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EVOLVING AN INNOVATIVE DESIGN EDUCATION ENVIRONMENT: THE FORMULA DIT STORY

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ABSTRACT
This paper describes the evolution of a Design Education Learning Environment within the School of Manufacturing & Design Engineering at the Dublin Institute of Technology. The environment has evolved to facilitate successful participation by a team of undergraduates in the Formula Student competition. The Formula Student (FS) competition is an International competition (with more than 120 international participating teams) which challenges 3rd level students to design and build a single-seat racing car, which is then put through comprehensive evaluative testing at the famous Silverstone Circuit. Unlike traditional pedagogical approaches, this learning environment requires a team of students to develop and apply their design and technical skills in a business context, whilst *simultaneously* employing a range of transferable skills including project management, teamwork and communication. The development and evolution of the learning environment at DIT has been an important lynchpin in facilitating the progression of the undergraduate teams from "non-participants" in 2009 to "top 25 finishers" in the Class 1 Formula Student competition by 2012.

Keywords: Formula student, engineering design, teamwork, communication

1 INTRODUCTION

Design is at the heart of all Engineering disciplines and engineering design projects are a fundamental contributor to the development of interdisciplinary and multidisciplinary learning in 3rd level engineering education. The focus of this paper is the development of a Formula Student Learning Environment within the School of Manufacturing & Design Engineering at the Dublin Institute of Technology. It presents the implementation stages and principal features required to transition from a traditional student project environment to a Formula Student learning environment. The primary focus will be on the evolution to a learning environment which can facilitate and nurture learning in engineering design thinking, conceptualization and the subsequent realization and implementation of solutions. The real-world nature of the project results in valuable student exposure to the dynamics of industrial design and engineering. The principal elements examined here include the physical environment, student team selection, structure and continuity, the integration of business elements into Engineering projects, evolving team project management procedures, the development of a continuous improvement cycle and student assessment. Reference is also made to aspects of integration between the core curriculum of study and student projects. External engagement and future challenges and project sustainability into the future are assessed.

2 ENVISIONING ENGAGEMENT AND PEDAGOGICAL CHANGE

Interest in the Formula Student competition began in 2007 and accelerated within the school of Manufacturing & Design Engineering at DIT following a visit by school staff to the Silverstone competition in July 2009. These staff began to envision DIT's undergraduate students engaging with, and participating in, the global Formula Student competition. An internal review of the "environment" for engineering design projects within DIT, and specifically within the relevant schools, was carried out to establish the viability of the endeavour. The nature and scope of undergraduate engineering project work at DIT prior to Formula Student closely mirrored that within the 3rd level sector with, in general, a more application-focussed aspect to the work. Principally, these projects could be identified as technically-driven challenges undertaken by individuals with little evidence of collaboration/teamwork with peers both within, and outside, the particular discipline. A detailed analysis of this existing environment contrasted against that required to support the Formula Student Competition identified substantial variance. A summary of these differences are outlined in Table 1.

Table 1. Formula Student (FS) Vs Traditional DIT Project Environment

Project Characteristic	Formula Student Project	Traditional DIT Final Year Undergraduate Projects
Project Owners	Team-Based (with well-defined individual responsibility). Team sizes often 12-20 members	Final Year Degree Students with individual “stand-alone” projects
Design Specifications	200 Pages Strict External Specification	Often Internally generated by Student
Design process	Clear “What, Why, How” justification of options chosen expected. Each system’s design must be controlled in context of overall “upfront” published team performance, cost and financial goals.	Clear justification of design choices required but no consequence of the design to higher level external numerical design goals.
Project Timeline	External Final Assessment in July. Staged reporting requirements (with strict and severe consequences for late submission)	Completed by end of Academic Semester in May. Consequences of ‘lateness’ of staged reporting at discretion of the supervisor
Project Elements	Engineering, Business and Finance integrated in a single project with the full range of Automotive Technologies employed	Largely “Engineering/Technology” only focus with wide-ranging technological content fully dependent on specific project
Project Management Process	Requirement to dynamically manage individual projects in context of well-defined overall numerical team goals	Individual Project Plan monitored
Product Test Timeline	Final test dates “set in stone” & team are committed “up-front” to undergo testing of vehicle	The extent of final testing is sometimes dependent on level of project progress attained
Consequence of failure	Consequences to peers of not reaching “team goals”	Consequences are only to the individual
Project Benchmarking	Team Ranked and Benchmarking versus International Peers	Rated versus internal individual peers only
Visibility of Results	Team’s ranked result publically available internationally	Individual result available internally only between student and 3 panel member assessment team.
Feedback & Continuous Improvement	Annual benchmarking & feedback drives annual continuous improvement goals	Individual formative feedback weekly & throughout the project. However, no external benchmarking feedback and typically no continuity of feedback beyond individual annual in relation to “improving management processes” or results
Student Assessment	External Team assessment across multiple elements i.e. Design, Cost, Business & Sustainability	Individual assessment on Technical and Communication Elements

