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DEVELOPING A STUDENT-CENTRED STUDIO CULTURE FOR EFFECTIVE LEARNING AND TEACHING IN PRODUCT DESIGN ENGINEERING.

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ABSTRACT

Product Design Engineering (PDE) is a multidisciplinary course jointly run between Product Design Engineering at Glasgow School of Art and Mechanical Engineering at Glasgow University and is offered as either a 4 year BEng (Bachelor) or 5 year MEng (Master) Degree. All students in Y4&5 (Y4 BEng, Y4 MEng and Y5 MEng) share the same studio learning experience whilst following specific year group curricula and pursuing individual projects.

PDE at Glasgow School of Art has over the past decade evolved a strong student-centred studio culture. This paper provides a general overview of current PDE studio practice and in particular describes the major strands of development in years 4&5 and discusses how the changes have been achieved and potential future developments.

The learning programme for years 4&5 has evolved substantially in recent years to meet the evolving needs of students, industry, academia and the professional institutions. Adjustments have also been made to years 1, 2 and 3 to ensure that learning is relevant, progressive and provides the students with practical skills, intellectual abilities and confidence during their learning process. Together the full 4 or 5 years of studio experience complemented by the engineering subjects learnt at Glasgow University forms a coherent and integrated course, which is capable of producing creative multidisciplinary graduates, ready for industry, business and enterprise. It is this multidisciplinary studio culture and learning process which make PDE distinctive and appealing to students and employers alike.

Keywords: PDE, Student centered studio culture, Design Engineering Folio, multidisciplinary, transferable skills, creativity and innovation, reflective practice.

1 THE NEED FOR CHANGE IN STUDIO PRACTICE

Product Design Engineering has always been a forward-looking profession, capable of rapid response to changing needs and circumstances. Today, industry and markets are undergoing rapid and significant changes in response to diversification in users requirements and a high level of manufacturing mobility. There has for some considerable time existed a demand for a reduction in time to market and the risk associated with New Product Development (NPD). There is no doubt that the companies which bring the right product to clearly identified markets in the shortest time and also produce excellence in design, specification and manufacturing will be the winners in the foreseeable future. Design studio working practices are changing to meet

these challenges and we as educators of product design engineers have a duty to ensure that our graduates are equipped for the challenges and tasks waiting for them in industry and business. The PDE Y4&5 projects provide the students with a realistic experience of a NPD process in a typical industry timescale and with typical industry working practices.

PDE has sought out and investigated best professional practice in the design process. The work of IDEO [**1**] (Kelley 2001), Dyson [**2**] (Dyson 1998), the Design Management Institute, our industry partners, including the PDE Industry Liaison Board, graduates working in industry and the ISO 9001standard [**3**] have all informed and influenced thinking and practice. PDE also has a successful student exchange programme with Product Design at NTNU in Trondheim, Norway. Visiting Professor Stefan Klein from the Bratislava Academy of Art in the Slovak Republic, has enriched the course immensely with his multidisciplinary skills and talents over many years.

The innovation and experience of staff has continued to influence studio-based learning and teaching. Sources such as the Learning and Teaching Support Network [**4**] and the Institute of Learning and Teaching [**5**] have proved valuable references. The studio is staffed by a mixture of full time and part time staff who between them offer a very broad industrial and academic experience and skills base, including design, engineering, enterprise, consultancy, prototyping, manufacturing, management and innovation across many diverse fields. Staff who have this level of relevant experience of working in the profession and who share that experience with their students represents valuable role models for the students to emulate. This is reinforced by visits and lectures/workshops from business organizations and graduates who are active in NPD for today's diverse and demanding markets.

The students themselves are intellectually demanding and sensitive to the relevance and quality of the education they are receiving. They have a strong desire for the best possible learning experience, including the resources, facilities and tools available to them.

In the past ten years, a range of new technologies supporting 3D visualization, simulation and animation as well as rapid prototyping have become available to designers and matured to the point where they are highly relevant and affordable. PDE students benefit from learning to use these and becoming aware of how the future developments of these technologies can influence the profession and studio practice.

