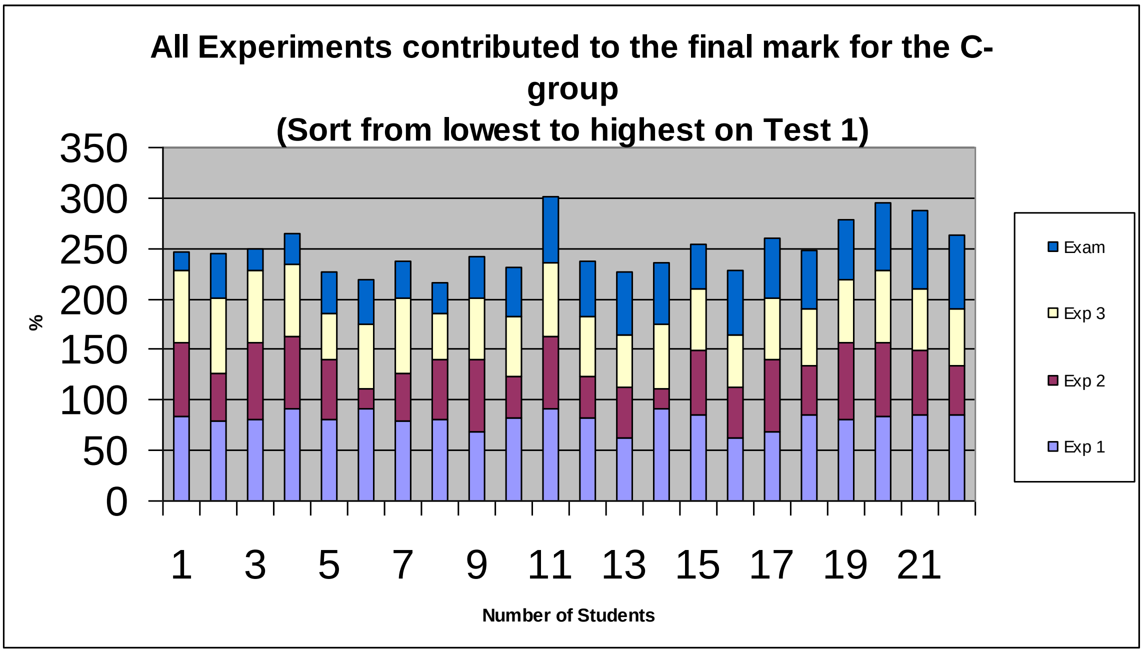


Figure 75. Marks sorted on T1 for C-group

Many of the R-group students with low marks during Test 1 improved a lot during the exams and it turned out that they actually did better than some of the other students in the R-group (see students 1-6 in Figure 76 This was not the case for the C-group students as indicated earlier.

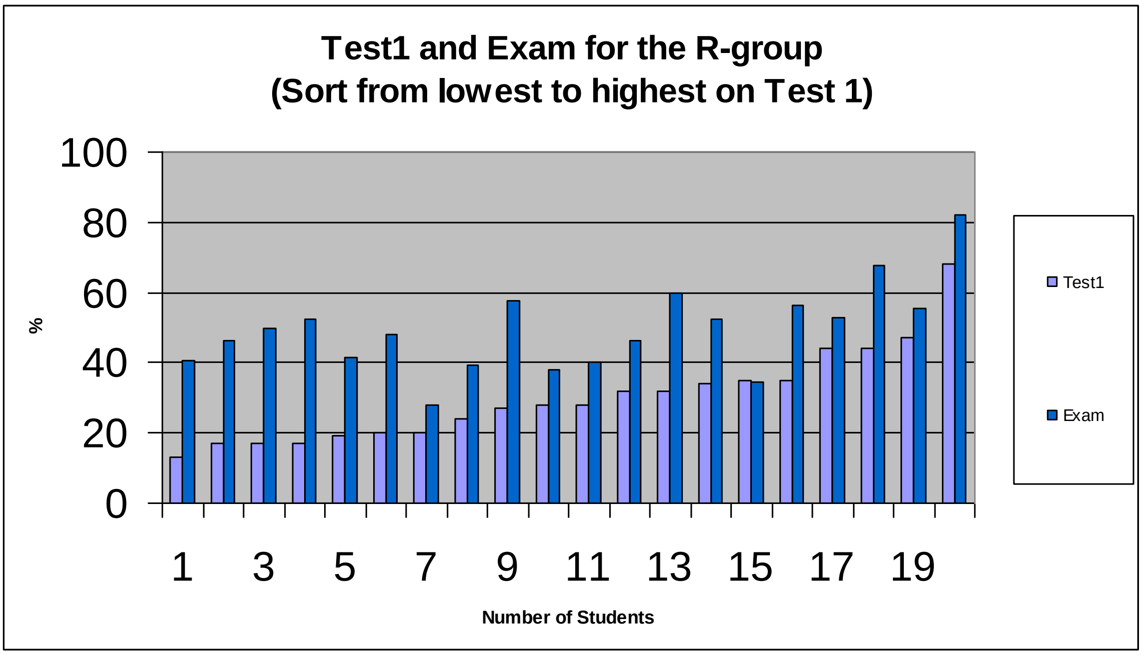


Figure 76. Test1 and Exam Marks for R-group

No correlation could be found between the Test 1 marks and any of the experiments as shown in Figure 77.

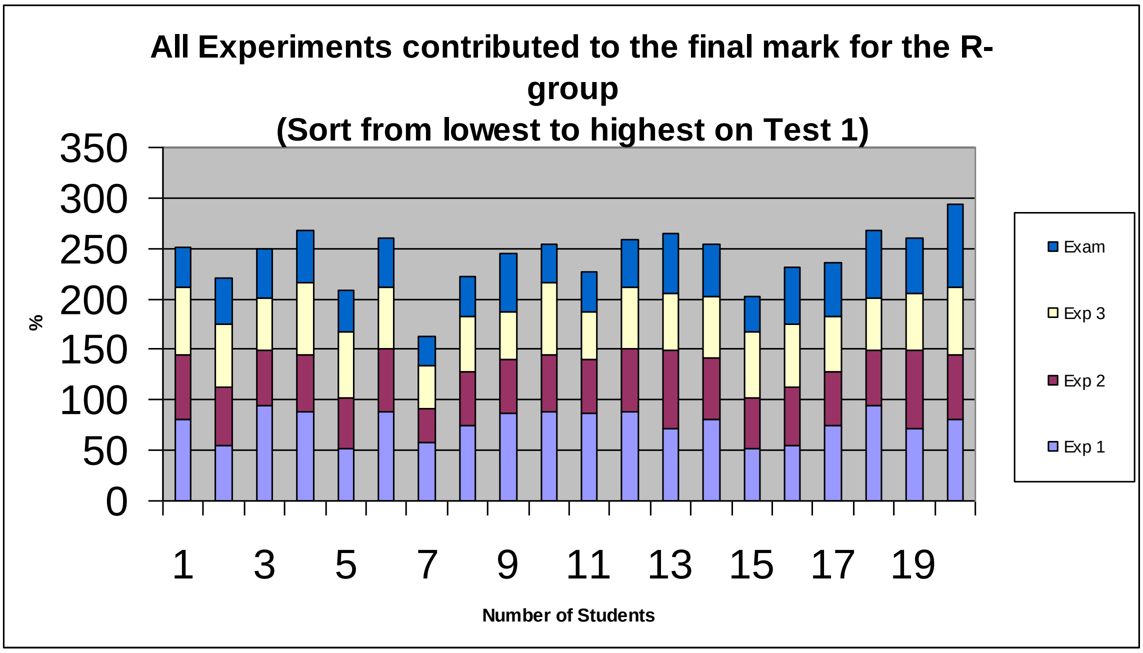


Figure 77. All Tests contributed to the final Mark for the R-group

It seems that most of those R-group students with low marks during test 1 actually improved a lot during Test 1B and even more during Test 2 – see Figure 78. Could the PBL and later the PBL and Remote Lab have caused this?