Further momentum to radically examine our design environment was provided by the Irish Innovation Task Force report [1] to government (March 2010) which recognised that "*a key element of the* ecosystem of innovation is the "*education system, in particular higher education institutions*" that a "*radical shift is now needed in the experience which our undergraduates and postgraduates undergo at our HEIs*" and that "*a stronger foundation for new product design and development excellence in Ireland should be developed through close collaboration between industry, HEIs and professional…*" Indeed Education research was also pointing to the need for change. Biggs [2] whose wide-ranging review of tertiary education literature found four principal factors which encourage a deep approach to learning; namely, an appropriate motivational context, a high degree of learner activity, interaction with others both peers and teachers and a well-structured knowledge base. It was clear that Formula Student style projects and the associated attributes would address all four factors better than the pre-existing model. Though the advantages cited by Nichol [5] that "group learning involves shared goals which leads to increases in students' sense of responsibility and self-efficacy" were clear to the team, Karl Smith's [3] cautionary note that "there is a crucial difference between simply putting students in groups to learn and structuring cooperation amongst students" was a primary concern to the initiators in the design of the learning environment.

3 PROCESS IMPLEMENTATION

A five year plan was envisioned by the initiators with the ultimate goal being a learning environment which would properly support a credible Formula Student entry. Iteratively, in manageable chunks, progression milestones and deliverables were prescribed. Table 2 outlines the development chronology.

Table 2. DIT's Formula Student Development Chronology

Academic Year	Key Deliverable Envisioned	Noteworthy Deliverable
2007-08	Develop knowledge internally in Automotive Technology	Individual Student Projects Completed On Frame & Suspension Design
2008-09	Extend Internal Knowledge in Automotive Technologies	Continuity & expansion of '08 project to five students and two academic supervisors. Engine Test Bed developed
2009-10	Officially enter a team in Formula Student "starter" class	Fourth place finish in this Class. Drivable vehicle 85% complete
2010-11	Participate in all phases of Class 1 Formula Student competition	Ranked 47th overall in Class 1 competition
2011-12	Compete competitively in Formula Student Class 1	Ranked 23rd overall in this Class

4 CORE ELEMENTS/PRINCIPAL FEATURES OF THE FORMULADIT STUDENT ENVIRONMENT

The principle achievements outlined in Table 2.0 were as a direct consequence of the multi-faceted educational environment which evolved between 2007 and 2012. This section outlines the principal features of the environment and the nature of interactions of the DITFS community accommodated within.

4.1 Physical Environment

DIT academic management recognized that the physical environment is an important pre-requisite in facilitating the extent of communication (both amongst peers and tutors), integrated design, manufacturing and teamwork that is required for success in Formula Student. Despite significant space constraints, DIT spent more than €86k between 2009 and 2012 in developing a CNC machining centre, purpose-built workshop and acquisition of associated ancillary items in support of the project. The current physical environment includes a computer based lab/team meeting area, a dedicated Formula Student fabrication area and a dedicated assembly and test area. The success of this project critically hinges on a range of key soft-skill factors; student engagement and ownership, acceptance of responsibility, communication and support, dispute resolution, safety and situation management. These considerations, coupled with the fundamental design and technical requirements, were key drivers in the progression of the physical workspace layout. The resulting space is conducive to effective learning and performance within all key aspects of the FS competition.

