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# An Integrated Delivery and Assessment Process to Address the Graduate Attribute Spectrum

Mark Symes, Dev Ranmuthugala, Christopher Chin
Australian Maritime College, Newnham, Australia

Anna Carew
University of Tasmania, Newnham, Australia

In the past, engineering programmes were developed with separate technical learning outcomes supplemented by generic attributes. The latter were in most cases a standalone set of attributes developed by academic institutions or professional societies overseeing engineering accreditation processes. Although the technical learning outcomes were well assessed and tracked, the generic attributes were at best partially addressed by artificially incorporating them into the curriculum as a way of "ticking-the-boxes". The current trend is to define competencies that map attributes required across the industry and develop programmes that have imbedded tools to deliver and assess these 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! Concurrently with this development is a practical and simple method of tracking and quantifying the achievement of the attributes by the students, yielding useful data to improve processes within the programme, and hence, the quality of the graduates.

*Keywords:* generic graduate attributes, accreditation, holistic

## Introduction

Graduates from engineering degree programmes must have a good understanding and appreciation of the profession and industry they are about to enter through sufficient professional development within their programme of study. Most within the industry and academia recognize the need for adequate and relevant technical contents supplemented by appropriate graduate attributes, as supported by Barrie and Prosser (2004, p. 244) who stated that,

> Graduate attributes seek to describe the core outcomes of a higher education. In doing so, they specify an aspect of the institution's contribution to society and carry with them implicit and sometimes explicit assumptions as to the purpose and nature of higher education.

Although the value of graduate attributes was recognized as important in improving the lifelong learning skills of the graduates, most academic institutions wrestled with the issues of quantifying the level of emphasis required as well as identifying how to meaningfully deliver and assess these attributes. This was further

Mark Symes, BEng (NA), The National Centre of Maritime Engineering and Hydrodynamics, Australian Maritime College.
Dev Ranmuthugala, Ph.D., The National Centre of Maritime Engineering and Hydrodynamics, Australian Maritime College.
Christopher Chin, Ph.D., The National Centre of Maritime Engineering and Hydrodynamics, Australian Maritime College.
Anna Carew, Ph.D., Post Doctorate researcher, University of Tasmania.

exacerbated due to the continuous pressure to increase the technical content to meet technological advances, multi-skilling and changing work practices.

In the past, 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 that were usually given a lower level of importance. Most higher education institutions have embedded generic skills and attributes into their curricula in an attempt to force their delivery, although the results have been mixed.

The teaching, learning and assessment of generic attributes in Australian undergraduate engineering programmes are mandated by the professional accreditation body, EA (Engineers Australia) (The Institution of Engineers, Australia). EA has created a number of competency standards and linked attributes that graduates are required to meet during their period of study (EA, 2006). However, the actual strategies in delivering, assessing and tracking are left to the individual academic institutions, although these methods are audited during the cyclic accreditation process. The old "tick-the-box" approach of reporting generic attributes is no longer deemed sufficient, as it provides little quantitative and qualitative evidence, as well as failing to differentiate between what was taught and learnt.

The current trend within academic institutions providing professional engineering education is to define competencies that map attributes required across the industry and develop programmes that have imbedded tools to define and assess these attributes throughout the learning process. Defining competencies that can accurately map attributes with the aim of addressing generic industry requirements as well as maintaining technical competence has and will continue to prove to be challenging. As a result, new and innovative methods of imparting generic attributes are rare and often short-lived. The department of maritime engineering at the AMC (Australian Maritime College) (an institute of the UTAS (University of Tasmania)) has embarked upon an integrated approach that describes the objectives, outcomes and attributes as a continuum to ensure that the subsequently developed learning strategies adequately address the needs of both industry and society. The delivery and assessment is carried out through problem-based learning projects imbedded within the programmes, while tracking is based on a database, albeit yet under development.