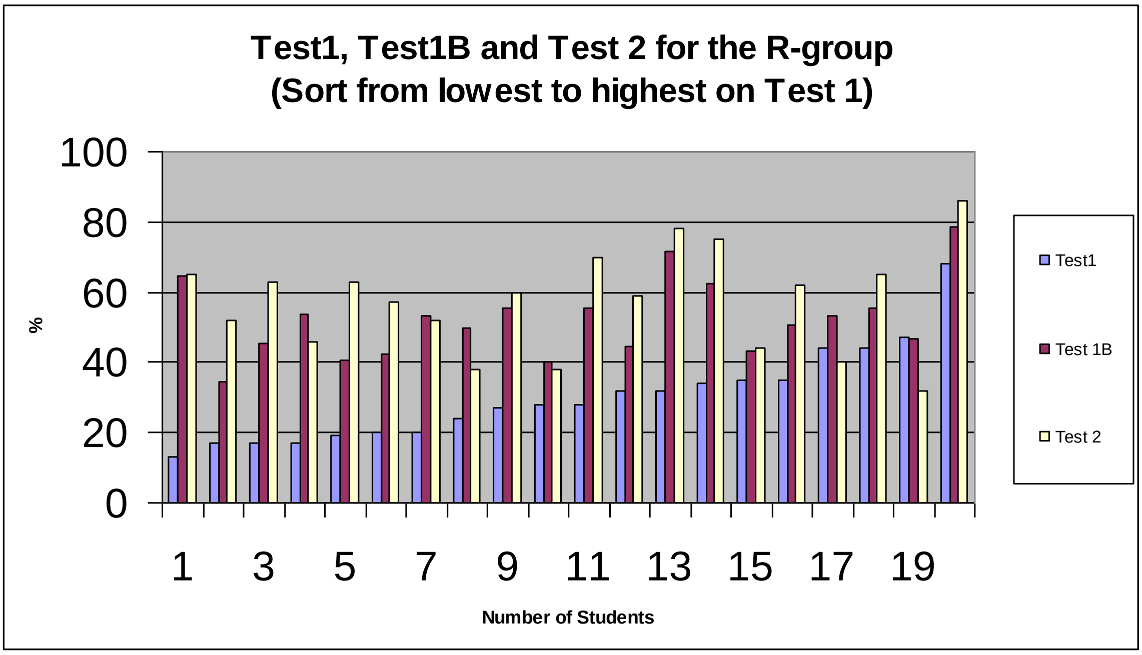


Figure 78. Marks sorted on T1 for R-group

<u>All of the graphs to follow are sorted from low to high based on Test 1B marks</u>

When sorted on Test 1B

Those students from the C-group who had the lowest marks during Test 1B (1-13) were also the lowest during Test 1, but it is interesting to note that the Test 3 marks for many of them improved dramatically (see 2, 6, 7 and 9 in Figure 79. (They used the PBL method during experiment 3 and Test 2 was written just before they completed the experiment)

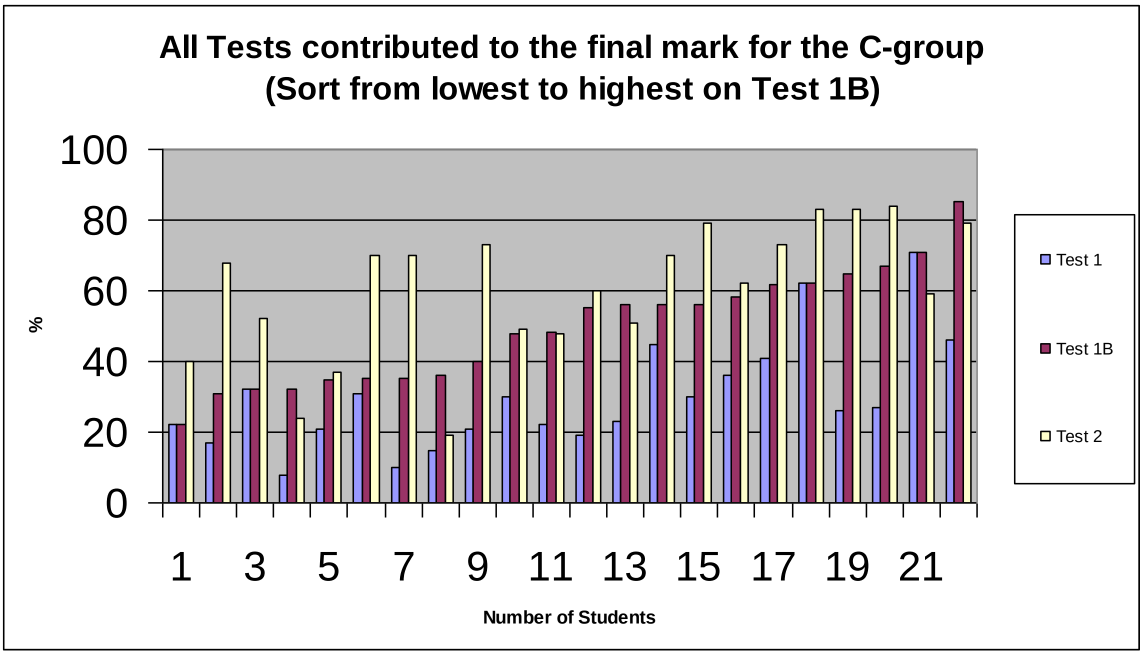


Figure 79. Marks sorted on T1B for C-group

There is no real correlation between Test 1 and Test 1B for the R-group. (This group used the PBL method from experiment 2 onwards and Test 1 was written after experiment 2). Some of the lower achievers like student 1, 3, 4, 6 and 7 did actually improved a lot during Test 2 – see Figure 80. (The PBL based Remote Lab was done during the time of Test 2)

