Journal of Modern Education Review, ISSN 2155-7993, USA
January 2012, Volume 2, No. 1, pp. 30–37

http://www.academicstar.us

A Sequential Project Based Learning Programme Designed to Meet the Graduate Attributes of Engineering Students

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Abstract: Current Australian engineering curriculum focuses strongly on engineering science and is typically technically based and content driven. Often insufficient emphasis is placed on relating content to current industry practice and generic skills. Courses taught with many practical examples drawn from real life or incorporate industry practice better prepare students for situations that they have not previously experienced. Theoretically bias courses are often taught at speed, without providing students with time to assimilate the material. Many institutions utilize "assignment projects", "problem based learning" (PBL), or "project based learning" (PoBL), but are they adequately structured and assessed? There is a need for better alignment of assessment with the overall course outcomes therefore bringing about the desired behavioural change within undergraduate students, enabling them to attain the required graduate attributes. The Australian Maritime College is progressively developing new techniques to deliver and assess these attributes through holistic tasks, thus ensuring a broader coverage of the Attribute Spectrum within an environment of limited resources and time. This provides students with realistic and challenging tasks, a far cry from the traditional mundane "engineering laboratories", thus promoting interactive and practical problem based learning, making the study of engineering enjoyable! The paper shows that by integrating PoBL aligned with industry practice and assessed against graduate attributes, it is possible to addresses the needs of both industry and society.

Key words: graduate attributes, learning programme, "problem based learning" (PBL), "project based learning" (PoBL)

1. Introduction

The values of graduate attributes are recognized as being important in improving the lifelong learning skills of graduates. These attributes can broadly be divided into two categories, one focusing on the technical knowledge and skills required within the relevant industries and the other emphasizing the generic attributes that are defined as "skills, knowledge, and abilities of graduates beyond disciplinary content knowledge, which are applicable in a range of contexts" (Barrie, 2006; p. 217). It can be argued that most academic institutions wrestle with the issues of quantifying the level of emphasis required in each category as well as identifying how to meaningfully deliver and assess the generic attributes. This is further exacerbated due to the continuous pressure to increase the technical content to meet technological advances, multi-skilling, and changing work practices. As Barrie &

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Prosser (2004) state graduate attributes must seek to describe the core outcomes of a higher education programme, and thus the purpose and nature of the programme, not just the technical outcomes.

In the past, the Australian Maritime College (AMC) engineering programmes were developed with separate technical learning outcomes supplemented by generic attributes. Unfortunately the emphasis during delivery and assessment was on the former, with the generic attributes addressed, if at all, through secondary activities which were usually given a lower level of importance. As stated by Radloff et al. (2008) embedding graduate attributes into the curriculum "has thrown up major challenges for universities". Engineers Australia has mandated the requirement for the teaching, learning, and assessment of generic attributes in Australian undergraduate engineering programmes by creating a number of competency standards and linked attributes that graduates are required to meet during their period of study (Engineers Australia, 2006). However, the actual strategies in delivering, assessing, and tracking these are left to the individual academic institutions, although these methods are 'audited' during the cyclic accreditation process.

In the past the trend within academic institutions was to develop engineering programmes focused on delivering, assessing, and tracking the technical attributes, with the generic attributes addressed through secondary processes usually "added on" to the programme at convenient locations (Barrie, 2006; Hguyen, 1998). However, there has been a significant awakening within the sector, with the educational institutions, industry, and the accreditation bodies all placing a far greater importance on the generic attributes, resulting in a push to develop innovative and efficient methods to impart these skills to graduates (Carew & Therese, 2007). This has required educators to clearly identify the required attributes, develop methods of delivering and assessing both the technical and generic attributes through integrated processes, and track the attainment of all attributes. This requires a rethink of the programme structure rather than superficial changes to existing programmes, as well as a commitment to move away from traditional delivery and assessment processes.

