Differential effects of variations in problem-based and lecturing sequences

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Abstract: This study describes how problem-based learning (PBL) can best be used as a supplementary to the lecturing mode. The lecturing mode followed/supplemented by PBL is compared with PBL followed/supplemented by the lecturing mode. The PBL problem was project-based and integrates various concepts to match a real-life situation. The attitudinal effects, motivational effects and amount of 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 supplemented in the lecturing mode. The PBL component improves the student's teamwork and communication skills whilst they also learn to apply their knowledge to solve complex engineering problems. There is a real need to address gaps between employer expectations and higher education outcomes in South Africa and it might be worth it for universities to move at least in part to PBL.

Keywords: apply knowledge; electronics practical; engineering education; PBL; problem-solving.

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1 Introduction

South Africa's matric results are among the worst in the world with only one in 10 qualifying for university (Bloch, 2010). Under-prepared students, usually with a score below the minimum entry requirement, may enter some universities in South Africa through 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.

Graduates today might not be as successful in the work place as expected and the authors 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. Engineers are hired, and succeed, for their ability to solve problems. 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.

One of the advantages of PBL is its ability to improve student motivation (Hmelo-Silver, 2004). 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. People acquire knowledge and skills through practice and reflection and not 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 et al., 2005, p.175).

This study investigates the effect of using PBL as a supplement to the normal lecturing mode and vice versa. The extra work is meant to provide an additional foundation to students to facilitate them in the understanding of the course material. "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). According to Boud, Keogh and Walker (1994), when students reflect, they consciously looking at and thinking about their experiences, actions, feelings and responses. They learn from the interpretation or analyses thereof.

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). This together with Costa and Kallick (2008) who indicated that reflection enhances the meaning of work and encourages insight and complex learning from experiences, inspire the decision to compare students who were in the PBL instruction followed by the lecturing mode (G1) and those who were in the lecturing mode followed by PBL (G2) in terms of both their attitude, motivation and reflection.

1.1 Research questions

How does the sequence of supplementing PBL with traditional lectures effect the attitude, motivation and reflection of university students?

It is important to determine the optimal instructional sequence between PBL-lecture and lecture-PBL in the interest of future classes. Using the correct sequence may produce students with a sound theoretical knowledge and be able to solve problems in a critical way.

1.2 Hypotheses

Previous research at WSU shows that with the PBL method, students learned to do research, learned better how to work in groups, developed greater confidence, had more positive attitudes and reflected more (Podges et al., 2014). The positive effect that PBL instigated during the previous research was clear, but the risk of neglecting some important relevant theories had to be addressed. These theories had to be covered either before or after the PBL and the sequence of application may influence the students' attitude, motivation and reflection, and this had to be tested.

Previous groups at WSU who applied PBL with little prior knowledge found it tiresome to familiarise themselves with the theory. It is therefore hypothesised that the sequence, lecturing-PBL produces better results than PBL-lecturing as far as university students' attitudes, motivation and reflections is concerned.

2 Experimental setup

The class of 29 students was divided into Group One (G1) and Group Two (G2). Groups were balanced based on 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 unstable supply voltages and variable loads. The students were not familiar with components such as variable transformers and high power loads and they were also not used to the integration of various modules. Table 1 shows the activities around the experiment.

Table 1 Activities during Semester (related to a portion of module 5)

Week	*Activities*	
9	Pre-survey: attitude, motivation, reflection surveys (G1 and 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 and G2).	

The magnitude of the PBL problem was larger than the traditional 'problem sets' and continued over several laboratory meetings. These students accomplished a working device, similar to the experience of Nedic, Nafalski, and Machotka (2010). Students in the PBL mode used 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%.

The "Adaptive Learning Engagement in Science" questionnaire from Velayutham, Aldridge and Fraser (2011), composed of 31 questions, was adapted to assess students' attitudes toward the Electronics I course (see Appendix A1). It contains four factors of attitudes and perceptions:

1 Learning goal orientation
2 Task value
3 Self-efficacy
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 (1993), who applied the theory of relevance, satisfaction, attention and confidence (ARCS). 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 A2.

The National Council for Curriculum and Assessment (2011) key skills student reflection sheet (as shown at Appendix A3), 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
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 such as

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?"