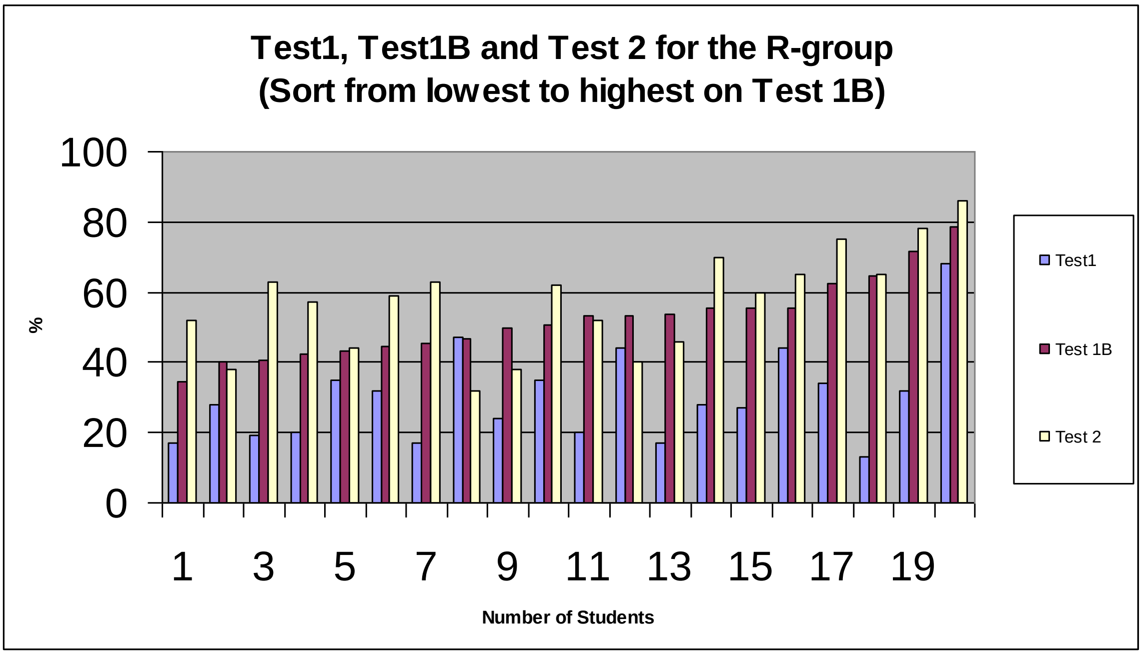


Figure 80. Marks sorted on T1B for R-group

<u>All of the graphs to follow are sorted from low to high based on Exam marks</u>

When sorted on Exam marks

There is a strong correlation between the exam marks of the C-group students and those questions in the exam that relates to experiment 3 (that was done in a PBL way). This might shows that experiment 3 had a big influence on the overall exam results for the C-group – see Figure 81.

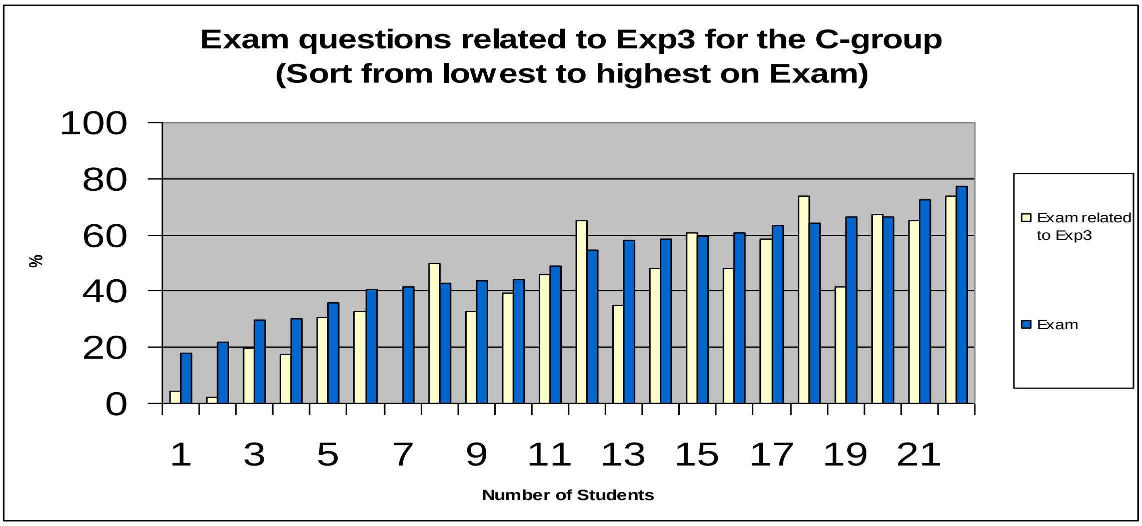


Figure 81. Exam versus Experiment 3 for C-group

The correlation between the exam marks of the R-group students and those questions in the exam that relates to experiment 3 (that was done in a PBL way and the Remote Lab) is not as obvious, as for the C-group. Only 5 students of the C-group achieved higher results for the questions in the exam that relates to experiment 3 when compared to the overall exam result. This figure rise to 8 students for the R-group in spite of the fact that there are less students in this group – see Figure 82.

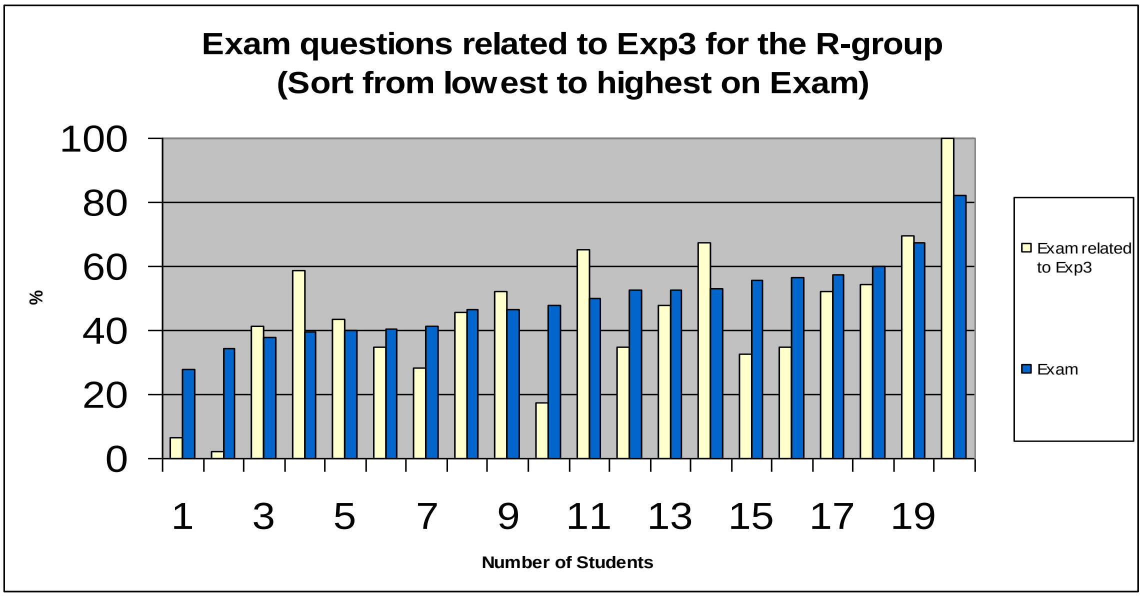


Figure 82. Exam versus Experiment 3 for R-group

Conclusion

It appears as if there is a strong correlation between test and exam mark whenever theory and experiments are done in the traditional way.