The AMC has embarked upon an integrated approach that describes the objectives, outcomes, and attributes as a continuum to ensure that the developed learning strategies adequately address the needs of both industry and society. These are delivered and assessed through a series of problem based holistic practical projects carried out early in the programme.

2. The Attribute Spectrum and Mapping

AMC has embarked on a process of redefining the graduate attributes by developing an integrated set of course objectives, outcomes, and attributes defined as the Attribute Spectrum, that incorporates both the technical and generic attributes. It provides the foundation to develop comprehensive learning and assessment strategies and tools. The complete Attribute Spectrum consisting of 63 attributes within 10 course outcomes is described in Symes et al. (2011), which differs from the traditional approach of having separate technical and generic attributes as in the example given by Carew et al. (2008). In addition, the spectrum delves deeper into the required competencies, forcing those involved in the delivery and assessment to develop appropriate tools and strategies.

The development and implementation process of the Attribute Spectrum, its delivery, assessment strategies, and tracking system is shown in Figure 1. Unlike previous processes, the use of the Attribute Spectrum links the technical and generic outcomes across all AMC engineering programmes. To ensure that attributes are not treated discreetly, assessments should be structured and undertaken as holistic activities. No individual unit will address every attribute however, it is expected that the students will attain and develop the attributes incrementally across the degree programmes. Carew et al. (2008) reports that the early approach of using the "tick-a-box matrix" method to report generic attributes is deemed insufficient and requires a comprehensive explanation of how the programmes help students systematically develop these attributes, and how the assessment procedures ensure they have done so.

