AC 2008-246: MILESTONE-BASED ASSESSMENT: AN ALTERNATIVE STRATEGY FOR ASSESSING LABORATORY LEARNING OUTCOMES

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Milestone – Based Assessment: An Alternative Strategy for Assessing Laboratory Learning Outcomes

Abstract

Engineering programs often feature units that contain a semester-long laboratory project, in which students complete an extended piece of work throughout the full duration of the semester. The traditional model of assessment for such units is for the students to present a series of demonstrations of intermediate stages throughout the semester – for instance, in weeks 5, 9 and 12. This approach can lead to large amounts of high-stress productivity in weeks 4, 8 and 11 and much frustration on the day as circuits that had previously been seen to be working don't function under assessment conditions. There is also a danger that this kind of burst-mode learning promotes shallow learning, rather than emphasising deep learning outcomes.

This paper presents an alternative assessment approach called "Milestone-Based Marking". Simply put, students could be assessed at any time on the milestones that would otherwise have been set for the demonstrations. As incremental progress is made, students claim incremental marks, and are able to receive incremental feedback on their progress. In this way, the date of the deadline becomes the last opportunity at which credit for those milestones could be claimed, rather than the only opportunity.

A further extension of this approach to improve assessment and feedback was to rate each of the milestones for difficulty – Easy, Standard, Hard or Challenging. The Easy and Standard milestones are intended to determine whether a student should pass or fail, while the Challenging milestones provide motivation for the students to extend themselves and enrich their learning. This rating and feedback process further assisted students in the management of their workload through the semester. Easy milestones require less effort than Hard milestones, providing students with a clear guide as to how best to invest their time and effort.

One of the hidden benefits of the Milestone-based approach is that it changes the nature of the assessment from a purely **summative process** to a largely **formative process**. Students whose performances are borderline can be given specific feedback about what they need to do to reach the expected competency levels.

The overall result of this initiative is that a strong majority of students believe that the assessment is a fair measure of their learning, and that the feedback they receive actively contributes to this learning process. They also overwhelmingly report that they are reflecting on their learning and becoming more independent learners.

Introduction

The Mechatronic Engineering degree program at Curtin University of Technology has a strong hands-on focus, with students involved in semester long design and build activities in most semesters of the course. These activities are embedded in semester long units where the focus is upon applying what the students have learned, and in producing functional solutions to real-world (or near real-world) problems. A continuous assessment paradigm is used to assess the students in these units, to allow for faculty to evaluate the students' work as they progress throughout the project.

The way in which students are assessed affects the way in which they engage with their learning[1]. The use of continuous assessment has meant that students work throughout the semester, rather than leaving everything to the last minute – almost. By setting deadlines

throughout the semester (eg phase one in week three, phase two in week six) the students cluster their work around these smaller deadlines instead of around one large deadline at the end of the semester. Whilst having the students complete the work in four bursts is preferable to seeing them attempt to complete it in one burst, the more desirable solution is to have the students working consistently throughout the whole semester. To do this, the students must be provided with motivation – be it the opportunity to earn marks, or obtain feedback – all throughout the semester.

The Milestone based assessment approach was first developed in the unit Mechatronic Project 332, and this paper describes its use in that unit. This unit is a semester long project in which students design and build a toy car to navigate autonomously around a track (Figure 1). The vehicle is controlled through differential steering (Figure 2), and powered through transistor amplifiers which are developed by the students (Figure 3):
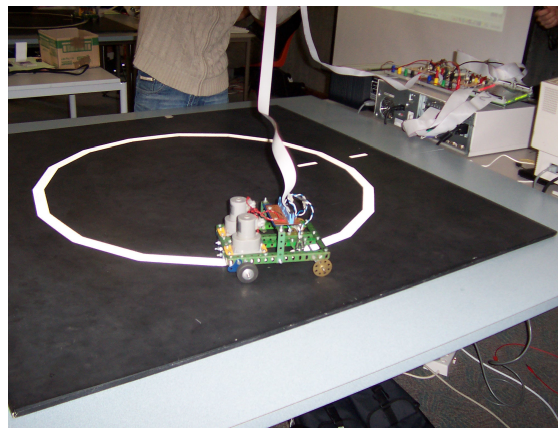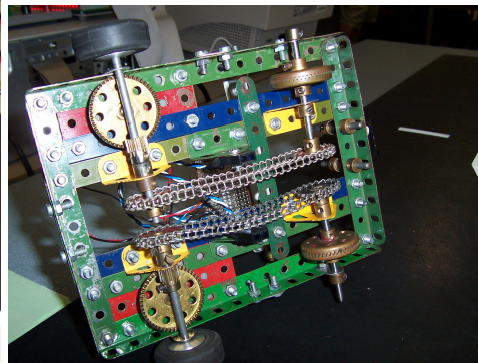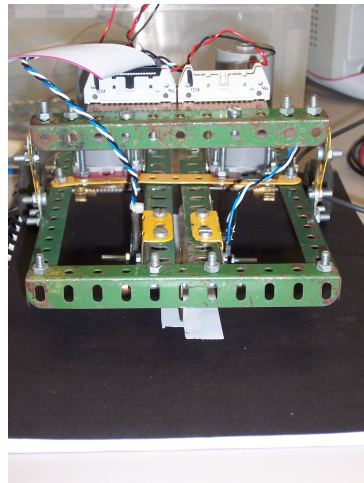

