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A Template for Designing an Effective Learning and Assessment Package for a First-Year Engineering Topic

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The aim of this project is to investigate the different modes of assessment, especially those used in engineering education, and to design a package of appropriate and effective assessment schemes within a learning strategy, in order to more effectively teach a first-year engineering topic, namely Circuits and Devices 1A.

Background

Engineering is a creative activity based on science applied with art and skill, with social and economic dimensions added. The Engineers' Council for Professional Development defines engineering as: "... the profession in which the knowledge of the mathematical and physical sciences gained by study, experience and practice is applied with judgement to develop ways to utilise economics, materials and forces of nature for the progressive well being of human kind."

Circuit and Devices 1A (CD1A) is the very first engineering topic undertaken by engineering students at Flinders University. Its objective is to provide material that will lead to some proficiency in the subject of engineering circuit analysis. Circuit analysis is simply a mathematical study of some useful interconnections of simple electric devices, which are the basic building blocks for our modern technological society. CD1A offers two components: theory and practice. In the theoretical part, students are introduced to the analysis, synthesis and design techniques of electric circuits; whereas in the practical part they gain hands-on experience in assembling and testing electrical designs, as well as gaining an insight into how electrical systems work. CD1A plays a vital role in the engineering course as it is the very foundation on which other engineering topics are built.

CD1A is a challenging and somewhat difficult topic to teach and to learn. Most first-year engineering students are confronting engineering terms and concepts not previously covered in high school. This can be daunting for them, and if not monitored carefully, these students find themselves drowning in a lot of new and difficult material. How to teach more effectively in this topic is the big question. For this project, the focus is to explore the design of appropriate assessment methods within an effective learning strategy that can aid student learning. The purpose of the learning strategy is to encourage students to become more active learners and take responsibility for their own learning.

Learning Strategy

Research has shown that how students learn has a major implication on how well they will fare in university education (Fuller, 1998; Ramsden, 1992). Fuller (1998) remarks that effective learning is more about the learner than the teacher and suggests that a cooperative learning process be used to encourage students to be actively involved in learning. This helps them in trying to understand material covered as well as developing their ability to work as a part of a team. Research has shown that the cooperative learning strategy can successfully help students to be active learners and be responsible for their own learning (Balkcom, 1992; Rivera, 1996).

Cooperative Learning Strategy

Cooperative (or collaborative) learning (CL) is an instructional methodology whereby students work together in small teams in order to maximise their own and each other's learning (Johnson, Johnson and Smith, 1991). According to the California Department of Education (2000), CL is successful because it involves small heterogeneous teams working together towards a group task where each member is individually accountable for their work and group members are positively interdependent. Each member of a team is responsible not only for learning what is taught but also for helping teammates learn, thus creating an atmosphere of achievement (Balkcom, 1992). Positive interdependence is important to the success of the group because students learn the importance of "give and take". This will help them to realise that cooperation with team-members will lead to the success of the group. Rivera (1996) believes that CL is highly effective because it helps to reduce peer competition and isolation while helping to promote academic achievement and positive interrelationships.

Johnson, Johnson and Holubec (1994) describe five basic elements of CL, namely positive interdependence, face-to-face interaction, individual accountability, group behaviours and group processing. Positive Interdependence is the essence of a cooperative group, where students have a sense of connection that allows them to receive emotional and academic support (California Dept of Education, 2000). This enables them to cope with any education problems they may face. Students come to realise that they have a responsibility to the group's work. In face-to-face interaction, students learn to work in a social environment where they have to listen to one another, ask
questions, engage in discussions, state points of views and clarify issues. Individual accountability involves students being responsible for their share of the work. Group behaviours symbolise the teamwork skills needed in order to work successfully together. And lastly, group processing is a way for group to assess how they are functioning as a team and identify ways for improvement. Rivera (1996) remarks that these five elements can be structured to promote teamwork and collaborative skills.

Assessment

While a learning strategy plays an important part in the education process, it needs to be supplemented with a suitable assessment package in order to be more effective. Hence the main questions to be considered are: What role do assessments play in the learning-teaching relationship? Are they a tool to obtain information about a student’s present state to be reported or are they a diagnostic tool used to gain information about the student to be used to enable the student to learn and grow?