Students who used the PBL method seemed to be more motivated and they also have a better attitude. The experiments which are done in at least a hybrid way with the PBL method should be of a reasonable magnitude to make it valid and it usually took a substantial amount of time to complete.

When PBL is used, instead of the traditional way of covering the theory and related experiments, then the following might be true:

- The marks for those students that would have performed poorly when the traditional methods were used might increase their score (even when traditional tests and exams are used to assess them).
- The marks for those students that would have achieved high scores under traditional methods might still do so.

The marks for the experiments do not really correlate to the overall final marks, (but the students had to work in pairs and that might have caused some distortion to these results).

APPENDIX M

Attitude survey examples - Velayutham et al. (2011).

Learning goal orientation

In this Electronics 1 class:
One of my goals is to learn as much as I can.
One of my goals is to learn new Electronics 1 contents.
One of my goals is to master new Electronics 1 skills.
It is important that I understand my work.
It is important for me to learn the Electronics 1 content that is taught.
It is important to me that I improve my Electronics 1 skills.
It is important that I understand what is being taught to me.
Understanding Electronics 1 ideas is important to me.

Task value

In this Electronics 1 class:
What I learn can be used in my daily life.
What I learn is interesting.
What I learn is useful for me to know.
What I learn is helpful to me.
What I learn is relevant to me.
What I learn is of practical value.
What I learn satisfies my curiosity.
What I learn encourages me to think.

Self-efficacy

In this Electronics 1 class:
I can master the skills that are taught.
I can figure out how to do difficult work.
Even if the Electronics 1 work is hard, I can learn it.
I can complete difficult work if I try.
I will receive good grades.
I can learn the work we do.
I can understand the contents taught.
I am good at this subject.

Self-regulation

In this Electronics 1 class:
Even when tasks are uninteresting, I keep working.
I work hard even if I do not like what I am doing.
I continue working even if there are better things to do.

I concentrate so that I will not miss important points.
I finish my work and assignments on time.
I do not give up even when the work is difficult.
I concentrate in class.
I keep working until I finish what I am supposed to do.

APPENDIX N

Motivation survey adopted and modified from an Instructional Materials Motivation Survey (IMMS) of Keller (1993b).

Relevance

In this Electronics 1 class:

It is clear to me how the content of this material is related to things I already know.

There were stories, pictures or examples that showed me how this material could be important to some people.

Completing this lesson successfully was important to me.

The content of this material is relevant to my interest.

There are explanations or examples of how people use the knowledge in this lesson

The content and style of writing in this lesson convey the impression that its content is worth knowing.

This lesson was not relevant to my needs because I already know most of it.

I could relate the content of this lesson to things I have seen, done, or thought about in my own life.

The content of this lesson will be useful to me.

Satisfaction

In this Electronics 1 class:

Completing the exercises in this lesson gave me satisfying feeling of accomplishment.

I enjoyed this lesson so much that I would like to know more about this topic

I really enjoyed studying this lesson.

The wording of feedback after the exercises, or of other comments in this lesson, help me feel rewarded for my effort.

I felt good to successfully complete this lesson

It was a pleasure to work on such a well-designed lesson

Attention

In this Electronics 1 class:

There was something interesting at the beginning of this lesson that got my attention.

These materials are eye-catching.

The quality of the writing helped hold my attention on it.

This lesson is so abstract that it was hard to keep my attention on it

The pages of this lesson look dry and unappealing.

The way the information is arranged on the pages helped keep my attention.

This lesson has things that stimulated my curiosity.

The amount of repetition in this lesson caused me to get bored sometimes.

I learned some things that were surprising or unexpected.

The variety of reading passages, exercises, illustrations etc., helped keep my attention on this lesson.

The style of writing is boring.

There are so many words on each page that it is irritating.

Confidence

In this Electronics 1 class:

When I looked at the lesson, I had the impression that it would be easy for me.

This material was more difficult to understand than I would like for it to be

After reading the introductory information, I felt confident that I knew what I was supposed to learn from this lesson.

Many of the pages had so much information that it was hard to pick out and remember the important points.

As I worked on this lesson, I was confident that I could learn the content.

The exercises in this lesson were too difficult.

After working on this lesson for a while, I was confident that I would be able to pass a test on it.

I could not really understand quite a bit of the material in this lesson.

The good organization of the content helped me be confident that I would learn this material.

APPENDIX O

Reflection survey adopted from National Council for Curriculum and Assessment (NCCA) (2011).

Information Processing

I got information from different sources.
I had to make my own notes in my own words.
I had to present information in different ways like tables and graphs.
I had to summarise the most important points.
I had to choose how to present information most effectively.
I used Information and Communication Technology (ICT) such as computer, video clips or digital camera.

Critical and Creative thinking

I had to look carefully to find information.
I had to find the pattern in information.
I identified similarities and differences.
I asked critical questions.
I used critical thinking to understand problems.
I tried to see things from different angles.
I looked at different ways of solving a problem.
I looked at the results and reached my own conclusion.
I put forward my opinion and/or ideas.
I used my imagination.
I reflect critically on the ideas raised during the experiment when the class is over.

Communicating

I examined the experiment carefully, looking at it from different perspectives.
I checked the reliability and credibility of different sources.
I gave my own opinion.
I listened carefully to what others had to say.
I asked questions and responded to what others had to say.
I expressed myself in a variety of ways:

- Art
- Computer based design and Graphics
- Oral Presentation
- Written Presentation
- Other (Specify)

Working with others

I worked in pairs.
I worked in small groups.
I cooperated with my partner/group member to agree how we would get the task done.
I played my part within the group and took my share of responsibility.
I communicated my ideas.

I listened to the ideas of others and showed respect for other people.
I helped someone else in doing his/her work.
I made helpful suggestions about ways forward.
I helped resolve conflict/disagreement.
I kept to our agreed task and deadline.

Being personally effective

I set out my own objectives and knew what I want to achieve.
I made a plan to help me reach my target.
I went looking for help and resources that I needed to help me.
I received help and feedback from my fellow students.
I received help from my lecturer or lab technician.
I used that feedback to help me to plan my next action and progress further.
I keep up with the requirements even when it was difficult.
I made mistakes and learn from them.
I tried different ways/solutions until I was satisfied that I had found the best.
I kept to my agreed task and deadline.
I felt good about what I have done.
I enjoyed the experiment.

Class experience

I am confident about Electronics I.
When it is not working out, I give up.
I like it when we are doing simulations in the class.
I like it when we are doing the activities in the class.

APPENDIX P

Operational definition of PBL according to Barrett et al. (2005).

