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COLLECTIVE DESIGN: MERGING INDUSTRY AND EDUCATIONAL METHODS FOR MULTIDISCIPLINARY STUDENT DESIGN PROJECTS

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ABSTRACT

Design Background: This study seeks to enhance students learning through the development and application of the *Collective Design Method;* combining industry tools and techniques with educational approaches. By applying industry best practice in terms of project planning and implementation tools, case studies and examples of best practice, alongside student lead teaching techniques, students can build up their live project experience and confidence while working with industry processes, helping them transition from education to industry.

The study University has significant developmental experience in undergraduate level practice based learning through - CONCIEVE, DESIGN, IMPLEMENT, OPERATE - the CDIO approach to student-led practical learning at University level. The European Shell Eco-marathon challenge will form the basis of the practical design project and will involve a multidisciplinary team of students including Mechanical Engineering, Product Design and Design Management students.

Methodology: A large scale, year long, team project has been running at the University annually for a number of years through the Shell Eco-marathon competition. This then provides the benchmark project for the new study.

Review and Conclusions: The study will evaluate the teams' progress and learning gained through the application of the *Collective Design Method* process and tools in comparison to the previous student teams. Results are to be presented in the form of statistical data, qualitative user feedback and case studies to highlight areas of best practice.

Keywords: Collective Design, CDIO, multidisciplinary, collaborative working, experiential learning.

1 INTRODUCTION

Helping students develop their knowledge and understanding whilst practising their subject is a crucial aim of a good university education. The professional design and engineering workplace is indeed multidisciplinary by nature and can be very varied in its demands as a career. This study seeks to develop a design approach to help students to broaden and deepen their learning on their journey to becoming professional designers and engineers through the application of the *Collective Design Method*.

The *Collective Design Method* seeks to help students build their knowledge, understanding and practical confidence in design and engineering while better aligning them to the challenges of a professional career. Industry provides us with many tools, techniques, methods and procedures which graduates will need to embrace in their early careers. However many of these methods, so familiar to industry, rely on a certain level of prior knowledge and broader industrial understanding which often comes from years of experience in the workplace. It can be this disconnect between the academic student experience and the professional industry experience that causes graduates the biggest challenges as they start their careers [1].

This study draws on approaches form two perspectives: (1) the CDIO approach to practice based learnings, and (2) industry recognised tools and processes in combination to form the *Collective Design Method*. The aim is to better introduce students to the various working methods employed by industry while also recognising that they are still building their experience as they become designers and engineers (Figure 1).

Figure 1. The evolution of the Collective Design Method

The Shell Eco-marathon competition sees student teams challenged to design, build and race a fuel-efficient vehicle each year [2]. This then forms the project platform for the study (Figure 1). Aston University students have entered a car in the Shell Eco-marathon for several years and the teams are traditionally made up of a mixture of Product Design and Mechanical Engineering students. This large, year-long project with a multidisciplinary student team gives the ideal case study to examine best practice and review the success of the *Collective Design Method* tools and processes that the team applies, both in terms of competition success but also the impact on the students themselves in terms of their learning.

Figure 2. Aston University Shell Eco-marathon car

2 THE ASTON UNIVERSITY SHELL ECO-MARATHON TEAM 2015 REVIEW

The Aston University Shell Eco-marathon car of 2015 will form the benchmark case study for comparison with that of the 2016 team [3], allowing the new *Collective Design Method* to be reviewed and compared between the two teams.

A review of the 2015 team carried out with student team members and academic staff allowed some analysis and conclusions to be drawn about how the team functioned through a *Lessons Learnt document* along with team and individual interviews. The interviews and de-brief sessions recorded through a *Lessons Learnt* document highlighted some general findings:

Lesson Learnt:

- Students underestimated the scale and depth of the project, often running out of time.
- Task and priority was often ignored, leading to time spent on less critical job.
- Communication channels and responsibility/ownership was undefined.
- Students often turned to solution they were already familiar with, rather than exploring beyond their comfort zone of knowledge.
- Project time line suffered from time creep and missed deadlines.
- Students' levels of confidence and their capabilities were not always aligned.
- Staff supervisors could be viewed by students as lacking professionalism.

