A Preliminary Motivational Evaluation of Milestone-Based Laboratory Assessment

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Abstract – **Milestone based marking is an asynchronous assessment approach used for semester-long projects. By providing students with a fine-grained marking scheme – the milestones – at the start of semester, and allowing students to claim these marks at any point in the semester, students can better plan and self-manage their learning.**

The milestone-based assessment approach is intended to motivate the students by making the assessment process transparent and accessible. To determine whether or not this has occurred, it is necessary to evaluate the initiative through the lens of motivation theories. Since the connection between motivation and learning is well understood, looking specifically at motivation should shed light on how deeply students are learning in this new approach.

In this paper, student data from three semesters of implementation is reviewed and explained using various motivation theories: Self-Determination Theory, Flow Theory, Self-Efficacy Theory, Goal Theory, and Expectancy-Value Theory. Results show that many of these theories have opportunity to explain the students' engagement and learning and provide insight into how better to examine student motivation in upcoming semesters.

Index Terms – Assessment, Milestone Based Marking, Motivation Theory

INTRODUCTION

The connection between motivation and learning is already understood: for students to learn there must be motivation [1]. Promoting and developing motivation for learning is one way to address the ABET criteria pertaining to lifelong learning [2], as lifelong learning requires not only the ability but also the *motivation* to learn new things throughout the graduate's lifespan.

One motivator that affects learning is the method by which students' work is assessed; that is, what is measured is what is learned [1]. Therefore, particular attention should be paid to the effects that different assessments have on student motivation, so that the assessment regime promotes motivation for learning.

This paper looks at five motivation theories to identify the hallmarks of a motivational assessment regime. The paper then looks at the Milestone-Based Marking approach [3] to determine whether it demonstrates these hallmarks,

and then analyzes the students' patterns of mark acquisitions to determine whether the students' behavior is consistent with these motivation theories.

MOTIVATION THEORIES

Five theories of motivation are presented here as a lens through which to analyze students' engagement with the Milestone based marking scheme: Self-Determination Theory, Flow Theory, Attribution Theory, Goal Theory, and Expectancy-Value Theory. These theories were chosen because each has a large literature base and each has been applied in various educational contexts.

Self-Determination Theory

Self-Determination Theory is founded on the principle that motivation lies on a continuum from amotivation to extrinsic motivation to intrinsic motivation. Intrinsic has the most internalized source of motivation, whereas extrinsic has the most externalized source of motivation; amotivation is a lack of any drive to act. Internalized motivation has been shown to produce the deepest levels of affective, behavioral, and cognitive engagement in tasks, including learning. Externalized motivation, on the other hand, not only gets lower quality engagement, but also moves more easily into amotivation when the external motivator is removed or temporarily not present [4].

There are three underlying motivational needs that affect the process of internalizing motivation for a task: autonomy, competence, and relatedness. Autonomy requires not only choice but that the options align with internal values of the person. Competence is similar to self-efficacy in that it requires the perception of ability and opportunities to demonstrate that ability. Relatedness is a need to feel connected to others and/or something bigger than the self. Satisfaction of these needs, as perceived by the individual, leads to increasingly-internalized motivation, which obtains the aforementioned benefits [4].

Flow Theory

Flow Theory states that there are various regions of motivation regarding the interaction of an individual's ability and the difficulty of a task. If the individual's ability is high and the task challenge low, then motivation will be impeded by boredom. If the ability is low and the challenge is high, motivation will be hampered by anxiety. However, in the region where challenge and ability are closely-matched, positive motivation exists. Further, ideally the task challenge is slightly higher than the individual's ability,

providing opportunity to learn and improve. Over time, the individual should move up in ability and the task challenge can be consequently increased, maintaining optimal motivation throughout [5].

Goal Theory

Goal Theory focuses on the reasons that individuals have for engaging in particular tasks. Mastery goal orientation considers an individual's focus on developing their abilities, mastering new skills, accomplishing challenging goals, and trying to understand new things. Mastery-approach goals are those intended to learn, master, and understand the task, whereas mastery-avoid goals are those that seek to avoid misunderstanding or not being able to learn from a task [6].

