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PRACTICE BASED LEARNING APPROACHES IN COLLABORATIVE DESIGN AND ENGINEERING EDUCATION: A CASE STUDY INVESTIGATION INTO THE BENEFITS OF A CROSSDISCIPLINARY PRACTICE BASED LEARNING STRATEGY

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ABSTRACT
This study explores the ongoing pedagogical development of a number of undergraduate design and engineering programmes in the United Kingdom. Observations and data have been collected over several cohorts to bring a valuable perspective to the approaches piloted across two similar university departments while trialling a number of innovative learning strategies. In addition to the concurrent institutional studies the work explores curriculum design that applies the principles of Co-Design, multidisciplinary and transdisciplinary learning, with both engineering and product design students working alongside each other through a practical problem solving learning approach known as the CDIO learning initiative (Conceive, Design Implement and Operate) [1].
The study builds on previous work presented at the 2010 EPDE conference: *The Effect of Personality on the Design Team: Lessons from Industry for Design Education* [2]. The subsequent work presented in this paper applies the findings to mixed design and engineering team based learning, building on the insight gained through a number of industrial process case studies carried out in current design practice. Developments in delivery also aligning the CDIO principles of *learning through doing* into a practice based, collaborative learning experience and include elements of the TRIZ creative problem solving technique [3]. The paper will outline case studies involving a number of mixed engineering and design student projects that highlight the CDIO principles, combined with an external industrial design brief. It will compare and contrast the learning experience with that of a KTP derived student project, to examine an industry based model for student projects. In addition key areas of best practice will be presented, and student work from each mode will be discussed at the conference.

Keywords: CDIO, cross-disciplinary, practice based learning, knowledge transfer partnerships

1 CONTEXT

The multidisciplinary design team is established as an effective mix of skills for tackling the complex process of design development from concept development through to production. A case study of the European design team at Arup associates was carried out from 2007 to 2009, which followed the Arup design team through the entire process of two products. A distinctive advantage exploited by Arup was the combination of expertise assembled during the design process, which included significant input from designers and engineers working together [4]. Aston University identified the teaching approach of *practice based learning* through a CDIO methodology built on current industry practice, highlighting best practice and a greater understanding of the critical design to engineering spectrum (figure 1). The CDIO initiative is an innovative educational framework for producing the next generation of engineering designers. The framework provides students with an education stressing engineering fundamentals set in the context of Conceiving – Designing – Implementing – Operating real-world systems and products. In universities worldwide, CDIO initiative collaborators have adopted CDIO as the framework of their curricular planning and outcome- based assessment [1].

Figure 1. The student team spectrum of Engineering & Design

The CDIO initiative was the ideal pedagogic vehicle to bring the multidisciplinary engineer and design teams together in a structured team-working format, while allowing students to develop their own processes and team working within the CDIO structure. This followed the industrial case study set at Arup [4]. The new programme of CDIO based learning was introduced at Aston University in 2008 with the important implementation of both BEng Mechanical Engineers and BSc Designers working in mixed teams from the first week of the first year throughout the first two years of their undergraduate studies. This programme is showing very positive feedback through students applying for industrial placements and reporting that the mixed CDIO classes have provided them with skills and experience highly valued by industry, translating to placement offers and excellent feedback from industry employers. Indeed the approach has been commended by the Aston University industrial advisory panel members from Jaguar Land Rover, Proctor & Gamble, Aston Martin and Gillette.

2 METHODOLOGY

Several drivers have contributed to the curriculum developments and learning approaches outlined in this paper. Industrial case studies at Arup associates were carried out into the Arup European product design team, specifically in the team composition, application of the design process and the personalities involved [2,4]. This indicated that mixed multidisciplinary teams working in collaboration could provide both the depth and breadth of understanding well suited to product design and development, with the different personality types in the team working in mutually beneficial ways. The application of this multidisciplinary approach to curriculum design was applied in different ways within similar departments in Aston University and Buckinghamshire New University, with similar student groups, allowing some comparison and examples of best practice to be drawn from the two longitudinal case study approaches, advocated by Yin (2003)[5]. Evaluation is made through the feedback from students and importantly the perception and of industry on the students during and after the projects. Findings from two specific projects are discussed further but it should be noted that this is an on going process, with examples of project outputs being presented at the conference.

