# PBL: YEAR ONE ANALYSIS—INTERPRETATION AND VALIDATION

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## ABSTRACT

We report on the parallel introduction of PBL to years one (CS1) and two (CS2) of an undergraduate computer science degree programme, with the aim of showing the important role of subjective validation of the way in which any data collected is analysed and interpreted. PBL has not been as widely accepted in computer science education as one would expect, or wish. This may be due to the scepticism of many CS educators with respect to the way in which claims for the effectiveness of PBL are presented. We will focus on addressing this problem by showing that there is an important role for subjective reasoning in the validation of any (objective) analysis. The key is that it is not possible to carry out perfect scientific experimentation and consequently data gathered can often be interpreted in many different ways. We argue that such interpretation is particularly important when first introducing PBL—where one is restricted by the amount and type of data that can be analysed—and that validation against more subjective criteria is necessary. The report compares two very different approaches to data and analysis: which we will call *structured* and *ad-hoc*. The structured approach—where the data collection and analysis was well-informed by standard practice in PBL — was used in the introduction of PBL to year 1 students (CS1). The ad-hoc approach — where analysis was primarily subjective based on the experience of the lecturer — was used in year 2 (CS2). Our comparison is *fair* in the sense that both CS1 and CS2 are concerned with teaching computer programming, and that the students are taken from the same environment. We conclude that both approaches require a complementary mix of objective and subjective analysis. There is little advantage to be gained, in the short term, from the more structured approach. However, an ad-hoc approach will not scale to reasonable analysis over a number of years of PBL teaching.

**KEY WORDS**
PBL-Pilot, Analysis, Interpretation, Validation.

## INTRODUCTION

This research is based on work undertaken by two lecturers in the department of Computer Science and the National University of Ireland, Maynooth (NUIM), in the academic year 2003-2004. Each lecturer had previously experimented with a more interactive style of lecturing and both were teaching a programming course, a first year programming course (CS1), which runs for 24 weeks and second year programming course (CS2), which runs for 12 weeks. Within computer science (CS) programming requires that students be creative in generating ideas towards possible solutions, as well as being logical and systematic in the implementation of these solutions.

The framework for this study is based on the work of Woods (1996), Boud and Feletti (1997) and Duch et al (2001) who provide guidance through the PBL process; Lister (2000), McCracken M et al, (2001), and Robins et al, (2003) who have shown that students find programming hard. The McCracken study is of significant interest as it was multi-national and multi-institutional, and it found that the students' level of skill was not commensurate with their instructors' expectations, and that the most difficult part for students seemed to be abstracting the problem to be solved from the exercise description.

In trying to address these problems each lecturer, independent of the other, implemented a problem based learning (PBL) approach to their course. Amongst other things, Duch et al (2001) state that problem-based instruction addresses the ability to:

- Think critically and be able to analyze and solve complex, real-world problems.
- Work cooperatively in teams and small groups.
- Demonstrate versatile and effective communication skills, both verbal and written.

It was our belief that if we could improve the student's ability in these areas there would be a discernible positive result. Our overall methodology of determining this was to:

- Collect data
- Examine student performance
- Interpret the data
- Critically analyse the role of subjectivity in this interpretation.

Due to constraints within the University timetable the time slots allocated to both modules could not be altered, however, how each lecturer subsequently used their module time slots altered dramatically. Our methods of setting out to implement PBL differed, in that, with CS1, the lecturer introduced a workshop into the module and changed the relative ordering of the lecture, lab and workshop. She also selected a number of postgraduate students with experience of working with first year students; the lecturer and postgraduate students undertook training in PBL (specifically in facilitation) in advance of the academic year, with a further training session mid way through the year. The lecturer allocated the first year students to formal groups with a dedicated workspace for each group. For CS2 the lecturer also changed the relative ordering of the lecture and lab, however, he had no support by way of facilitators, did not undertake any specific PBL training, used informal groups and did not have dedicated workspaces. The remainder of this paper which is composed of four sections reports our two different approaches to data and analysis; the following section outlines the more structured analysis framework undertaken in CS1, this is followed by the ad-hoc analysis undertaken in CS2, then we discuss the need for more informed data gathering as we look to the future and finally our conclusions.

## CS1: A MORE STRUCTURED ANALYSIS FRAMEWORK

PBL was integrated into a first year programming module in the academic year 2003. An overview of its implementation has been previously discussed (O'Kelly et al., 2004a).

