Mathematics in Marine Engineering: Significance of Formative-Feedback within a Diverse Student Cohort

Sudhakaran EDATHIL
Australian Maritime College, Launceston, Australia
s.edathil@amc.edu.au

Dev RANMUTHUGALA
Australian Maritime College, Launceston, Australia
dranmuth@amc.edu.au

Mark SYMES
Australian Maritime College, Launceston, Australia
m.symes@amc.edu.au

ABSTRACT

Purpose:
This paper aims to examine and propose how to enhance learning of theoretical engineering units with considerable mathematical content in marine engineering courses with diverse student cohorts.

Methodology:
It is proposed that the competence of students will be improved by adopting a self-directed learning approach. This is achieved through a web-based assessment tool incorporating dynamic-feedback and used within formative assessments. This is further supplemented by integrating theoretical units with operational units having practical applications. A semi-structured questionnaire was launched to seek student feedback on their experience in this study.

Findings:
Performance levels improved in all students who utilised the assessment tool, although multiple uses maybe required. Dynamic-feedback in formative assessments improved student learning as it encouraged self-directed studies and enhanced motivation for learning among the majority of students. The students agreed that integrating theoretical units with operational units enhanced their learning and enabling them to see the relevance to their work roles.

Conclusions:
Formative assessments with dynamic feedback improved student learning in mathematics dominated marine engineering units. Properly designed tools, integrating theoretical and practical content and providing adequate and appropriate dynamic feedback, will motivate self-directed learning.

Keywords:
Mathematics, marine-engineering, formative-assessment, feedback, competence, Australia.

INTRODUCTION

Mathematics is an integral part of engineering studies in general. The implicit mathematical content with its inherent complexity in engineering subjects compounded by inadequate mathematical skills have traditionally posed problems of attrition. This acts as a barrier to their learning (Willcox & Bounova, 2004) and promotes a negative attitude towards mathematics. In order to address such situations various learning strategies have been adopted. For example, the minimal-mathematics strategy (Otung, 2001) encourages students to study engineering by employing mathematics to the level that is absolutely essential and the just-in-time mathematics strategy (Klingbeil, Mercer, Rattan, Raymer, & Reynolds, 2005) adopts an application-driven approach by shifting the traditional emphasis on mathematics pre-requisites. They both put engineering first and mathematics second, while motivating the students in learning.

The education and training of marine engineers follows a competency based learning model culminating in the issue of a Certificate of Competency, which enables graduates to commence practice as a marine engineer on merchant ships. These courses are designed to meet the Standards of Training Certification and Watchkeeping (STCW) developed by the International Maritime Organisation (IMO) and approved by the regulatory authorities of the individual nations. They straddle both the vocational and higher education sectors utilising a sandwich course structure combining a series of institution and workplace based components, with the former consisting of a significant mix of theoretical and practical elements. Traditionally in marine engineering programmes, the institution based academic components have largely been content driven, with the theoretical units consisting of significant mathematical content.

At the Australian Maritime College (AMC), application driven mathematics strategies similar to the just-in-time and minimal-mathematics have been in place within the marine engineering courses. The course structure incorporates a mathematics orientation week at the commencement of year two and an additional two weeks mathematics refresher course prior to the commencement of the theoretical units in year three. Additional support such as peer assisted study sessions and mathematics foundation courses are offered as optional but highly recommended strategies, especially to those with lower mathematical knowledge.

Generally marine engineering students in Australia can broadly be spilt into two distinctive cohorts based on their entry qualifications: conventional school-leavers with relatively higher mathematical background following a 'cadet' programme; and mature-age trade qualified students following a 'trade pathway' possessing significant practical skills but with relatively lower mathematical knowledge. The cadet stream further comprises of domestic and international student cohorts. Practicing trade technicians often enter the courses through the trade pathway after a significant gap since completing their mathematics studies at school and as a result struggle to cope with the mathematical content. Often they do not seem to appreciate the relevance and the application of mathematics at the workplace. As a result of the observed resistance to learn theoretical units with mathematical content, the delivery of these units poses considerable challenges. In most cases, these units are delivered and assessed separately from the practical units within the programme, with little integration and interaction between the two. Traditionally the delivery of theoretical units is largely done in a conventional teacher-led approach within a class-room environment. The issue is further exacerbated by the need to deliver content and assess competence of the different student cohorts in common classes with large reliance on a single summative assessment. Minimal formative feedback and little feed-forward towards the summative assessments in mathematics linked units are seen to reduce the opportunities for self-directed student-centred learning.