Performance goal orientation focuses more on comparative evaluations, where ability and standards emanate from social comparison. Performance-approach goals seek favorable evaluations of competence from others. Performance-avoid goals are those intended to avoid negative evaluations of ability from others [6].

Attribution Theory

Attribution Theory deals with the beliefs that individuals have about the causes (sources) of their successes and failures. The first dimension of attribution is locus, where the individual considers whether the outcome was driven by internal or external sources. The second dimension is stability, where the duration of causes is considered, often in a temporary or permanent sense; e.g. one might believe the ability to write well is a permanent ability, not one that is contextual. The third dimension of attribution is controllability, which considers the ability of the individual to have influence on the cause of outcomes. Altogether, a person can evaluate any outcome with these three dimensions; for example, getting an "A" on an exam might be perceived to be the result of internal, permanent, controllable causes like skill and abilities, or getting an "F" the result of external, temporary, uncontrollable causes like illness or an unfair test [7, 8].

Expectancy-Value Theory

Expectancy-Value Theory evaluates individuals' motivations based on their anticipation of positive outcomes (expectancy) and their desire to obtain such outcome (value). The evaluation of expectancy involves one's perception of their competence, at the time when the task will be undertaken. The evaluation of task value depends on the task's quality, which leads to an increase or decrease in probability that the individual will prioritize the task in comparison to others [9, 10].

The task value may depend on four variables: attainment, intrinsic, and utility value, and cost. Attainment value is the importance associated with the outcome based on the individual's internalized value for that outcome. Intrinsic value is that which stems purely from interest in and enjoyment from the engagement in the task. Utility value is the value associated with the outcome toward other future goals and interests. Finally, cost, in the context of motivation, is associated with how the decision to engage one task may limit the ability to engage others, as well as the effort required to perform the task [9, 10].

THE IDEAL MOTIVATIONAL ASSESSMENT REGIME

There are some substantial commonalities that emerge from these five motivational theories, and these emergent parameters could be used to develop an assessment regime designed specifically to motivate students. The key motivational variables, taken from the theories above and grouped, that would need to be addressed are:

1) autonomy / locus / controllability
2) competency / expectancy
3) relatedness
4) value / cost / interest / enjoyment
5) goals of mastery and performance
6) challenge / difficulty
7) stability

An assessment regime that addressed all of these parameters would have the following elements (affected variables in parentheses):

A. Maximal autonomy for the students, such that all success and failure is their own (1)
B. Present challenges that neither bore nor bog students down, yet give opportunity to demonstrate competence and master tasks (2, 5, 6)
C. Make the earning of grades/marks very explicit (7)
D. Tie the tasks to real-world problems, to maximize interest, enjoyment, utility value, etc. (4)
E. Allow opportunity to compete with other students without fear of negative assessment/grading (5)
F. Allow opportunities to collaborate (3)

Stepping back out to the theories, it could be said that Flow Theory suggests that the overall *system* should be motivational, which the combination of A and B above constructs. In this way, the student can match their ability to the challenge, knowing that going too easy will be boring and will not earn a good grade, and too hard will incite anxiety and possibly failure.

Self-Determination Theory states that the autonomy in A, competence demonstrated in B and E, and relatedness from F can incite the most intrinsic forms of motivation for learning, also maximizing positive engagement in the tasks.

Goal Theory states that different people are motivated by different goals, and as such, B and E provide opportunities for both performance- and mastery-oriented students with minimal compromise to either.

The direct responsibility in A and C is likely to assist students in better understanding the cause and effect relationship of their efforts to success and failure, according to Attribution Theory.

Finally, related to Expectancy-Value Theory, B and D are intended to maximize students' abilities to work toward valuable tasks and have a self-evaluated measure of expectancy, similar to the effects discussed with Self-

Determination Theory above. On initial inspection it appears that the Milestone Based Marking system possesses the ideal elements from student perspective elements; however, a deeper analysis is necessary to be sure.