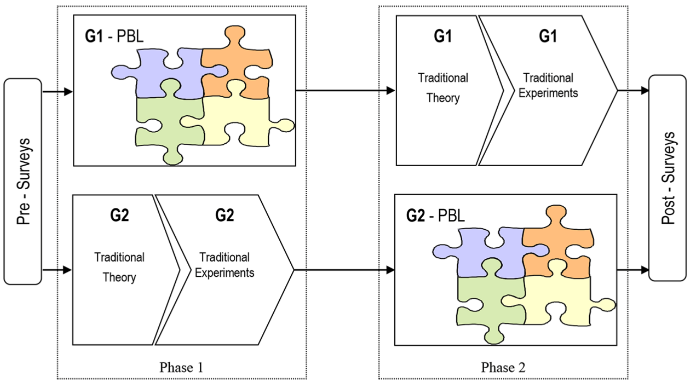
3 "So what was the main thing that you learned?"

4 "Now what - what skill would you like to develop more?"

3 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 1.

Figure 1 Illustration of how the experiment was conducted (see online version for colours)



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 Figure 1.

4 Results

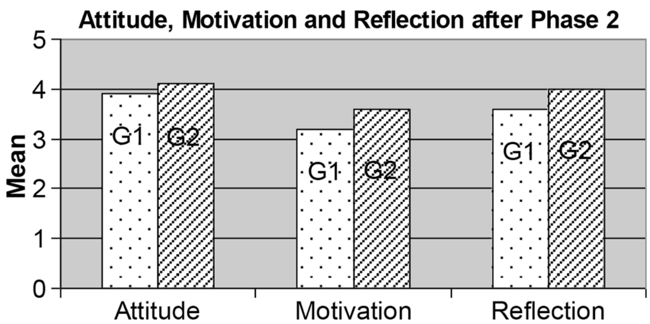
The Cronbach's Alpha coefficient calculated from the overall data for all pre- and post-surveys was ≥ 0.7, showing acceptable to good reliability for all. (See Table 2).

Table 2 Cronbach's Alphas for the overall attitude, motivation and reflection surveys

	Cronbach's Alpha (α)	
Subscale	*Pre-survey*	*Post-survey*
Attitude	0.923	0.930
Motivation	0.920	0.923
Reflection	0.953	0.969

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, but Figure 2 shows that the attitude, motivation and reflection were higher for G2 after the second phase.

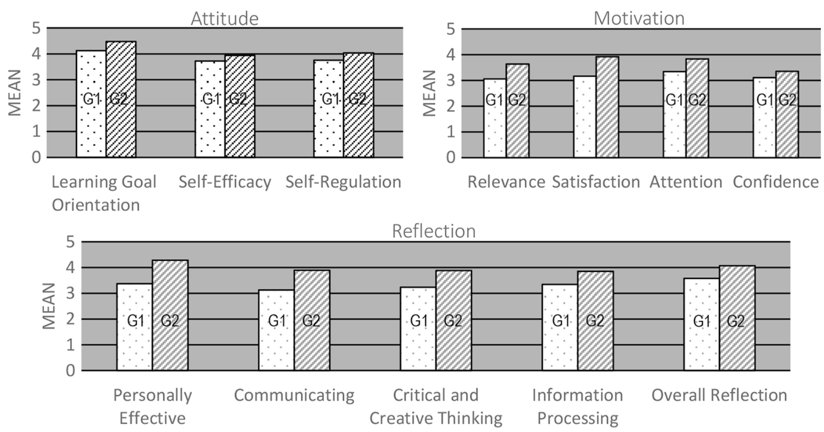
Figure 2 Overall attitude, motivation and reflection after Phase 2



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 done 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.

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-group's were met and those who did not were excluded in the results. Figure 3 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 Appendix C1-C3.

Figure 3 Comparison of the attitude, motivation and reflection sub-groups after Phase 2 between G1 and G2 when the ANCOVA method was used



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

4.1 Attitude

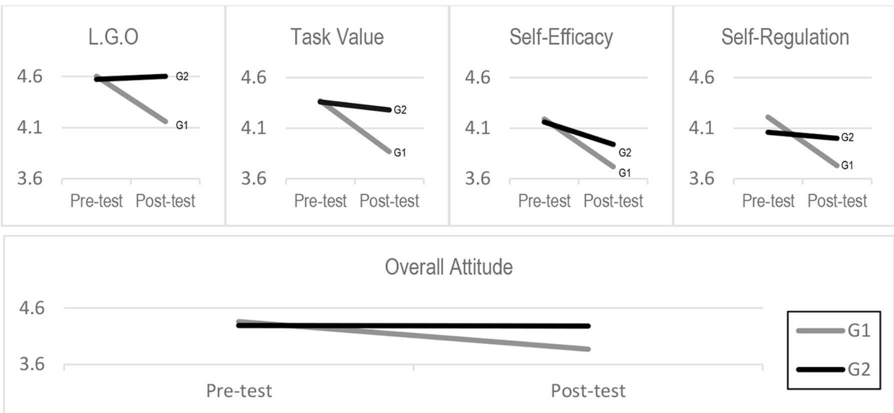
The Cronbach's Alpha coefficient calculated from the data was ≥ 0.7 for most subscales, showing acceptable to good reliability for all but 'Learning Goal Orientation' during the Pre-survey (see Table 3).