The above analysis and reflections on the 2015 team identified potential areas to develop and form the basis of the new *Collective Design Method* to provide a more successful project in terms of competition results and better student learning in terms of depth and context in the 2016 team:

- Applying a more defined CDIO staged structure to the project, critically to be put into context of the real project deliverables.
- Defining the team structure. Through clear communication and recording processes and appointing an external industry mentor.
- Employing more formal, recognised industry processes such as defined Design Review stages to the process.

- Helping students better understand and evaluate their design decisions through a Functional Requirements approach to the vehicle and its components.

The above objectives for the 2016 team seek to introduce more industry recognised ways of working while integrating them together with the *Collective Design Method* approach which builds on the CDIO learning approach which has been used thought-out the students undergraduate programme. This combination of education derived CDIO process and the industry recognised best practice in the *Collective Design Method* seeks to help students better learn their professional practice.

3 APPLYING THE CDIO STAGES WITHIN THE COLLECTIVE DESIGN METHOD

The CDIO philosophy has been developed for academia to give a more integrated and structured learning model and CDIO provides some useful guidelines to help staff and students develop their learning in more cohesive way (Figure 3). The four stages of CONCIEVE, DEISGN, IMPLEMENT, OPERATE at the heart of the philosophy provide logical and adaptable steps for both for tackling a project, and for enabling students to understand the context of their position within the project [4]. The CDIO standards also support academic institutions in bringing subject areas and topic together, rather than segmenting the curriculum, through a more student-led practical programme of integrated subject learning. This practical approach has helped to give students a more engaged learning experience but there remains some opportunity to bring their academic learning closer to the practice familiar to industry through the *Collective Design Method*. [5].

The 2016 team has been using the CDIO stages to help define the project timeline and in turn mapped these CDIO stages on their own project planning and review process within the *Collective Design Method*.

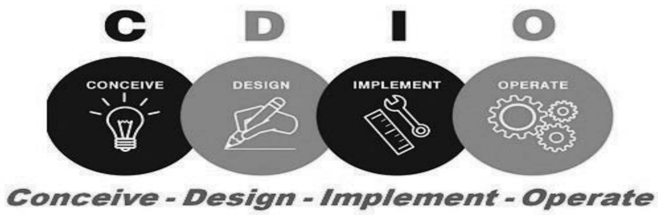


Figure 3. The CDIO engineering education principle

4 TEAM STRUCTURE, COMMUNICATION & PLANNING

Traditionally the previous teams would set out the group structure with a student manager and academic supervisor. Working with the academic staff can bring some benefits but it can also lead to over familiarity.

For the 2016 team the addition of an industry mentor has been used to give the team an objective professional industry viewpoint on their progress. Regular reviews, presentations and conference calls have been arranged. Key to the *Collective Design Method* is that the industry mentor expects students to engage with industry standards and approaches to working, thus building their knowledge of correct working practice.

The project planning process usually takes the form of a large Gantt chart with deadlines added in reverse order from the competition deadline. Typically deadlines would slip as students discovered that they had underestimated the complexity of the task and the time demands of activities such as ordering and logistics. Traditionally academic staff had managed the student team alone. However, in response to the Lessons Learnt review of the previous year’s team an external industry mentor has been introduced. A design engineer from Rolls Royce is now providing important industry perspective to the team, again reinforcing industry practices, such as project communication and management processes. Students now present formal meeting minutes to record progress and define objectives and, crucially, accountability during the process, all with the external industry mentor using conference call reviews, online updates and design review presentations. [6].

5 FUNCTIONAL REQUIREMENTS & THE SCHEMATIC APPROACH

In previous years students would often underestimate the scale of the project. CDIO provides a staged approach with the crucial CONCIEVE stage used to explore the problem. This stage can highlight the students' relative lack of experience and knowledge of a problem area, with students often turning to the previous year's design as a solution, rather than making a deeper rational examination of the problem fundamentals (as the CONCIEVE stage recommends). Students are often led by the desire to quickly fix on a solution and so a more robust process of problem understanding and investigation is needed. The *Collective Design Method* adds an additional tool from industry to the process with a schematic drawing to help students visualise the elements and interconnections of a design challenge.