In order to achieve similar standards of academic performance in mathematics-dominated units across the three student cohorts, it was hypothesised that a self-directed learning approach that motivated their learning would encourage students to learn and achieve competence. In addition, it was proposed that integrating the learning content and approach to their prospective work roles will enable the students to overcome their fear of mathematics and enhance student motivation. While earlier work has confirmed the significance of formative assessments and feedback (Shute, 2008), there is little evidence of real-time feedback in the learning of mathematic-dominated units in particular with diverse student cohorts. A web-based assessment tool incorporating dynamic feedback was developed and formed the basis for a formative assessment in a second year theoretical unit. It was trialled on 24 marine engineering students with differing mathematical backgrounds, with the results showing a change in their learning. The effects of the process were further evaluated through a survey of the participants.

THE ROLE OF ASSESSMENT

Assessments are recognized as probably the most influential factor related to how students learn, with their role and practice increasingly changing in a student-centred learning environment. Rather than being an end to the learning process, assessments must be a means to motivate the student to achieve what is expected of their learning by engaging learners successfully in productive learning activities.

Formative assessments have proven to be increasingly beneficial to low-achieving students (Boston, 2002). Additionally formative assessments are claimed to have a significant role in making teaching more inclusive and learning more accessible to diverse learners by recognising, accommodating, and meeting the learning needs of all students (Jenkins, 2004). There is evidence on the improvement in student achievement by formative assessments (Black, Harrison, Lee, Marshall, & William, 2003) and in developing lifelong learning strategies (Martin, 2010). Nicol (2006) argues that learners monitoring, assessing, and correcting their own work are essential for lifelong learning. Self-evaluation is enhanced when students are given the opportunity to reflect on their work and have particularly showed improved performance in mathematics (Fontana & Fernandes, 1994).

In order to achieve the intended purpose of formative assessment, feedback needs to be provided to students in a timely manner. This allows students to benefit in the preparation of future assessment tasks and their progress. It is claimed that feedback in assessment is the most important factor that can influence the extent to which its purpose is achieved (Brown, 2004). Having integrated feedback within the assessment task leads to a feed forward process moving towards summative assessments (University of Tasmania, 2011).

MARINE ENGINEERING COURSE STRUCTURE

Marine engineering courses were traditionally apprenticeships that over time progressed towards 'sandwich' type programmes in the early 1980's, which included institutional and work-based components (Wood, 2007). The courses have increasingly moved from the vocational sector to the higher education sector. In order to guide the implementation of the STCW standards, model courses have been developed by the IMO, which many nations have adapted. However, these programmes are highly content-driven and prescriptive in nature, thus impeding the student-centred learning process and lacking in innovative and motivating learning strategies.

The typical structure of the institutional component of courses in Australia can broadly be divided into two groups of units: those that are purely theoretical, commonly known as Part A units with considerable mathematical content and Part B units that are operational units consisting of a higher level of practical elements. The units within Part A are: Marine Thermodynamics, Applied Mechanics, Marine Electro-technology, and Naval Architecture; while the units in part B are: Marine Engineering Knowledge (Motor), Marine Engineering Knowledge (General), Marine Engineering Knowledge (Steam), Marine Electrical Knowledge and Practice, Marine Control Systems and Automation, and Marine Management and Maritime Law.

The difficulties faced by the mature-aged trade-qualified students are mostly associated with the Part A units, which are usually delivered and assessed separately from those in Part B, due to legacy reasons and delivery patterns.

DEVELOPMENT AND DEPLOYMENT OF A WEB-BASED ASSESSMENT TOOL

A two-step process of improving the student learning is devised by primarily integrating the relevant Part A and Part B units to motivate student learning and then providing means to enhance their problem-solving skills in mathematics. This paper discusses an example utilised at AMC, where the Part A theoretical unit Marine Thermodynamics was integrated with the relevant sections of the Part B practical focused unit Marine Engineering Knowledge (General), thus bringing together the theory with relevant applications on ships. The process is enhanced by providing students with adequate practically focused opportunities to improve their mathematical skills required for Marine Thermodynamics.

This process improves student competence and the application of their knowledge and skills relevant to their work roles.