## The Attribute Spectrum

AMC embarked on a process of redefining the graduate attributes, using a "clean slate" approach to develop a single structure that is a common set of course objectives, outcomes and attributes for all (three) programmes taught at AMC, which incorporated and integrated the course technical and generic outcomes and attributes. These were derived through lengthy consultation and negotiation processes with internal and external stakeholders, to provide an outcome that represented an all encompassing structure as well as a clear and comprehensive statement of the graduate qualities, knowledge and experience, specific to graduates from AMC's maritime engineering degrees.

The first step was to develop the integrated course objectives, outcomes and attributes. This had to meet the technical contents as well as the generic attributes, while adhering to the requirements stipulated by the relevant industry sectors, accreditation bodies and UTAS, while also catering to students of varying backgrounds.

AMC embarked upon an integrated approach that described the objectives, outcomes and attributes as a continuum, defined as the attribute spectrum, to ensure that the subsequently developed learning strategies adequately met all required attributes.

This also allowed academic staff to develop delivery and assessment tools that inherently met the competencies expected by the graduates. The complete attribute spectrum consisting of 63 attributes under 10 course outcomes is given in AMC (2010), with the latter reproduced as follows:

(1) Demonstrating technical knowledge;

(2) Designing for the maritime environment;

(3) Solving maritime engineering problems;

(4) Managing, creating, using and disseminating information;

(5) Communicating effectively;

(6) Working in teams;

(7) Managing self and others;

(8) Negotiating the business environment;

(9) Behaving as a professional;

(10) Considering wider context of engineering knowledge and work.

The self-explanatory flow diagram shown in Figure 1 represents the processes undertaken during the consultation and development stages. The objectives, outcomes and attributes were developed by the course coordinators, with due consideration to the EA competency standards for professional engineers (EA, 2006) and the UTAS graduate attributes.

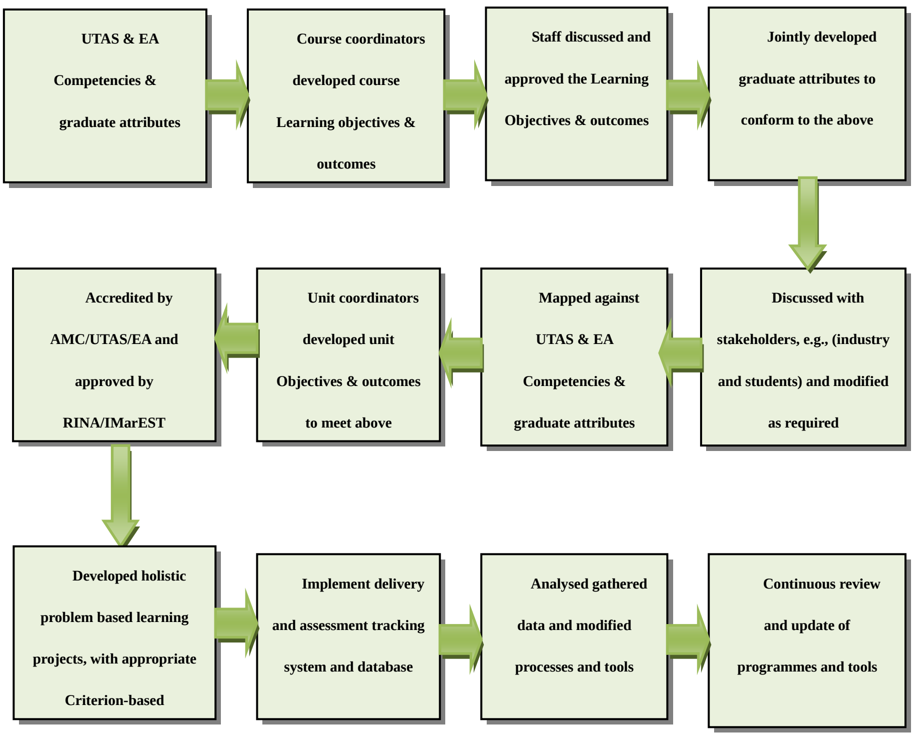


*Figure 1.* Flow diagram.

