Project-based learning for first year Maritime Engineering students: manufacturing and testing of skateboards

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Structured abstract

BACKGROUND
Materials science is concerned with three primary inter-connected elements; material structure, properties and processing. Applying the principles of materials science in practice leads to Materials Engineering, which deals with adapting materials and converting them into products required by society. To develop these skills, students need time, practice and experience, which cannot be adequately achieved outside a practical work environment. This paper proposes that a well-structured pedagogically-sound team project, supported by laboratory work, greatly assisted students in developing a mature approach to understanding and applying the generic and technical skills that are important in the field of engineering.

PURPOSE
Without focused teaching and assessment methods, it is an unachievable task to bring together the two strands, science and engineering into a single unit of Maritime Engineering courses (programmes). The objective of the present work was to introduce a team based project to facilitate student's motivation and achievement. This change of teaching methodology was based upon well-researched pedagogy, which supports the principle that project based learning leads to improved motivation, engagement and positive learning outcomes for students. Hence, a team-based student-focussed project was developed to challenge first-year students to integrate materials selection, processing and testing, in order to meet a specific engineering outcome.

DESIGN/METHOD
This project involved the design and manufacture of a skateboard from polymeric composite materials. Students began their projects by researching the essential material characteristics of a skateboard such as flexural and torsional strength in order to optimise street performance criteria like stability and manoeuvrability. Students then selected a suitable composite material, and made the board of their choice. These skateboards were laboratory tested to determine their flexural properties, and then street tested for performance characteristics. Final group reports outlining the results were provided for assessment.

RESULTS
Results obtained demonstrated a good correlation between composite flexural properties and street performance of the skateboard. The composite materials used in a skateboard are similar to those used in high performance yacht construction, and many other sporting and maritime applications. Practical knowledge and experience gained in this activity can be translated into larger scale engineering material selection, evaluation, and application.

CONCLUSIONS
It was found that students gained motivation from taking responsibility for each stage of their work. This was achieved by working collaboratively with others, but at the same time having to think independently, and then share ideas with the group. An important result of this collaborative approach was reflected in students gaining an enhanced awareness of the pit-falls of translating theoretical information into practical outcomes. Analysis of the student evaluation questionnaires for the project indicated that 83% agreed/strongly agreed that the project work was well regarded and motivational. This observation has been anecdotally consistent over the years, but our results confirm the contention that pedagogically-sound team-based laboratory and project work enhances student motivation and learning outcomes.

KEYWORDS
Team-based, project-based learning, laboratory, Maritime Engineering and Material Science.

Introduction

Materials Technology is a first year unit across all engineering undergraduate programs leading to specialisation in Naval Architecture, Ocean Engineering, and Marine and Offshore Engineering. This unit consists of two basic components; materials science and materials engineering. The materials science component relates the three inter-connected elements; structure, properties and processing, and relies heavily on the individual students' background in chemistry, physics, mathematics and mechanics. Materials engineering is concerned with applying the conceptual knowledge of materials science by converting the material into a product required by society. This process involves an informed selection of the appropriate material from a large number of possibilities in order to meet the engineering and environmental needs of the community. The inter-relationship between the basic sciences and the engineering disciplines is illustrated in Figure 1.

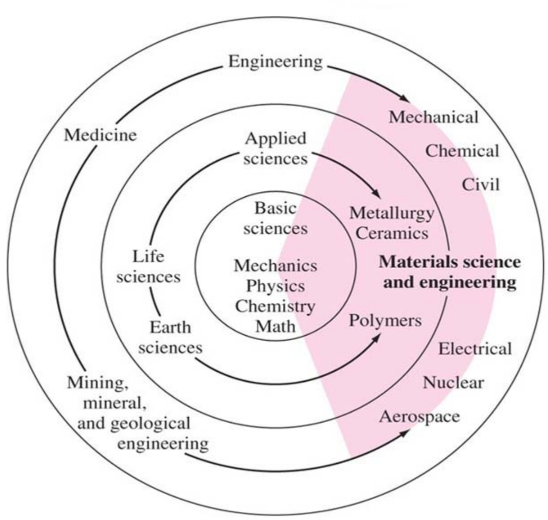

Figure 1: Materials Science and Engineering (Smith et al., 2010)

Perhaps the most important under-pinning discipline for materials science is chemistry. It has been observed that whilst most first year students have a good background in mathematics and physics, a significant minority are deficient in chemistry. This problem is a considerable draw back to these students in the first few weeks of the Materials Technology unit, when most of the scientific foundation is being laid. With this background in mind it was decided to attempt to overcome the reduced level of chemistry by introducing a short course in Refresher Chemistry before Materials Technology, and to further reinforce concepts through a series of structured laboratory exercises, covering the major topics in the syllabus.