2 THE PDE STUDIO

The PDE Studio concept is a broad one. Apart from the physical environment in which students work, the studio also encompasses the practices of research and investigation, experimentation, speculation, reflection and user trials, some of which may take place off site as appropriate. Students often develop collaborations with companies, user groups and other universities/academic departments and will from time to time have access to external resources through these collaborations. This makes for a very rich learning experience suited to the endeavours of individual students, which can then be shared with the whole student cohort. Throughout this work, students are encouraged to develop a professional style of working, to broaden their outlook/experience and to learn from the professionalism of other disciplines.

The studio environment is very important. Each student has a dedicated desk, pin up space and flat work storage. Dedicated spaces are available for group tutoring, prototype trials and small group meetings. Computers are provided in the studio, running a range of advanced design tools such as CAD and analytical software as well as web access.

Students have access to all the usual HE resources plus well-equipped workshops staffed by highly skilled technicians. The studio exercises both left-brain and right brain aptitudes as well as eye-hand-mind coordination and application of engineering theory and knowledge, leading to a multi disciplinary skills set which is highly attractive to the students, their clients and industry.

3 THE PDE ANNOTATED DESIGN ENGINEERING SKETCH FOLIO

The PDE Annotated Design Engineering Sketch Folio is central to the studio learning practice. The inspiration for the folio has been the visual work of the Scottish engineer James Nasmyth and the sketchbooks of Brunel. Earlier annotated work by Leonardo has also had an influence. The folio now forms the main deliverable for PDE, supported by 2 A1 posters (visual project summary) and 3D work. The students are working to a Folio specification, which details the required contents of the Folio and the studio curriculum. The Folio is a fully annotated visual record of the students learning and design process. It is more formal than a sketch book, being closely linked to the stages of the design process and the learning outcomes. By visualizing and annotating their creative ideas and the applications of engineering theory with calculations in the same manner as Nasmyth and Brunel, the students assimilates best practice and gain a better understanding of their own learning and how the different learning elements fit together. This reflective practice and externalizing of the creative and learning processes provide the students with a deeper insight into how they learn and how to relate this cognitive process to others. There is immense value in being able to present ideas in appropriate media and in a manner which allows others to understand the ideas.

The Folio may be used for presentations and formative assessment at interim stages. The Folio is also used for end of year exam presentations, degree shows and as a very effective presentation tool at job interviews.

The students have available to them examples of previous students Folios, which provide benchmarking of standards as well as inspiration and encouragement. Both hand drawing and computer-based drawing are equally acceptable. The folio provides the students with a record of and template for their transferable skills.

4 PROJECTS AND STUDENT INTERACTION WITH CLIENTS

The Y4&5 year students have a high degree of freedom in their choice of project (albeit with tutorial guidance) and the studio practice has an element of one to one teaching focusing on the individual learning needs of each student as well as group tutoring for general learning needs.

Student motivation and ownership of their projects is strongly promoted. Students undertake 8 month long individual projects in years 4 and 5. The project identification process starts several months before the projects start. Students research and investigate an area of their own interest and make contacts with people working in this area. From this a project proposal is generated and discussed/evolved in consultation with staff. Students make contact with potential clients within their chosen area, leading to live client interaction throughout the project. This mechanism ensures that projects are based on real life issues, which gives the students a realistic experience of designing products for real people and solving real life problems.

The students are encouraged to expose their work to independent 3rd party elevation and to reflect on their own learning process and outcomes. [**6**] (Schøn 1984)

5 CREATIVITY AND INNOVATION

Creativity and innovation is an essential part of the studio experience, in fact the studio is a creativity and innovation factory. Creativity and Innovation at work [**7**] (West 2000) proposes the following preconditions for creativity and innovation: High creativity in individuals, diversity of knowledge bases, external threat and challenge, organizational commitment to innovation, processes that support innovation, mutual trust in teams, acceptance of failure as well as success, clear targets combined with freedom from rigid rules, conflict resolution through constructive controversy and hard debate in an atmosphere of mutual respect and co-operation. Most, if not all, of these preconditions are present in rich measure in the PDE studio. The studio and the projects represent a supportive and challenging environment where the freedom of choosing and executing the project is matched with an equal level of responsibility and maturity. The studio and project 'rules'/deliverables and expected learning outcomes are simple and clear, communicated at the beginning of each session, yet allows considerable scope for individual freedom. These findings are strongly supported by the author's observations from a wide range of NPD/creativity and innovation projects in industry.