Applying the points by Duch, listed above, we hypothesised that:-

i. Through the use of the PBL process a student's critical thinking skills would improve and this in turn would help overcome the difficulty with abstraction.

ii. Through the collaborative process of the group environment more creative ideas would be generated and the discussions involved to determine which idea to run with would improve a student's problem solving and communication skills.
iii. A student who performed well in the workshops would be able to transfer this knowledge to their laboratory work and their examinations.

**Data Collection**

We used a number of different methodologies to gather data throughout the year. An on-line student questionnaire was completed by 71% of the students. A paper based anonymous student questionnaire was completed by 84% of the students. A more detailed end-of-year anonymous student questionnaire was returned by 80% of the class. We also interviewed 30% of the class consisting of 60% of the mature students, 88% of the repeat students, 88% of the denominated entry students and 50% of the foreign students in the class (O'Kelly et al., 2004b). The facilitators also completed a review form each week for every workshop group and a review on every student in every group. The lecturer performed the role of a 'roaming facilitator' and observed and took notes on every group in action each week. A weekly meeting took place to gather information about the previous workshops and to prepare for the coming workshop. At the end of the year facilitators also completed questionnaires and the lecturer of the course was interviewed on the PBL process.

For every student in each group the facilitators formatively assessed their performance each week based on their role of team member plus any additional role they were performing in that week, for example, chairperson, reader, writer or archiver. We used a Likert type scale of 1 to 5, where 1 was strongly disagree to 5 strongly agree, tables 1, 2, 3, 4 and 5 give an example of the type of statements used.

Table 1: Team member evaluation statements

| | |
|---|---|
| | The student is **open** to new ideas and perspectives |
| | The student can **support** their beliefs/opinions |
| | The student's **critical thinking** helps the group to **understand the problem** |
| * | The student tries to **enforce** their beliefs **without** taking other opinions into account |
| | The student **actively participates** in the group |
| * | The student's participation is **disruptive** to the group |
| | The student's **participation** helps the group to **solve the problem** |
| | The student demonstrates **effective communication skills** within the group |

Halpern (1996), states that critical thinking is used to describe thinking that is purposeful, reasoned and goal directed - the kind of thinking involved in solving problems, formulating inferences, calculating likelihoods, and making decisions when the thinker is using skills that are thoughtful and effective for the particular context and type of thinking task. Critical thinking also involves evaluating the thinking process. We used this description when we defined what critical thinking meant for us.

As the students had to explain to the group their reasons for suggesting a particular strategy or their reasoning behind disagreeing with a particular viewpoint we were able to rate their performance for each given workshop. In relation to statements above marked *, to receive anything above a 1 for these statements over time would indicate a potential problem with the student within the group. While our preferred solution was that peer pressure within the group would bring about a change in a troublesome student's behaviour, sometimes we were forced to intervene.

All additional roles to the team member role were rotating. The role of the chair was to manage the workshop by keeping the team on track; maintain full participation and resolve conflict. The chair was formatively assessed in the following way.

Table 2: Chairperson evaluation statements

| |
|---|
| The chair tries to **actively involve** all the group members |
| The chair was able *(would have been able)* to **direct** the group when *(if)* the problem-solving process appeared to be breaking down |
| The chair ensured that **everyone** understood the problem/solution |
| The group **listened to** and **respected** the chair |

The role of the writer was to record an accurate account of the workshop.

Table 3: Writer evaluation statements

| |
|---|
| The writer was excluded **by the group** |
| The student passively accepted their role as writer and **excluded themselves** from the problem solving process |

The role of the reader was to read any material relevant to the problem.

Table 4: Reader evaluation statements

| |
|---|
| The student passively accepted their role as reader and **excluded themselves** from the problem solving process |

The role of the archiver was to write the final draft and distribute it to the other members and ensure the original copy is kept in the team's PBL journal.

Table 5: Archiver evaluation statements

| |
|---|
| The student passively accepted their role as archiver and **excluded themselves** from the problem solving process |

The facilitator also assessed how the group performed overall, in relation to:-

- workshop objectives,
- student participation,

With this data coming on a weekly basis in conjunction to the weekly meetings and the observations and written notes of the roaming facilitator, we were able to identify which groups were working well, particular students in groups who were working well, and students who were having problems early on in the process. As the roaming facilitator observed every group each week, she was able to identify common trends (both positive and negative) over all groups and raise these issues at the weekly meeting. Consequently, this weekly meeting tended to use a PBL approach to resolve any difficulties raised or look at ways to enhance what was working well. In addition to this we reviewed the student and group evaluations and discussed and reached consensus on issues through brainstorming sessions.