4.2 Management of Student Selection, Team Structure & Continuity

Student selection, team structure and developmental continuity are important elements of successful participation in FS. Prospective student applicants are interviewed by four team supervisors for membership of the Formula team. Academic performance, attitude and ability to work with other team members and commitment to work to a timeline beyond the end of the academic year are criteria used in the assessment of potential team members. By 2011, when it had become apparent that greater continuity between Formula Student competitions would greatly assist the team, it was decided that a number of third year students would thereafter be co-opted on to the team. Their participation, effectively over two years in the competition strengthened multi-annual continuity of the project. By 2013, a formal team structure has evolved as per Figure 1.0.

4.3 Developing Team-Project Management Processes

Smith's[3] five elements he considered essential for successful cooperative learning groups were clear considerations in the design of the learning environment i.e. positive interdependence, promotive interaction, individual and group accountability, development of teamwork skills and students' learning to evaluate their group's productivity. Equally Chickering and Gamson's [4] principles of Good Practice for Undergraduate Education underpinned the team-management systems i.e. communicating high expectations, encouragement of student-faculty contact, co-operation amongst students, active learning, prompt feedback, an emphasis on "time on task" and respecting diverse talents and ways of learning. Focused bi-weekly team meetings which by their nature involve interaction and formative peer review complemented individual project meetings between students and supervisors. These team meetings and summary projections by specific team leaders of progress versus specific numerical goals are important to keep the overall project on track. The innovative FormulaDIT team structure exposes students to an intricate multi-factorial project management environment; an environment where time and resource management are critical. There are real consequences (apart from 'grades') to the team for the poor performance of an individual and there is clear visibility to this within the team. This generates an innovative educational environment where co-operation and co-learning from peers becomes essential to success.

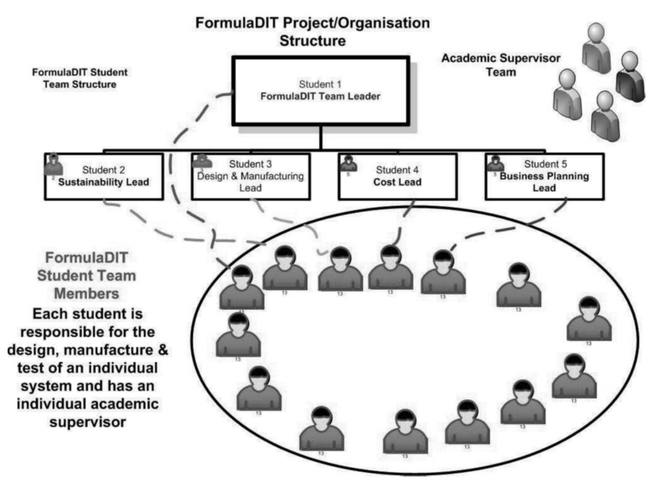

Figure 1. Team Structure & Responsibilities

4.4 Integration of Business Elements

One important challenge in developing the Formula Student environment was to appropriately integrate the requisite business element within the overall project. The business element of the project required the development, presentation and defence of a business plan clearly based around the vehicle being developed for competition. This activity did not suit the activity typically rewarded in an Engineering Design project within the department. Initially, in the 2010-12 period, a small sub-team of designated students worked on the business plan for the competition but without getting any credit for it in their academic programme and with little integration with other team members. While this 'worked to some extent', it was important that it was integrated better into the project and with learning within relevant modules and that this activity got better rewarded within the students' programme. To address this, in 2013 the team with the assistance of other academic colleagues integrated some of the business activity required by this module into the stage 4 Professional Development module where students traditionally undertook a business plan (albeit traditionally different in nature and emphasis to the requirements of Formula Student). Engineering students have conventionally undertaken learning on business topics but credit for this learning is obtained in discrete "professional development modules" rather than within integrated "engineering project" modules. However, academic advisors also saw the need to develop an environment which better integrates the Business elements within Engineering learning. With assistance from academic colleagues, significant progress has also been made towards this integration in 2013. A key mechanism to achieve this has been the development of a transparent, well-structured unified team project plan which coherently integrates students' individual project plans, each with technical and some business content, as part of a rational overall technical and business plan which has an emphasis on "time on task". This overall integrated transparent planning framework is a key enabler of structured multi-faceted cooperation, positive interdependence and promotive interaction amongst the student team.

