11. ASSESSING PROBLEM-BASED LEARNING: A CASE STUDY OF A PHYSICS PROBLEM-BASED LEARNING COURSE

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**INTRODUCTION**

In 2001 the School of Physics in the Dublin Institute of Technology set up the Physics Education Research Group (PERG) to carry out research to inform curriculum development, teaching and assessment practices. The group has engaged in a number of research projects aimed at obtaining a better understanding of how students learn and how educators can help students learn and develop. In September 2001 the Physics Education Research Group engaged in collaborative action research in order to design, implement and evaluate a Problem-based Learning first year physics course (Bowe and Cowan, 2004).

**ASSESSMENT STRATEGY**

**Rationale for Change**

Possibly the most significant and externally visible changes made in the move from the use of predominantly traditional pedagogical approaches to Problem-based Learning were made to the assessment strategy. The Problem-based Learning team was aware of the important and vital role assessment plays in driving learning and viewed the assessment strategy as having a supportive and formative role in helping students develop as learners and as individuals within the groups. The team saw assessment as not just a way of checking students have learned but an integral and integrated part of the learning process, as defined by Angelo (1995: 7):

> Assessment is an ongoing process aimed at understanding and improving student learning. It involves making our expectations explicit and public; setting appropriate criteria and high standards for learning quality; systematically gathering, analysing, and interpreting evidence to determine how well performance matches those expectations and standards; and using the resulting information to document, explain, and improve performance.

The team was also very aware of the role assessment plays in determining the “hidden curriculum” (Margolis, 2001) and approaches to learning adopted by the students. Previously, the assessment strategy was comprised primarily of summative tests during the academic year, in both theory and laboratory practice, and an examination at the end of the year, where the emphasis was on examining students’ knowledge and understanding of physics principles. It was felt that this sort of assessment strategy encouraged surface and strategic approaches to learning. As it was envisaged that the Problem-based Learning approach would encourage students to adopt a deep approach to learning (Marton et al., 1984), it was important that the assessment strategy also required students to take this approach. Therefore the assessment strategy had to be better integrated into the learning process so that the students would see it as something that is there to help them learn and develop. Hence, more continuous assessment methods are used and extensive feedback is provided to each student. The assessment strategy not only examines the products, such as reports, presentations and logbooks, but also examines...
each individual’s contribution to the process in such a way as to support each student’s development and learning.

The development of the new assessment strategy began by first determining the purpose of the assessment strategy itself. Research in Problem-based Learning and group learning has already established that students can find it difficult to adapt to these new pedagogical approaches (Savin-Baden, 2000; Jacques, 2002). Students entering tertiary education may also be unsure of how to participate in a learning group and may not know how to chair such a process. Students may also feel working in groups is unfair in terms of workload and the distribution of tasks. The new assessment strategy was developed to take all these factors into account and to be an integrated part of the learning process and not just something extra the students must complete. In addition to the aims of the original assessment strategy, this new assessment strategy aimed to:

- Examine conceptual understanding and problem-solving skills
- Encourage and reward individual contribution to the group process
- Support and evaluate the development of group, communication and presentation skills
- Identify problems and areas of potential improvement
- Monitor progress

Previously, the assessment strategy would have been aligned with learning outcomes associated solely with knowledge and understanding of physics concepts and principles, and laboratory skills. In order to achieve the aims of the new assessment strategy it was necessary to introduce learning outcomes associated with conceptual understanding, problem-solving, group processes and key skills. On successful completion of this course the learner will be able to:

- Identify and analyse potential solutions to the mechanics problem
- Deal with omitted information and use a proper technique to solve open-ended mechanics problems
- Work effectively in, and lead a peer group
- Communicate effectively through oral presentations and written reports
- Research a topic and retrieve information

Once the learning outcomes had been devised it was important to choose appropriate assessment methods that would ensure the achievement of each learning outcome could be determined. An alignment matrix (Biggs, 1999; Cowan, 2002) was used to ensure the learning outcomes, assessment and the facilitation of learning matched each other in a pedagogically sound manner (Bowe and Cowan, 2004). In terms of the assessment strategy, this meant choosing appropriate assessment methods and devising suitable assessment criteria.