MILESTONE-BASED ASSESSMENT

The Mechatronic Engineering degree program at Curtin University has a strong hands-on focus, with students involved in semester-long design-and-build activities in most semesters of the degree program. The students work in pairs in the laboratory to complete an ongoing project, and are required to plan, implement, and document their work as they progress. These activities are for the most part embedded in subjects that do not have final examinations – students are instead assessed only on their work in the laboratory.

An assessment approach known as Milestone Based Marking [3] is used to desynchronize the assessment, allowing students to claim marks at any point in the semester, rather than only at a few distinct points.

The students are presented with a fine-grained assessment scheme – the list of milestones - at the start of the semester. The students can explicitly see what is required of them to acquire their marks; it is then up to them to perform the work and claim the marks for doing so.

While Milestone Based Marking was not developed from a basis of motivational theory, it still nonetheless matches many of the elements identified in the section above.

Some of these elements (such as D & F) are addressed by the group-based practical nature of the subject; others are achieved through a range of features of the Milestone based approach.

Rating for difficulty

Each of the milestones is allocated one of four difficulty ratings: Easy (20% of the available marks), Standard (40%), Hard (20%) or Challenging (20%). While each of the milestones is equally valuable to the students, and counts equally towards the overall assessment of the subject, the milestones are not equally difficult to acquire. This is normally an implicit part of marking schemes, but the milestone system allows for this difficulty rating to be made explicit to the students. This was intended as a guide to the students as to how much effort was required for each milestone, to assist them in planning their work.

In some instances, a particular project outcome would have two milestones of different difficulties allocated to it. 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.

Providing guidance as to the difficulty of tasks assists the students in allocating their efforts appropriately (element B). There also emerged a degree of competition (element E) between the students as to who could claim the most Challenging marks.

Formative Feedback instead of Summative

A synchronized submission approach to assessment provides only two marking options – yes or no. The milestone approach, with its flexible timing, allows for an "almost" – a "no" grade that comes with feedback, and allows the student the chance to make the necessary changes and improvements to get to "yes." In this way, the feedback process dramatically shifts from summative feedback to formative feedback.

This approach had the effect of moving the subject towards a mastery learning paradigm. Students were able to attempt the same milestone multiple times, improving their efforts with each iteration. This returns the locus of control to the students – if they are unsuccessful in claiming a mark, they have control over whether they wish to reattempt, whereas is a "submit a progress report and be marked" paradigm, this control resides only with the professor. This autonomy in assessment outcomes supports element A.

Prerequisites

The assessment cannot be totally desynchronized – there is still a critical path through the overall project that must be followed. Planning must come before implementation, which in turn must come before testing. By designating some milestones as prerequisites for other milestones, the students are given guidance as to how best to progress through the overall project. Further, some milestones required a week to have passed since the prerequisite was claimed, to force the students to plan before they implemented. The overall critical path for the project involved six week-long delays.

The prerequisite structure addresses element C – it makes explicit the linkages between the milestones, and guides the students as to the processes necessary to complete the overall project.

Laboratory-based Implementation

The Milestone approach also reduces the (artificial) distinction between work in the laboratory and assessment of that work. Students sometimes feel that writing a report is an exercise in (guessing and then) writing what the professor wants to read; in this situation the assessment becomes a non-authentic task added on to a realistic laboratory problem. By performing the assessment in the laboratory, the milestones are made available for authentic achievements and behaviors (element D), eliminating some of the "guesswork" of report writing (element C).

In order to manage the assessment workload, teaching assistants (TAs) are empowered to award marks for the milestones. The TAs are largely drawn from students who have previously completed the unit successfully; this ensures a familiarity with both the technical content and the milestone assessment approach. This brings a range of

different perspectives – and feedback styles – into the laboratory. By having more than just the Professor able to award marks, the students are effectively given some control over the assessment process – they can choose who they will claim the marks from, based on their preferred style (element A).