It is important to note that learners who emerge from the vocational background learn and perform better when they are able to see the capacity to apply knowledge and skills being learnt in the context of their work and as such linking learning to their work roles can be a key motivator (Oates, 1989). Students with vocational background are increasingly trained through practice to improve their skills and hence competence. It is argued that as knowledge, skills, and contextual understanding increase, so does student competence (Stanton & Burke, 1989).

Mathematics based engineering units are those that aim at problem-solving techniques. In traditional marine engineering programmes there has seldom been an approach used to provide instantaneous feedback on formative assessments in these units. It is increasingly necessary for students to be allowed to 'do' and it is this active behaviour of the student that needs to be assessed (Biggs & Tang, 2007). This allows them to learn and apply concepts in problem-solving and carry out a self-assessment of their problem-solving skills. Modern e-learning strategies are beginning to make an impact within the previously conservative maritime education and training sector, as it is recognised that they provides an effective way to increase student skills and competence (Jurian, Chiotoroiu, & Buibas, 2006).

In order to enhance learning and to improve problem solving skills through practice, a web-based self-assessment tool was developed, primarily to target students with relatively weaker mathematical skills. The validity and credibility of using the tool for assessment was maintained by integrating the tool into the existing assessment schedule. The reliability of the assessment tool was ascertained by testing the tool with a marine engineering cohort at AMC consisting of 24 students of mixed ages and experience. This tool was used to guide students through a series of problem solving exercises incorporating formative product-feedback at each stage in the process of learning. The exercises were designed to link with practical marine engineering problems (the link between the theoretical and practical units), enabling students to see relevance.

The learning and self-assessment of problem solving is achieved through an iterative process, which provides students with instantaneous feedback on their numerical answers. Thus, the students are provided with a set of questions online, with the answers pre-defined in the system with a prescribed error margin. Students work through the problems using their workbooks, with the solutions entered into the online answer slots. The system then provides instantaneous feedback to the students, enabling them to re-visit the question to remedy any errors. This enables them to learn and apply concepts in problem solving, carry out a self-assessment of their problem-solving skills, and reflect accordingly (Nicol & Macfarlane-Dick, 2006). The answer booklets are further used to provide detailed feedback.

The assessment tool incorporates the following features as identified by James (2002) in capturing the potential of online assessments:

- provide immediate feedback and an inherent self-check on completion of each problem;
- provide better opportunities for students to practise and improve problem-solving skills;
- randomise assessment tasks, simultaneously minimising cheating/plagiarism;
- provide flexibility in time and space, thus enabling learning at their own pace; and
- recognise students' unfamiliarity with the use of online interface.

The implementation of the web-based assessment tool (a screenshot is shown in Figure 1), was aimed at achieving a variety of pedagogically accepted learning and teaching practices. The use of an online learning and assessment environment posed threats to some of the mature-age student cohort due to their lack of familiarity with such media. To minimise this, the students were provided with two orientation and assessment sessions prior to its deployment for assessment.

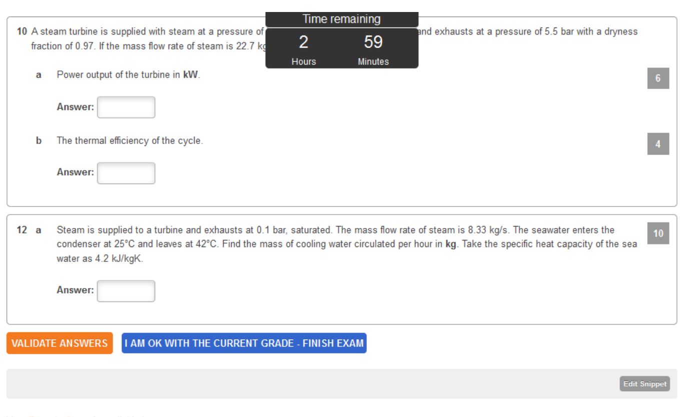


Figure 1: Screenshot of web-based assessment for the unit Marine Thermodynamics.

RESULTS AND STUDENT FEEDBACK

Table 1 shows the performance summary of ten out of the 24 students who utilised the tool to improve their scores due to the opportunity to re-visit the problem and self-review their own work (the rest of the cohort passed the assessment in their first attempt and chose not to utilise the multiple attempt option to improve their scores). It can be seen that all students improved on their initial scores (although some did not meet the required pass level of 50%) due to the instantaneous feedback available during the assessment task. It was interesting to note that two of the high performers also used the tool to improve their scores. Thus, although the tool was targeted to assist the weaker students, it also motivated the higher performance students. The confidence levels and competence of the students improved through better understanding of their own errors.