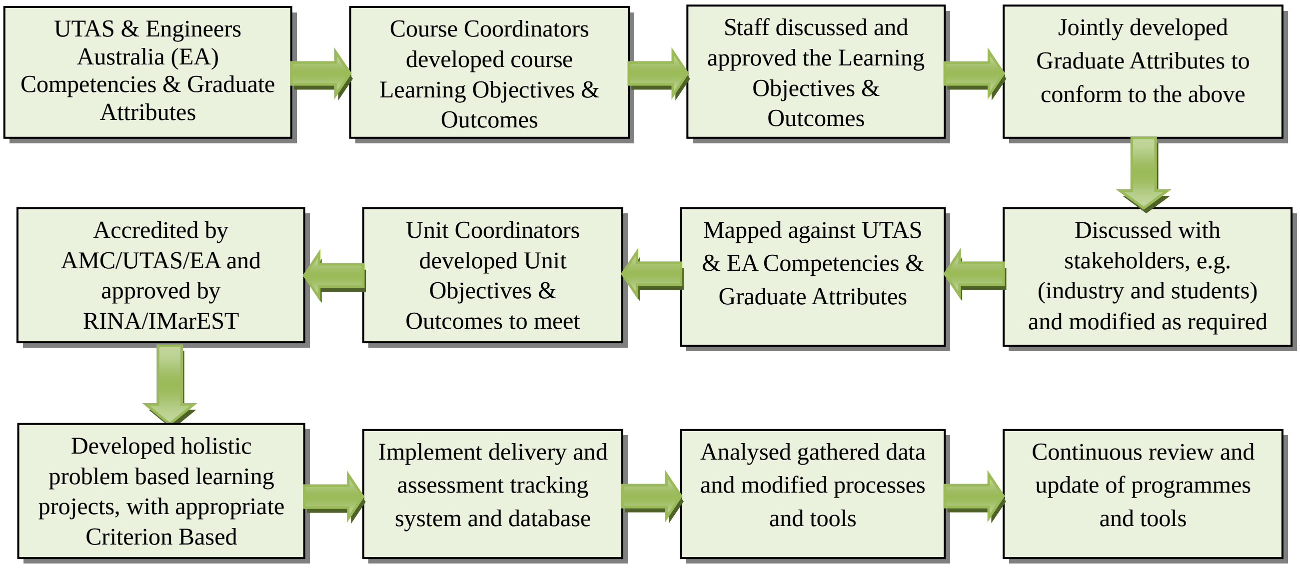

Figure 1 Developing, Assessing, and Tracking the Attribute Spectrum

The Attribute Spectrum developed for the AMC engineering degree programmes are tabulated and monitored through an online database, of which a screen dump is shown in Figure 2. The intention is to develop a system that tracks the attributes attained by each student however; currently the system only tracks annual cohorts of students. In its current form, it allows the course coordinators to "fine-tune" the programmes in both delivery and assessment strategies. The database provides a number of output graphs to assist in the analysis of the delivery and assessment processes as shown in Figure 3. It provides a basis for discussion on the extent of coverage, timing of coverage, and intensity of assessment within the programme in line with the objectives. A more detailed description of these is given in Symes et al. (2011).