The journey of the learner in the acquisition of knowledge is defined and underpinned by pedagogical platforms, and is also defined by the engagement and application by the learner of the teaching methodologies and resources. Learning is a hierarchical multifaceted and multipart process (Gagné, 1977). Using Gagne's learning hierarchy, Merrienboer & Croock (2002) argued that complex learning requires the coordination and integration of structural progression through progressive skills. Collins et al. (2001) defined knowledge, learning and transfer as incrementally applying data (knowledge) through a process where association and skills are applied (learning) and transfer occurs when learning is applied in different contextual situations. They add motivation to the knowledge/learning/transfer paradigm and define motivation as "a state of the learner that favours formation of new association and skills - primarily involving incentives for attending to relevant aspects of the situation and for responding appropriately".

Project based learning is a systematic pedagogical approach which supports motivation, engagement and positive learning outcomes for students. Research into project based learning began in the 1980's (Bredderman, 1983; Tobin et al., 1988) and whilst there was agreement that the research showed positive student learning outcomes, actual practice of these methodologies was not always adopted into the teaching curriculum. Blumenfeld et al, (1991) cited previous works which supported task-oriented projects providing "critical links among student motivation, student cognition, instruction, and learning". However, in a review of project based learning Thomas (2000) cautioned that much of the research on project based learning "has not had a substantial influence on PBL practice". Hmelo-Silver et al. (2007) found that the use of project based learning situations "provide students with opportunities to engage in the scientific practices of questioning, investigation, and argumentation as well as learning content in a relevant and motivating context". Esche (2002) in a study showed that project based learning "heightened student motivation, stimulated student self-learning and promoted communication skills". Esche's study involved students in a mechanical engineering course using group work to develop realistic products. Research by Neal et al. (2011) and Oakley at al.(2007) supports the view that project based learning has significant educational value over the more traditional approaches. Furthermore, research into the various learning styles by Boles (2010) clearly indicates a strong student preference for visual over verbal approaches. The emphasis on visual methodologies favours hands on demonstrations, laboratory work, and the use of pictures and simulations as part of the teaching armoury.

The present paper outlines a team-based student-focussed project concept, students' opinion about this project, findings of the project questionnaires and future work to improve student motivation in achieving a combination of the interactive social, practical and theoretical skill-sets that are important in the field of engineering.

Approach

The idea which led to this project began in 2011, when the syllabus relating to polymers was modified to place more emphasis on the materials that are considered important in the field of maritime engineering. Designing a skateboard presented an ideal choice, since a significant number of students were themselves skateboarders. Furthermore the size of a skateboard was easily accommodated into workshop practice and existing equipment. Of equal importance was that certain types of composites represented the top-end of skateboard performance capability. The design and implementation of this project had to take into account the key elements of the intended outcomes, that is to enhance student motivation, and ultimately to lead to an improved understanding of composite materials, in an applied context.

The Concept

The introduction of a project over and above the structured laboratory work was expected to increase motivation because of the opportunity to work in small groups, and to take ownership of selecting, making and testing the composite skateboard. The following lists of activities were assigned to the students, and summarises the sequential steps of the project.

- Research the role and application of composites in both general and maritime engineering and supplement with plant visits to local industries where composite materials are used.
- Research the connection between the street performance characteristics of skateboards and the specific material requirements for the composite. To assist in this exercise the material requirements such as camber, flexibility and strength had to be specified in order to meet the skateboard characteristics and its performance as defined by the skateboarder.
- Perform the flexure test on a contemporary "high end" board as a comparison standard to assist in composite design.

- Design a sandwich composite, specifying core and re-enforcing outer layers, using a range of woods, foams and carbon fibre prepregs provided.
- Prepare a test panel using these materials, and then vacuum bag and oven cure the panel in accordance with the procedure given.
- Perform flexural tests on the panel, and compare these results with those obtained from the comparison standard.
- Lay-up skateboards from the best performing composites.
- Street test the manufactured boards, and compare their performance with that of the commercial board. A selection of the skateboards manufactured by students is shown in Figure 2.
- Correlate the test data from all the participating groups, and rank the new boards in terms of their performance criteria.
- Prepare the final report discussing all experimental data and conclusions drawn from it.

Figure 2: Manufactured skateboards.

Intended Learning Outcomes (ILOs)

The following learning outcomes were expected from the project and laboratory work;

1. The ability to work from first principles.
2. The ability to design and conduct experiments.
3. The ability to perceive sources of error and to quantify them.
4. The ability to test systems in a laboratory setting.
5. The ability to think ahead, troubleshoot, and to develop contingency plans when necessary.
6. The ability to translate laboratory test data into the external applied environment.
7. The ability to work cooperatively as a team member.