Table 1 – Performance summary of students who improved scores

Student Number	Marks Obtained Initially (max 100)	Marks Obtained After Feedback	% Improvement in Marks
1	80	100	25
2	10	20	100
3	90	100	11
4	38	50	32
5	50	60	20
6	28	60	114
7	50	60	20
8	12	32	167
9	32	60	88
10	20	30	50

In order to evaluate the effectiveness of the tool as a method of improving student learning, feedback was sought via Likert-type and open-ended responses from the entire student cohort of 24 students through a survey launched using 'Survey Monkey', with 33% of the students responding to the survey. The results indicated that a considerable portion of respondent students (37.5%) agreed that they have difficulties with the learning of mathematics content at the level required for the course (Figure 2) and 25% felt that the mathematical content in the course is a barrier to their learning and overall performance (Figure 3).

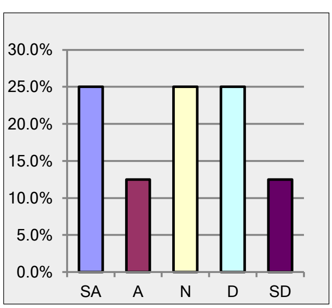


Figure 2: Student's extent of agreement on the difficulty with the Maths content at the required level for the course

SA = Strongly Agree
A = Agree
N = Neutral
D = Disagree
SD = Strongly Disagree

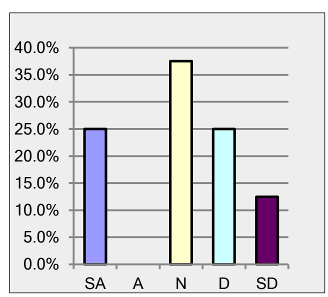
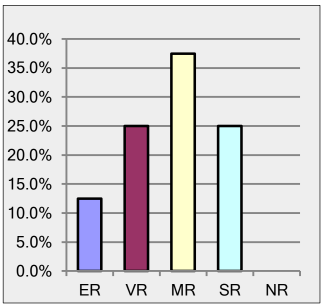


Figure 3: Student's extent of agreement on the Maths content being a barrier in their learning and overall performance

A similar portion of students also believe that the mathematical content in the course is only slightly relevant to their work roles (Figure 4). A student responded:

"Talking to marine engineers working in the shipping industry, very little of what is learnt is actually used at sea."

The majority of the respondent students (62.5%) agreed that integrating theoretical units like Marine Thermodynamics with operational units such as Engineering Knowledge would enhance their learning and be more relevant to work roles (Figure 5).



ER = Extremely Relevant
VR = Very Relevant
MR = Moderately Relevant
SR = Slightly Relevant
NR = Not at all Relevant

Figure 4: Student's opinion on the extent of relevance of maths content in relation to their work role

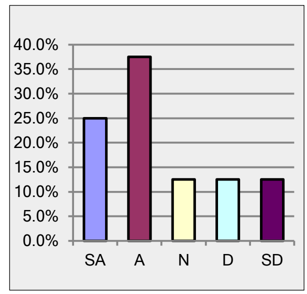


Figure 5: Student's extent of agreement on integrating units to enhance learning relevant to work roles

Students' learning and assessment experience indicated improved learning through self-directing their studies, with enhanced motivation for learning among the majority of students (Figure 6).

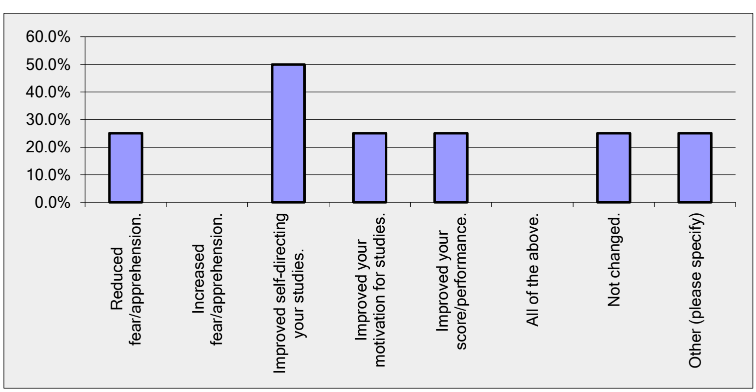


Figure 6: Student learning and assessment experience with the web-based assessment tool

