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Vicarious Learning in PBL Variants for Learning Electronics

Martin Podges[1*] Piet Kommers[2]
1. Department of Electrical Engineering, Walter Sisulu University, PO box 811, Gonubie, South Africa, 5256
2. Faculty of Behavioural Sciences, University of Twente, Box 217, 7500 AE Enschede, The Netherlands

Abstract
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.
Keywords: PBL, vicarious learning, engineering education, electronics practical, applying knowledge

1. 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, Maxwell, and Bellisimo (2006), low-verbal students may learn more in PBL classes than in traditional classes. 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 et al. (2006) through this process. PBL also increases motivation according to Bartscher, Gould, and Nutter (2009). Additionally, PBL develops collaborative skills such as understanding multiple perspectives (ChanLin, 2008).

Through PBL, students should be able to acquire knowledge and know how to apply this knowledge in real situations (Sockalingam & Schmidt, 2011). Savery and Duffy (1995) recommends that authentic contexts be used in PBL. It is also preferred that the information is to be learned in context to improve retention according to Brown, Collins, and Duguid (1989). Relevant problems engage students and contribute to the learning process. Reasoning ability and the successful completion of the task are factors that had a direct and indirect impact on achievement according to Araz and Sungur (2007). Results by Des Marchais (1999) suggests that PBL confrontation stimulates thinking or reasoning and leads to self-directed learning.

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. 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 to confront the WSU first-year extended stream students with multiple PBL problems at once. 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).

1.1 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 vicarious learning when multiple PBL problems are being solved by other groups in parallel?
3. Does PBL improve attitude, motivation, and reflection and does it lead to a lower dropout rate?

1.2 Hypotheses

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

1. A PBL problem which is achievable yet challenging, can turn into a spectacular final product will be most suitable in terms of learning effectiveness.
2. That the students who solve a PBL problem by themselves will learn most, followed by the students who inherit the project from another group. Students not-involved with a specific PBL problem will only learn from it if it caught their attention.
3. PBL improves motivation, attitude, and reflection in students. It finally results in fewer dropouts.

2. Method

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

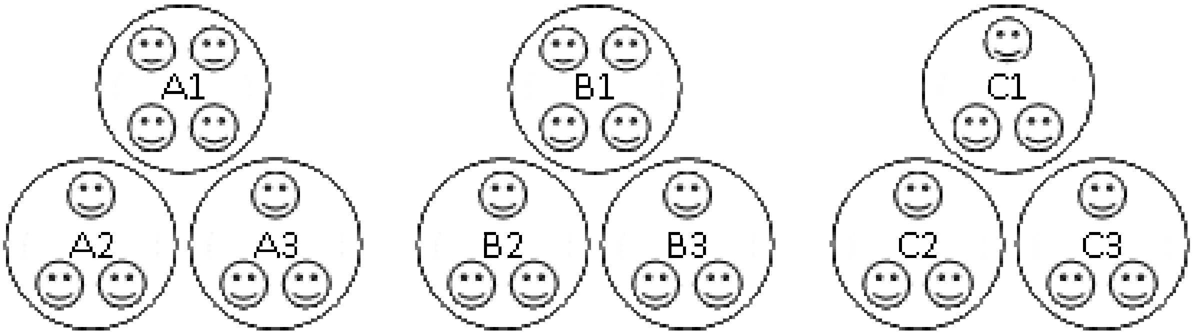

Figure 1. Twenty nine students were divided into nine groups, with three or four students in each group

The experiment was designed and conducted (Figure 2 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 A to C 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 (LEDF) 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 LEDF) as shown in Figure 2.
- 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 LEDF 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 A to C in the Appendices for more detail about the surveys.