Table 3 Cronbach's Alphas for the various subscales of the attitude surveys

	Cronbach's Alpha (α)	
Subscale	*Pre-survey*	*Post-survey*
Learning goal orientation (eight items)	0.654	0.894
Task value (seven items)	0.846	0.903
Self-efficacy (nine items)	0.856	0.855
Self-regulation (seven items)	0.850	0.818

Figure 4 shows a sharp decline in the attitude of G1. They became more negative since they received related theory after the PBL. They would have preferred to enter the PBL with the theory already covered, similar to what G2 has done.

Figure 4 Multiple comparison between the LS means of pre- and post-survey results related to attitude for G1 and G2. Includes the least square means of learning goal orientation (LGO), 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 Appendix B1. Appendix C1 also shows that after controlling for pre-test scores, the average 'Learning Goal Orientation' and 'Self-efficacy' attitude subgroups post-test scores for G2 were statistically significantly higher than the average post-test scores for G1. The sequence, lecture-PBL versus PBL-lecture resulted in a big contrast, and the overall in-between difference in the attitude between the two groups reached significant level as shown in Table 4.

Table 4 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	0.278	11	4.28	0.374	14	0.028*

*$p < 0.05$.

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' attitudes are concerned.

4.1 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 5).

Table 5 Cronbach's Alphas for the various subscales of the motivation surveys

	Cronbach's Alpha (α)	
Subscale	*Pre-survey*	*Post-survey*
Relevance (9 items)	0.652	0.657
Satisfaction (6 items)	0.848	0.895
Attention (12 items)	0.666	0.716
Confidence (9 items)	0.719	0.770

The least square means show a similar tendency for all motivational subgroups as well as for the total (overall) as shown in Figure 5. 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 5 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 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- and post-survey as shown in Appendix B2. 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.

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.

4.2 Reflection

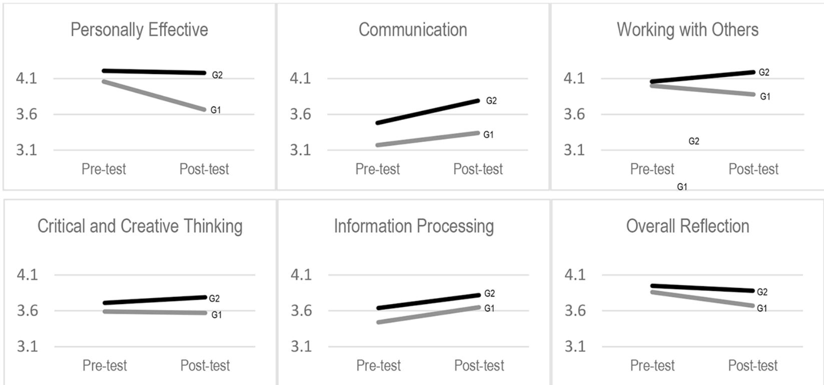
The Cronbach's Alpha coefficient calculated from the data was ≥ 0.7 for most subscales, showing acceptable to good reliability (see Table 6).

Table 6 Cronbach's Alphas for the various subscales of the reflection surveys

	Cronbach's Alpha (α)	
Subscale	*Pre-survey*	*Post-survey*
Personally effective (12 Items)	0.899	0.905
Communicating (10 Items)	0.842	0.818
Working with others (10 Items)	0.698	0.836
Critical and creative thinking (11 Items)	0.855	0.864
Information processing (6 Items)	0.802	0.803
Overall reflection (6 Items)	0.866	0.934

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 6. The reflection of G2 students increased in most of these subgroups whilst it was the other way round for G1.

Figure 6 Multiple comparison between pre- 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 processing as well as the overall reflection.