Initially our idea was to use on-line student questionnaires to gather data on the PBL process, as this would allow us to compare the feedback the students gave with our assessment of how they as individuals were performing in the workshops and how their team was performing overall. However, after the first questionnaire was released we found that the students were not inclined to fill it in and only after much coercion on our behalf did we get the response rate of 71%. We also felt that students were not as forthcoming with their comments, this may have been partially due to the fact that the on-line method of feedback is not anonymous. Subsequently all feedback was paper based and anonymous. Table 6 outlines a section of the student questionnaire relevant to our hypothesis. The students were asked to respond to the statements on a range of 1 to 5, where 1 was strongly disagree and 5 was strongly agree.

Table 6: Student feedback

| STATEMENT | S/M AGREE | S/M DISAGREE | NEUTRAL |
|---|---|---|---|
| The workshops develop my critical thinking skills | 79.53 | 7.32 | 12.67 |
| I actively participate in the workshops | 84.78 | 3.57 | 11.42 |
| My problem solving skills have improved since I started the workshops | 73.78 | 6.69 | 18.92 |
| My communication skills have improved since I started the workshops | 71.83 | 10.44 | 17.35 |
| I am comfortable working in groups | 86.25 | 5.00 | 8.75 |
| I feel comfortable sharing information with others | 87.50 | 2.50 | 10.00 |

A comparison of the data gathered through the student questionnaire with the data we gathered on a weekly basis as outlined in table 1 was conducted. We used the Pearson correlation formula (1), as it measures the strength of the linear relationship between two variables.

$$r = \frac{n(\sum XY) - (\sum X)(\sum Y)}{\sqrt{\left[n\sum X^2 - (\sum X)^2\right]\left[n\sum Y^2 - (\sum Y)^2\right]}} \quad (1)$$

We ranked students according to their workshop performance (highest to lowest) and using Pearson correlation for continuous assessment (CA) mark and exam mark resulted in r = 0.8076. As the students come from three unique course disciplines: (a) Computer Science and Software Engineering (CSSE), (b) Computer Science through a Science degree (SCI) and (c) Computer Science through an Arts degree (ARTS), we subsequently grouped the students by their disciplines and performed the same ranking and correlation, which resulted in CSSE r = 0.7701, SCI r = 0.8161 and ARTS r = 0.9450. We then looked at the top 10% of the class ranked according to workshop performance and once again using Pearson correlation for CA with exam mark returned r = 0.8290. We examined the percentage of males (61.45%) and females (38.54%) in the class, and applying the same ranking performed the same correlation for CA with exam mark, the results r = 0.8430 for females and r = 0.7865 for males.

For the group, which our data rated as the highest performing group, we found a very high correlation between CA and exam mark (r = 0.9644), CA and workshops (r = 0.9355) and exam and workshop (r = 0.8940). We also found a very high correlation between CA and exam mark (r = 0.9055), CA and workshops (r = 0.9702) and exam and workshop (r = 0.9773) for mature students.

**Summative student performance**

A comparison of CA and exam results against the previous academic year results indicate an improvement in student performance as outlined in Table 7 and 8. This comparison is fair as it was our method of delivering the course that changed and not the course content itself. In addition, we did not change the manner in which we summatively assessed the students, ensuing that both sets of students were assessed under the same conditions. The following example shows how the result was computed for the number of students passing:

- In each year count the number of students with a CA (exam) mark greater than 40.
- Divide this number by the total number of students in the class *n*, this gives the percentage of students passing in each year.
- Subtract the 2003 percentage from the 2004 percentage, resulting in the difference between the two years.

Where the result is positive, a higher percentage of students were found in that category in 2004, where the result in negative a lower percentage of students were found in that category in 2004.

Table 7: Comparison of Continuous Assessment Marks 2003-2004

| | |
|---|---|
| Increase in the percentage of students passing (Pass Mark 40%) | 21.87 |
| Increase in Average Class Mark | 10.20 |
| Increase in the percentage of students with CA mark >= 70 | 16.29 |
| Decrease in the percentage of students with CA mark < 30 | -11.92 |

Table 8: Comparison of Exam Marks 2003-2004

| | |
|---|---|
| Increase in the percentage of students passing (Pass Mark 40%) | 14.96 |
| Increase in Average Class Mark | 11.10 |
| Increase in the percentage change in students with CA mark >= 70 | 6.16 |
| Decrease in the percentage change in students with CA mark < 30 | -8.45 |

We subsequently divided the students within their class into *poor* (bottom 1/3), *average* (middle 1/3) and *good* (top 1/3) and we found that:

- Average laboratory performance increased for all students, with the *poor* students demonstrating the most significant improvement.
- Average written exam performance increased for all students, with the *middle* students demonstrating the most significant improvement.
- Overall performance (70% written exam, 30% practical work) – the normal distribution moved to the right, the change in standard deviation was insignificant.
- The correlation between exam performance and laboratory performance decreased for the *good* students and increased for the *middle* and *poor* students. Further investigation of the *good* students showed the normal distribution shifted significantly to the right for both the exam mark and the CA mark, with a reduction in the standard deviation for the exam mark.