Figure 1: The Circular Track

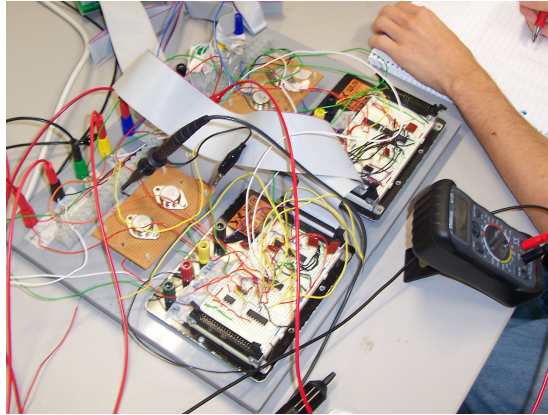**Figure 2: Car layouts showing differential steering**

Figure 3: Transistor Amplifiers

Historically, the students had been assessed through a number of in-class demonstrations of their progress, and through the submission of reports throughout the semester, with each report covering one of the phases of the car's development.

This approach led to considerable stress upon the students and on faculty, mostly due to "last minute" factors. Many groups want to be the last group to demonstrate their work, to give themselves a few extra precious minutes to improve their performance. A laboratory of students who wish to be assessed last causes problems – not all of them can be satisfied, but choosing which ones to disappoint is potentially stressful. It is also frustrating when a project doesn't work under demonstration conditions – "it was working yesterday" serves only to frustrate everyone involved.

The key motivation in this synchronized approach is that the students should achieve project milestones by the given deadline. Without regular progress, the overall completion of the project is less likely, and regular milestones keep the project on track. This demonstration- and report-based assessment strategy does not quite implement this philosophy. Instead, it provides a single opportunity to the students to demonstrate their learning – once in the laboratory for the demonstrations, and once at submission time for the reports. Marks cannot be acquired later; nor can they be acquired earlier.

The reason for the deadline is to provide a latest time by which students should have achieved particular outcomes. There is no reason not to reward the students if they have successfully achieved the outcomes earlier. To do this, the Milestone based assessment system was developed.

Milestone based assessment

The initial implementation of the milestone based assessment was straightforward. Each demonstration and report had a number of marks associated with it, each for a particular learning outcome. The marks for each outcome were made explicit, and the list distributed to the students in advance, with instructions to claim the marks from the laboratory demonstrators or the lecturer whenever they had achieved the milestone. The submission deadline for the demonstration and reports became the last opportunity at which students could claim these milestones.

Once this framework was established, further expansions of the concept were possible, such as rating the milestones for difficulty, offering multi-part milestones, and linking milestones through each other as prerequisites.

Rating for Difficulty

The listing of milestones gives the students a clear idea of what is expected of them, and what marks are available in the assessment task. For a student who wishes to earn 100% of the available marks, it is therefore a matter of completing all milestones.

Students who aim for 100% are rare; students who achieve 100% even rarer. Most students are more pragmatic, and will choose not to complete some of the milestones if they are not essential to the success of the project. Not all milestones are equally difficult, or equally valuable. Some require significant understanding and reflection; others are straightforward simple tasks. By providing an indication to the students as to which milestones are which, the students have more information with which to plan their work.