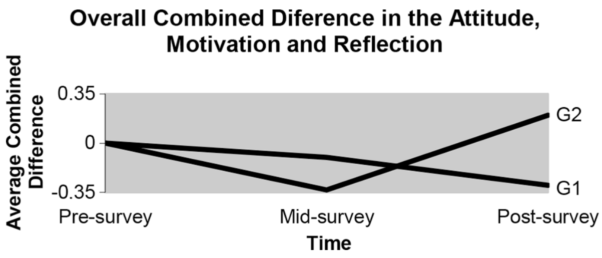
Post hoc comparisons using the Fisher LSD test revealed that G1, who entered the PBL mode with almost no prior knowledge and then replicated similar content in the lecturing mode, showed a significantly greater reduction in their reflection than G2 who entered PBL with a much higher level of prior knowledge. The drop in the reflection of G1 reached significant levels in the 'Personally Effective' subgroup category between the pre- and post-survey time periods as shown in Appendix B3. Appendix C3 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.

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.

5 Conclusions

Many of the graphs (see Figure 4-6) give the impression that there was a decline in the attitude, motivation and reflection of the students of both groups. Mid-surveys were also done after phase 1, but that was omitted to simplify the results of this document apart from Figure 7 that shows the overall combined 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, because they 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 subject 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 and a possible reason why the attitude, motivation and reflection of both groups declined during the first phase.

Figure 7 Comparison of the combined attitude, motivation and reflection before and after the study



Both groups managed to complete the second phase in substantially less time (see Table 1). The G1 students obtained lot of 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 7 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 their sequence was the other way round.

Figure 4 shows a much higher 'Task Value' and 'Learning Goal Orientation' for G2 at the post-survey (when compared to G1). These students found the lecture-PBL method useful, interesting, of practical value and they felt that they have master the content and skills. They were also more 'satisfied' according to Figure 5, 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 6, a strong indication that G2 students felt that they have reached their targets and meet the requirements.

A summary of possible reasons for the difference in results between the groups are shown in Table 7.

Table 7 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 second phase. Probably because:	Student's attitude, motivation and reflection were positively affected when they moved from lecturing mode to PBL during the second phase. Probably because:
• They had already gained most of the theoretical knowledge during the PBL activities.	• They entered PBL with a higher prior knowledge.
• They had to repeat similar work in the lecturing mode.	• 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.

Table 7 Possible reasons for the difference in attitude, motivation and reflection between the groups (continued)

G1 - PBL activities followed by the lecturing mode	*G2 - Lecturing mode followed by PBL activities.*
• They prefer practical's, working in groups and applying skills to theory.	• Their increased confidence helps to solve the PBL problem by means of calculation and critical thinking.
• The theory seems to be the least attractive to them.	• PBL is student-centered and they had to take responsibility of their own learning.
• 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.	• They were busy with PBL activities

These students were 'under prepared' from the schooling system, the reason for ending up in the 'extended-stream. PBL has the goal to make learners 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.

6 Discussions

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 conventional methodologies where it is possible for the teacher to lecture on, and continue with the course regardless if the students participate or not. With PBL it is not easy to alter the pace during the study due to the student-centered teaching strategy, and therefore it is more suitable for extended stream students who have more time available to complete the syllabus.

It is a good starting point for students to enter PBL activities with a high prior knowledge (like 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 arise 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 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 those theory not required to solve 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's after the theory. Perhaps because of the specific instructions that they had to follow from the handouts, 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 following came from the qualitative data in the reflection survey:

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

PBL - 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 content of the theory. Many of them found it tiring to search and find the information themselves.

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

Traditional mode - Enjoy 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.

PBL - 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.

6.1 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 learners 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, Northwood and Northwood (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.

6.2 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.
- Different 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.

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APPENDICES

Appendix A1

Attitude survey examples - Velayutham, Aldridge and Fraser (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 A2

Motivation survey adopted and modified from an IMMS of Keller (1993).

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 organisation of the content helped me be confident that I would learn this material.

Appendix A3

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

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 fell good about what I have done.

I enjoyed the experiment.

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.

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.

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 summarize 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.

Appendix B1

A comparison between pre- and post-survey results related to attitude for both groups

		Pre-survey			*Post-survey*			
Subgroup		*M*	*SD*	*n*	*M*	*SD*	*n*	*p*
Learning goal orientation - goal to learn, understand and master content and skills	G1	4.60	0.320	16	4.16	0.431	14	0.002*
	G2	4.57	0.403	14	4.60	0.389	13	0.947
Task value - useful, interesting, relevant and of practical value	G1	4.37	0.560	14	3.87	0.470	14	0.009*
	G2	4.36	0.415	14	4.28	0.647	14	0.657
Self-efficacy - students self-belief in producing a desired effect	G1	4.19	0.508	16	3.72	0.457	14	0.000*
	G2	4.16	0.408	14	3.94	0.561	14	0.091
Self-regulation - work ethics	G1	4.21	0.559	16	3.73	0.426	14	0.000*
	G2	4.06	0.686	14	4.00	0.657	13	0.685
Overall - includes all subgroups	G1	4.36	0.392	14	3.87	0.278	14	0.000*
	G2	4.29	0.402	14	4.28	0.374	12	0.696

*$p < 0.05$.