According to Biggs (1999), what and how students learn depends greatly on how they think they will be assessed. Every act of assessment sends a coded message to students about what they should learn and how they should go about it (Boud, 1995). Students always try to second-guess the assessment task and thus try to learn what they think will meet those requirements. This is termed backwash and refers to the fact the assessments seem to drive student learning, as opposed to the curriculum. Backwash can be positive or negative depending on how well aligned the assessment is to the curriculum. So if we make our assessment requirements mirror the curriculum, then students will be learning what the lecturer intends them to be learning.

How students perceive the nature of the assessment task will determine the approach they will adopt to learning. Students will adopt surface approaches to some circumstances and deep approaches in others. According to Brockbank and McGill (1998), deep learning is associated with an active approach to learning, where students have a desire to learn and are actively involved in understanding the material. In the case of surface learning, students take on a passive approach to learning. They learn without reflecting and understanding the material taught. Boud (1995) remarked that students will discover that in order to maximise their marks, rote learning should be used in most circumstances even if they believe that this would distract them from the most important aspects of the course.

If not monitored carefully, assessments can encourage passive, reproductive forms of learning while simultaneously hiding the inadequate understanding to which such forms of learning inevitably lead (Ramsden, 1992). This means that in terms of assessment, student approaches to learning are a function of:

- The intrinsic qualities of the form of assessment being used;
- The ways in which the assessor translates the material to be assessed into the given format and selects assessment tasks appropriate for the subject and the specific learning goals;
- How the student interprets the task at hand and the context of the assessment.

According to Brown, Race and Smith (1996), assessments should:

- Be based on the understanding of how students learn;
- Accommodate individual differences in students;
- Have its purposes made clear;
- Be valid;
- Be reliable and consistent;
- Allow students to receive feedback on their learning and performance;
- Provide staff and students with opportunities to reflect on their practice and their learning;
- Be an integral component of course design;
- Be a suitable amount;
- Have understandable, explicit and public criteria.
According to Gronlund (1981), assessments are used:

- to diagnose student learning;
- to evaluate teaching effectiveness;
- to provide guidance to students in making decisions about the future;
- to make predictions about future abilities;
- to make selections and determine suitable candidates for a course, or university;
- to grade and rank students.

**Purpose of Assessment**

According to Pope (1989), the purpose of assessment is:

- to assist and enhance the learning of all students;
- to motivate students;
- to control students;
- to credential students;
- to structure student learning;
- to engage students in critical discourse.

Murray-Harvey, Silins and Orrell (1996) remark that assessments have multiple purposes. They have three main foci: student, teacher/curriculum and institutional.

**Problems in Assessments in Engineering**

Hessami (1999) reports that many assessment tasks in engineering are assessed in a summative manner, that is students receive a single mark for their work without any other form of feedback which they can use to improve their learning. According to Hessami all tasks, except for examinations, can be assessed in a formative style so that students are given the chance to improve their performance in the subject. Formative assessments can be used to give poorer students ample guidance on how to improve their knowledge and understanding of the topic and to adequately reward the better students for their successes. Hessami remarks that by carefully analysing the results of assessment tasks, teachers can use it not only to gather information about how students learn, but also as a tool to improve their teaching methods.

**Designing an Assessment Package**

To design a package that would work for the given teaching structure, we need to address the following questions:

- What do we want to assess?
- What are our objectives?
- What are the practical ways of assessing given the present constraints; i.e. how can we manage within the resources allowed?

The best assessment method is the one that achieves the objectives, within the allowed resources.

**Structured Assessment Process**

Before the above questions can be answered, a structured assessment process, as illustrated in Figure 1 below, should be adhered to. The outcome of which leads to a working assessment package.
Step #1 Define Objectives, Strategies and Outcomes

McGourty describes this first step to be of primary importance in the overall process. He warns that academics should not jump into the selection of assessment modes without first defining objectives, strategies and measurable outcomes. In the case of CD1A, its objectives (or mission statement) are:

- An ability to apply knowledge of mathematics, science and engineering;
- An ability to design and conduct experiments, as well as to analyze and interpret data;
- An ability to identify, formulate and solve engineering problems;
- An ability to use the techniques, skills, and modern engineering tools necessary for engineering practice;
- A recognition of the need for and an ability to engage in life-long learning.

The outcome will be a student who can apply knowledge gained in this topic proficiently and transfer that knowledge to further engineering topics.