They were refined through a series of consultations with stakeholders, such as industry, staff and students. The approved structure provided the foundation to develop and/or modify the individual unit objectives and outcomes, which in turn led to the development of appropriate delivery and assessment strategies.

The formal step in this process is the cyclic accreditation, which began with the UTAS internal accreditation. This was followed by the EA external professional accreditation. The latter included the RINA (Royal Institution of Naval Architecture) and the IMarEST (Institute of Marine Engineers, Science and Technology) in order to secure their recognition.

The difference between this and the conventional method of developing such strategies was the use of the attribute spectrum, which reflected the technical and generic outcomes across all maritime engineering programmes at AMC.

A major revelation evident early in the process was that the delivery and assessment process 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 significant 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. An example of a project employed to meet the attribute spectrum is given later in this paper.

The attribute spectrum also provided the basis for the assessment criteria required to develop a CRA (criterion based assessment) schedule, an essential tool to provide guidance for the students during the project and assist in the grading of the process and the product. The use of the attribute spectrum made the process a lot simpler, a welcome development to any academic who has had to develop a comprehensive CRA.

## Graduate Attribute Mapping

Research has shown that in industry, generic attributes tend to cluster (Hagar & Holland, 2006), while academically it may be useful to assess attributes 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, while reasoning analytically within budgetary constraints.

To ensure that attributes are not treated discreetly, assessments should be structured in such a way to ensure they are undertaken as a holistic activity. No individual unit will address every attribute, however, it is expected that the attributes be developed incrementally across the degree programmes.

Carew, Lewis, and Letchford (2008) reported that the early approach of using the “tick-a-box matrix” method to report generic attributes is deemed insufficient and EA accreditation panels expect academic institutions to provide “comprehensive explanations of how the programs help students systematically develop these (generic) attributes and how the assessment procedures ensure they have done so” (p. 2).

The attribute spectrum developed for the AMC engineering degree programmes (AMC, 2010) are tabulated and monitored through an online database, of which a screen dump is shown in Figure 2. This approach evolved from the previous work carried out by Carew (Australian Learning and Teaching Council, 2009) to audit and map teaching and learning of graduate attributes in engineering. The intention is to develop a system that tracks the attributes attained by each student, however, the system is in its infancy and only tracks annual cohort of students. Although this system in its current form has limitations, it allows the course coordinators to fine tune the programmes in both delivery and assessment strategies, in other words provides quality feedback essential to meet the required outcomes.