3 CASE STUDY 1: CDIO LEARNING APPROACH USING EXTERNAL INDUSTRY BRIEF

Aston University approached the challenge of bringing industry engagement to multidisciplinary student teams through the CDIO learning structure. The Design and Engineering undergraduate programmes at Aston have undergone a major curriculum re development in 2008 with 50% of the first two years of both course routes sharing large project based CDIO modules [6]. This approach requires considerable support in terms of physical resources: team benches and seating, took kits, technical support and out of class workshop support for prototype building and testing, see figure 2.
The academic programme also took into account the professional body requirements of both the Institute of Mechanical Engineers (IMechE) or the Institution of Engineering Designers (IED). This lead to a teaching module delivered across one full day per week with a variety of learning activities filling each day, such as a theory session followed by interactive button test, class exercise and group practicals. The mixture of the session varies and often involves a term long design project with smaller individual projects running concurrently with students being exposed to a variety of design and engineering tools, such a TRIZ (A creative problem solving tool) [3] to help them structure their design thinking and develop their problem solving skills. One such project that represents the combined live project and multidisciplinary team working was that of a medical health product for a local surgeon. Students were split into mixed teams of Engineers and Designers in teams of five or six. The project was generated by early discussion with Aston staff who developed the initial starting brief

after identifying the design opportunity of; ‘*Improving the patient and healthcare practitioner interaction process’* which provided an open and free starting point for the project.

Figure 2. The CDIO student team learning workshop

The surgeon outlined the current challenges and implications for healthcare workers with a number of patient case studies. This external brief brought a welcome realism to the second year undergraduate students in contrast to the internal staff derived projects. Students were tasked with interpreting the brief and presenting their design concepts at an early stage with substantial research and product feasibility. This presentation was to the external client and proved to be highly motivating to the students. While the client was impressed with the presentations and work shown by the students there was some initial disappointment that students had not taken the design opportunities as far as possible. In discussion with the Aston teaching staff and the client it was decided to ask the student teams to submit additional design work. The resubmission was initially a surprise to the students, who had produced a good amount of work in relation to previous university projects, however the external client did not engage with the proposals. The realisation in the student teams that the client wanted more from them was a hugely valuable step that an internal staff lead brief could have not replicated. Student teams reviewed and improved their designs with much more insight into the needs of the client and soon responded with much more in-depth proposals. An example of one student team product for the Healthcare brief was a fully functioning mobile health monitor made using the ARDUINO microcontroller electronics system (figure 3). The device uses a rapid prototyped case and was achieved by a team of four students (two engineers and 2 designers) over eight weeks.