1. First students are given a problem.
2. The problem is then discussed by the students within their small PBL groups. They determine the certainties within the case and define the problem. They then come up with ideas based on their prior knowledge. They also make out what they still need to learn to work on the problem. They debate with reference to the problem. They agree on the way forward, how to work on the problem.
3. Now students work individually in finding a solution to the problem. They can make use of: the library, databases, the web, people consultations and observations etc.
4. They then meet again within their PBL groups, let the other in on what they found, explain the detail if necessary and working together on the problem, finding the best solution.
5. They present their solution to the problem.
6. They reflect, and look at what they have learned from working on the problem. All group members participate in a self, peer and tutor review of the PBL process and reflections on each person's contribution to that process.

APPENDIX Q

Power Supply Problem

Assume that you are working for WSU Electronics. They have developed a wireless alarm system that operates from a 12V battery and have sold thousands. Some of the customers are complaining that the battery life for this system is very short and they would prefer that it rather operates from a 220V 50Hz supply. Your boss came to you (and your group mate) and asked you to design, develop and test a suitable power supply for this system. He warned you that the alarm system is very sensitive to voltage changes, but it should work fine if the voltage remains between 11.9 and 12.2 V. He also mentioned that the 220VAC from some of the Electricity Suppliers can go as low as 180VAC and as high as 240VAC from time to time, usually for small periods. The alarm system uses at least 12 mA when passive, but it can go as high as 51 mA when the siren is activated. Thousands of these power supplies are expected to be sold and you are requested to make the system as cheap as possible in an effort to maximise the profit. WSU Electronics are manufacturing various low cost transformers at different power ratings, but they cannot make the ‘centre-tapped’ type. Your boss insisted that you should use one of the transformers from WSU Electronics in your design. The following transformers are available: 8V, 16V, 19V, and 38V.

APPENDIX R

Experiment 2 – The DC Power Supply

Traditional Group

This is the 2nd experiment of Electronics I and you should carefully observe and reflect the strong and weak points of this method to allow for improvements during the planning of the next experiment in an attempt to solve the problem mentioned before.

Software needed	**Components needed**	**Instruments needed**
Multisim Microsoft Excel	Transformer, Diodes, Resistor/s and Capacitor/s 1 x Breadboard	Digital multimeter Oscilloscope

1. **Complete the theory related to the "Full-wave bridge" rectifiers and the Capacitor filter with staff member. (The PBL students should not be part of this group).**
2. **The full-wave bridge rectifier with Zener diode as a regulator.**

(Use the Answer sheet at the back)

Aim: To determine the various waveforms, voltages and frequencies in a full-wave bridge rectifier circuit with zener regulation. Determine the effect of adding a capacitor as a filter.

A. Without Capacitor

Steps:

6. Record all the required values for Fig 5.1 in Table 5.1 after you have calculated them, **using Excel**.
7. **Simulate** Fig 5.2 and record the required values in Table 5.1
8. **Construct** Fig 5.1, on a breadboard and record all values in Table 5.1 (*be careful, the Oscilloscope ground is also connected to all other grounds*)

B. With Capacitor filter

1. Repeat steps 1-3 above, but add a 1000µf capacitor between the + output of the rectifier and ground. (*Be careful, electrolytic capacitors are polarised*)

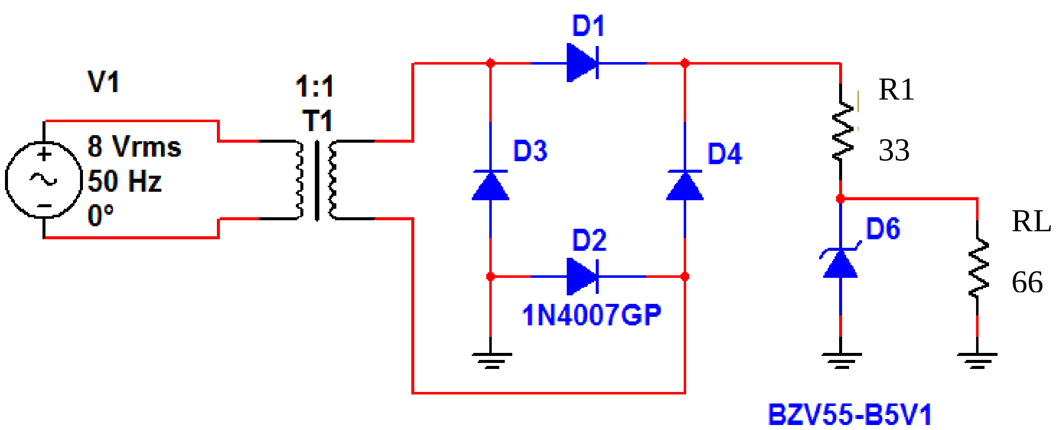


Fig 5.1

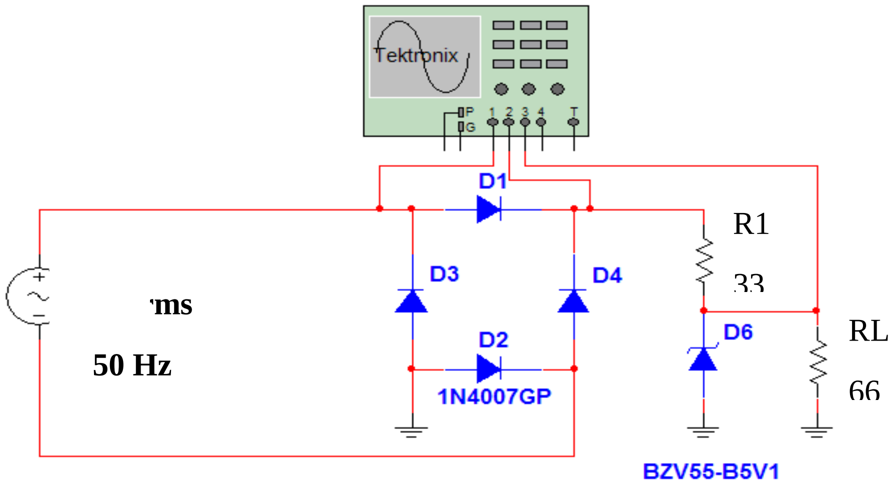


Fig 5.2

Assessment

Students will have a formative and summative assessment. Students will write a small individual test in the beginning to determine their prior knowledge.

On completion of the experiment, each small group needs to submit the Answer Sheet and making a public presentation. The presentation is followed by a discussion period, in which students may be individually asked different questions. Complementarily, self and peer assessment will also be included. Students will also be required to write a small individual test and complete the reflection questionnaire.

Answer Sheet for ETRO1 Unit/Objective 5 Practical - Traditional group

Student Number: ____________________ Date: _________________

Table 5.1 - Full-wave Bridge Rectifier with Zener Diode Regulation.