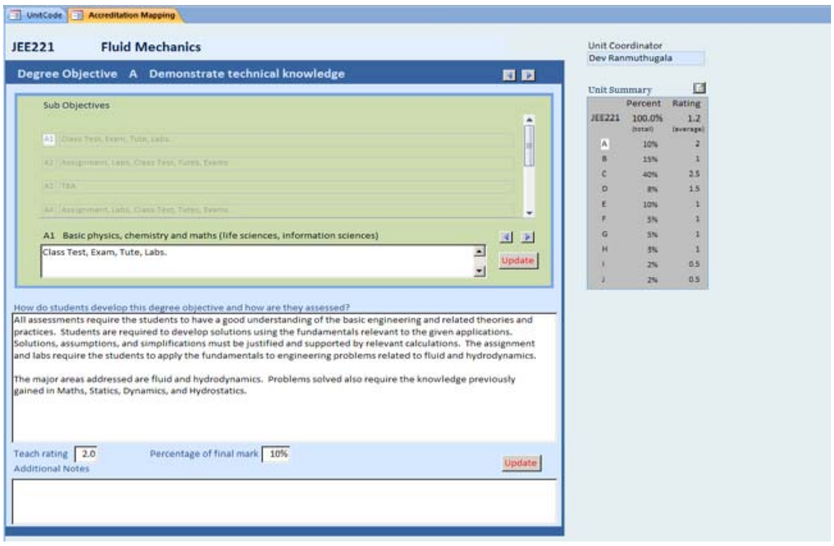

Figure 2 Attribute Mapping Database

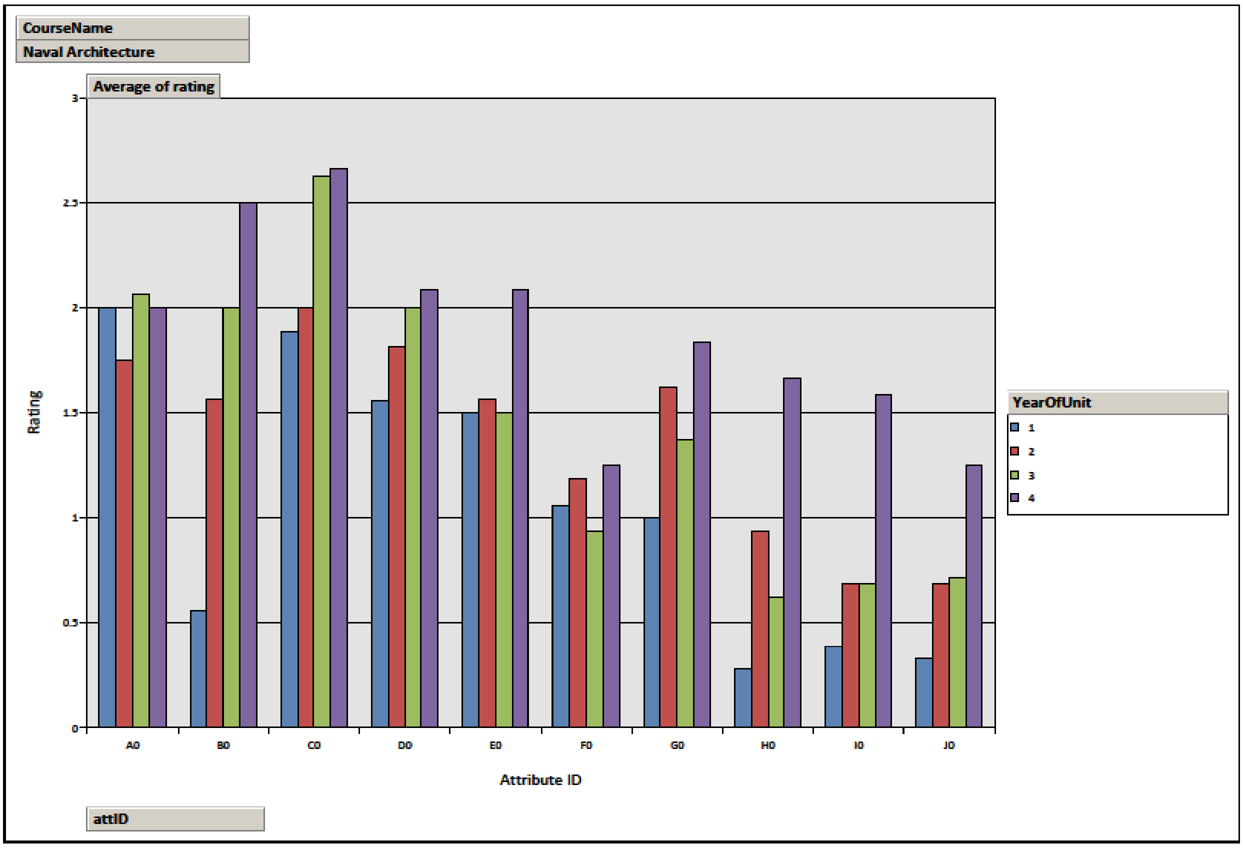

Figure 3 Average Percentage of Final Mark against the Course Outcomes

3. Attainment of the Attribute Spectrum

In industry, generic attributes tend to cluster (Hagar & Holland, 2006), while academically it is easier to assess them individually. In practice however, they tend to overlap and interlace. Professional engineering practice is holistic and requires the use of attributes in changing combinations. For example, an engineer developing a solution for a client may simultaneously communicate with the client to meet their requirements, whilst reasoning analytically within budgetary constraints.

During the development of the mapping database it was evident that the delivery and assessment processes had to cover a wider spectrum, which could not be achieved successfully under the existing system due to time constraints and student fatigue. As the existing delivery and assessment processes were targeting technical content, the inclusion of generic attributes would require additional processes. This required a rethink on how to deliver and assess both the technical and generic attributes through integrated holistic processes. The approach taken by AMC was to develop a series of problem based holistic practical projects across the programme that addressed a number of attributes. The advantage of the Attribute Spectrum was immediately evident as it allowed the development of appropriate projects, and equally important, the direction these projects were allowed to evolve (Symes et al., 2011). The links within the Attribute Spectrum and the feedback from the tracking database provided a foundation to create projects that covered a range of attributes, while maintaining focus within the relevant industries.

The Attribute Spectrum also provided the basis for the assessment criteria within the Criterion Based Assessment (CRA) schedule, an essential tool to provide guidance for the students during the projects and assist in the grading of the process and the product. While the use of the Attribute Spectrum made the process a lot simpler, it also enabled the programme coordinators to track the delivery and assessment of the attributes early in the learning process and provide input to the tracking database.

The AMC's engineering programmes consist of four problem based holistic practical projects, carried out in the first four semesters of study and increasing in complexity over that period. These group projects gradually introduce the students to the relevant content, while providing a vehicle to attain the required attributes. The last of these projects is carried out in the unit Fluid Mechanics, where the students' design and build a working model submarine. This is an example of a project providing realistic and challenging tasks, promoting interactive and holistic problem based learning that links the relevant theory to practical work. Students engaged in active learning are able to directly create the link between theoretical knowledge and the practical problem (Chartier et al., 2007), as well as allowing the facilitation of learning in students who might otherwise be disadvantaged. During subsequent years, the students build on the attributes attained to develop their knowledge and skills, and perform more complex tasks.