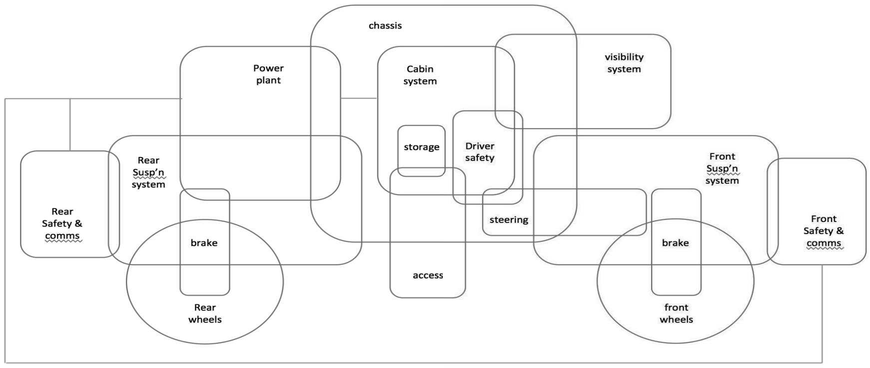


Figure 4. Vehicle level schematic of Aston Hydrogen car

The 2016 team has been introduced to the industry approach of Functional Requirements, a tool familiar to professional engineers. The use of a top-level vehicle Functional Requirements established the overarching project parameters, helping to link the various student projects together more coherently in the team. Presented in tabulated list driven by Schematic diagram (Figure 4) the vehicle level and subsequent sub-assembly and component level can then be shown in context of each other and their interconnected requirements visualized. Each sub-vehicle element was then further deconstructed to provided sub-assembly and component-level Functional Requirements.

This process highlighted a significant deficiency in the students' ability to genuinely examine and break down the constituent elements of a problem. Many made rather general assumptions and others struggled to understand the value of the process.

6 DESIGN REVIEW STAGES & DESIGN HISTORY FILE INCORPORATED INTO THE COLLECTIVE DESIGN METHOD

Formal design reviews were incorporated into the *Collective Design Method* to connect the planning stages and the actual progress of the project (Figure 5). In the past teams had indeed had staged reviews but not fully understood the process and function of such reviews.