Biasing	**Unit**	**Calculated (Excel)**	**Simulation**	**Breadboard Circuit**
	$V_{P(sec)}$	**11.312 V**	**10.5 V**	
	$V_{DC(sec)}$	**0 V**	**0 V**	
	$f_{(sec)}$	**50 Hz**	**50 Hz**	
Without Capacitor	$V_{P(rectifier\ out)}$	**9.912 V**	**9.75 V**	
	$V_{DC(rectifier\ out)}$	**6.3 V**	**5.84 V**	
	$f_{(rectifier\ out)}$	**100 Hz**	**100 Hz**	
	$V_{P(RL)}$	**5.1 V**	**5.1 V**	

	$V_{DC(RL)}$		3.534 V	
	$f_{(RL)}$	100 Hz	100 Hz	
With Capacitor	$V_{P(sec)}$	11.312 V	10.5V	
	$V_{DC(sec)}$	0 V	0V	
	$f_{(sec)}$	50 Hz	50 Hz	
	$V_{P(rectifier\ out)}$	9.912 V	9.75 V	
	$V_{DC(rectifier\ out)}$	9.2 V	9.195 V	
	$f_{(rectifier\ out)}$	100 Hz	100 Hz	
	$V_{P(RL)}$	5.1 V	5.1 V	
	$V_{DC(RL)}$	5.1 V	5.156 V	
	$f_{(RL)}$	0 Hz or (100 Hz if small ripple exist)	0 Hz or (100 Hz if small ripple exist)	
	$Vr_{(p-p)\ (rectifier\ output)}$	1.46 V	950 mV	

(9)

Examine the results in table 5.1 (without capacitor). Do they relate? (Explain) (2)

Discuss the difference in results when the capacitor is added. (2)

What if the value of the Capacitor, R_L or Supply Voltage was changed to a different value?

(10)

What if the capacitor was placed in parallel with R_L (instead of between the + output of the rectifier and ground)? (2)

TOTAL [25]

APPENDIX S

Guidelines to follow in using PBL based on Moebs et al. (2006) and (Maastricht University, 2018).

1. Clarifying the task – The purpose of the first step is to explain the task, to agree on the meaning of the various words and terms and on the situation described in the problem. Group members may be familiar with some of these whilst some can be retrieved from a dictionary.
   Questions:
   - Do you understand words, terms and notions?
   - Do you agree on what they mean?
2. Defining the problem - The group discuss and reach an agreement on the issues, which need explanation.
   Questions:
   - What are the problems?
   - What are the sub problems?
   - Decide on the problems/sub problems
3. Brainstorming - Viewpoints on the basis of prior knowledge are bring together and thoughts on how to structure the problem are articulated. Explanations are arranged into tentative solutions.
4. Rating of Brainstorming outcomes
5. Creating learning objectives to cover knowledge shortfalls - Group agree on the learning objectives; tutor ensures learning objectives are focused, achievable, comprehensive, and appropriate.
   Questions
   - What knowledge do you need before you can solve the case problems?
   - Write down the learning goals
   - Where can you learn about it?
6. Self-study of the group participants. This part provide students an opportunity to acquire a more intense knowledge of concepts at the root of the problem. The group members gather information related to the defined learning objectives individually. Information is obtained from the literature, library, journals and the internet etc.
7. Assessing possible solutions and determining a final solution – Each person in the group shares their findings of self-study. The tutor examine the learning and may assess the group.
8. All participants reflect and provide feedback on the case, process and tutor in an attempt to improve the learning process. Students also need to justify that the course was valid and comment on the value of the problem as well as on the worth of the group process and the functioning of the tutor.
   Questions:
   - What have you learnt?
   - Did you use what you have learnt to solve the case problem?

The purpose of tutors/trainers of PBL groups is to facilitate the students in the PBL process by guiding and supporting them. Tutors/trainers need to make sure that students understand the problem, encourage them to keep on asking questions and give details on their way of understanding which can include the use of diagrams and drawings. Tutors/trainers should also encourage clinical thinking and make sure that groups accomplish their learning goals. Students who study using the PBL method needs to be more active during the process. Students essentially become each other's teachers.

APPENDIX T

Level Descriptors for the South African National Qualifications Framework - NQF Level Ten (SAQA, 2012)

a. Scope of knowledge, in respect of which a learner is able to:
    - Demonstrate know-how and decisive knowledge in an area at the forefront of a field, discipline or practice.
    - Be able to conceptualise new research platforms and generate new knowledge or ideas put into practise.
b. Knowledge literacy, in respect of which a learner is able to:
    - Prove that s/he got the ability to play a part in scholarly debates around concepts of knowledge.
    - Construction of knowledge in an area of study or practice.
c. Method and procedure, in respect of which a learner is able to:
    - Demonstrate the ability to develop new novel techniques, methods, systems, processes or technologies
    - Use innovative and creative ways suitable to a particular and involved situation.
d. Problem solving, in respect of which a learner is able to:
    - Show the skill to make use of professional knowledge and theory in spontaneous, critically, creative and innovative ways to deal with compound practical and theoretical problems.
e. Ethics and professional practice, in respect of which a learner is able to:
    - Prove that they have the ability to recognise, tackle and deal with developing ethical issues.
    - To move forward with procedures of ethical decision-making, including scrutinising the consequences of these decisions where applicable.
f. Accessing, processing and managing information, in respect of which a learner is able to demonstrate the ability to:
    - Make judgements on his/her own about dealing with lacking or unreliable information or data in a repetitive process of investigation and generating from the known, for the expansion of significant original insights into new, complex and abstract ideas, data or problems.
g. Producing and communicating information, in respect of which a learner is able to:
    - Produce a considerable amount of publishable in-depth work that comply with international standards as an individual.
    - Produce publishable work which makes a significant contribution to the discipline, field, or practice.
    - Produce publishable work which is believed to be new or innovative by peers.
    - Develop a communication strategy to spread and support research, tactical and policy initiatives and their implementation to professional and non- professional audiences by means of academic and professional resources or work-related discourse.
h. Context and systems, in respect of which a learner is able to:
    - Show a perception of theoretical foundations in the administration of complex systems to accomplish systemic change.
    - Show the capacity to design, sustain and manage change within a system or systems without the help from others.
i. Management of learning, in respect of which a learner is able to:

- Show the ability to demonstrate intellectual individualism, study leadership and administration of research and research growth in a discipline, field or practice.

j. Accountability, in respect of which a learner is able to:
    - Prove that s/he can operate independently and take full responsibility for his or her learning, and, where appropriate, lead, oversee and be held ultimately accountable for the overall control of procedures and procedures.

APPENDIX U

Self-assessment checklist based on Jurković et al. (2005).

Please answer how you were able to cope with all the different tasks required in problem-based learning. Tick either “Not Yet”, “With Difficulty”, “With Ease”. (Tick in block of your choice).

STUDENT NUMBER ______________________________	I can do this		
Situation	Not Yet	With Difficulty	With Ease
Study/Research Skills I can access all the facilities available for finding information.			
I can integrate information from a number of different sources.			
I can plan my own learning to address the problem.			
I can judge what I know and what I still don’t know.			
Group work Skills I have acquired skills necessary to work in the group.			