**Methods**

Once the purpose of the assessment strategy had been determined the next step was to decide on what was to be assessed. Each problem would involve the students working together in groups, with and without a tutor present, and then presenting their solution either orally or by a
written report. Some of the problems also involved laboratory work. Therefore it was decided to assess using the following methods:

- Oral presentations
- Written reports
- Individual contribution to the group process
- Chairing of the group process
- Laboratory
  - Experiment proposal
  - Logbook
  - Report
- End-of-year open-book examination

Devising assessment criteria and assessing “products” such as the oral presentations, written reports, proposals and logbooks did not pose any significant problems as these are standard assessment methods used in many courses. However, the fact that these “products” were completed and submitted by groups and not individuals did raise a number of important issues. It was felt that each individual’s contribution to the “product” should be assessed, particularly as the students were in first year and it was felt there would be problems associated with some individuals doing much more work than others. Also, there was a concern about awarding marks to individuals who may not have contributed anything to the “product”.

A far greater challenge arose from the aspiration to assess individual contribution to the group process. It was felt that the assessment strategy should reward those students who work hard in the group process and endeavour to contribute constructively to the process. In this way the strategy should also penalise those students who do not make an effort to contribute to the group process. For the purpose of formative, developmental assessment, it was felt that the feedback should be individualised to help each learner and this required assessing each student’s contribution to both the process and the products. To overcome some of the problems associated with assessing individual contribution to both the process and the product, it was necessary to involve the students in the assessment process through the use of self and peer assessment.

Another reason for involving the students stemmed from the fact that in the Problem-based Learning course each tutor roamed from group to group, and hence was not present at all times while the group were working together. Therefore the tutor’s assessment alone may not be reliable or reflect any individual’s true contribution. As the students themselves are in the group throughout the process, they can observe contributions with and without a tutor present. Along with the pragmatic reasons for involving the students there are also pedagogical benefits as self-assessment helps students develop the ability to be realistic judges of their own performance and to monitor their own learning. These skills are needed to become self-directed and lifelong learners (Candy et al, 1994). Self-assessment therefore allows the student to develop metacognitive skills - "the capacity to learn, the capacity to know how to learn, [and] the capacity to know what he has learned" (Heron, 1988: 78). states that self assessment involves two key elements:
The development of knowledge and an appreciation of the standards and criteria for meeting those standards

The capacity to make judgements about whether or not the work meets those standards

Developing these self-assessment skills is worthwhile and beneficial but it is also a slow process that must be facilitated by the tutor. It requires the students to engage in dialogue regarding the assessment criteria and the quality and standard of their work and contributions. However, in order for this dialogue to take place students need to able to understand the concepts of quality held by those making the judgements (Sadler, 1989). This can be achieved through practice making judgements, and having the responsibility to make these judgements, against the criteria. Inherent in the process is the opportunity for the students to discuss, debate, and negotiate these assessment criteria. The use of self-assessment in the Problem-based Learning course requires students to reflect on their experiences in the group process and make judgements on their contributions not only to the “product” but also to the process. McGill and Brockbank (1998) state the fact that reflection, which draws on both the cognitive and meta-cognitive levels is a great strength and an assessment system which addresses reflective learning should do so in terms of both outcome and process.

Criteria

Devising the criteria to assess the chairperson and each individual’s contribution to the group process was very problematic and many different models were piloted. After four years, and through progressive reflection and evaluation, a model has emerged that works very well from both the students’ and tutors’ perspective. As the assessments are primarily developmental, providing timely and effective feedback in the learning process is imperative. The assessment of the process has to be clear and transparent to the students and relative easy for the tutors to facilitate. The feedback had to be directly related to the criteria so the students can use the same criteria to assess themselves. It was decided that the criteria the tutors would look for when assessing the process (contribution and chair) would be a set of actions that demonstrate the students are constructively contributing to the process. Table 1 shows the “criteria” used to assess individual contribution to the group process, as a list of actions under five headings.