The key rationales behind the above ILOs were to achieve;

- A specified goal by sharing ideas and working collaboratively within a group.
- Practical involvement in researching information on a modern engineering material.
- An enhanced understanding of the properties of composite materials, with particular emphasis on the inter-relationship between the structure, properties, mode of manufacture, and the final performance characteristics of skateboard.
- An insight into the importance of laboratory and field testing, and the adjustment that often needs to be made to match textbook theory with practice.
- Investigation of the use of composite materials in a wider engineering context, with particular emphasis on maritime applications.
- Preparation of a technical report in a format that optimizes interpretation and clear presentation of experimental data, leading to logical conclusions and recommendations.

Project Organisation 2012

The total student body of 132 was randomly divided into 22 groups of 6. Each group was requested to nominate a group leader/spokesperson, who would be required to coordinate the activities of their group. The students were briefed by the lecturer on all the components of the project. In addition several keen skateboarders talked to the students about the key features of a skateboard essential for the rider to achieve optimal performance. In order to assist students in their choice of material, a commercial skateboard was purchased. The objective was to test the flexural properties of this commercial board and make the results available to the student as benchmark.

Each group recorded their choice of sandwich composite make-up, based upon the available range of core materials and prepreg outer layers. Each group was required to lay up their chosen test panel, and carry out mechanical testing including flexural strength, flexural modulus and flexural strain tests. The panels that most closely matched the flexural properties of the commercial board were chosen for making into skateboards. The skateboards were layed up as a group exercise, using pre-prepared moulds. The prepared boards were then street tested and evaluated by a volunteer group of skateboarders. Their evaluation was based upon performance characteristics such as manoeuvrability, stability, flexure and “feel good factor”. The final rankings were based upon a consensus at the conclusion of testing. A careful analysis was carried out on boards that either failed or under performed. It was anticipated that this information would be useful for the next generation of boards in 2013. Students compiled and submitted their reports as a group. The final assessment mark was based upon a weighting that comprised both an individual mark and a group mark.

Results and Discussion

The popularity of the 2011 skateboard project among the students, based upon oral feedback, suggested a more formal structured approach. The most significant constraint in 2011 was the lack of detailed data on the flexural properties of sandwich composites suitable for down-hill skateboards. As a result of this problem the design of the project in 2012 was primarily to test a range of materials. It was hoped that this approach would enable judgements to be made as to which combinations were likely to be acceptable, and equally important, which materials could be eliminated. A downside to this necessary approach was that the instructor had to issue somewhat more detailed specifics for material options to the students, in order to manage the practical constraints of time and technical support, and to optimise the chances of testing the best materials. The upside was that a reliable data bank representing the widest possible range of material choices for skateboard materials was gained, and could be used as guidelines for choices in 2013 and thereafter. A Likert Scale student survey, using the statements below, was carried out at the end of 2012.

1. The topic of composites addressed the key learning outcomes stated in the unit outline.
2. The laboratory for composite material, (preparation and testing of a sandwich material suitable for a skateboard), stimulated my interest in this topic.
3. The project enhanced my understanding of the adaptability of composites to achieve a performance outcome.
4. The project and lab work contributed to my understanding and appreciation of the key concepts.
5. My motivation towards this topic was increased by the integration of practical aspects into the broader presentation.
6. What were the best aspects of the project and lab work?
7. What aspects of the project and lab work could be improved?

A total of 121 students (approximately 90% of the cohort) provided feedback. Analysis showed that 92% agreed (A) or strongly agreed (SA) that the composite materials project addressed the key learning outcomes stated in the unit outline. This demonstrated that the project concept is well aligned with the unit ILOs. This concurs with Biggs et al. (2007)

findings that the goal of education is for learners to construct their own knowledge, rather than being passive recipients of the knowledge created by others. Biggs et al. explained that ‘what the learner has to do to create knowledge is the important thing' and hence what students are asked to do within the curriculum must align with what those designing the curriculum intend them to learn. Almost 75% of the student cohort responded with SA or A for Statement 2 and the remaining 25% were neutral in their opinions, indicating that not everyone in this sub-group had grasped the broader aims of the project, or perhaps were not interested in skateboarding. This was also clear from comments such as *“Not all group members were as interested in the topic, but for me it got me excited about building composites”.* However, 87% and 88% SA/A to Statement 3 and 4 respectively, showing that although they were not skateboard enthusiasts, the project enhanced their understanding of the adaptability of composites to achieve a performance outcome in other broader fields of engineering. A student commented “*The success/failure rate of test panels did enhance my understanding of composite performance”*, which clearly reflects that the lab helped students understand the theory. In Statement 5, 76% SA/A that their motivation was increased by the integration of practical aspects into the curriculum. In addition, students provided very useful feedback about the integration of practical work such as; *“Always does. Please do not remove practical from theory.”, “Plant visit was fantastic!”, “Practical applications are very important to get appreciation for theory”, “Being able to see a practical application of the material we learn greatly helped my understanding” and “Was good to have an assignment relating to youth activities”.*