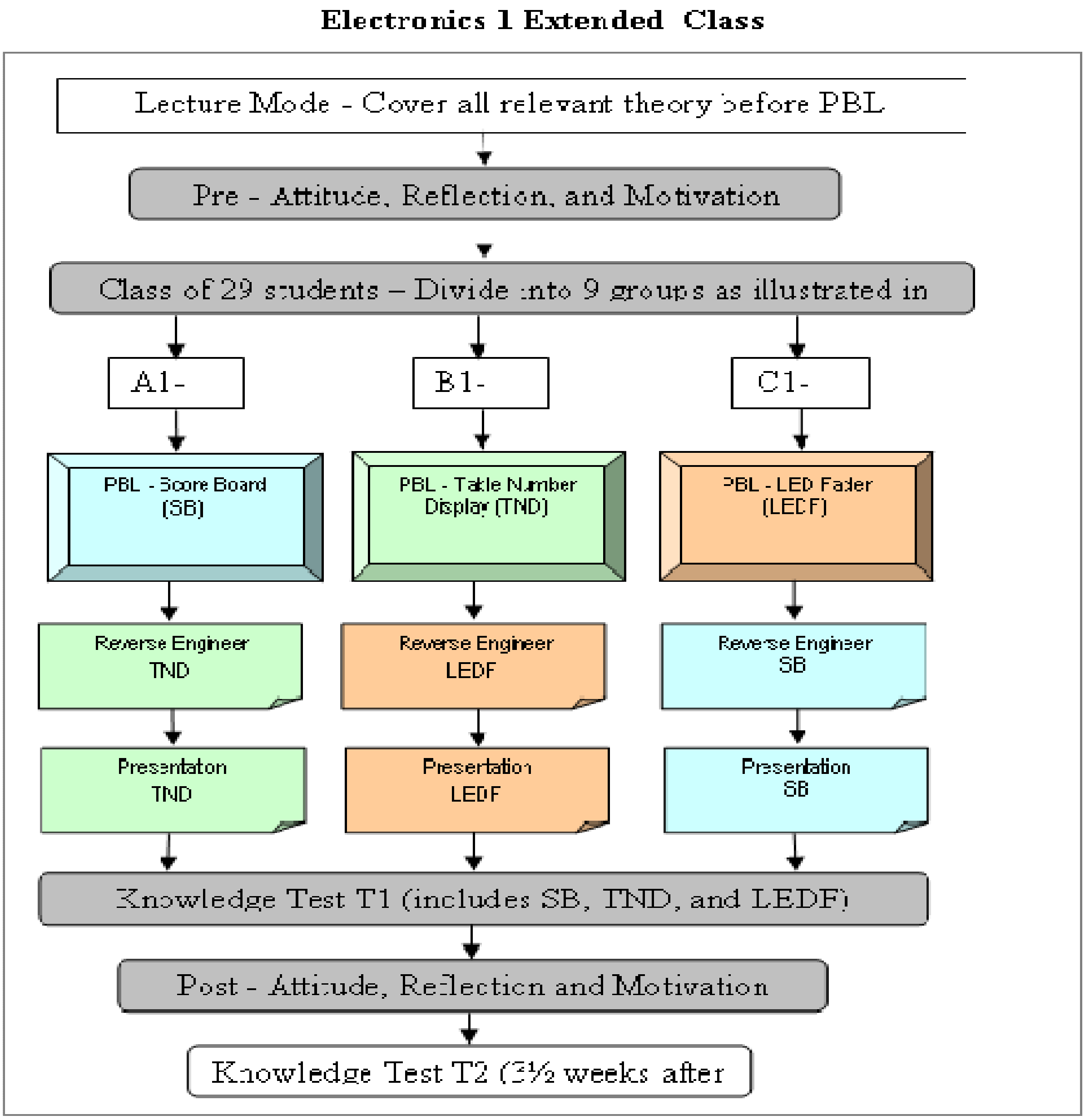

Figure 2: Illustration of how the experiment was conducted

2.1 The PBL problems

According to Mauffette et al. (2004, pp. 13,15), "interest-focused problems from the student's perspective would begin to develop more interesting learning activities, provide more choice and ensure the tasks are optimally challenging" and "students 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:

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.

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.

LED Fader (LEDF)

The LEDF should indicate the position of a potentiometer, using six LED's. The two centre 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 centre. 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.

3. Results

3.1 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 and
2. The second test (T2) about three-and-a-half weeks later.

The test marks of the students improved between 4 to 11% between T1 and T2 on those questions related to the project they originally started with, as shown in Figure 3a. This was not the case for those questions related to the inherited projects from other groups as shown in Figure 3b.

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 Figures 3a to 3c:

- 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.
- 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.

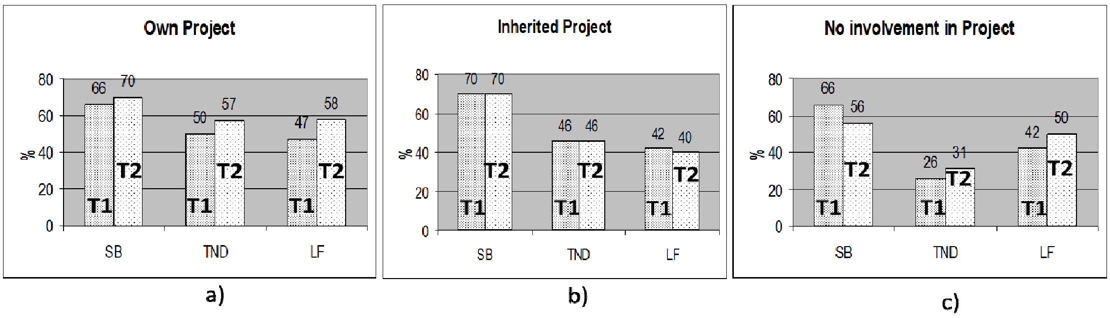

Figure 3: Student performance during the 1st and 2nd knowledge tests (T1 and T2) for those questions related to their own, inherited and project not-involved in.