4.5 Developing a Multi-Annual Continuous Improvement Cycle

In the traditional project environment, typically once a discrete design project, typically there was little if any formal feedback or product development continuity into the following year. By contrast, in the Formula Student team environment, it was clearly necessary to review annual team performance as one input to the following year. A performance SWOT analysis was naturally undertaken every year from 2010 onward and emerging from this analysis, improvement goals in process management and product design emerge. The availability of benchmarking data (across dynamic and static events) from the Formula Student competition has been a key enabler of continuous improvement. It has facilitated a detailed numerical analysis of the "product's relative performance" and therefore it has driven a strong 'continuous improvement' process facilitated by the four project supervisors. This, coupled with the inclusion of Year 3 students, greatly enhances product design as well as project management.

5 INTEGRATION WITH CORE ENGINEERING CURRICULUM

In addition to the links with the professional development module outlined above, the project team saw the importance of developing links to other modules across a number of stages of the programme. In stage 3 one of the design modules now focuses on the design of a formula student race car. Students are required to design a frame, body and suspension within the constraints of the competition. They are also required to present their designs and submit a technical report. This module lays the foundation stone for progressing to a final year project as part of the formula student team or elsewhere. It also assists the lecturing staff in identifying suitable candidates for roles within the team the following year.

6 ASSESSMENT & FEEDBACK

Traditionally, students are individually assessed and this process remains as before (since all students including those not doing the FS project all undergo a common assessment process) for the purpose of academic assessment. We see future possibility to potentially incorporate a criterion related the achievement of "team goals" becoming a part of individual assessment.

A uniquely motivating aspect for the FormulaDIT team is the fact that they represent their DIT community in competition. The fact that they are externally assessed and benchmarked against international peers by a panel of industry professionals is a huge performance motivator.

7 EXTERNAL ENGAGEMENT

One of the advantages of the formula student project is the growth in engagement with industrial partners. Over two years this engagement has grown and continues to grow as the project evolves. The FormulaDIT now has the following sponsors; xElvin (technical recruitment company), Galway carbon (specialist in carbon composites), National Instruments (telemetry equipment), TDP (engine mapping specialists), OC tuning (suspension specialists), TRL (Impact testing and simulation), CRE (3d modelling software), McNally (wood working specialists), and Volkswagen. These are mutually beneficial partnerships. The students have been exposed to real engineering companies which offer advice, expertise and sometimes provide specialist software and equipment which the students would otherwise not have access to. Links with companies like Volkswagen have exposed students to the importance of marketing, business and costings. The students have had to develop and maintain their on-line presence through a dedicated web site and a social media presence. Links with xElvin, a Dutch technical recruitment company have proven particularly beneficial to both parties. xElvin offer financial support for the project and in return get first access to the students who are highly sought after by Dutch engineering companies such as Daf Trucks, ASLM and Marcel. Communication between students and industrial partners greatly contributes to their education as engineering professionals and the skills developed are much sought after by potential employers.

8 THE FUTURE

Future education developments include the integration of the project into a newly launched ME programme in Manufacturing Management & Innovation; a one year “”add-on” to the current BE programme requiring a 30 ECTS credit project. The ME will support a three year integration of the Formula student project and facilitate bringing the learning experience to Level 9. Supporting ME modules such as commercialization, innovation & knowledge management, lean & sustainable manufacturing will significantly enhance the learning experience within the project. Other future plans include the development of electric or hybrid vehicles which will enhance the sustainability of the project and facilitate collaborative teamwork with electrical engineers from DIT Kevin St.
The team’s ultimate goal is to finish in the top 10 teams of the competition which requires an extremely high level of engineering and business excellence. The team is confident that with suitable funding and a continuation of the level of research in all areas of the car this is achievable.

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