Step #2 Identify Assessment Methods

This next step is to identify appropriate and effective assessment methods to be implemented into the engineering topic. There is a range of assessment tasks available and they fall into 3 main categories:

- Quantitative – Multiple Choice; short answer;
- Qualitative – gobbets; critical incident; letter to a friend; problem-solving;
- Procedural – laboratory reports;

It should be noted that assessment methods should be evaluated for ease of administration and cost effectiveness.
Modes of Assessment

Biggs (1999) suggests that we should look at the kinds of understanding we require from our students and what the modes of assessments might be used which would be suitable, with the resources available. Table 1 illustrates the required levels of understanding and suitable assessment tasks for those requirements.

<table>
<thead>
<tr>
<th>Objectives</th>
<th>Kinds &amp; Levels of Understanding</th>
<th>Suitable assessment tasks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Basic Facts, terminology</td>
<td>Recall, recognition</td>
<td>MC or short answer</td>
</tr>
<tr>
<td>Topic knowledge</td>
<td>Individual topics, relational, some multistructural relations between topics</td>
<td>Gobbets, critical incidents</td>
</tr>
<tr>
<td>Discipline knowledge</td>
<td>conception of unit as a whole</td>
<td>Letter to a friend, concept map</td>
</tr>
<tr>
<td>Functioning knowledge</td>
<td>topic or discipline knowledge put to work</td>
<td>problem-solving, research project</td>
</tr>
<tr>
<td>Laboratory Skills</td>
<td>procedural knowledge</td>
<td>laboratory behaviour, laboratory reports</td>
</tr>
<tr>
<td>Monitoring and evaluation</td>
<td>metacognitive knowledge, self-directed learning</td>
<td>Self and peer-assessment</td>
</tr>
</tbody>
</table>

Table 1. Suitable assessment tasks for given objectives (Taken from Biggs, 1999)

Critique of Some Assessment Methods

The question to be asked and answered is what is effective assessment for engineering. Engineering is about methodology rather than memorising facts and regurgitating them. Hence problem-solving here is significantly important.

Multiple Choice questions are good for testing basic facts. For example, they could be used to test equations for laws and such. Their main advantage is that they are easy to administer and to mark. These days with software available like WebCT, one can create MC qts and get the software to administer, mark and grade them. They also allow fast responses to students and staff. The main disadvantage of them in terms of engineering is that they do not show whether students have understood the process involved in arriving at the answer. Wrong answers due to mathematical errors and wrong answers due to wrong methodology cannot be distinguished by MCs. In this way, teachers cannot determine the learning process undertaken by students.

Problem solving questions, on the other hand, are ideally suited for engineering assessment tasks. They are good for testing functioning knowledge. Their main advantage is that they test the analytical skills of students. Their major drawback is that they can be time-consuming to mark.

Appropriate Assessments for Engineering

So, considering the resources we have in Engineering, what would be an appropriate and effective assessment package? The solution that has been arrived at is a mixture of short weekly tests, CL group assignments, laboratory reports and a final examination, as seen in Table 2, together with a cooperative learning strategy which will aid students in their learning process.
<table>
<thead>
<tr>
<th>Cooperative Learning Strategy</th>
<th>Weekly tests</th>
<th>CL group Assignments</th>
<th>Final Examination</th>
</tr>
</thead>
<tbody>
<tr>
<td>small groups (2-4) students</td>
<td>low-stakes tests in tutorials</td>
<td>more complex and challenging questions</td>
<td>integration of material covered throughout the semester</td>
</tr>
<tr>
<td>2-3 questions prepared for the tutorial</td>
<td>short 10 min qts - test basic analytical skills</td>
<td>CL group work</td>
<td></td>
</tr>
<tr>
<td>work together to maximise their own and each other's learning</td>
<td>creates less student anxiety</td>
<td>help students to get a feel for the exam</td>
<td></td>
</tr>
<tr>
<td>helps to motivate student learning</td>
<td>easy to administer and mark</td>
<td></td>
<td></td>
</tr>
<tr>
<td>positive interdependence</td>
<td>prompt feedback</td>
<td></td>
<td></td>
</tr>
<tr>
<td>each member held accountable for the complete final outcome</td>
<td>can address common student problems in lecture</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 2. Cooperative learning strategy and assessment tasks for engineering

**Implementing a Cooperative Learning Strategy**

The intention is to incorporate cooperative learning, in order to facilitate a better understanding of the material covered. In previous years, students in this topic had great difficulty with the material covered and many had left the problems they were facing until the end of the semester to be addressed. It is envisaged that with a CL strategy in place, students will be able to get help from their other group-members and hence will not feel so isolated within this topic.