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 3c 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 LEDF during T2.

Although the LEDF 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 3b), even when it was an own project (Figure 3a). The only explanation for this result is the poor level of science education that children receive in the South African schools.

Students obtained good marks for the SB project, regardless if they were the originators, inheritors or not even involved as shown in Figure 3. The SB project was achievable and challenging plus it turned into a spectacular final product (which caught the attention of most students), therefore it was perhaps the most suitable in terms of the learning experience, hence supporting Hypothesis 1.

Students obtained the best marks throughout all the project if it was their own project (Figure 3a), supporting 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 4a-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.

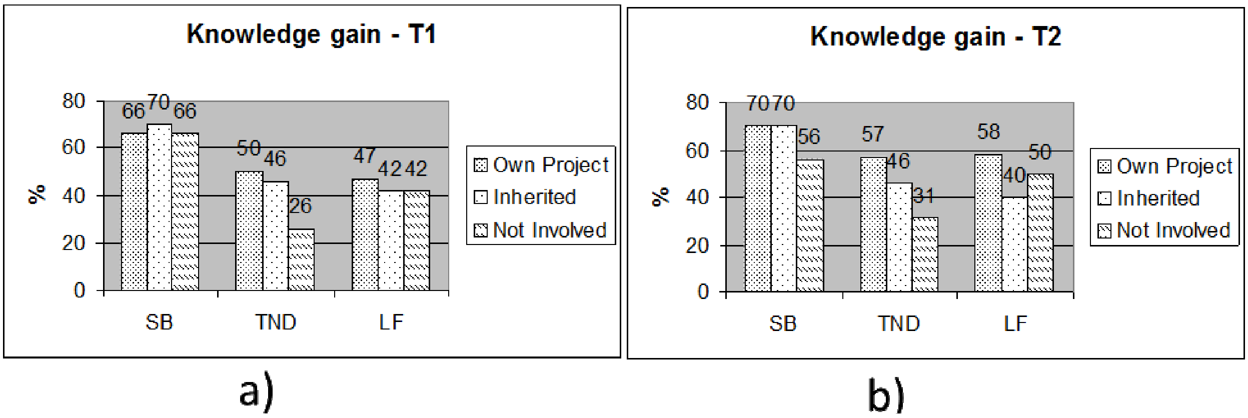

Figure 4: Comparison of knowledge transfer between students own, inherited- and not-involved projects.

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 1. Groups C1 and C2 were not-involved with this project and scored significantly less than the other groups.

Table 1. 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		
LEDF	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 1 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.

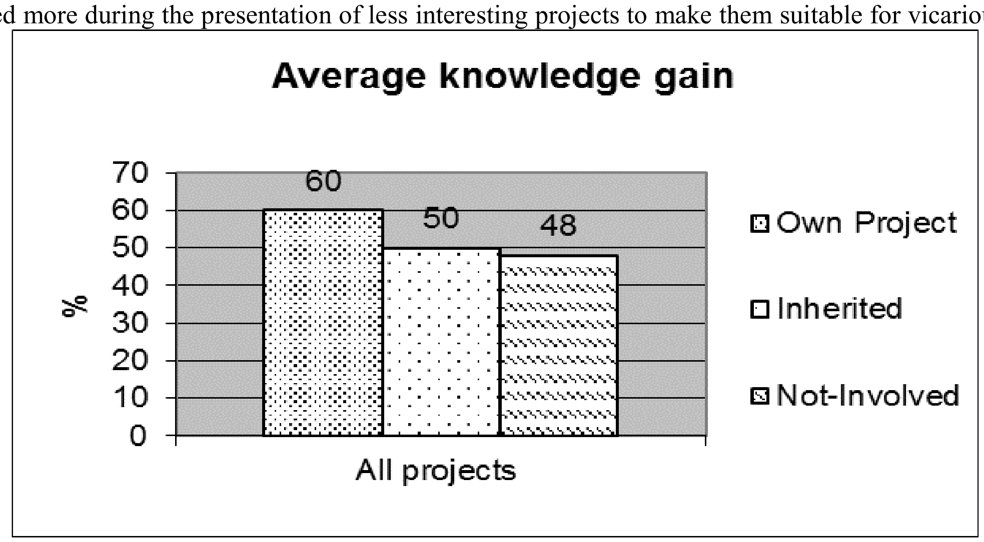

Figure 5: Average knowledge gained on own-, inherited and not-involved with project.