What can you do now that you couldn’t do before?

____
____
____
____

Do you think working in problem-based learning group has changed your way of learning Microcontrollers IV?

____
____
____
____

APPENDIX V

Example of a Peer Assessment Form (Busfield & Peijs, 2003).

Case Study Number: ___________

Title: ________________________

Group Number: _______________

Group Tutor: __________________

Name: _________________________

Individual performance marks:	
Student	Performance mark

APPENDIX W

Typical scaling multipliers.

Student performance	Multiplier
Excellent	1.1
Good	1.05
Average	1.0
Below average	0.95
Poor	0.9

APPENDIX X

Example of Group Assessment Form (Busfield & Peijs, 2003).

Case Study Number: ___________ Date:___/___/___

Title: ________________________

Group Number: _______________ Group Tutor:__________

Presentation: ___/10 Report:___/10

Average mark: ___/10

Group assessment form		
Student Name	Individual Scale Factor (multiplier)	Total Individual Mark /10
	1.1	
	1.05	
	1.0	
	0.95	
	0.9	

APPENDIX Y

Example of Rating Scale for Group Report (Jurković et al., 2005).

Case Study Number: ___________ Date:___/___/___

Title: _______________________

Group Number: _______________ Group Tutor:_________

Please assess the report by giving a grade from 1 - 5 in each of the following categories:

(1 = not at all, 5 = very much so)

Rating Scale for Group Report					
Student's Name					
Contains relevant, insightful information, the solution offered is based on factual data (preferably assessed by subject teacher)					
Demonstrates awareness of structure (either Problem/Solution or Introduction, Methods, Results, and Discussion pattern)					
Shows ability to plan and complete own elements of written team report.					
According to Standard of English? Acceptable, appropriate word order, appropriate vocabulary, spelling correct.					
Meets the standards of academic writing, uses referencing, citation conventions broadly observed.					

APPENDIX Z

Peer-assessment checklist based on the Kosel, B. design (Jurković et al., 2005).

Please assess the other members of your group by giving a grade:

3 - better than most of the group

2 - about average for this group

1 - not as good as most of the group

0 - no help at all

-1 - hindrance to the group

Topic	Student A	Student B	Student C
Attend meeting regularly, accepted fair share of work and completed by the required time.			
Contributed to the group discussions, helped to identify the key issues of the problem and made meaningful contributions to the group discussions.			
Positive attitude to the group, encourager, supporter of team decisions.			
Has researched the topic well, the quality of his/her contribution.			

APPENDIX AA

Laboratory C2.4 when Converted as a PBL Laboratory

Figure 83. Photos of the Laboratory after Conversion to PBL Orientated Lab.

APPENDIX BB

Assessment methods that could be used during PBL

Formative Assessment

Students' learning is largely influenced by the teaching and assessment methods used (Wood, 2003). If assessment solely relies on factual recall then PBL is unlikely to succeed in this, or in any curriculum, for that topic. The students should be evaluated and tested within the predetermined curricular outcomes and an appropriate range of assessment methods should be used, e.g. activities within the PBL groups (Wood, 2003). The goal of assessment is to monitor the progress of the student. The goal of ongoing (formative) assessment is to monitor the students' learning and to provide feedback that can be used by instructors to improve their teaching and for students to improve their learning. More specifically, formative assessment aims at:

- Helping students to identify their strengths and weaknesses; it needs to spot areas that need attention and particular improvement.
- Helping teachers to recognize where students start struggling and address problems immediately.

Both summative- and formative approaches to assessment are needed (OECD, 2005), especially for obtaining a final grading of the student at the end of the course. "When the cook tastes the soup, we may speak of formative assessment. When the guests taste and like/dislike the soup; that is summative assessment." --Bob Stake (Waters & McCracken, 1997a). The distinction between formative and summative assessment can be opaque in some cases, (e.g. in the case of in-course assignments). Sometimes, assignments are deliberately designed to be both formative and summative – "formative because the student is expected to learn from unexpected sources" (Trauth-Nare & Buck, 2011).

Formative assessment is based on the idea that students should learn to take control of their learning, and be able to comprehend, understand and profit from prior experiences (Hall, 2014). Formative assessment relies on any principle and applied instructional method in order to determine students' understanding at any point during instruction (Trauth-Nare & Buck, 2011).

The learning process should be transparent through:

- establishing and communicating learning goals,
- tracking student progress and, in some cases,
- adjusting goals to better meet student needs (OECD, 2005).

Formative assessment improves self-reflection by students and reinforces the idea that one's ability to comprehend, understand and profit from prior experiences can be optimized all the time and is not fixed (Hall, 2014). Implementing assessment as an instructional approach requires a cultural change within schools and education in general (Hall, 2014). Trauth-Nare and Buck (2011) indicate that a large amount of formative assessments may be time consuming.

One should thus plan and choose assessment methods very carefully based on the available time.

Summative Assessment

Summative assessment concerns the extent to which a student has achieved and mastered the outcomes specified in the curriculum design (Yorke, 2005).

The Teaching-and-Learning-Team (2017) suggests that tests or exams need to be given back to the students so that they can learn from mistakes and to have another look at those questions that gave most students problems. It is also possible to use reflective journals and contributions from tutors (who award a mark with feedback) as part of the summative assessment (Wood, 2003). A group mark could also be awarded for e.g. a poster with individual marks contributing towards the individual student's performance during a question and answer session which occurs directly after the posters have been assessed and also for attendance (Trauth-Nare & Buck, 2011).

Self-Assessment

Individual student contributions within group learning are assessed through self-assessments and peer-assessments in addition to teacher assessments, which are later combined to arrive at the overall course grade (Aliasa, Masekb, & Salleh, 2014). During peer assessment, students judge the work of other students, while during the self-assessment process, each student makes an evaluation about their own work (Aliasa et al., 2014). Self-assessment can be done several times within a module, while students are still learning (Trauth-Nare & Buck, 2011) and it works well with PBL according to MacDonald (2005).

Each student evaluates his own work and thinks about his own learning during self-assessment. This stimulates them to make sense of what the teacher says, relates it to previous learning and uses it for future learning (Teaching-and-Learning-Team, 2017). Former feedback from teachers is often used by students as a reference for judging their own work. Hence, a good idea for teachers is to discuss particular skills students need in a certain task (Teaching-and-Learning-Team, 2017). Making student self-assessment an integral part of the course assessment process is ultimately beneficial for all who are involved (Joham, 2008). Self-assessment is an additional tool for reaching beyond traditional testing and widening the perspectives of both teachers and students (Jurković et al., 2005). Self-assessment enables students to set their own learning targets and to be in charge of their own learning (Teaching-and-Learning-Team, 2017). When rubrics are used as part of the evaluation, it is then recommended that it is shared with the students at the very moment that the assignment is made. This will not only guide the performance of each student but also assist in self-assessment (Joham, 2008). A typical example of a self-assessment questionnaire is shown in APPENDIX U.