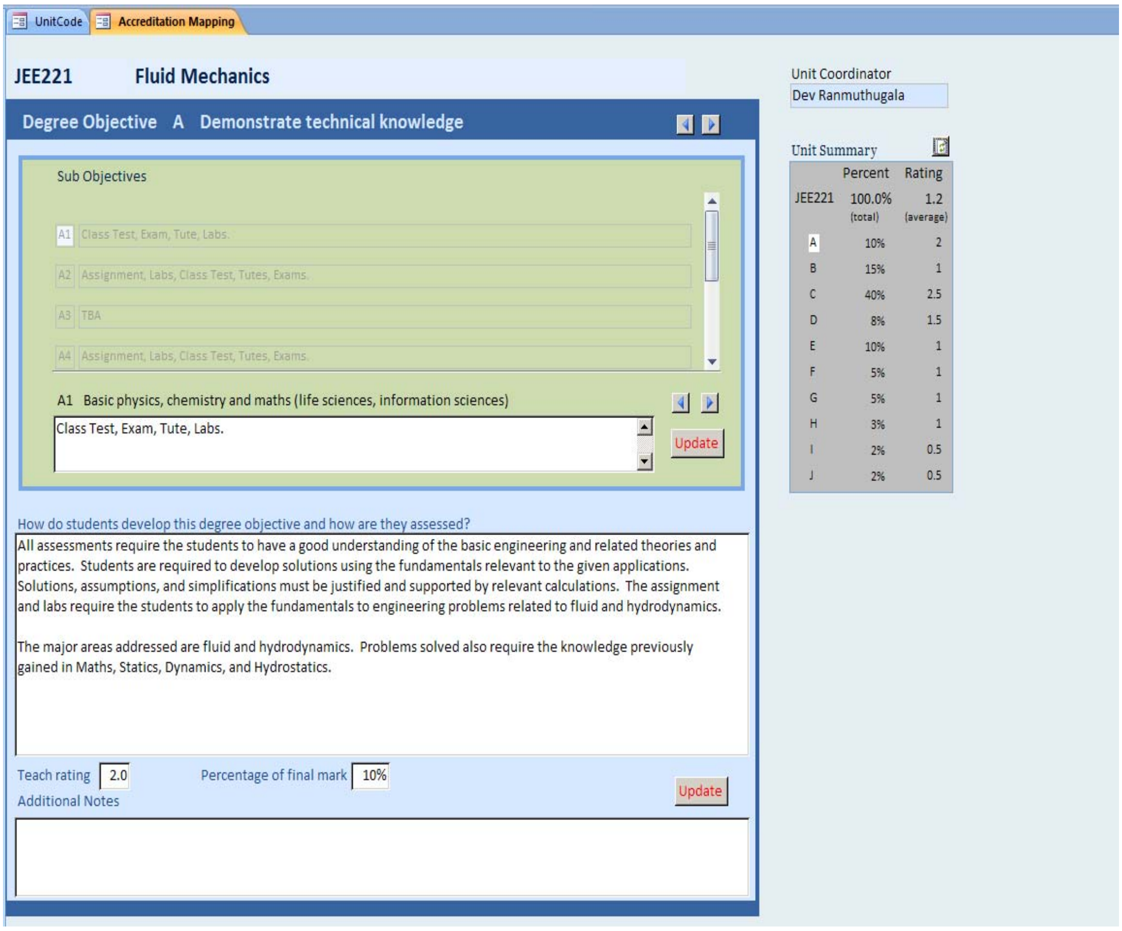


*Figure 2.* Mapping database.

The database provides a number of output graphs to assist in the analysis of the delivery and assessment processes. The graphs shown in Figures 3 and 4 are examples of such outputs for the Bachelor of Engineering (Naval Architecture) programme at AMC. 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.

Figure 3 shows the average teach rating an indicator of teaching “input”, that is the extent of effort and time committed by academics to teaching each degree objective given in the attribute spectrum. It provides a rough measure of the exposure and potential for learning that students have for each degree objective. Figure 4 provides the “output”, the average percentage of final mark, which gives an indication of the extent the assessments address the degree outcomes within the attribute spectrum. A rating of “0” signifies the outcome is not covered while a rating of “3” signifies the attributes of the outcome were a major focus of the unit. Figure 2 is a brief interpretation of the data analysed for the programme in 2009.

The data were collated and averaged for each of the years of study (years one to four). The graphs generally provide quantitative evidence that all of the degree objectives are being taught (see Figure 3) and assessed (see Figure 4). Due to the alignment between the AMC engineering objectives and EA competencies, these graphs provide evidence that the degree is meeting requirement stipulated by the latter and that students are taught and assessed against each of the competencies. The graphs demonstrate that students are exposed to and assessed on these skills in most years during their undergraduate experience.

