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Innovative Curriculum Development within the Motorsport BEng course at Coventry University

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Abstract:The need to produce engineering graduates who are 'fit for purpose' has been discussed worldwide since the late 1980s. The development of professional skills to permit engineering science to be applied in society has identified the need for communication, team working and project management skills. A method for achieving this by incorporating an international competition entry, Formula Student, into the curriculum with the accompanying changes to teaching methods and spaces is described, with student and staff reflection indicating high levels of motivation and achievement. The lessons learnt, and the continuing refining of the teaching and learning process will become an integral part of the Activity Led Learning pedagogy within the faculty of Engineering and Computing.

Introduction

'Fitness for purpose' is an expression for describing how well a system, component, or method of operation best fits the purpose for which it was designed.

Engineers are constantly striving to achieve this in every aspect of their working life, and if applied to the conventional education of engineers by lecture, practical and tutorial assessed by examination then Fitness for Purpose would not describe or be associated with that practice.

Technical expertise in an engineering discipline is a necessary but insufficient set of skills for an effective engineer. Professional skills are needed to apply successfully their technical expertise and enable them to lead and develop society, encompass communication, team working, project management and life long learning skills. These and many associated issues have been the subject of many conferences and discussions worldwide as discussed by McCowan and Knapper (2002) which led to his development of the Active Building Project at Queens's University, Kingston, Ontario.

Following the recommendations of the Dearing Committee in 1997 (In QAA 2002), the Quality Assurance Agency for Higher Education (QAA) met with the Engineering Professors' Council (EPC) to examine the compatibility between the QAA bench mark statements for Engineering (QAA 2000) and the EPC Engineering Graduate output standard (EPC 2002). These two approaches listing standards to be achieved by a graduate entering the Engineering Profession are seen as a welcome step in incorporating the professional skills and capabilities required by a practising Engineer into the education process.

The EPC Standard takes the form of "Ability to - - - - - -Statements" which were also used by Griffiths (1991) to describe the learning objectives for a then, 1989, new course for the teaching of Automotive Engineering Design at Coventry University, which is further reported in Griffiths, Perks and Sheldon (1993).

It was the desire to consolidate the development of the professional skills through the acquiring of knowledge, and teaching methods, which included group working, problem oriented approaches and a blurring of the distinctions between lecture, tutorial and laboratory activities that resulted in the innovative curriculum development in the Motorsport course described below and in so doing ensuring that the resulting Graduates are ‘Fit for Purpose’.

Formula Student

Formula Student is a UK competition organised and run by the Institution of Mechanical Engineers (IMechE), which is derived from Formula SAE, organised by the Society of Automotive Engineers (SAE). Further details of which are given on the Formula Student web site (Formula Student, 2008).

> “Formula Student is about building future engineering talent by designing and producing a single-seater racing car, not just in design and manufacture, but in many of the management, marketing and people skills so vital in the modern world, across all sectors of employment.”
>
> (Formula Student 2008)

The competition attracts entrants from across the world and has an aim of giving students the opportunity to design, build, test and race an open wheeled single seat “formula” style racing car using a four stroke engine of up to 610cc. In 2007, the entry consisted of sixty-nine newly designed cars (Formula Student, 2008)

The design rules are very clearly defined and the vehicle has to be produced to a detailed specification in order for it to be accepted into the competition. The vehicle must be fully costed and must be built within a budget of twenty-five thousand US dollars. Students are required to produce written cost and design reports, which are submitted before the actual competition, and they must also take part in the respective oral presentations which are an integral part of the competition.

In order to check compliance with the rules, scrutineering is rigorous and strictly adhered to and any vehicle failing with regard to compliance is prevented from participating in the competition. In addition to this activity, the vehicle must pass the following tests; exhaust noise, braking test (all four wheels must lock), tilt test (to ensure that the vehicle will not leak fluids) and the driver must be able to exit from the vehicle placing both feet flat on the floor within a five second time period.

What makes Formula Student such a captivating project is its ability to provide students with a competitive challenge; one which demands ability, dedication and enthusiasm. Coventry University has taken part in the competition since 1999 and each year has attracted students who are willing to pursue the project significantly beyond the academic requirements of their course. This is much more than simply building a car; it is about working within a set of rules, working to a budget, producing both individual and integrated designs, focussing on optimisation of all aspects of the car, in engineering terms, in order to maximise performance and minimise weight, working effectively as a team, working to deadlines, dealing with people and being involved in a project that provides exposure to other professionals within the engineering industry. In essence the competition encapsulates the professional skills needed by an engineer to work effectively in modern society.