Peer Assessment

In PBL, students are subjected to assessments from many stakeholders such as teachers, by themselves and by peers. All of these are combined in order to obtain an overall course grade (Kolmos & Holgaard, 2007). Peer assessment seems to be an appropriate evaluative process for the PBL tutorial setting since they both focus on group collaboration and they also share key objectives and philosophies (Kritikos, Woulfe, Sukkar, & Saini, 2011).

Peer feedback, or peer assessment, is the process by which students assess each other's work and give each other feedback (Teaching-and-Learning-Team, 2017) based on an understanding of what successfully completes a certain task (Team, 2016). Teachers are vital to this process, since they know their students and they can help them to develop their own critical and reflective thinking skills (Team, 2016). Students, above all, need to think critically during peer assessment activities since they need to critically evaluate their peers work as well as digest feedback from their peers (The University of Texas at Austin, 2016-2017).

Peer assessment is typically used in evaluating projects and practical presentations (MacDonald & Savin-Baden, 2004), but it is in reality also useful and highly informative to students and educators when essays are used (MacDonald, 2005).

Group work is an essential component in PBL and a confidential peer assessment checklist can be used for administering which students of a certain group are asked to assess their peers in terms of their contribution to the group: regular participation, active collaboration, commitment to the common goal, readiness to share knowledge, etc. (Jurković et al., 2005). APPENDIX Z shows a typical example of such a tool and it should be made known to students from the very beginning or at latest at the second meeting according to Jurković et al. (2005).
Peer assessment and feedback works well with PBL as it imitates an environment where teams work together, similar to what would be expected from professionals in the working environment (MacDonald, 2005). The process of giving and receiving feedback is accepted as an important aspect of student learning (Kolmos & Holgaard, 2007), as this process provides students with valuable skills for professional environments and prepares them for learning yet to come (Aliasa et al., 2014). Peer feedback can encourage the more gifted students to reinforce their learning by explaining ideas to their less-talented classmates. Also it improves the diplomacy and communication skills of all students (Team, 2016). Students who assess one another support the learning process and actually get the lazy students to work (Jurković et al., 2005).

Some limitations of peer assessment (O'Neill, Huntley-Moore, and Race (2007b) are:

- A lack of confidence by students to evaluate each other.
- A lack of seriousness during exercises and camaraderie with classmates which may influence their marking.
- Distortion of information due to lack of knowledge - the lecturer may need to intervene.
- Sacrifice the reliability of scores given, leading to an issue of validity of the grading system.

Group Assessment

Students with prior knowledge usually identify brittleness in their understanding when they teach the subject to their peers (Bowe, 2005). Ideally, all group members should achieved the same level of understanding at the arrival of the problem solution. Students can do so by asking each other questions (Bowe, 2005) to ensure everyone understands.

O'Neill, Huntley-Moore, and Race (2007a) suggest that a group mark needs to be assigned to the revealed product, and individual marks for attendance and the quality of any student's contributions at the question and answer session. The assignment product can be:

A device or structure as part of a case study that needs to be submitted at the end of the study period for either evaluation or testing (Busfield & Peijs, 2003).

A written report that is assessed as a "single product" and awarded a mark based on standard assessment criteria (Bowe, 2005). (The report according to Busfield and Peijs (2003), should be structured, include details of any experimental work undertaken, include plots/tables of all the essential discoveries during the investigation and include notes of all group meetings as a record of how the PBL case study progressed).

A twenty minute group presentation that is also assessed as a "single product" and awarded a mark (Bowe, 2005).

A poster presentation (which should be clear, concise, attractive, and easy to read) (Busfield & Peijs, 2003).

A web-based report to explain the students' findings. (This should incorporate colourful graphics and should be easy to navigate). (Busfield & Peijs, 2003).

Take on a role or work within a particular context or scenario, (ideally one that is as authentic as possible) (MacDonald, 2005).

Students who work hard in the group process (Bowe, 2005) and endeavour to contribute constructively should be rewarded whilst those students who did not make an effort to contribute to the group process be penalised. A confidential peer-assessment checklist can be used by which students of the same group assess their peers in terms of their contribution to the group e.g.:

- collaboration
- commitment
- knowledge sharing problem-solving ability
- weigh up group suggestions
- prior and newly acquired knowledge
- practical skills

Performance in team roles (Busfield & Peijs, 2003; Jurković et al., 2005; Pawson et al., 2006)

Busfield and Peijs (2003) suggest that each student in the group completes a typical form at the conclusion of each project. APPENDIX V shows an example of such a Peer Assessment Form.

An easy way to ensure individual marks is to use "scaling factors" that can be generated for each individual student from the data available from the peer assessment forms. These scaling factors act as multipliers, and the average of the multipliers for the whole group must be 1.00. For example, if a tutor wants to award a higher mark to a member of the group, then one or more members' marks must be reduced by a similar amount (Busfield & Peijs, 2003). The average of the multipliers should always be 1.00 as illustrated in APPENDIX W. The group assessment form as shown in APPENDIX X can then be used to calculate the individual marks for each student in a specific group based on the group mark and individual scale factor. Students can also be evaluated individually when they submit a report where each student's contribution can be identified. In such a case, a report rating scale such as the one shown in APPENDIX Y could be used to generate the individual marks (Jurković et al., 2005). During PBL, assessment is conducted within the instruction resulting in meaningful feedback to students (MacDonald & Savin-Baden, 2004). This is in line with Busfield and Peijs (2003) who suggest that immediate feedback is provided on team performance after a presentation. O'Neill et al. (2007a) indicate that students are expected to give and to receive regular peer feedback on their individual contributions within their project groups.

Summary of Assessment

To summarise, various assessment methods could be used in PBL, for instance formative-, summative-, self-, peer- and group assessment. Assessment should be aligned to the curricular objectives, and it is better to test knowledge and competences instead of stand-alone factual knowledge. Assessment should focus on multiple skills and abilities, on processes as well as products. Formative assessment is meant to monitor the students' learning and to provide feedback that can be used by instructors to improve their teaching and for students to improve their learning whilst summative assessment concerns the extent to which a student has achieved and mastered the outcomes specified in the curriculum design. Each student makes an evaluation and thinks about their own work during the self-assessment process, and it can be done several times within a module, while students are still learning. Peer assessment imitates an environment where teams work together, similar to what would be expected from professionals in the working environment. It is the process by which students assess each other's work and give each other feedback. Students can ask each other questions to ensure everyone understands during group assessment. A group mark can be assigned to the revealed product, and individual marks for attendance and the quality of any student's contributions at the question and answer session. Those who worked hard in the group process and endeavour to contribute constructively should be rewarded whilst those students who did not make an effort to contribute to the group process be penalised.

There are various forms of assessment methods, e.g. formative, summative, self, peer and group assessment. All of these can be used when in the PBL mode. Ideally, one should test students in a way that emulates what they had done whilst in the PBL mode, for instance, if students had to design and build a certain electronic unit, then they should be examined in a similar way. Using traditional exams may be irrelevant in many cases when students operated in the PBL mode. The application of knowledge should rather be tested.