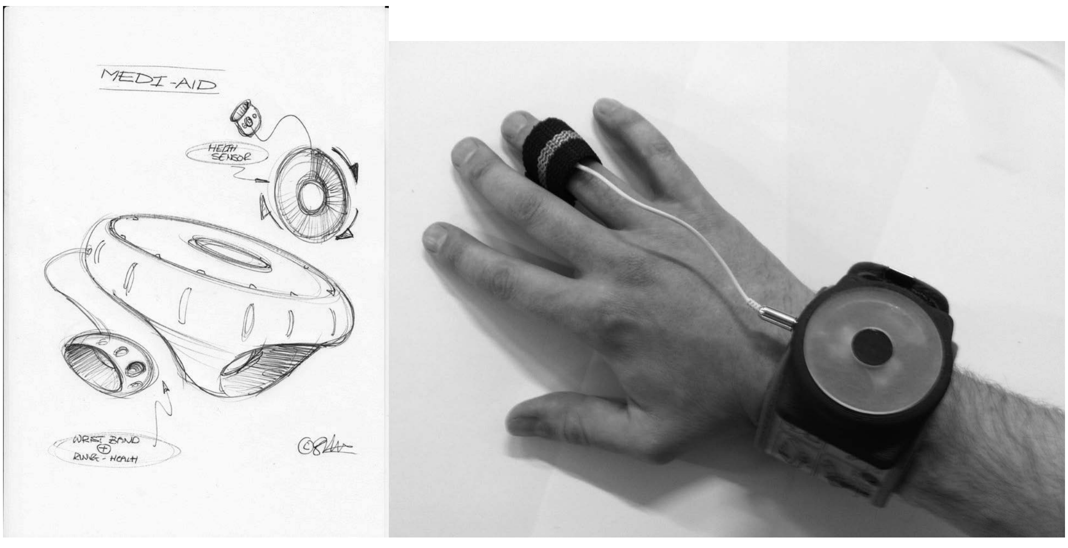

Figure 3. Example of student designs & working Healthcare device prototype

4 CASE STUDY 2: INDUSTRY BASED BRIEF DEVELOPED FROM KTP PROJECT

Student learning through multidisciplinary groups and industry relevant projects was a key focus for both the case studies. Buckinghamshire New University approached the multi disciplinary group working with a project linked to a Knowledge Transfer Partnership (KTP) project that brought the project from the industrial partner into the university and to the undergraduate students. This brought a live design project into the curriculum to reflect the aim of real life experience, which brings its own problems associated with live external projects, but with the aim of benefitting both parties. This live industrial brief required a great deal of coordination, management and alignment from both the company and the university, with both parties learning and developing new techniques form the collaboration, and also gaining great enthusiasm and motivation. The key advantage of linking to the KTP project was the tightly defined timescales and project outcomes, which helped planning, but this also prevented the projects from deviating too much from a pre-defined outcome. The project involved undergraduate design and engineering students designing and developing a new filtered water tap that incorporated an automated filter and feed system; the Quatreau Tap System, see figure 4.

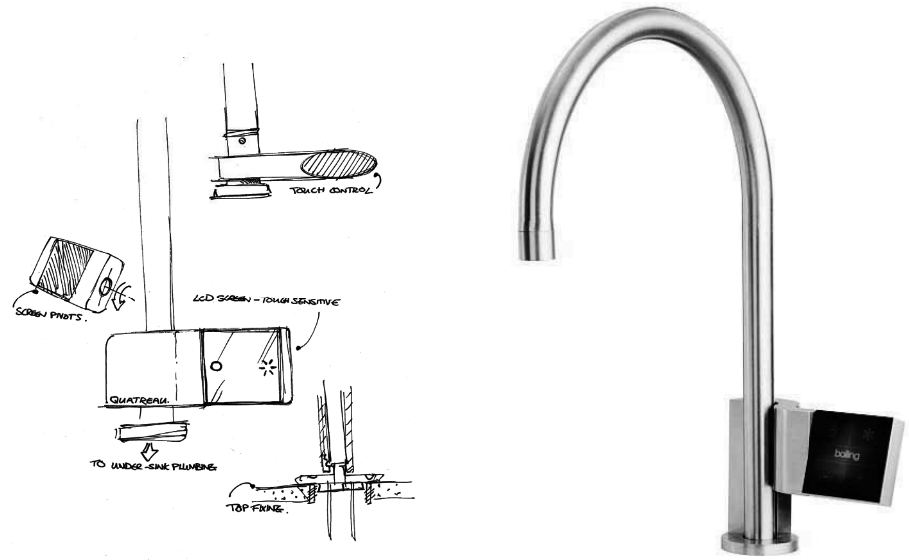

Figure 4. Quatreau Tap System: Development & final product

5 DISCUSSION

The impact of the external client brief had a significant effect on both the student's motivation and their approach to the project. Observations of the teams in action and interviews with the teams showed the students themselves sort greater collaboration between the engineers and designers. One of the Aston University engineering students noted: *'It really made the research key, you needed to ask the right questions of the brief and properly understand every part of the design. This is why having both designers and the engineers in our team really worked, we could develop all the areas for our design, it looked good and worked too.'*

At one point the client requested an additional review having been dissatisfied by the earlier students submission. The Aston staff then arranging additional project sessions and set up new review meetings, not something the students were familiar with on their previous university projects. One student referring to the healthcare project and the client request for an additional presentation noted;

'Bit shocked, we thought we had done everything ok, but then when we reviewed our designs we found so much more to improve, it was well worth being knocked back at that stage.'

At Buckinghamshire New University the KTP based case study provided a rigid prescribed timescale of Key Performance Indicators (KPIs) at set points in the year. This allowed the student case studies to be preplanned and ordered in such a way that they fitted in with the timescales of the modules and curriculum without the need for any last minute changes. This did mean however that the students sometimes felt that they had little influence on the final design outcomes, although this was not the case [7]. Working alongside a graduate designer in real time allowed for factory visits and excellent industry engagement. Generally live projects experience some problems with timings of interactions, causing clashes with the academic timetable causing delays, this has not been a problem in this case. One of the students involved with the project noted: *'We (The students) knew this was a real brief and it was a product that was really going to be made and sold so you could not cheat or hide any bits, it all had to work together.'* This comment was echoed by many of the students and demonstrates the value of an external and 'real' design brief as a motivating factor to student lead learning and engagement.