It was also noted that some students who were apprehensive or feared the use of the web-based assessment tool had overcome these due to the real-time feedback supplemented by the use of workbooks. As this assessment tool was designed for internal formative assessments, students were generally happy about the dynamic feedback it provided, but felt that it did not assist in the final summative assessments due to the limitations in utilising such tools in the final examination. However, they felt that it had the potential for greater flexibility in delivery and assessment. Some of the comments by the students were:

"It does not account for making slight errors in calculations. Worked solutions still need to be marked ……"
"I like the feedback, but it was not helpful for the final exam"
"This computer test is good but I think paper work should be taken into account"
"I enjoyed it, thought it was a great way to get instant feedback on questions"
"Less class time = better!"

CONCLUSION

Results and feedback clearly indicated the advantage of integrating a theoretical unit with a relevant practical unit to build the required mathematical skills and appreciate the relevance to the profession. An assessment tool incorporating dynamic feedback for formative assessments was developed for the theoretical unit, which was able to motivate student in self-directed learning. The performance levels of the students who used the tool improved, although multiple uses may be required to achieve the desired competence. Students' motivation and confidence levels were raised, as they gained trust in its multiple objectives: flexibility, prompt feedback, and reliability.

The current tool limits feedback to the product of problem being solved, with the tool currently being updated to provide additional detailed feedback to identify where they have erred. It also has the potential to be enhanced to provide staged feedback along the 'process' of problem-solving, informing the students of their progress and increasing self-directed learning. The student population, though small, is a true representation of the Australian marine engineering student population, and thus provides valuable information in identifying deficiencies in student learning and designing learning and assessment tools for marine engineering programmes. Further developments to the tool will be tested against future cohorts, and it is envisaged that more students will utilise the tool as the benefits become clearer and tangible to them.

REFERENCES

Biggs, J. B., & Tang, C. (2007). Teaching for Quality Learning at University Retrieved from http://UTAS.eblib.com.au/patron/FullRecord.aspx?p=332709

Black, P., Harrison, C., Lee, C., Marshall, B., & William, D. (2003). *Assessment for learning-putting it into practice*: Open University Press.

Boston, C. (2002). The concept of formative assessment. *Practical Assessment, Research & Evaluation*, *8*(9), 1-5.

Brown, S. (2004). Assessment for learning. *Learning and teaching in higher education, 1*(1), 81-89.

Fontana, D., & Fernandes, M. (1994). Improvements in mathematics performance as a consequence of self-assessment in Portuguese primary school pupils. *British Journal of Educational Psychology, 64*(3), 407-417.

Jenkins, M. (2004). Unfulfilled Promise: formative assessment using computer-aided assessment. *Learning and teaching in higher education, 1*(1), 67-80.

Jurian, M., Chiotoroiu, L., & Buibas, M. (2006). *Work in progress: E-Learning Impact on Romanian Maritime Education.* Paper presented at the Frontiers in Education Conference, 36th Annual.

Klingbeil, N., Mercer, R., Rattan, K., Raymer, M., & Reynolds, D. (2005). *Work in progress-the WSU model for engineering mathematics education.* Paper presented at the Frontiers in Education, 2005. FIE'05. Proceedings 35th Annual Conference.

Martin, I. (2010). Handbook of formative assessment–Edited by Heidi L Andrade & Gregory J Cizek. *British Journal of Educational Technology, 41*(3), E59-E59.

Nicol, D. J., & Macfarlane-Dick, D. (2006). Formative assessment and self-regulated learning: A model and seven principles of good feedback practice. *Studies in higher education, 31*(2), 199-218.

Oates, T. (1989). Emerging Issues: The Response of Higher Education to Competency-based Approaches. *Competency based education and training*.

Otung, I. (2001). Reassessing the mathematics content of engineering education. *Engineering Science and education journal, 10*(4), 130-138.

Shute, V. J. (2008). Focus on formative feedback. *Review of educational research, 78*(1), 153-189.

University of Tasmania. (2011). Guidelines for good assessment practice Retrieved May 16, 2013, from www.teaching-learning.utas.edu.au/assessment

Willcox, K., & Bounova, G. (2004). *Mathematics in engineering: Identifying, enhancing and linking the implicit mathematics curriculum.* Paper presented at the Proceedings of the 2004 American Society for Engineering Education Annual Conference and Exposition.

Wood, P. (2007). British Merchant Training-Policy - A Chronological summary.pdf. [Chronicle].