It should be noted that the rationale for each assessment method, along with the criteria, are discussed with the students in the induction process as well as at various intervals throughout the academic year. The level of contribution is assessed by the extent to which each student displays the attributes and actions in Table 1. However it must be noted that a student it not expected to complete the entire list of actions. In practice the tutors tend to look for extremes, that is, actions that are being completed properly, as well as uncompleted actions, which have negative effects on the group process.
**Figure 1: Assessment of Contribution to the Group Process**

<table>
<thead>
<tr>
<th>Assessment of Contribution to the Group Process</th>
<th>Category and Description</th>
<th>Actions</th>
</tr>
</thead>
</table>
| **Working towards Understanding** | It is each member's responsibility to strive towards a complete understanding of the physics involved in each problem. It is not sufficient to just sit back and listen in the hope of learning something later but you must be actively engaged in the process and trying to understand the physics. | • ensuring you understand the other group members by asking questions stating what you understand to be correct  
• summarising the groups' position  
• looking for mistakes in the process, thinking and calculations  
• offering evidence  
• persuading and defending a position |
| **Working towards Group Understanding** | One of the aims of the process is that by the end of a problem the group has achieved the same level of understanding. | • asking each other questions to ensure everyone understands  
• asking others to explain their understanding  
• asking for justification and/or supporting evidence |
| **Tasks** | It is each group member's responsibility to complete this task to the best of their ability and report back to the group. | • Completing tasks on time  
• Reporting back to the group |
| **Peer Tutoring** | In many cases some of the group members will have a greater prior knowledge of the subject matter. In this situation it is their responsibility to help the other students learn by explaining and teaching the physics involved. In this way the students can learn from each other and also by teaching the subject the students with prior knowledge can identify any holes in their understanding. | • teaching others  
• explaining your understanding |
| **Assisting Group Focus** | It is each members responsibility to help keep the group focused on the problem and to maintain a good group working environment. | • supporting opinions of others  
• showing openness and acceptance of ideas  
• helping to analyse and reconcile differences  
• commenting on group process, giving recognition to others |

The role of the chair is to manage the group as they work towards a solution. The chair is not expected to contribute to the content of the solution but to ensure the group members work well together. Table 2 shows the “criteria” used to assess the chair in the group process, as a list of actions under four headings.
Figure 2: Assessment of the Chair

<table>
<thead>
<tr>
<th>Category and Description</th>
<th>Actions</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Time management / scheduling / structure</strong></td>
<td>• setting deadlines and milestones</td>
</tr>
<tr>
<td>It is important that the time in class is used efficiently and the group schedule tasks and structure the process to enable them to complete the problem in the time allowed. It is the responsibility of the chair to ensure the group is aware of the time constraints and to schedule and structure tasks.</td>
<td>• monitoring the time</td>
</tr>
<tr>
<td></td>
<td>• scheduling meetings</td>
</tr>
<tr>
<td></td>
<td>• planning the session</td>
</tr>
<tr>
<td></td>
<td>• delegation of tasks</td>
</tr>
<tr>
<td><strong>Equal opportunity and participation</strong></td>
<td>• asking questions of all group members</td>
</tr>
<tr>
<td>It is the chair's responsibility to ensure every member of the group is given an equal opportunity to contribute and participate. Everyone's opinion is valid and must be considered and discussed.</td>
<td>• ensuring everyone is included in the discussions</td>
</tr>
<tr>
<td></td>
<td>• ensuring everyone has the opportunity to contribute</td>
</tr>
<tr>
<td><strong>Focus</strong></td>
<td>• asking group members questions to ensure they are following the solution and understand</td>
</tr>
<tr>
<td>It is the chair's responsibility to ensure the group stays focused and remains concentrated on the problem.</td>
<td>• periodic summarising of learning</td>
</tr>
<tr>
<td><strong>Questioning Tutor</strong></td>
<td>• organising the group to ask the tutor relevant and pertinent questions</td>
</tr>
<tr>
<td>If the group feel they cannot continue without the tutor intervening and they have tried all alternative avenues, they can then ask the tutor focused questions relating to the content. However the tutor can respond with more questions in an attempt to get the group thinking about the problem from different perspectives.</td>
<td></td>
</tr>
</tbody>
</table>

Implementation

The students work in groups on approximately one problem per week. For each problem the students are awarded individual marks comprised from the assessment of both the process and product - report or presentation. Table 3 shows the continuous assessment methods used throughout the academic year.