The project spans a whole semester and is undertaken in groups of six to eight students allocated from all degree programmes. They are required to design, construct, and test a model submarine (see Figure 4) to meet operational specifications. The group submits two reports, which include: project plans, resource allocation, literature review, relevant theory, design calculations, drawings, testing schedule, results, discussion, conclusion, and recommendations. The assessment includes testing the vehicle against the specifications and a peer review process. The discussion provided below under each course outcome explains how the content is delivered and the outcomes assessed through a predefined CRA based on the relevant technical and generic attributes identified through the Attribute Spectrum.

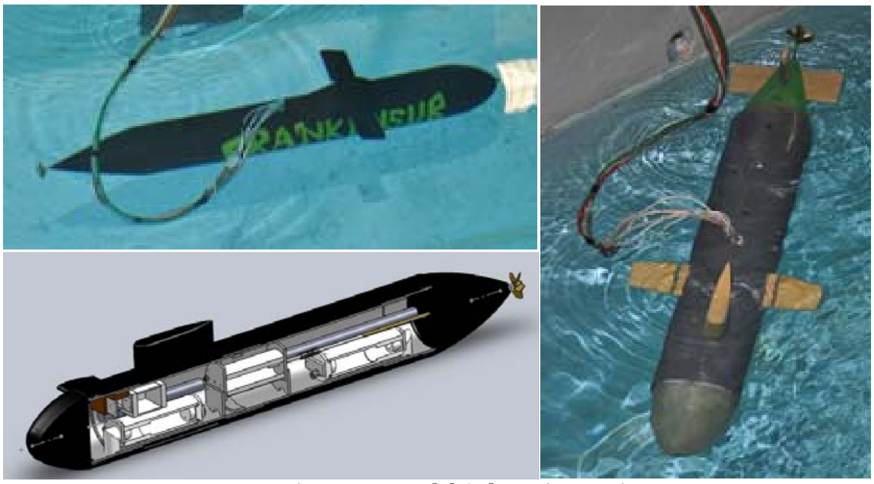

Figure 4 Model Submarine Project

3.1 Outcome A—Demonstrate Technical Knowledge

The assessment tools, wherever possible, are linked to actual problems, with students required to apply industry standards and practices, and knowledge from other units to their solutions. They are encouraged to look for options and solutions from industry. Given that the submarine itself is designed from minimal information (non-prescriptive), the solutions generated by the students are unique, effectively creating a barrier against plagiarism, while promoting design and innovation.

3.2 Outcome B — Design for the Maritime Environment

Design is embedded within the project, with the students given a design brief to produce a workable submarine model to given specifications using industry standards and practices, and importantly common sense, an attribute frequently overlooked. The design must be supported with adequate and accurate calculations, clearly stating the assumptions made during the process.

3.3 Outcome C — Solve Maritime Engineering Problems

Students are given engineering problems, which requires them to identify the requirements, constraints, and the "tools" required to solve the problems, an important attribute as most students find it difficult to decide on a solution approach. They are required to identify various operational conditions peculiar to submarines, such as stability, internal and external forces, and structural integrity, including making drawings of the vessel and related systems. They then carry out calculations, including stability, pressure, drag, lift, thrust and power to identify limitations, failure, and vessel dimensions, relating them back to their drawings. The project makes students identify logical patterns and pathways to solve the problems rather than taking a "scatter gun" approach.

3.4 Outcome D—Manage, Create, Use and Disseminate Information

The design brief requires the students to search for information through a number of avenues, including references, publications, internet, and discussions with external sources. The project is heavily dependent on students collectively and individually acquiring information from a range of sources, and their ability to sort the data into different categories depending on their speciality, relevance, currency, and quality. They are required to maintain evidence in the form of design files, work plans, and controlled documents that are all assessed.