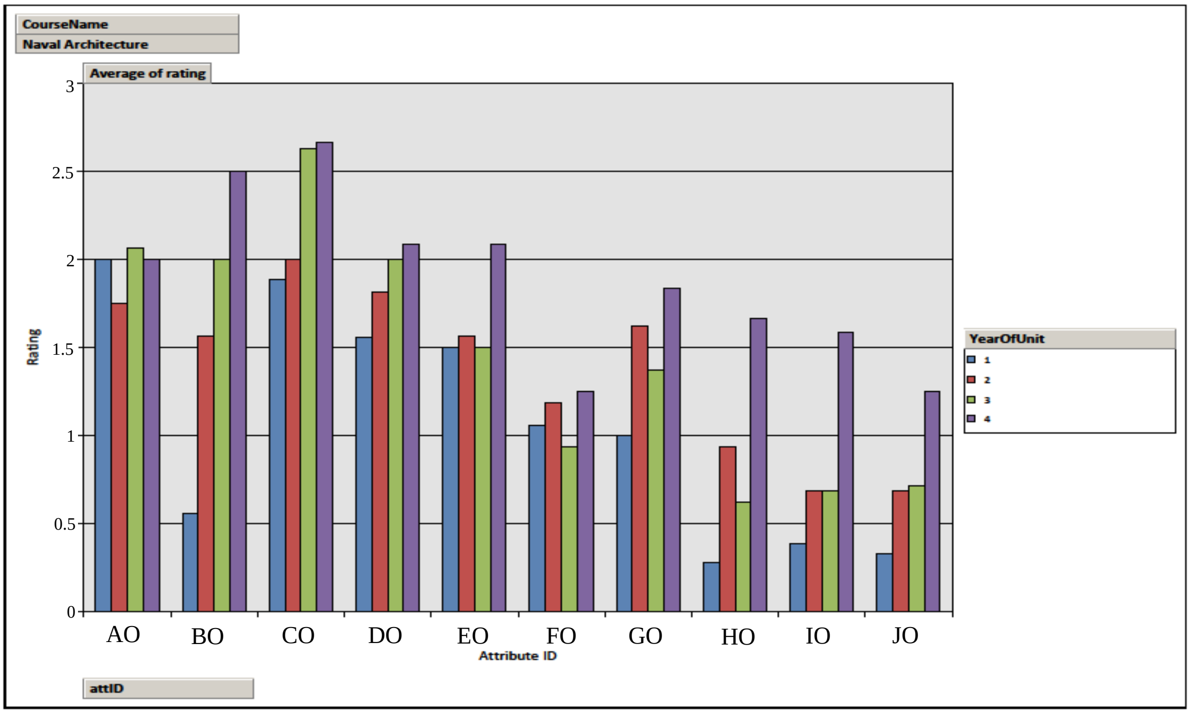


*Figure 3.* Average teach rating for the BE (NavArch) against the course outcome.