### Interpreting the data

A high percentage of the students believed that the PBL workshops improved their critical thinking skills; similarly, a high percentage of students believe their communication skills have improved and are comfortable working in groups. When we view this with the correlations outlined above, and the summative student performance data, it supports our hypotheses i and ii . On the surface, the data also seems to support hypothesis iii, however, further examination shows that a number of students who performed extremely well in the workshops did not perform well in CA and examinations, therefore we cannot corroborate the transfer of knowledge from workshops to labs. However, it was found that students who performed well in the labs also performed well in the workshops, which suggests that looking at a student's lab results is a good indicator of their workshop performance. Which leads us to re-look at the high performers in the workshops; some students are better at seeing the 'big picture', but are not good at (or perhaps not interested in) the finer details, they are however, good motivators and leaders. This type of person will not be ranked as one of the top students at the end of the year and yet they have demonstrated skills, which according to Computing Curricula (2001) computer science students must have, in addition to the technical skills. The mature students were the most consistent in their performance; they tend to be more focused and are able to apply their life experiences to enhance their course of study. We also observed that they brought good leadership skills to the workshops and through asking open-ended questions or by playing devils advocate improved the quality of the workshops.

### The role of subjective evaluation

What would be an equally valid subjective evaluation of the results? One could propose that the formal group structure and the dedicated work space gave first year students a sense of identity and belonging earlier than might have otherwise happened; and through the workshops, students got to know each other better and this in turn facilitated an informal support network in which they helped each other throughout the year. Observations in the lab would support this view in that, students tended to help each other, whereas in previous years they would have constantly depended on the demonstrator for help. One could also surmise that it just happened to be an exceptionally good group of students in that year. Another equally valid interpretation is that the enthusiasm and focused attention of the lecturer and the facilitators carried through to the students and resulted in higher interest and involvement by students in the module than in previous years. With more data, we can of course refute, or substantiate, these alternate viewpoints.

## CS2: A MORE AD-HOC ANALYSIS

In this section, we report on the introduction of problem based learning into the second year of the undergraduate computer science degree, in a module concerned with more advanced programming (using algorithms and data structures). In total, there were 35 students.

The problem based learning method employed in CS2 is much less prescriptive than that which was done in CS1, even though both modules were concerned with programming. Rather than deciding on a fixed structure for the presentation and evaluation of material, the lecturer decided to be as flexible as possible in order to be able to adapt to the new demands of always keeping the problems central to the learning experience.

In previous years of teaching this module, the teaching approach was traditional in nature: lectures were used to present new material to the students, and laboratory sessions were used to test that the students had understood, and could apply, the lecture material to programming problems. The experience of the module lecturer was that the traditional approach was becoming less effective. We hypothesised that PBL would help us to address the main weaknesses:

- more students were failing the module (both written and practical examination) because the students lacked understanding of the complementary nature of the practical and theoretical work;
- attendance at lectures and practical laboratory sessions was falling because of lack of motivation, arising out of failure to apply the lecture material to solve the practical problems;
- the students who did pass the module were becoming less able to apply their learning in subsequent modules and programming projects because of their focus on passing exams rather than on life-log learning; and
- the best students were frustrated at being held back by the weaker students because problems had to be set that all the class could benefit from working on, and lectures focused on preparing weaker students to be able to do something practical rather than pushing the stronger students to their limits.

It is beyond the scope of this work to analyse the reason for the failings of the traditional teaching method; however, we should state that there was no doubt that these failings needed to be addressed.

The module lecturer had taken an interest in PBL and had already experimented with non-traditional lectures where the lecturer and students worked together to write a programme that solved a problem suggested by the students. In this way, students got to see how the lecturer worked (and, more often than not, struggled) to solve a problem that they had not explicitly prepared for. The relative success of these types of *interactive* lectures – in terms of their popularity with the students – motivated the lecturer to move away from traditional lectures as the default teaching mechanism.