For instance, a ±10% error margin may be acceptable in the project specification, but a ±1% is preferable. If the accuracy milestones are rated for difficulty, students who find themselves within the 10% margin can then decide whether they wish to invest the time and effort to achieve the smaller tolerance, and thus the additional mark, or whether to focus their energies elsewhere.

Four difficulty categories were chosen for the milestones: Easy, Standard, Hard and Challenging. The intention is that all students should achieve all of the Easy marks. Standard milestones determine who passes and who fails; a student who is able to complete all the standard milestones should successfully complete the unit. The Hard marks are intended to separate the passing students from the honours students, and the Challenging marks separate the excellent from the exceptional. Accordingly, the milestones were allocated to these difficulty categories in the following ratios: Easy 20%, Standard 40%, Hard 20% and Challenging 20%.

Engineering students are strongly visual learners, and it was felt that a visual representation of the different difficult categories would be more useful than repeated use of the words themselves. A colour-based scheme was considered; however this would not translate well to black-and-white printing, which is still the dominant printing method amongst students.

In Australia, movies are rated by the Office of Film and Literature Classification on a six point scale, with each of the different classifications represented by a different shape. This provided a framework for expressing increasing levels of complexity and difficulty, ranging from Easy (the G-rated shape) through to Challenging (the R-rated shape):

Easy	Triangle	G
Standard	Square	PG
Hard	Hexagon	MA
Challenging	Diamond	R

Many students did not realise their familiarity with these classifications until it was made explicit in class. Once it was made explicit, however, the shape-based naming convention in

fact became the dominant paradigm. Milestones were referred to by their shapes, rather than by their difficulties:

- Don't put in too much work for an easy mark became "*it's just a triangle*"
- You're at the border line between getting the mark and not – "*you have a square, but not a hexagon*"

An unintended consequence of the selection of shapes was that the hardest marks were classified as Diamonds – which themselves are valuable. This led to some of the most ambitious and motivated students proudly identifying themselves as Diamond Hunters, which served as a valuable motivational tool.

Multi-part Milestones

Some of the more significant milestones had multiple marks allocated to them. When combined with the difficulty ratings, this allowed for more subtle distinctions to be made in what was expected from the students.

Some multiple-part milestones consisted of two (or more) milestones of the same difficulty. This indicated to the students that there is a task that needs to be repeated. For example, the vehicles are controlled through differential steering – each side of the vehicle has its own drivetrain, both of which need to be constructed. Completion of each drivetrain constitutes its own milestone, with both milestones having the same difficulty level.

Other multiple-part milestones consisted of two (or more) milestones of differing difficulty. This allowed for differing levels of understanding and achievement to be assessed. Making a circuit work could be rated as a Standard milestone; but the discussion of why it works could be a Hard milestone. In this way the students understand the different depths of achievement (and thus different levels of effort) required to earn both marks, and can choose to allocate their efforts accordingly.

Pre-requisites

Pre-requisite links were identified between some of the milestones, requiring students to complete some tasks before completing others. This encouraged students to develop planning skills, and also helped scaffold their progress through the work. The usual pre-requisite chain is planning-results-reflections, although other combinations have been implemented.

A sample set of milestones is illustrated in Figure 4, overleaf.

The impact

Overall, the Milestone based marking scheme has been overwhelmingly positive, from both a student and a staff perspective. Students report that the approach provides them with a clear understanding of what is expected of them, and staff find that this clearer expectation allows for a stronger focus upon the learning, rather than upon the assessment.

Push-Pull Amplifer – Total 10 marks

All Push-Pull Milestones also have { 1.2, T(6) } as a pre-requisite.