The procedure, which will be undertaken to implement this CL strategy into the CD1A topic, is as follows:

- The tutorial class will be divided into small groups of 2-4 students. Initially students will be asked to form their own CL groups within the first week of university.
- Each week CL groups will have to prepare the solutions to 2 to 3 questions assigned for their tutorial session.
- This implies that CL group members will have to meet on their own time outside the normally scheduled classes to discuss and prepare the solutions.
- The idea behind this is for students to work together to maximise their own and each other’s learning.
- It is hoped that this will help to motivate student learning.

Previously, tutorials conducted in CD1A have been like mini-lectures, where students simply listen to tutors summarize the main points of the lectures and work through problems on the white-board, i.e., students were passive learners. Bonwell and Eison (1991) remarked that students learn more by doing something active than by simply watching and listening. It is envisaged that with the CL strategy in place, the tutorials will be conducted such that students will work through the tutorial...
problems within their CL group and each CL group will present their solutions to the rest of the class for discussion. In this way, students take on a more active role in the tutorials sessions. The tutor takes on the role a facilitator, making sure that students do not get stumped in their way to working out solutions.

**Weekly Tests**

According to Wankat and Oreovicz (2000), tests help to motivate students to study harder. They help in the learning process as they require students to be active and provide practice in problem-solving questions. Tests also play an important part in that they offer feedback to both the student and teacher on the various learning parts of the topic. However, there is a downside to tests in that they can be stressful to students as they are associated with the grading scheme. So how do we reap the advantages of tests while trying to reduce the stress associated with them? The answer, according to Wankat and Oreovicz (2000), is to have frequent tests. This will help reduce the stress of each test. Frequent tests will also help to spread student workload throughout the semester and thus helps students in the retention of the material taught. Most students learn best when they receive frequent evaluation combined with feedback to correct and improve their work (León de la Barra, 1996). The more frequent the tests, the more frequent both students and teachers can get feedback. The other benefit of short tests to the teaching staff is that they are easy to administer and mark. With these tests, teachers can get a feel of how students are coping with the material taught, and they can address, in the lectures, any problems faced by the general student population.

A further advantage of the weekly tests is that they will help to determine the effectiveness of the cooperative learning strategy. Since tests are an individual contribution, they will hopefully show how well students are working within their CL group.

**Assignments**

Assignments play an important part in the whole assessment package. Firstly, the assignment questions themselves are more complex and challenging compared to the weekly tests, and are comparable to the examination questions that students will face at the end of the semester. In this way, students will help get a feel for the type of questions to be expected in the examination. Secondly, assignments will be worked upon by each CL group. It is hoped that working out these complex questions together as a group will help students to maximise their learning, and help prepare them for the examination. And last but not least, with each CL group handing in one solution script, there will certainly be less to mark.

**Final Examination**

With the CL strategy in place, it is hoped that by the time students reach the end of the semester, they would have understood and integrated all the material covered. The final examination is then used as a way to gauge how well students have learned.

**Step #3 Develop/Pilot Assessment Processes**

The focus in this step is on the initial development and running of the new assessment methods. These assessment methods need to be tested to ensure that they meet certain criteria for effectiveness such as reliability and validity, cost-effectiveness, ease of administration, perceived fairness, and information leading to improvement (McGourty, 1998).

**Further Work**

**Step #4 Implement/Expand Assessment Process**

The next stage will be to have the assessment package reviewed by colleagues in Engineering, and then implemented into the curriculum of the CD1A topic.

**Step #5 Apply Results**

The last step to this process is to establish mechanisms, for example student evaluations of teaching (SETs) and peer evaluations, to review the results. Based on the review, recommendations of specific strategies and actions can be undertaken and educational objectives and outcomes can be revised as required.
Continuous Improvement

It is important to note that the whole process is geared towards continuous improvement. So once the review has taken place, the steps are repeated to improve the whole assessment package.

Conclusion

This paper has provided an overview of the design process undertaken to arrive at an effective assessment package and cooperative learning for first year engineering. The scope of assessment was defined and the five steps to implement a comprehensive assessment program were described in some detail. A cooperative learning strategy was described as a means of aiding student learning. Finally, the objective of this work is to create an assessment package within a learning strategy that will provide feedback to students and staff, in order to support continuous improvement initiatives on the part of all concerned.
References