Figure 5 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 it if it is extraordinary and had caught the student's attention, like the SB and LEDF but not the TND as shown (Figure 4). There was a high amount of vicarious learning between the different projects and students had the opportunity to observe each other's projects and investigate their 'inherited' project first-hand in more detail. 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.

3.2 Attitude, Motivation, and Reflection

There was a significant improvement in the attitude, motivation, and reflection of the students as shown in Table 2. The data collected were factor analysed and 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 help them to realise that they still have a lot more to learn, something that usually comes with time and more experience.

Table 2. 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	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% of 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 achievers only show significant improvements for: 'Relevance', 'Critical and Creative Thinking' and 'Communication'. There were no significant difference between 'low' and 'high' achievers' matriculation results (based on English, Math's and Science), but it is interesting to note that the 'low' achievers actually outscored the 'high' achievers by almost 5% during matric as shown in Table 3.

Table 3. A comparison between two halves of a class. Top 50% achievers versus bottom 50% - based on PBL knowledge test T1. (Paired sample T-test)

	Low achievers			***High achievers***				
Subscale	***M***	***SD***	***n***	***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 than 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 3 shows that these students scored significantly better during the course, especially during T1, which was PBL related. Nevertheless, Table 2 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.

4. Conclusions

Sockalingam and Schmidt (2011) identified eleven problem characteristics of PBL (see Table 4).

Table 4. 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.

4.1 A PBL problem that is achievable yet challenging and that can turn into an extraordinary final product will be the most suitable in terms of learning experience.

The SB with its large dimensions was the most visible and impressive project and it received the most attention from all the students in the class once the first group achieved success with this project. The SB was extraordinary and its visual presence inspired most students to become more interested in the detail operation of this project. Students scored well on the SB project, regardless if they were the originators, inheritors or not even involved (as shown in Figure 4). The SB was therefore probably the most suitable from the three projects and met, at least criteria 1, 2, 4, 5 and 8, as shown in Table 4, the best.

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. This is perhaps the reason why those students who were not-involved in the TND scored so badly during the knowledge tests (see Figure 4). Criteria items 2, 4 and 7 as shown in Table 4 were most probably lacking in this project.

The LEDF 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 as they give up". The LEDF 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 4). These students initially struggled with criteria 6, 7 and 9 as shown in Table 4.

4.2 The students, who solve a PBL problem first-hand, will learn the most from that problem, followed by the students who inherit the project from another group. Students not-involved with a specific PBL problem will only learn from it if was extraordinary and caught their attention.

The scores of the SB was almost the same for the originators, inheritors and those not-involved during the 1st test (as shown in Figure 4a) There was a great amount of vicarious learning for this project since it was extraordinary and it attracted much of attention.

The scores of the TND and LEDF was slightly higher for the originators when compared to the inheritors during the 1st test, and the scores of those not-involved in the LEDF, matched the score of the inheritors (see Figure 4a). 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, 'uninteresting'.

The scores related to the students original projects increased during T2 (see Figure 3a), 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. The scores related to students who inherited projects remained almost the same between T1 and T2 as shown in Figure 3b. Figure 5 confirms that the students learned the most from their original, own project and the least from the project that they were not-involved in.

4.3 PBL improves student's motivation, attitude and reflection, which result in fewer dropouts.

Students benefited from working on the three PBL problems, resulting in a significant improvement in their attitude, motivation, and reflection as shown in Table 2. 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 motivate students. The students experienced most of these and enjoy solving the PBL problems, and this was perhaps the reason in the improvement of their attitude, motivation, and reflection.

5. 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 different student groups (see Figure 5). 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 concepts of the PBL problems were not covered. Once confronted with the PBL problem, they had to find a solution to the problem by integrating various components, including some unknown ones.

5.1 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 pleasing to look at, and reasonable visible over 100m or so 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 LEDF which they found difficult, that they never made the time to observe what the TND groups did).

LEDF – 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. Students are used to applying 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', and 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 commendable. 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 effect 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.

6. Recommendations

From completed research with extended stream students, it appears that it is better to do all the relevant theory first followed by a relevant PBL problem. It is also better to do multiple PBL problems in parallel with different groups, and exciting problems should get preference. It might also be beneficial to increase the variety of PBL problems even further. The course should also include some smaller PBL problems to emphasize important concepts. Small PBL-like problems should replace the tradition-like experiments as far as possible.

The amount of time taken by students to execute these PBL problems is still of a concern and means should be found to reduce the time spent to solve a problem.

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APPENDICES

Appendix A

The 'Adaptive Learning Engagement in Science' questionnaire from (Velayutham, Aldridge, & Fraser, 2011), composed of 31 questions, was adapted in order 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.

Attitude survey:
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 B

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 ARCS (attention, relevance, confidence, and satisfaction). 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.

Motivation survey:

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 C

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 towards 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 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?'

Reflection survey:

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.