## The teaching approach

The module was taught over a period of 12 weeks. Every week there were two 1-hour lectures. Also, every week – except the first and last – there was a single 2-hour laboratory practical session. Students would have immediate feedback on their performance in the laboratory (they would be given a mark out of 10 before they left the laboratory).

The planned initial approach was based upon a simple structure: every week there would be a laboratory PBL session where students could work as individuals or in teams in order to solve a problem (using a computer programme). The following lecture would be used to review what the students were supposed to have learnt from the problem; and this would follow a more traditional style. The lecture after that would follow the *interactive* model, and would attempt to re-use the skills that were acquired in solving the previous problem in preparing for the next problem.

The lecturer had already prepared a set of 10 problems that would, it was hoped, form the foundations for the 12 weeks of work. The best two from a specified three of these problems would contribute to their overall continual assessment mark. After the second week of lecturing it became clear that the plan would have to change on a weekly basis, and that much of the preparation had been in vain:

- What the students learned, from a particular problem, did not always correspond to what the lecturer thought they would, or should, learn;
- Some problems were ineffective, and the students appeared to learn nothing from them;
- There was an interdependency between problems and, as a consequence, ineffective problems often had to be re-engineered and presented to the students for a second (and sometimes third) time;
- Often, 1 hour of standard lecturing was not enough time to cover the material required by the module curriculum;

As a result, the lecturer was forced to follow a week-long cycle of reviewing the previous week's work in order to develop a new problem that best addressed the needs of the class for the next week. In all, only 1/3 of the material prepared in advance was re-used during the 12-week semester.

**Data Collection**

The lecturer made a deliberate decision not to gather any additional data with respect to the success (or otherwise) of the PBL approach in addressing the problems mentioned previously. It was felt that no matter how much data was gathered there was a reasonable risk that the complexity of the teaching environment, and the number of variables involved, would mean that the data would be meaningless (in the sense that it would be open to a number of different, often contradictory, yet equally plausible, interpretations). Furthermore, it was not clear what additional information would be useful in testing the hypothesis that the new PBL approach had had a positive influence in addressing the educational problems. Consequently, the lecturer's approach to validating the hypothesis was based on observation of the students' day-to-day work and interaction.

The lecturer observed (informally) the following:

- Student attendance at lectures and laboratory sessions improved dramatically (absenteeism dropped from an average of more than half the class to only a handful of students)
- The most effective sessions – in terms of helping the students to learn – were not always the sessions in which the students scored the best marks
- After ineffective problem sessions, students were less keen on the interactive lectures and requested a return to more traditional lecturing
- The very good students tended to solve problems as individuals, and rarely got 10/10 for their work (as would have been common under the previous, traditional, approach)

- The very poor students tended to work in teams (mostly in pairs), and rarely got 0/10 for their work (as would have been common under the previous, traditional, approach)
- After a marked assignment where students performed poorly, absenteeism increased
- Students were concerned about preparing for their written exam – they did not have a standard set of lecture notes from which to revise
- The lecturer was concerned that students had covered less than half of the material that the curriculum had specified, and this concern had a negative impact on the students' confidence.

The lecturer's own experience and observations suggested that the PBL approach was helping; but that there was no scientifically sound way of demonstrating it. However, could these intuitive feelings be validated through analysis of students' performance in written and practical examination?

**The results**

The best indication of the success of the PBL is in the future performance of the students who took the module. Unfortunately, this information is not (yet) available.

The next best indication is through making comparison with performance of students in previous years. We need to be aware that such a comparison can never be done in a perfect, fair manner; however, this should not discourage us from making such a comparison, and trying to interpret the results in a reasonable manner. In particular, we note that the style and standard of the written exam did not change when we adopted the new PBL approach.

The small number of students (and years of students) concerned suggests that absolute comparisons are worthless, and so we highlight statistical trends. In the following, students are divided into *poor* (bottom 1/3), *average* (middle 1/3) and *good* (top 1/3) within their class:

- Attendance improved for *poor* and *average* students, but remained the same for *good* students
- Average laboratory performance increased for *poor* and *average* students but *decreased* for good students
- Average written exam performance remained the same for *poor* students, decreased for *average* students but *increased* for good students
- Overall performance (70% written exam, 30% practical work) – the normal distribution moved slightly to the right (so the class as a whole appeared to improve slightly), but – more importantly – the distribution was 'squashed' (standard deviation reduced) significantly so that there were fewer extremely good or extremely poor marks.
- The correlation between exam performance and laboratory performance did not increase, as expected

Even with the information highlighted by the trends, above, it is open to question as to whether it is reasonable to interpret the data to support the hypothesis that the PBL has, in some way, done its job in addressing the teaching problems.