6 CONCLUSION

The two academic case studies highlighted different ways of approaching the design-to-engineering spectrum, well recognised in modern industry practice such as at Arup. The approach from either engineer or designer is valid but as the CDIO teams show a specialist focus is important. This wider perspective and understanding can prove commercially very effective, and a valuable skill for both engineering and design graduates. The effect is to create the T shaped professional discussed by Karjalainen *et al* at EPDE 2011[8]. We have also observed through collaboration with a number of companies, including Dyson, that design intensive success stories often emerge from the use of multidisciplinary team practices. Multidisciplinary approaches bring together experts from different professional backgrounds and contribute to creation of business through design (Karjalainen et al 2011).

CDIO provides a framework around which projects can be built around, and a network of similar courses running similar project briefs. It also allows sufficient variation in team roles and project outcomes to appeal to a wide range of students from the full spectrum of engineering and design courses. The KTP based project on the other hand is dependent on the flow of the project and on the particular challenges posed by the partnership at any one time – this might be a design, manufacturing, financial or other issue, and this can be hard to predict. This can allow for some very interesting design and engineering challenges and be a very useful learning vehicle for staff and students, but it can be hard to predict and plan for. In some instances it works well for teams from different courses.

The T shape professional developed by Tim Brown of IDEO highlights this combination of multidisciplinary working. The collaboration is not simply using different professionals within their own area of knowledge but encouraging the additional learning of compatible areas of knowledge in a truly team working approach, see figure 5. Clearly CDIO can be a very effective vehicle for both providing the learning structure for external industry design briefs but also gives the opportunity for engineers and designers to work together. This multidisciplinary, live project brief working can bring very relevant and real life experience whilst at university and hence build valuable skills. While the programme is still relatively new and developing the feedback from the undergraduates seeking industrial work placements are showing the approach is valued by industry.

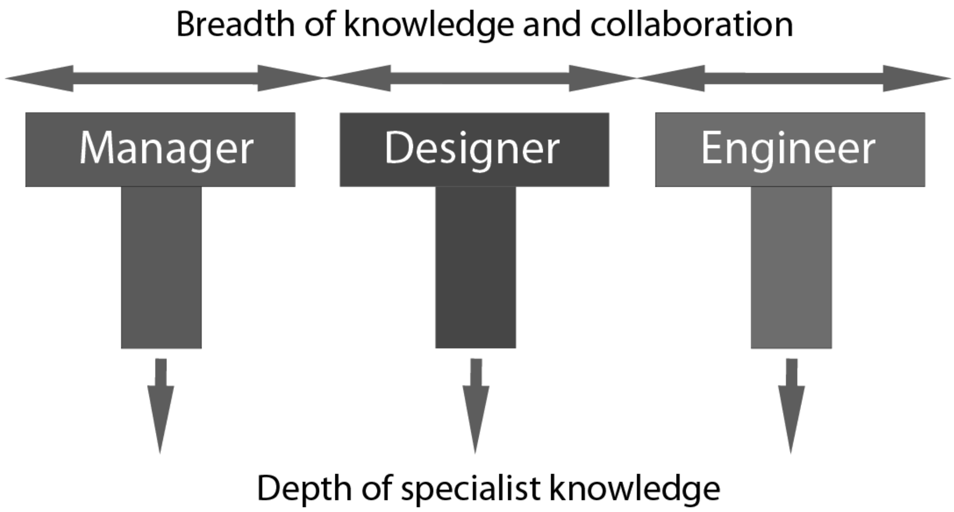

Figure 5. T shaped professionals combining depth and breadth in collaborative working

An Aston University student noted a discussion during an industrial placement interview with a manufacturing company in the United Kingdom; *'I talked about the CDIO classes and the live briefs,* *the interview panel were very interested in the mix of designers and engineers, they saw it as a perfect reflection of industry, so I would be up to speed'*. Another Aston university student noted the following after a placement interview process; '*My placement interview at JCB involved a day long interview, the industry brief was highlighted as a good thing. We were put into mixed teams for the afternoon to run a group design project, I was good at this as I was very used to working in teams with different people from CDIO'*

7 FURTHER WORK

This current study involved Level two second year engineering and design students. 2012 will see a continuation of the industrial derived briefs as well as at level one, first year students also tackling industry set brief. It is anticipated these will need a little more structure and supervision. The team dynamics have been observed as a significant element to a team's success, future studies of these multidisciplinary engineer and design teams will involve more formal personality type evaluation to examine the role of personality within such teams. Further results and conclusions will be presented at the EPDE conference 2012.

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