The integration of Formula Student into the course

When the project was run initially at Coventry University, it was only offered to final year students and consequently, it was an activity that most undertook as an extra-curricula project. Coventry University were the first UK HEI to produce a “class one” entry in the first year that they participated; (class one is defined as a complete, running and fully mobile vehicle). Such is the work-load and steep learning curve required to produce a “class one” vehicle that previously UK universities participating in this competition had taken two or even three years to get to “class one” status, producing partial designs (“class two” or “class three”) for their initial entries. The success of the project, and the necessary level of student commitment, demonstrated that the Formula Student competition was capable of motivating, enthusing and driving the students. Experience has shown that they would work tirelessly and selflessly to complete the task. In some cases, students prioritised this “voluntary” project before their summative studies, and such was the level of their commitment to be successful in this activity that they would work day and night if necessary in order to complete the project within the defined timescale. This level of commitment had seldom been experienced before the introduction of Formula Student and illustrated the opportunity to utilise the enthusiasm of the students to enhance their learning experience by integrating the Formula Student project within the their study programmes.

In order to provide this integration, the course and related learning outcomes were modified to embrace both individual (single module) and group projects (double module), which also resulted in Formula Student activities contributing significantly towards student learning and assessment. Invariably, students involved in the project also make use of other module content to supplement the requirements for Formula Student. Examples are Finite Element Analysis for assessing loading and subsequent stress levels in order to optimise strength and mass, and Computer Aided Drafting which may allow aspects of the car to be modelled, thus providing required geometrical data, to satisfy the Formula Student project, and which also allows the student to demonstrate a level of skill required to create and manipulate geometry, so satisfying the CAD module learning outcomes. Level one and two students are now encouraged to become involved with the Formula Student project by aligning their development modules with the FS project, and ensuring that the module learning outcomes map across.

The advantages of this overall strategy are numerous and include more effective knowledge transfer both through and across the student year cohorts, providing students with the opportunity to reflect more on their learning process through having gained knowledge by experiencing the competition, and providing continuity of knowledge and experience as final year students graduate from the course. Students in this position can also act as advisers and mentors to those less experienced and consequently the design of subsequent Formula Student vehicles tends to be more coherent as an effective design should embrace a combination of established, proven and fresh ideas. It is important that there is a balance of both, with the fertile mind of a student not being prevented from developing fresh ideas; however, this must be balanced with an effective knowledge transfer platform to provide the integration of experience, which will assist in the successful design of subsequent vehicles. The Formula Student project therefore provides a “vehicle” for integrating engineering knowledge gained from subject oriented modules and for the development of professional skills.

Provision of the teaching and learning environment

For effective Activity Led Learning, Appendix 1, to be successful, it is essential that careful thought is given to the provision of teaching and learning spaces, access to laboratories and equipment, and levels and types of staffing. At Coventry University, the environment has been continually developed; the laboratories, student study work areas and the build areas have been expanded in line with the growth of the Motorsport undergraduate course and associated Formula Student operation. Enhanced student support in terms of staff and mentoring opportunities has been provided. One example of the expansion of the teaching and learning space has been the removal of non-essential equipment in order to provide increased space for the Motorsport build area. This extra space has made it possible to develop the 2007 car and enter it into the "200 series" class of the Formula Student competition in addition to the build of a new 2008 car. Vehicles that have previously been entered into the "class one" category but have been developed and are being re-entered into the competition have to be entered into the "200 Series" category which operates under the same rules but is segregated from class one in terms of points awarded and final classifications. Within the course structure the 200 Series entry relies on team members from the second year of the course, however, the captain was actively involved as a member of the 2007 class one team. This individual is ideally placed to mentor his "same year" colleagues due to his team membership from the previous year, again helping to ensure continuity and the spread of good practice.

The students are provided with a large computing facility, which is equipped with industry standard software for a range of Computer Aided Engineering (CAE) activities. This software is comprehensive and wide-ranging in its application and provides assistance with regard to the creation and subsequent verification and refinement of the engineering design from component level to complete assembly. For example, students can use industry standard Computer Aided Design (CAD) software to develop components and sub-assemblies as individual projects which can then be combined together into group assembly models and thus provide verification of the resulting overall design. Examples of CAE activities include geometry definition to assess design viability, prediction of ride and handling characteristics, stress and mass distribution, engine performance simulation, telemetry and programming aids for computer numerical control (CNC) machining.

Students at Coventry University are encouraged, as an integral part of the overall Activity Led Learning regime, to carry out as much of the complete task themselves as is practically possible. This may not be the most "efficient" approach, as some of the tasks may be completed by utilising experienced engineers with specialist skills from outside the University. Such an example is that of the manufacturing processes, because Formula Student is a "design and make" exercise, the manufacturing element is key and, as such, it offers students a quite unique opportunity to complete the design-make loop by manufacturing their own designs.