3.5 Outcome E — Communicate Effectively

A greater focus is placed on informal communication, group dynamics, and internal and external stakeholders. The project requires the teams to provide a complete preliminary design, including supporting documents in line with industry practice. The students are required to source information through a number of avenues, which include communicating with internal and external personnel, providing continuous updates on their progress, and presenting a final report. The large and diverse groups require well thought out communication strategies.

3.6 Outcome F — Work in Teams

Students must manage and distribute the workload between the team members, and provide group reports on their findings and results. The groups are allocated by the lecturers rather than allowing like-minded students to form groups, requiring them to actively work on building good team dynamics with students from different backgrounds and resolving any conflict. Time and resource allocation is carried out by the team and its leadership, which requires acceptance by all to ensure success. The assessment includes peer assessment that relates group dynamics and individual contributions.

3.7 Outcome G — Manage Self and Others

The project is open-ended and deliberately lacks sufficient information for a straightforward solution. The students have to investigate the design requirements to fill in the gaps, before moving on to the solution. The latter requires an iterative approach, generating additional input and further investigations. Given the complexity of the task which is carried out within a normal semester, students are required to manage their time and workload. To ensure success, the team has to assist and mentor each other as well as managing the collective efforts of the group.

3.8 Outcome H — Negotiate the Business Environment

To successfully meet the design brief, students must investigate and incorporate commercial and industry requirements. To enable students to achieve the outcomes, a number of lectures, including those by technical and non-technical professionals from related industries and organisations are provided. They introduce new concepts, expand on current knowledge, and provide forums for discussions on relevant areas. Students also research and obtain information from various internal and external sources on commercial operating principles and procedures.

3.9 Outcome I — Behave as a Professional

Given that the project requires construction and testing in a freshwater pool of sufficient depth to ascertain the submarine's diving ability; identifying and adhering to all relevant safety and environmental issues are essential and assessed. Given the nature of the issues, staff members continuously provide advice and assistance as required. Students are also assessed on their professionalism during the project, especially when working within their team and dealing with internal and external personnel.

3.10 Outcome J — Consider Wider Context of Engineering Knowledge and Work

The project is assessed for technical content, innovation, feasibility, suitability, environmental impact, maintenance, etc. Thus, students are introduced to regulations, equipment, and procedures within the maritime and related industries to protect the environment, e.g., the prevention of marine pollution from vessels at sea. This includes incorporating them into the design and construction work. Students are also exposed to embedded lectures by qualified industry professionals during the project.

4. Conclusion

Engineering industries are continuously evolving to meet changing world demands and practices. Therefore higher education engineering programmes themselves have to change to remain viable and relevant to the industry, community, and the students. It is important that the programmes meet both the technical and generic skills required by the industry and the community. The trend in the past was to "append" the generic attributes to the technical content within course curriculum in the hope that they would be covered during the delivery and assessment processes that concentrate on the technical aspects. The tracking mechanisms for graduate attributes are in their infancy, a number of institutions are developing methods to track individual and group attainment of the attributes (Nouwens, 2007).

AMC has developed an integrated approach that describes the objectives, outcomes, and attributes as a continuum defined as the Attribute Spectrum. As this links the technical and generic attributes, it allows the development of integrated delivery and assessment processes. A major feature in the process is the introduction of four problem based holistic practical projects carried out in groups during the first four semesters of study, with the final project described in this paper. The Attribute Spectrum enabled the projects to cover a range of technical and generic attributes as well as the development of the required CRAs. They provide a holistic approach to the assessment and attainment of the required attributes. By creating a series of problem based holistic practical projects early in the programme, students attain required competencies to deal with more advanced tasks in later years of the programme. Tracking of the attributes is carried out via an online database that currently provides information on cohorts of students, with plans underway to upgrade it to track individual students. Although these projects cannot fully replace other delivery and assessment techniques, it should form a major component within any programme aiming to deliver industry ready engineers.

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