### Interpretation and validation – looking for consistency and plausibility

The key question to be asked is whether there are any other equally valid interpretations of the data. For example, one could suggest that poor students perform better in labs because they are more likely to work in teams; and good students perform worse because they are more likely to work as individuals. Is this trend due to the fact that there is not enough time in the labs to complete the assigned work – 'many hands make light work'? Is the trend due to working in teams – 'two (or more) heads are better than one'? Similarly, it was expected that the PBL approach would strengthen the correlation between practical work and written examination. We did not observe such a change. Was this because the style of written examination did not change, or because average students struggled to revise for the exam without the standard lecture notes, or was it just because PBL should not have any impact on this correlation?

These alternatives are consistent with the data, and seem equally plausible. However, are they consistent with other research results in general, in computer science, and in programming? Finding the answers to these questions may, or may not, be a fruitful line of inquiry in PBL research. It is very easy to ask the questions, and generate data that appears to give a particular answer. But, this new data may also be open to further interpretation. Are we the PBL research *dogs* running in circles chasing our tails?

### The (possible/future) role of objective data collection

The lecturer intends to make use of more structured data gathering to help resolve instances where two, or more, equally plausible interpretations of the students' performance have been identified, and where this leads us to question our original hypotheses.

The hypotheses must provide the focus for the data gathering. There should be a clear picture that any data gathered is sure to clarify any ambiguity in the analysis; there should be no gathering of data where there is a reasonable risk of the data clouding the interpretation through reinforcement of the potential ambiguity.

## FEEDBACK AND PROGRESSION

All educators are (or should be) continually improving the teaching/learning experience through feedback. Analysis of current and previous years helps to make informed decisions about changes to be made in future years. The overriding goal is to improve students' performance; but even this goal is open to interpretation, since there are many ways of measuring performance.

PBL research must never, if at all possible, compromise the students' performance. In essence, we cannot take risks through innovative experimentation that may have a negative impact on students. However, all change involves an element of risk.

There is risk in changing the teaching technique; but there is also risk in data gathering. Having too much data is a risk, having too little data is a risk, having the wrong sort of data is a risk, having to gather the data may be a risk. We need to make sure that the benefits of gathering the data outweigh the potential costs.

### Incremental Refinement

In a perfect world, the feedback process would be easy to manage and result in an incremental refinement of our PBL approach. However, the world is far from perfect and we need to be pragmatic in dealing with the realities of academia. Three simple examples illustrate this.

Firstly, we would like to refine individual modules on a year-to-year basis. However, in the case of CS2 the student intake in the second year is very different from the student intake in the first year: primarily because the new students will have experienced PBL from their CS1 programme. It could be argued that this invalidates any type of analysis with respect to how changes in our CS2 PBL approach impact the students.

Secondly, we would like to follow the same group of students from year to year. However, in the case of CS2 we do not have a curriculum that guarantees exposure to PBL teaching in CS3 or CS4 for all the students. This lack of continuity makes any form of objective long-term analysis very difficult to carry out, in a meaningful way.

Thirdly, curriculum development every year can, and usually does, mean that modules are moved between years. There is a strong chance that CS1 will become part of the 2$^{nd}$ year of the majority of our students; so that it is not their first exposure to computer science or programming. This makes things very difficult!

## CONCLUSIONS

In general while both lecturers were cognizant of their teaching styles and their students learning, they found that as a result of implementing PBL, they were consciously more observant of:-

- the types of problems they gave to the students,
- the students' problem solving process,
- the difficulties students had with particular problems,
- group dynamics, both in the formal and informal group structures,

so much so, that they are more informed in relation to the impact of PBL on each programming module. While recognising that (at this point in time) the subjective and objective data is open to other interpretations we believe that using a PBL approach has had a positive effect overall in the programming modules. The resulting analysis of both sets of data has allowed us to make more informed decisions in relation to changes required to improve the learning experience for the student and the lecturer. It is our conclusion that PBL research requires a complementary mix of objective and subjective analysis. There is little advantage to be gained, in the short term, from the more structured approach, as the data being gathered is meaningful only in relative rather than absolute terms. However, an ad-hoc approach will not scale to reasonable analysis over a number of years of PBL teaching. A combination of both is the most pragmatic way of validating any interpretation of the data being analysed.

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