#	Pre-reqs	Milestone	
Planning			
3.1		Circuit diagrams • Diagrams of whole circuit, and sub-systems as required • Must be implementable	1 mark ⬡
3.2		Clear specification of required amplifier performance • Range of operating conditions, tolerances • Anticipated performance	1 mark ⬡
3.3.		Software design & planning • Requirements & Flowcharts	1 mark ▢
Implementation			
3.4	3.2, ≤ Three attempts	Correct output voltage • matched at ±0.1v accuracy (eg 6.7V -> 6.6V-6.8V) • matched at 0.1v accuracy (eg 6.7V -> 6.7V)	2 marks △ ▢
3.5		Clear Articulation of Amplifier Performance • Graphs	1 mark ▢
3.6		Discussion of amplifier performance • With reference to anticipated performance	1 mark ◇
Reflections			
3.7	(I)	Evidence of Changed methodology in response to intermediate results • Proof that you were thinking as you went along	1 mark ⬡
3.8	3.5, (I)	The four most important things that you learned during this work • Meaningful things, not "transistors get hot" • Four is not three, nor is it five	1 mark ▢
3.9	(I)	Understanding of Feedback and it's role in linearisation • Far more than "Feedback Makes it Linear" • Issues that feedback can cause	1 mark ◇

Figure 4: Sample Milestones

Student Satisfaction

Curtin University of Technology uses an online end-of-semester evaluation of teaching tool to determine student satisfaction with the quality of teaching. This evaluation consists of eleven questions to which the students strongly agree, agree, disagree or strongly disagree, as well as the opportunity to make open-ended comments regarding the unit.

The student responses for the unit indicated 100% agreement to the items "The learning outcomes in this unit are clearly identified" and "Feedback on my work in this unit helps me to achieve the learning outcomes." In addition to this general feedback on the unit, the open-ended questions were very positive towards the milestone-based marking scheme:

"The marking strategy was clear and progressive, we could attain the level of results step by step to our own satisfaction."
"The new mark categorising scheme works wonders, it lets us see how much detail is required."
"New marking scheme is great, really lets you know what's expected and where to direct studies. I would recommend that this be used by all lecturers."

In addition to the general support for the approach, students also valued the hidden benefit of the Milestone-based approach: it changes the nature of the assessment from a **purely summative process** to a **largely formative process**. Students whose performances are borderline are given specific feedback about what they need to do to reach the expected competency levels, and the appreciate this focus:

"Most helpful is the depth of feedback, comments on how the work could be improved."

The overall result is that a strong majority of students believe that the assessment is a fair measure of their learning, and that the feedback they receive actively contributes to this learning process. They also overwhelmingly report that they are reflecting on their learning and becoming more independent learners.

Staff Satisfaction

It is not just the students that are happier with this assessment approach. The milestone approach has also improved staff satisfaction. The milestone based approach represents a change to a mastery learning paradigm. Rather than only allowing students a single attempt at assessment, they are able to attempt as often as is required, gaining feedback each time, until they reach the required level of competency.

This ability to say no, and to have the student re-attempt the assessment, removes one of the more stressful aspects of marking – making decisions in borderline cases. If a student is borderline in a written report, the marker has to decide whether they get the mark, or a half mark, or no mark, and needs to apply this consistently. If a student is borderline for a milestone, the marker provides feedback on what is required to clearly demonstrate what is needed to achieve outcome, and the student is given another attempt. As well as being a better approach educationally, this also lowers the stress levels involved in marking.

This approach also supported the involvement of teaching assistants in the laboratory, and also widened the range of possible teaching assistants to include undergraduate students.

TAs can be uncomfortable in the marking process, particularly when confronted with borderline calls as discussed above. The difficulty gradings on the milestones allowed for the TAs to avoid the more stressful decisions – the lecturer was responsible for assessing challenging milestones, whilst the TAs could happily assess easy and standard ones. This allowed for the lecturer to focus on the higher order outcomes, and empowered the TAs to handle the more straightforward outcomes such as "the circuit works".

Conclusion

The Milestone-based marking scheme has improved the learning process in the laboratory. Its key advantages are clarity of expectations, improved feedback about whether those expectations are being met, and the freedom to choose how to meet those expectations. This combination of factors ensures that the focus of the learning process is squarely upon the student, rather than upon the series of laboratory reports they are expected to write.

The students are happier and more productive with this approach, and they feel that it supports the development of their independent learning skills. The teaching staff are happier with the approach, with the clear expectations at different difficulty levels allowing for more meaningful and timely feedback to be provided to the students. Students learn more; they are happier; and the staff are less stressed. Overall Milestone based marking has shown itself to be a significant improvement in the assessment of semester-long design & build laboratory projects.

References

1: Albon, R. J (2003) *Assessment drives the learning: Raising the bar*. Paper presented at the Second Assessment and Learning Conference, Nov 24-25, Adelaide, Australia