Another advantage of the use of TAs and performing assessments in the learning spaces is that it employs the advantages of Lean Assessment Techniques [11]. These Techniques are "simple, efficient, and effective" (p. M2J-3) and modify the assignments and activities that already exist in a given course, to assess specific aspects of student learning. In the case of the Milestone-Based Assessments, the original laboratory project was modified to more directly assess student learning by breaking down the project into explicit tasks for students. In this way, the Professor can easily review the marking sheets to see if a team or the whole class might be struggling with a particular task or category of tasks. As well, TAs can easily evaluate student work, making the faculty's time investment in the course more efficient.

Summary

The overall goal of this approach was to give students control over their assessment destinies. Rather than a small number of primarily summative assessment tasks, the students now have an ongoing, primarily-formative assessment regime that allows them to choose when and in what order they wish to be assessed. It also provides them with guidance as to the marginal effort required for each additional mark, allowing them to make informed choices regarding their allocation of time and effort.

It was intended that this should help motivate the students, and in particular to provide an environment to support and reward the students for being self-motivated. In order to assess whether this has occurred, it is necessary to consider the way in which the students went about claiming the marks from milestone completion. Data from three years in the subject Mechatronic Automation 331 is used to illustrate the patterns of milestone acquisition.

MILESTONE ACQUISITION PATTERNS

The faculty involved in the teaching of Mechatronic Automation 331 are always seeking to improve the unit; as such, the unit evolves from year to year. This evolution led to some changes in the way in which the milestones were presented to the students. While it is difficult to control for variations between successive cohorts, the change in milestone presentation appears to have changed the systemic motivation for students to acquire marks.

In the 2007 data (Figure 1), it is clear that the dominant behavior is to leave the acquisition of marks as late as possible in the semester. This behavior is not uncommon amongst undergraduate engineers, and indeed, it was this kind of behavior that was part of the reason for the development of Milestone-Based Marking.
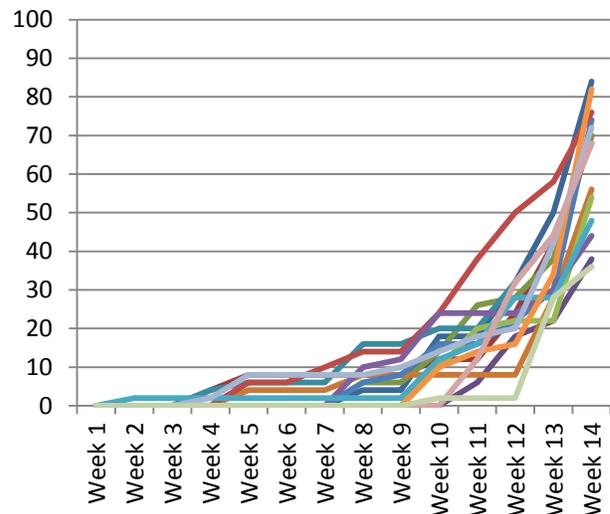

Figure 1: 2007 Milestone Acquisition

For most groups, the "sprint home" is triggered somewhere around week eight of the semester. This is an indication that students did not understand the value of early efforts or the cost of waiting for too long, which informed the instructors that this needed to be addressed more explicitly. This was indicated in student comments, as well. For example, many said the most valuable thing they learned was time management, and that late decisions made them prioritize what was important and compromise on others.

All milestones are equally weighted for marks; however, in week eight of semester, some of the milestones effectively become more valuable. Because the critical path through the semester's work is six weeks long, if students have not acquired the first milestone on that path by week eight, they will be unable to claim the last milestone in week 14. In effect, the cost of not claiming these earlier milestones increases from the one mark (the face value of the milestone) to three or four marks once the opportunity cost later in the project is incorporated.

Expectancy Value Theory makes it clear that people respond to changes in value; in particular, when an activity becomes more valuable it is more likely to be carried out. As the semester continues into weeks nine and beyond, each of the critical path milestones becomes inherently more valuable, as more and more of the available marks become dependent upon their completion. Similarly, the milestones that are themselves prerequisites for these critical path milestones also become more valuable, and it can be clearly seen that the students capture progressively more marks each week as the semester draws to a close.