Statements 6 and 7 were rather open-ended. However they provided useful feedback of what went well and what did not. In fact, virtually every student responded to these questions, showing their overall enthusiasm. A selection of the most valuable comments is cited below;

- *The project and lab work reinforced material learnt in lectures and prompted me to research specific topics to a greater extent.*
- *I particularly enjoyed seeing the lay-up of a skateboard and found interpreting the mode of failure of the test pieces and the impacts on performance very interesting.*
- *The plant visit was the best part that helped me to understand how a composite is critically useful in maritime field.*
- *It made what I considered a very complicated subject seems practical and realistic. Real-life applications are always the best way to learn and get intuitive perspective.*
- *Feeling of “ownership” over the project as it was relatable to a tangible, usable product. Being able to apply our efforts outside the classroom.*
- *They give a better understanding to the theory that we learnt from the lecture as it provides an opportunity for us to see it instead of just imagining it after reading from the notes.*
- *The project adds an interesting dimension to learning about composites, even for a non-skateboarder.*
- *It remained interactive, if it weren’t there, the unit would be dry and boring. The project was good because it showed how an everyday object to some was made and strengthened and helped entertain students when it came to making and testing the boards.*
- *It demonstrated a real-world application, rather than testing for tests sake.*
- *I think it was very good to be able to actually apply the knowledge we have learnt because it helps it to sink in! The project will help me to recall the content we learnt.*

These comments clearly support the intended learning outcomes and rationales of the overall concept. Moreover, the feedback received via other mechanisms such as formal feedback and student evaluation surveys, showed the overall student satisfaction rate for this unit was greater than 90%. Student satisfaction is strongly related to active and sensitive guidance of the teams by the instructor. It was also apparent that students acquired strong team working skills, including communication, both written and oral, and an ability to carry out and follow through to completion of a project. As a result of these learned attributes, students are more adaptable and employable after graduation, having learned to recognise the role of engineering in society. A well designed project based learning assignment, exposes students to the necessity of completing work within a framework of time and economic constraints, which relate directly to the work place. These conclusions coincide with Oakley et al (2004)'s remark that "*students working in teams are more likely to achieve their goals than when working individually".* Prince et al. (2006) concluded that PBL offers students an enhanced understanding of the application of knowledge over traditional problem based learning methodology.

Conclusions

This paper presents the authors' experiences, observations and analysis of a project within a first year engineering unit at the AMC. At present, most engineering schools are faced with the challenge of successfully motivating students in line with learning outcomes and graduate attributes. However, the analysis of the results of this project has shown that a well-designed project, that emulates the real-world engineering environment, can help to stimulate students' motivation and overall subject understanding. It is also important to note that a well-designed engineering course has to meet both technical and generic skills required by industry and society, and the authors have reflected upon this important outcome in this paper. As a consequence of experience gained in 2012, further improvements are intended as outlined below.

- The group size will be reduced from 6 to 4, and will consist of two pairs, where each student will choose their partner in the pair. This smaller group of 4 should encourage better individual participation, reduce the chance of some students "not pulling their weight", whilst at the same time maintaining the benefits of group diversity and social interaction.
- The assessment will be altered to ensure that the final mark more accurately balances the weighting of group and individual contributions. This will more realistically reflect the true achievement of the student, both as an individual as well as a group member of the project team.
- There will be emphasis on the continued support and guidance by the facilitator to assist students at each stage of their work. This will be re-enforced by sound initial briefing, including the provision of clear written instructions, backed up by scheduled times for consultation with the instructor.
- Focus on the broader applications of composites in engineering will continue to be emphasised, in order to accommodate students who are not skateboarders themselves. However the skateboard will continue to be the most convenient component for promoting the use of composites in the context of the project, and will be retained.
- The plant visits to workshops or factories manufacturing components from sandwich composites will be continued.
- As a result of the test data acquired in 2011 and 2012, students will have the advantage of being able to make more informed judgements when designing composites in 2013. An added benefit will be that teams will be required to take more responsibility for researching and independently selecting the best possible material from the many options available. As a consequence it is expected that teams will have a heightened degree of ownership of their part in the project.

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