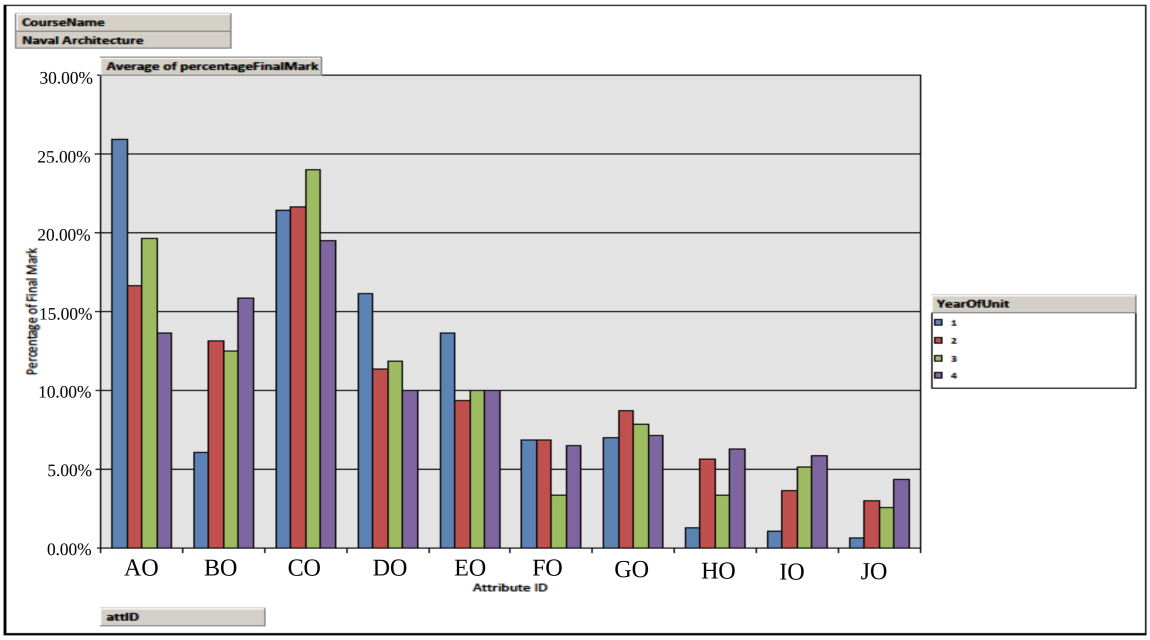


*Figure 4.* Average percentage of final mark for the BE (NavArch) against the course outcomes.

The general similarity in profile between teach rating graph (see Figure 3) and assessment percentage graph (see Figure 4) shows good alignment between teaching emphasis and two important artefacts of assessment: student motivation and course quality assurance for graduate attribute teaching and learning.

Figures 3 and 4 show the strong emphasis that the naval architecture degree has on technical and engineering science fundamentals, design and problem-solving in that all graphs show strong and consistent emphasis on degree outcomes A (technical knowledge), B (design) and C (problem-solving). It should be noted that the latter two (B and C) encompass a broad conceptualisation of these two activities and thereby subsume some “soft” or generic skills (see previous section for the degree outcomes).

The figures also demonstrate that the degree is providing students with solid grounding in fundamental skills of D (information management), E (communication), F (teamwork) and G (self/other management). Although the soft skills H (business environment), I (professionalism) and J (wider context) are taught across the degree, their assessment tends to be low.

It is possible that the mapping approach may have been ill-equipped to capture indirect and out-of-class type activities that develop students’ skills in these areas and thus, need improvement. However, this information was used to develop and enhance the delivery and assessment of the relevant attributes.

The attribute spectrum and the collection of the data through the database were developed and introduced during 2008 to 2009. Thus, the quality of the data and analysis will depend on improvements to the model and the relevant tools, as well as providing staff with the time and training to familiarise themselves with the concepts and systems.

## Delivery and Attainment of Competencies: An Exemplar

Students engaged in active learning are able to assimilate information at their own pace, as well as allowing the facilitation of learning in students who might otherwise be disadvantaged. All units within the AMC maritime engineering degree programmes attempt to relate back to maritime practice, thus, providing examples and problems linked to the industry. During subsequent years, the students build on the fundamentals to develop their knowledge and skills in their area of study.

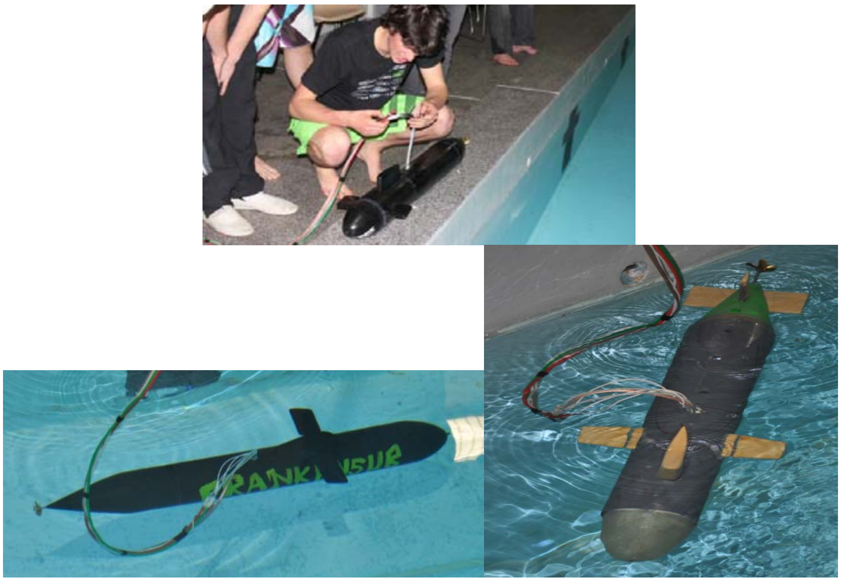

*Figure 5.* Testing of model submarine.