This part of the process demands a significant level of experience in order to produce components of the required level of dimensional tolerance and quality. Allied to this is the issue of safety as machine tools are potentially very dangerous in the hands of the inexperienced, and for this reason many higher education establishments shy away from involving students in this activity. The important issue here is that of providing the students with the opportunity to maximise their learning experience, regardless of perceptions of "efficiency". A system has been developed in the workshop to allow the students to carry out their own work under the supervision of chosen academics, development officers and technician instructors, all of whom possess the required level of skills in this environment. It is noteworthy that there was initial resistance to this idea and it was down to certain members of dedicated staff to introduce and almost forcefully "push forward" the system by showing that if it was run in a controlled manner it was perfectly viable and, above all, it was safe. The workshop facility now has dedicated machines for student use, and as a part of the Motorsport course, there are opportunities within the modules, starting from the first year, to use machine tools and gain some skill and ability in this discipline.

One potential downside of this approach is that some may look at the Coventry University car and comment that it does not look quite as "professional" as others in the competition. Our answer to such comment relates to the subject of this paper, and is of course one of maximising student education through Activity Led Learning rather than simply using professional engineering resource to produce the car. This statement may insinuate that at Coventry University, there is no input from the performance engineering industry; however, this is far from the case. The students are actively encouraged to collaborate with industry, and as an integral part of the course, they can choose to take a placement and spend a year in industry. This takes place after the completion of their second year of study and around twenty percent of the eligible Motorsport student cohort choose this option, which provides them with an opportunity to gain experience and develop contacts within the industry. Students are also encouraged to seek advice and to look into "sponsorship" deals with the industry. The team are invariably supported by various companies and individuals. Coventry University graduates who have participated in the competition and who have subsequently gained employment in the industry very often provide support to the team. It should be noted however, that irrespective of the amount of sponsor based support, the vehicle must be fully costed using the retail prices of all components, the final price target being less than the aforementioned maximum figure dictated by the rules.

With the move to integrate the Formula Student project into the Motorsport course, and develop the Activity Led Learning approach it became apparent that additional staffing would be required, and not in the traditional academic style. An additional permanent staff member was appointed as a Development Officer (DO) which is a role between that of and academic and that of a technician instructor. The DO is based in the main build area and they assist in the coordination of student activity. The officer is available to offer advice, guidance and experience, in addition to ensuring the adherence to safety procedures for both individual and group activities, and to provide specialist help; for example, the welding of a metal based space-frame chassis which needs to be carried out by a certified person.

A more recent development (within the last year) to the learning environment and experience has been the introduction of student interns. These are students who have completed their undergraduate studies and have embarked on the Motorsport Masters degree, which is run within the Faculty. These Masters Students have been integrated into the teaching and learning environment and have provided an invaluable addition to the student learning experience. Their personal experience more closely relates to the undergraduate cohort than any other permanent staff members and as such, they are able, through their own experiences and expertise, to mentor the students and offer advice and guidance, which, is generally well received. Members of the teaching staff within the Motorsport team have noted, with interest, the positive relationships and the level of mutual respect that exists between the undergraduates and interns.

Reflection

Coventry University students have produced a Formula Student car every year for the last nine years and, as such, the staff involved have developed a significant amount of experience with regard to the necessary outputs that are required in order to achieve a certain level of success. One of these outputs is that of reflection with regard to maximising the student learning experience. In order to address this fundamental requirement, the system and facilities that exist at Coventry University have been developed consistently, year by year.

Without doubt, the addition of a Development Officer to the team has proved to be invaluable, this individual is based in the immediate vicinity of the build area and is, therefore, able to assess situations in a very involved and pro-active manner. From this position, the individual is often able to see a wider picture than those (the students) who are mentally and physically “wrapped up” in the situation. As such, the Development Officer is able to offer invaluable guidance and provide suggestions to both individuals and the group. The officer also provides assistance with the ordering of raw materials, components and the manufacture of the car, all of which are extremely difficult for academic members of staff to carry out due to their other commitments. The machine tool area is also now accessible to students, which provides them with the complete facility to enable the entire design and make process to be executed.

All of this has provided a significant enhancement to both the level of control and the opportunities given to the students working within the Activity Led Learning environment.