In response to the dominant paradigm of delaying mark claims until late in semester, in the subsequent years students were encouraged to claim marks earlier. The 2008 milestone acquisition pattern (Figure 2) shows that this was

partly successful, but that there was still a substantial flurry of claims at the end.

Figure 2 shows that almost all teams claimed some marks in the early weeks of semester, and then plateau until around week seven, when the sprint to the finish begins again.
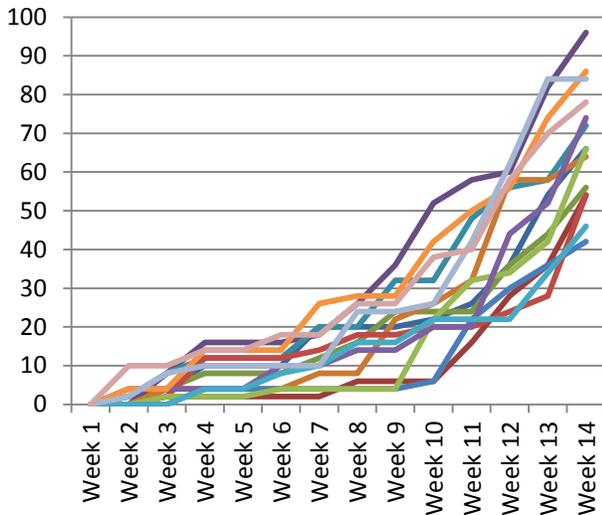

Figure 2: 2008 Milestone Acquisition

Self-Determination Theory suggests that students' motivations will internalize when they have autonomy to control their own destiny. The early flurry of mark claiming is representative of this autonomy; the freedom invokes the most desirable motivations – the internalized ones based in interest and enjoyment. For some groups the realization of this motivation is apparently instant. For other groups it can take until the beginning of the sprint home period for this to occur, confounded by lower competence or self-efficacy challenged by the unusually high degree of self-reliance.

In 2010 (2009 data are unavailable), the process was altered again, this time through the presentation of a graph – such as Figure 3 – in the lecture each week. In this way, each team could anonymously see how they were progressing relative to each of the other teams, giving them an external reference for their progress.

Figure 3 also displays the early burst of milestone claiming from the 2008 cohort, and the sprint for the finish that was present for both the 2007 and 2008 cohorts, but it also shows a steady acquisition of marks from weeks four to six. The consistency of this steady acquisition phase is most clearly visible when the marks claimed each week are illustrated (Figure 4), rather than the cumulative graph.

Figure 4 shows the three phases of the semester quite clearly – an early rush to claim marks in the first three weeks, a steady ticking over from weeks four to six, and then a much greater rush to claim marks as the semester progresses to its end.
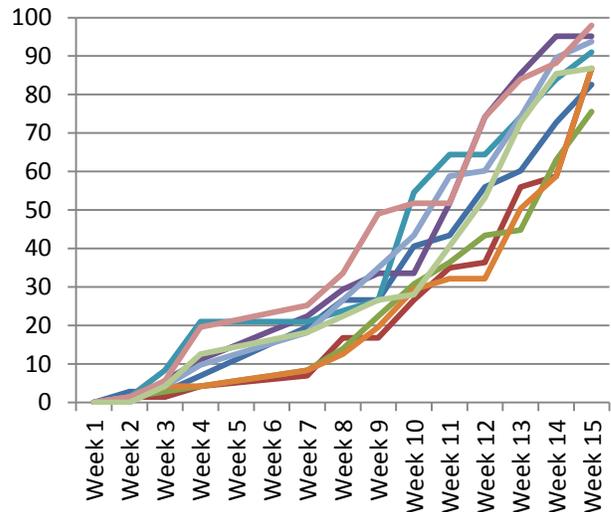