Appendix B2

A comparison between pre-survey and post-survey results related to motivation for both groups

		Pre-survey			*Post-survey*			
Subgroup		*M*	*SD*	*n*	*M*	*SD*	*n*	*p*
Relevance - relevant knowledge, important, worth knowing, relate to it and useful	G1	3.74	0.684	16	3.13	0.541	14	0.000*
	G2	4.20	0.378	14	3.69	0.554	12	0.005*
Satisfaction - accomplishment, enjoyment, curiosity, reward and achievement	G1	3.89	0.980	15	3.17	0.915	16	0.006*
	G2	4.19	0.694	14	3.94	0.776	12	0.521
Attention - interesting, variety and appearance	G1	4.01	0.553	14	3.39	0.573	15	0.000*
	G2	4.17	0.419	13	3.83	0.551	13	0.064

A comparison between pre-survey and post-survey results related to motivation for both groups (continued)

Subgroup		Pre-survey M	Pre-survey SD	Pre-survey n	Post-survey M	Post-survey SD	Post-survey n	p
Confidence - be able to learn and understand	G1	3.73	0.675	16	3.13	0.816	15	0.001*
	G2	3.94	0.516	14	3.35	0.475	13	0.002*
Overall motivation - includes all subgroups	G1	3.82	0.644	13	3.24	0.692	12	0.001*
	G2	4.14	0.438	13	3.71	0.505	11	0.036*

*$p < 0.05$.

Appendix B3

A comparison between pre-survey and post-survey results related to reflection for both groups

Subgroup		Pre-survey M	Pre-survey SD	Pre-survey n	Post-survey M	Post-survey SD	Post-survey 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	0.749	14	3.67	0.426	13	0.032*
	G2	4.21	0.564	11	4.18	0.658	14	0.703
Communicating - the activity of conveying information, investigate, validate sources, give opinion, listen, express	G1	3.17	0.824	16	3.34	0.575	15	0.252
	G2	3.48	0.648	11	3.79	0.559	14	0.089
Working with others - small groups, listen, participate, cooperate, responsibility, suggest, resolve conflict	G1	4.00	0.514	16	3.88	0.408	14	0.593
	G2	4.06	0.450	12	4.19	0.617	14	0.191
Critical and creative thinking - find information, solving problems, make conclusions, reflect	G1	3.59	0.736	16	3.57	0.390	13	0.775
	G2	3.71	0.666	12	3.79	0.615	14	0.510
Information processing - consult different sources, make notes, present, summarise, use ICT	G1	3.44	1.061	15	3.65	0.426	14	0.253
	G2	3.64	0.692	12	3.82	0.824	12	0.268
Overall reflection - includes all 51 questions	G1	3.86	0.564	13	3.67	0.343	9	0.214
	G2	3.95	0.517	10	3.88	0.660	12	0.610

*$p < 0.05$.

Appendix C1

A comparison between G1 and G2 at the post-survey results related to attitude

	G1		*G2*			
Subgroup	*M*	*n*	*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	0.019*
Self-efficacy - students self-belief in producing a desired effect	3.72	15	3.94	14	1.429	0.243
Self-regulation - work ethics	3.75	15	4.04	14	4.261	0.049*

*$p < 0.05$.

Appendix C2

A comparison between G1 and G2 at the post-survey results related to motivation

	G1		*G2*			
Subgroup	*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	0.082
Satisfaction - accomplishment, enjoyment, curiosity, reward and achievement	3.17	16	3.92	13	4.163	0.052
Attention - interesting, variety and appearance	3.34	16	3.83	13	3.983	0.057
Confidence - be able to learn and understand	3.11	16	3.35	13	0.388	0.539

*$p < 0.05$.

Appendix C3

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	0.012*
Communicating - the activity of conveying information, investigate, validate sources, give opinion, listen, express	3.13	16	3.90	12	6.120	0.021*
Critical and creative thinking - find information, solving problems, make conclusions, reflect	3.24	16	3.89	12	3.928	0.059
Information processing - consult different sources, make notes, present, summarise, use ICT	3.35	16	3.86	12	1.871	0.184
Overall Reflection - includes all 51 questions	3.58	15	4.07	12	6.601	0.017*

*$p < 0.05$.