Formula Student was integrated into the Motorsport course in 2005 and subsequent pass rate figures show that for an increase in cohort size (33-46) there was a ten percent rise in students progressing to level three and a ninety-six percent success rate at level three, which is greater than any previous year. Whilst these results are positive and encouraging, it is not possible to draw a definite conclusion on the benefits of moving to Activity Led Learning. However, taken with the positive comments from students, some of which are provided below, there is a strong indication that the integration of Formula Student into the course and the move to Activity Led Learning has been beneficial in terms of retention and improving the student experience,

In a recent survey (January 2008) Formula Student team members were asked questions relating to the best and worst aspects of the project, motivational issues and advice for those considering getting involved, what they would like to change and how well they thought the overall project fitted into their course curriculum, the most pertinent responses are as follows:

Best aspects:

> *“Helpful staff”, “Working as a team”, “The ability to gain experience” and “Do what you want”* (with little constraint from staff).

Worst aspects:

> *“Poor access to computer controlled machine tools”, “Difficulties with the university ordering system”, “Lack of organisation”, “Not enough time”.*

The best advice to other students:

"Be prepared to work consistently for fourteen plus hours a day", "You will find out that Motorsport is not all champagne and glitz".

Worst advice to other students:

"Do not get involved" and "You will easily make a car in a year".

Regarding how the project fitted into their course curriculum:

"Fantastic platform to learn from", "Enables us to apply what we learn within a real project", "We have to hand in our completed (written) work soon after Easter and the competition does not take place until July".

The Formula Student project can be looked at from two points of view, one of which is to provide a learning platform to integrate the subject specific knowledge which is fully integrated within the course; the other, is to provide an opportunity for those who wish, to see an engineering project through to completion by manufacturing, testing and entering the car into the Formula Student competition in July.

It is noteworthy that each year, irrespective of any teaching and learning techniques that have been employed, some students complete their academic work requirement and then promptly withdraw from the team, often with little warning. This clearly puts additional pressure on the remaining team members but either way, this result can be viewed as a positive outcome; the students who remain involved in the project experience all of the elements of a "real" industrial based Motorsport project activity whilst the others have benefited from an Activity Led Learning approach during their course and moved onto other things, the main reason being that they have been successful in winning employment immediately upon completion of their formal studies.

The way that the project is run provides a powerful problem based, Activity Led exercise that not only provides students with the opportunity for deep learning (Griffiths, 1993), but also enables them to reflect on their personal career aspirations as a result of being involved with the project and gaining real experience.

It does undoubtedly bring the reality of such tasks home to students and as a consequence, some decide that this type of activity is not what they want to do as a career, in the same way that it reinforces with some that this is indeed what they wish to do. Either way, it can be seen as a positive outcome because it provides the platform for real experience.

At Coventry University, significant effort has been made to integrate the project into the curriculum but as there is a significant time differential between assessment and the date of the actual competition, the question still remains whether the institution should insist that the car is "completed" before the end of the academic year.

This has been considered but it is the view of the Motorsport team that this will merely place significant additional pressure on the team relating to activities that may not, in all cases, be of an academic nature. Detracting from the academic rigour of students is clearly not a positive move. Such a development would require careful consideration and planning. A possible solution would be to get students in their second year to do the design work, using these designs, the car could then be constructed during the earlier part of their third year which would then provide an opportunity for a test and development regime, the final standard of vehicle achieved correlating to the level of academic reward given for the project and its elements.

Conclusion

This paper has referred to the background need for undergraduate courses to incorporate the development of professional skills needed by engineers within the curriculum, delivered by the appropriate pedagogy.

A specific example of using an international competition, Formula Student, as the focus for Activity Led Learning to develop these skills within the BEng Motorsport Engineering course has been described.

Reflection by the staff and students indicates that many of the benefits and objectives have been achieved, and continuing refinement is ongoing.

The necessity of changing the nature of teaching spaces, and the activities within them have been discussed, and the lessons learnt will be carried forward via the Activity Led Learning pedagogy into the new Engineering and Computing building due for completion in 2011. The teaching techniques and methodology started in 1989, and reported by Griffiths (1991) have developed to the extent reported here, and are helping to ensure that the graduates from the course are 'Fit for Purpose'.

References

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Appendix 1

Activity Led Learning is a pedagogic approach in which the activity is the focal point of the learning experience and the tutor acts as a facilitator. An activity is a problem, project, scenario, case-study, research question or similar in a classroom, work-based, laboratory-based or other appropriate setting and for which a range of solutions or responses are appropriate. Activities may cross subject boundaries, as activities within professional practice often do. Activity Led Learning requires a self-directed inquiry or research-like process in which the individual learner, or team of learners, seek and apply relevant knowledge, skilful practices, understanding and resources (personal and physical) relevant to the activity domain to achieve appropriate learning outcome(s) or intention(s). To be appropriate, the learning outcomes or intentions must be consistent with the aims, outcomes and intentions of the programme of study with which the student is engaged.