Figure 3: Continuous Assessment Strategy

<table>
<thead>
<tr>
<th>Assessment</th>
<th>Problems 1 - 12</th>
<th>Problems 13 –24</th>
</tr>
</thead>
<tbody>
<tr>
<td>Group Learning Process</td>
<td>Contribution or Chair</td>
<td>Tutor</td>
</tr>
<tr>
<td>Product</td>
<td>Report or Presentation</td>
<td>Tutor</td>
</tr>
</tbody>
</table>
At the start of the academic year, when the students are first introduced to Problem-based Learning, each student’s individual contribution to the group and learning process is assessed by a tutor based on the criteria in Table 1. Each student is awarded a mark out of ten and given constructive developmental feedback. In each group, one student acts as the chair, with the role rotated after each problem is completed. The chair is also assessed, but based on different criteria, as shown in Table 2, as they are only expected to manage the group process. This assessment of individual contribution and the chair is primarily formative, aimed at helping the students develop an awareness of their roles within the group and what it means to contribute constructively to the group process. However these marks do contribute to each student’s overall summative grade.

At the end of each problem, each group submits a written report that is assessed as a “single product” and awarded a mark based on standard assessment criteria, which is then given to each student within that group. For some of the problems, each group gives a twenty minute presentation that is also assessed as a “single product” and awarded a mark, which is then given to each student within that group.

The relative weighting between the process and product marks changes as the course progresses. At the start of the course when the students are first introduced to Problem-based Learning, the process mark (contribution or chair) has a weighting of 80%, with 20% for the report or presentation. This is to encourage the students to concentrate on the group process and develop their abilities to work in, and chair, a group. After a number of problems, and when each student has chaired the group process, the process weighting is reduced progressively until both the process and product are equally weighted.

After about twelve problems the students have become very aware of their roles and of the expectations the tutors have of them as individuals and as group members. Collaborative assessment is introduced about halfway through the academic year after the students have participated in a workshop where the rationale and objectives of self-assessment are explained, followed by a negotiation of the assessment criteria. From this point on, after each problem, each student is required to self-assess their own contribution to the group process and award a reasoned mark, provide a justification for that mark, explain where they lost marks and describe what they will do differently in the next problem session. The students’ self-assessments are in effect, reflective journals which the students return to after each problem. The tutors also continue to award a mark with feedback, and the average of these two marks goes towards the summative assessment. This same process is also used to assess the chair.

From about halfway through the academic year, upon completion of a problem, each group still produces a report or gives a presentation that is assessed as a “single product” and awarded a mark based on provided assessment criteria. However, in the reports and presentation each student is required to describe their contribution and state what percentage of the mark they feel they deserve. Complete justification must be provided with examples given of the level of contribution.

This continuous assessment and feedback process is designed to assist student learning and promote deep learning. To augment this process, a WebCT on-line learning resource centre was developed, which includes online tutorials, assignments, quizzes, individual students’ feedback pages, calendar, notice board and details of the laboratory project programme (Bowe,
The feedback from both the formative and summative assessments is provided through the WebCT site. The students are also required to complete regular online multiple-choice quizzes as part of the overall continuous assessment.

There is also an end of year examination that is open book, which involves the testing of the students’ abilities to problem-solve, as well as their understanding of the physics concepts.

CONCLUSION

The evaluation of the Problem-based Learning course (Bowe and Cowan, 2004) highlighted the important and vital role the assessment strategy played in success of the course. The assessment strategy was seen by the students as supportive and helpful in terms of their development as members of a learning group. As the students developed their group and communication skills the groups themselves worked better together thus improving and enhancing the learning. It also highlighted that fact that students need time to adapt to group learning and that this process can be supported through the use of an appropriate assessment strategy. It was also evident from the evaluation that the rate of development of group skills was greatly improved when the current assessment strategy was introduced. This development was further improved when self and peer assessment was introduced.

ACKNOWLEDGEMENTS

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REFERENCES