The submarine project (see Figure 5) introduced in the second year Fluid Mechanics unit 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.

The project spans a whole semester and is undertaken in groups consisting of six to eight students allocated from all degree programmes. They are required to design, construct and test a model submarine to meet design and operational specifications. The group submits a final report comprising of:

(1) Project plan, resource allocation and variances;

(2) Description of the design, including CAD (computer aided drafting) drawings, tables and graphs;

(3) Supporting literature survey, assumptions, theory and calculations;

(4) Testing schedule and results;

(5) Conclusion and recommendations;

(6) Description and percentage of work carried out by the team members.

The submarine project is used below as an example to clarify how a project addresses each of the 10 course outcomes. The discussion under each heading explains how the contents are delivered and the outcomes assessed (through a predefined CRA). The information is not separated into the underlying attributes; rather they address the outcome in a holistic manner.

**Outcome A—Demonstrate Technical Knowledge**

The assessment tools, wherever possible, are linked to actual problems, with students required to apply industry standards and practices to their solutions. They are encouraged to look for options and solutions from industry.

**Submarine project.** 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. Students are required to integrate the technical knowledge gained from other units to successfully complete the project.

**Outcome B—Design for the Maritime Environment**

Design is embedded within most projects, with students introduced to the concepts and required knowledge early in the relevant units.

**Submarine project.** The students are given a design brief for the submarine and are required to design a workable system to meet those specifications, using industry standards and practices, and importantly common sense, an attribute that tends to be frequently overlooked. The design must be supported with adequate and accurate calculations, clearly stating the assumptions made during the process.

**Outcome C—Solve Maritime Engineering Problems**

This is embedded across the three degree programmes, gradually building on the knowledge and skills acquired during the study programme. Students are given engineering problems which require them to identify the requirements, constraints and the “tools” required to solve the problems. The latter is an area that students need substantial support to develop, as most students find it difficult to decide on a solution approach. The problems attempt to make students identify logical patterns and pathways to take in their quest to solve the problems, rather than taking a “scatter gun” approach or trying out a haphazard mix of solution techniques with the hope that one will work.

**Submarine project.** Students 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 which include stability, pressure, drag, lift, thrust and power to identify limitations, failure and vessel dimensions, relating them back to their drawings.

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

These skills are introduced and developed through integrated activities throughout the programme. Although exposed to new technology, they are not always sure how to access information, efficiently sort and store them, and present them in a suitable high impact format. The approach was to provide appropriate tasks requiring these skills and guide them using a combination of instructions, examples and mentoring.

**Submarine project.** The design brief required 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 the students to collectively and individually acquire information from a range of sources, and their abilities 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 and work plans that are all assessed. Given the magnitude of the tasks, it is important that the teams manage the information in a logical format and maintain controlled documents.

**Outcome E—Communicate Effectively**

Communication skills are developed and assessed across the programme through a range of presentations. However, a greater focuses are now placed on informal communication, group dynamics and internal and external stakeholders, achieved through group projects and industry links, with the outcomes of these ventures and, thus, the assessments, dependent on these skills.

**Submarine project.** 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. They are required to provide continuous updates on their progress, including the use of project management tools, culminating in a final report. The relatively large size of the group requires the members to maintain good communication links within the group to ensure success.

**Outcome F—Work in Teams**

Introduction to teamwork commences right from the beginning through group activities and assessments. Students are required to work within teams to carry out investigations and provide group reports on their findings and results. Students must manage and distribute the workload between the team members.