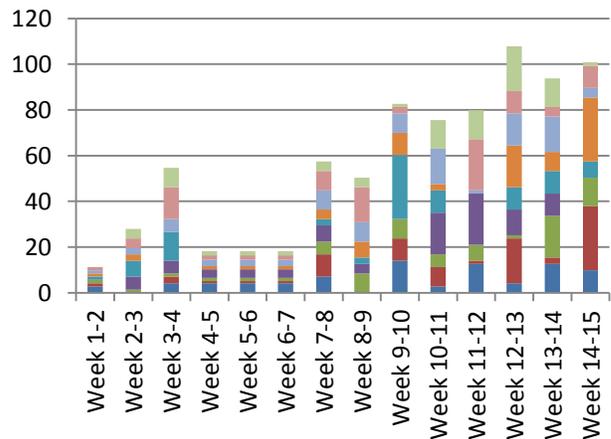**Figure 3: 2010 Milestone Acquisition**

Figure 4: Marks claimed by week, 2010 cohort

Goal Theory tells us that students with performance orientations will not wish to look bad in front of their colleagues; while the data were presented to the class anonymously, students are still aware of whether they are ahead or behind their colleagues, and this relative comparison has a motivational impact.

Figure 4 shows that this impact is in fact consistent across weeks four to six. For some teams this motivation is enough to push them to claim a single mark; for others three or four marks per week are needed to satisfy this motivation.

CONCLUSION

Students are motivated in multiple ways and this paper has provided preliminary evidence that the Milestone-Based Assessment offers motivators in many different forms. This approach offers increased student autonomy without removing consequences for success and failure; opportunities for both mastery- and performance-goal-motivated students; the opportunity for students to self-align challenge with their ability; and more. These are the types

of assessments that allow educators to reach more, diverse students with minimal time investment or alterations to how class is conducted.

Analysis of the patterns of mark acquisition has shown emergent patterns of student behavior, and that these patterns vary throughout the course of the semester. Motivation theory is able to explain these differences in behavior, and highlights that students are unique and respond to different kinds of motivation at the different stages of the project.

While not originally designed based upon motivational theories, assessments like the Milestone-Based approach evaluated here take a significant step toward improving student motivation opportunities in engineering classrooms and laboratories.

REFERENCES

[1] J. D. Bransford*, et al.*, *How People Learn*, Expanded ed.: National Academy Press Washington, DC, 2000.

[2] ABET. (2009, April 21). *Criteria for Accrediting Engineering Programs: Effective for Evaluations During the 2009-2010 Accreditation Cycle*. Available: http://abet.org/forms.shtml

[3] E. D. Lindsay, "Milestone-Based Assessment: An Alternative Strategy for Assessing Laboratory Learning Outcomes," presented at the American Society for Engineering Education, Pittsburgh, USA, 2008.

[4] E. L. Deci and R. M. Ryan, "The "What" and "Why" of Goal Pursuits: Human Needs and the Self-Determination of Behavior," *Psychological Inquiry,* vol. 11, pp. 227-268, 2000.

[5] M. Csikszentmihalyi, "Flow: The psychology of optimal experience," ed New York: HarperPerennial, 1990, pp. 43-93.

[6] J. L. Meece*, et al.*, "Classroom goal structure, student motivation, and academic achievement," *Annual Review of Psychology,* vol. 57, pp. 487-503, 2006.

[7] B. Weiner, "Intrapersonal and Interpersonal Theories of Motivation from an Attributional Perspective," *Educational Psychology Review,* vol. 12, pp. 1-14, 2000.

[8] L. K. S. Chan and P. J. Moore, "Development of Attributional Beliefs and Strategic Knowledge in Years 5–9: A longitudinal analysis," *Educational Psychology,* vol. 26, pp. 161-185, 2006.

[9] J. S. Eccles, "Subjective Task Value and the Eccles et al. Model of Achievement-Related Choices," in *Handbook of Competence and Motivation*, A. J. Elliot and C. S. Dweck, Eds., ed New York: The Guilford Press, 2005, pp. 105-121.

[10] A. Wigfield and J. S. Eccles, "Expectancy–Value Theory of Achievement Motivation," *Contemporary Educational Psychology,* vol. 25, pp. 68-81, 2000.

[11] K. Stanton, "Increasing assessment effectiveness in a time of decreasing budgets," in *Frontiers in Education Conference*, San Antonio, TX, 2009.

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