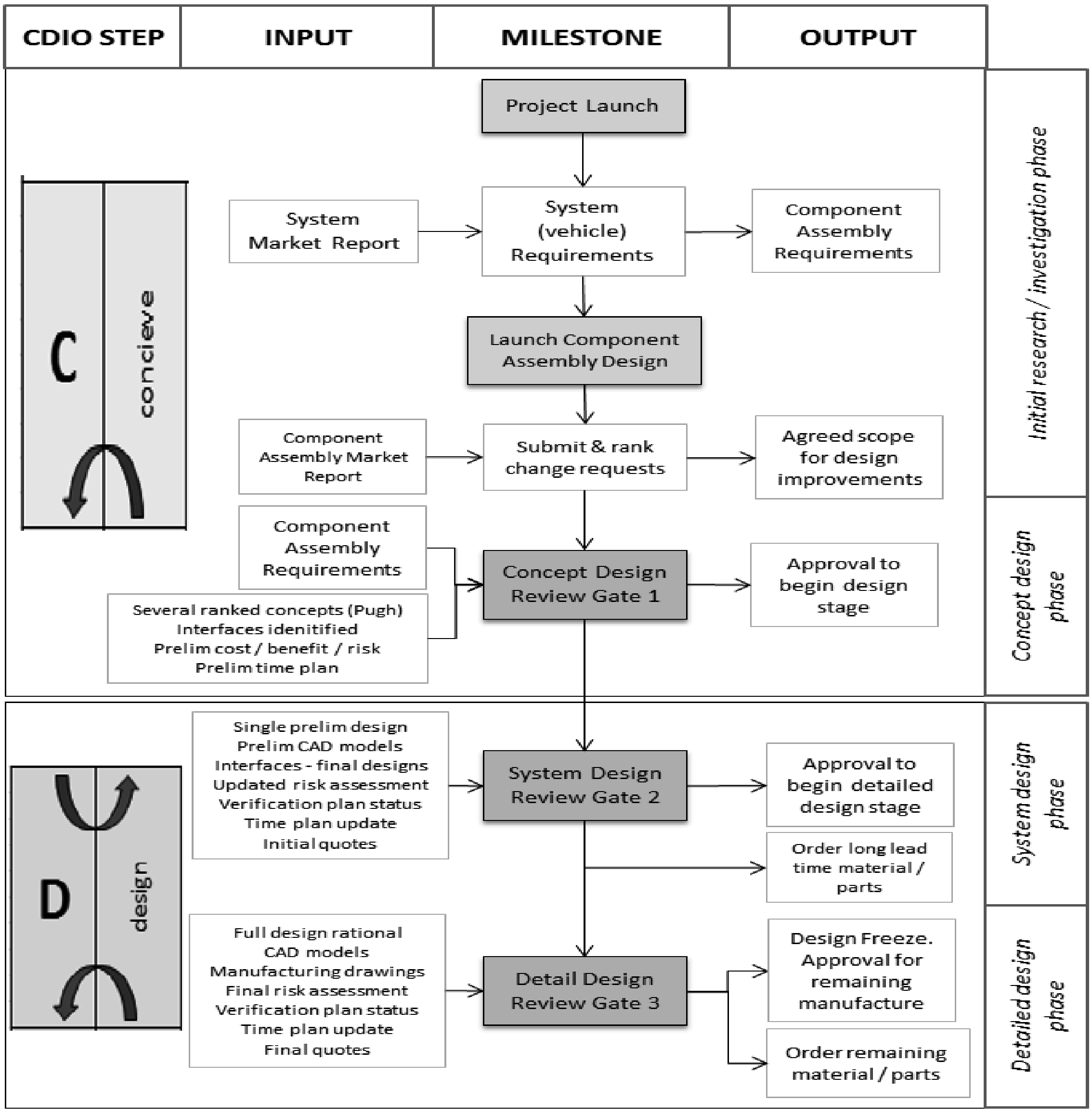


Figure 5. Collective Design Mathod with Key Design Review stages for the 2016 Aston vehicle

Previous teams would use reviews to fix an idea or decide on a design or part in a fairly arbitrary way. With the new *Collective Design Method* applied in 2016 the design review process was applied in conjunction with the CDIO stages and the Functional Requirements. This then sought to not simply fix on a design but to present the rationale behind the decision and to present the potential solution along with the recommended route in a comparative way. This opens the design review process up to proper scrutiny and by giving the requirements alongside the COST/BENEFIT/RISK analysis the team as a whole can make a much more informed decision as to the action to take (Figure 6).

The use of a formal *Design History File* document to record, track and communicate development was also introduced to students through the *Collective Design Method*. The Design History file, familiar to professional engineers, proved to be more of a challenge to students initially. The relevance was not always appreciated in the moment, although as the project progressed students realised that the Design History File allowed them to review and track progress well. This element of initial student resistance and then realisation of value with hindsight was observed. This is very much at the heart of the *Collective Design Method*; students with limited real world experience sometimes do not realise the value of industry processes and need to be led through an engaging structure that is both understandable and relevant to helping them learn.

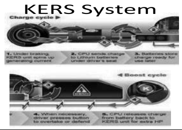
Brake System DA Matrix	Concept 1	Concept 2	Concept 3
	Hydraulic Disc 	KERS System 	
Comments	Existing Hydraulic Brake System	Adopting KERS style system to provide regenerative braking and	
Approx Cost	Free	£1000+	
Approx Mass	<5kg	<30kg	
Complexity (1=Simple -> 5=Hard)	1	5	
Layout Effects	None	Hub structure/Power delivery	
Pros	1. Known Performance 2. Meets vehicle and competition requirements	1. Recovers lost energy 2. Increases overall efficiency 3. Can use existing power delivery infrastructure? 4. Provides XX amount of kW	
Cons	1. Not optimised for minimum requirements	1. Requires many resources to become operational 2. Provides added complexity 3. Provides opportunity to fail w/o simple fix 4. Costly of time/money/manpower	
Recommendation			

Figure 6. Design Decision Matrix Example

The Initial Design History File documents were refined and simplified, still allowing good recording of decisions but helping students engage and appreciate the system more easily.

7 CONCLUSIONS AND FURTHER WORK

While the ultimate success of the project can be judged by the competition results, the evaluation of the team itself is perhaps more intangible. Success for students is often measured in securing a good graduate job and it is important that they can demonstrate their knowledge, understanding and practice of their chosen profession gained from this project in the job interview process.

Further developments of the *Collective Design Method* are to add a team communication tool in the form of a personality evaluation. Similar studies into the dynamics of a design team and the impact of personality type have been carried out by the Aston team, specifically examing the design process and individual's approaches at different points in that process depending on their personality preference [7]. Understanding and appreciating individuals' and team members' personality preferences, for example in decision making or communication, can be very valuable when combined with the variety of design stages and tools applied in the *Collective Design Method*. This is an area for further development.

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