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 nationalities. Team-based projects require teamwork and leadership to ensure success with individual contributions assessed.

**Submarine project.** The teams have to conduct regular meetings, keep records and monitor their progress. Although the overall timeframe is dictated by the unit outline, the internal time and resource allocation is carried out by the team and its leadership, which requires acceptance by all to ensure success. The team members should also deal with conflict resolution, although instructors will provide assistance, if required. The assessment includes peer-assessment that is depended on group dynamics and contributions.

**Outcome G—Manage Self and Others**

AMC have steadily moved towards more student-centred learning, with the students required to manage and take responsibility for their work, essential for successful learning. Group projects require students to manage team work, including the allocation and management of team resources and personnel.

**Submarine project.** 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 depth and breadth of the task that is carried out within normal semester time, students are required to manage their time and workload to meet the required outcomes. To ensure success, the team has to assist and mentor each other in areas of their speciality, as well as managing the collective efforts of the group. The assessment includes peer-assessment, where students assess the contribution of all members, which is included in the final grade.

**Outcome H—Negotiate the Business Environment**

Most projects are carried out to a design brief and are subjected to all commercial requirements. A number of projects are linked to industry, requiring students to liaise with relevant industry partners.

**Submarine project.** To enable students to achieve these outcomes, a number of lectures, including those by technical and non-technical professionals from related industries and organizations, are provided. These 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.

**Outcome I—Behave as a Professional**

Throughout the programme, students are introduced the ethics, practices and responsibilities of professional engineers. As a number of these projects are linked to industry, students have to communicate with partners and stakeholders from industry and the wider community. All relevant projects must conform to and are assessed against environmental requirements.

**Submarine project.** Given that the project requires construction and testing in a freshwater pool of sufficiently 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.

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

Students are constantly exposed to both technical and non-technical issues that affect their careers, their profession and the world at large. Guest lectures, student excursions and industry linked activities/projects provide students with an insight into non-technical aspects and examples on how industry operates within a global environment.

**Submarine project.** The project is assessed for technical content, innovation, feasibility, suitability, environmental impact, maintenance, etc. and as such the 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 and related professionals during the project.

## Conclusions

Gone are the days when academic institutions concentrated purely on the technical contents when developing, delivering and assessing engineering degree programmes. Industry and accreditation bodies insist that the programmes not only meet both the technical and generic attributes, but also show that the graduates have attained these attributes. An approach taken by many institutions was to “append” the generic attributes to the course curriculum in the hope that they would be covered during the delivery and assessment processes that tended to concentrate on the technical contents.

AMC has developed an integrated approach that describes the objectives, outcomes and attributes as a continuum defined as an attribute spectrum. This clearly defines the attributes the graduate will possess at the end of their programme and provides a basis to build unit delivery and assessment tools that meet all of the required learning outcomes. The size of the resulting attribute spectrum required a rethink on how to meet all attributes within the given time span and resources, which led to the development of a series of problem-based holistic practical group projects across the programme that addressed multiple technical and generic attributes. The success of these projects was made significantly easier by the use of the attribute spectrum that allowed the targeting of the relevant attributes and the development of the required CRA. In essence, the use of projects within the assessment model enabled a holistic approach to assessment, which provides a specific measure on how well the students have met the graduate attributes through explicit learning outcomes that are grouped into specific statements on what the student will be able to do as a result of the project.

Parallel with this development is a practical and simple method of tracking and quantifying the achievement of the attributes. It enables the institution to track various delivery and assessment processes linked to the attributes, yielding useful data to improve the quality of the programme and hence, the graduates. Although the current system tracks cohort of students, it is intended to update the system to track attributes attained by the individual students.

The industry is continuously evolving to meet changing world demands and practices. Thus, the programmes themselves have to change to remain viable and relevant to the industry, community and the students, while meeting the requirements of accreditation bodies. The process and tools described in this paper provides an efficient system to develop, track, update and modify the programmes to ensure relevance and quality.

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