Students use various creativity-generating techniques such as brainstorming, mindmapping, Osborn's list, incubation and cyclical, subconscious, Kaisen and deconstruction/reconstruction creativity. The students also make use of thought organizing software, which supports brainstorming and mind mapping and allow them to order chaotic thinking into logical arrangements (Mind Genius and Inspiration). It is widely recognized that students who are dyslexic are also highly creative. This has been noticeable within PDE and such students have through an enhanced awareness of their creative strengths been able to capitalize on it in their work. Mind Genius and Inspiration has proved particularly useful not only for these students, but indeed for all students. Creative thinking is often chaotic and intuitive with subconscious gestation periods, having these tools available makes it very easy to put chaos into order as the creative process develops.

6 TEAMWORK

As well as working individually on their projects, the students are encouraged to pool their resources and undertake research and evaluation of concepts as a team activity. Student peer groups undertake structured brainstorming sessions for each project at various stages of the project. Peer evaluation and support has proved highly successful in bringing forth excellence in project work and benefits in learning by reducing the sense of isolation in working individually and replacing it with a confidence building sense of peer support [**8**]. Projects are clustered to promote student interaction.

7 DESIGN, BUILD, TEST, EVALUATE, MODIFY

This iterative activity is at the center of the design process and is applied by students at both concept and detail design stages, covering full scale mock ups of product layout to test human factors and technical feasibility. Prototype mechanisms are built to refine design and verify engineering/technological assumptions. MEng students are required to build working prototypes of their products and subject these to appropriate testing. Over the years the level of achievement in this area has increased significantly and in many cases the students are delivering designs to 'proof of concept' stage.

Testing prototypes with users for high quality feedback is used extensively throughout the design process and the author has witnessed the generation of crucial design data, information and suggestions from such user trials. This process allows the coming

together of important fragments of insights which previously resided in the minds of several individuals and the combination of them in the domain of the student's project Folio to form a sound and well informed basis for the advance of their design.
The design process followed in the PDE studio is an amalgamation of the IDEO 5-step innovation process IDEO: Masters of Innovation [**9**] (Myerson 2001): Understand, observe, visualise, evaluate and implement and the Design Management Institute design process. These represent a simple, open and common sense approach to managing the design activities in the studio and allow the students freedom and latitude in their work. Students are free to adopt methodologies of their choice and the recommended text is 'Design Methods in Engineering and Product Design' by Professor Ian Wright [**10**] (Wright).

8 ADVANCED DESIGN TOOLS

Students have available to them a wide range of design tools, such as:

- Cad packages with facilities for structural and stress analysis
- Rapid realization tools: 3D printing and FDM rapid prototyping (RP)
- Creativity and mind mapping software
- Plastics moulding simulation and analysis
- Illustration, simulation and animation software.
- Virtual prototyping

Recently installed equipment includes a large flat bed 4-axis CNC router and a 3D Laser Scanner. This allows students to explore a wide range of routes to realisation of their designs. PDE has also successfully made use of other RP processes and secondary processes such as bronze and aluminium castings from RP patterns for prototype components.
A new course in Advanced Design Tools for the year 5 MEng students covering IT based aids to the design process is currently in development by the author and colleague Craig Whittet. This course will provide a broad overview of the emerging technologies combined with selective application in the projects. The applications have already started to appear in the student's projects due to the availability of the above equipment for the students use across the whole of PDE. There is a clear need to develop and evolve this aspect of studio learning and teaching and at the same time retain and reinforce traditional practices of visualization and realization.

9 THE STUDENTS EXPERIENCE OF THE STUDIO

The students benefit from working in a very positive and supportive environment. They have a high degree of freedom in choosing their project area with tutorial support and guidance. This contributes to their enthusiasm and ownership, which is a major motivational and driving factor during the final year projects. With this freedom comes an expectation of maturity and responsibility appropriate for developing young professionals.
Conflict resolution plays a role in the students experience in that they have to manage and resolve many conflicting requirements and advice from different disciplines while bringing it all together to create a product which meets the user and market requirements which can be manufactured and sold at a realistic price. Also, because the course is delivered jointly between two different institutions, the students have to achieve a happy balance between the two cultures and resolve any conflicts that arise between being a designer and being an engineer (In fact from being multidisciplinary). They usually achieve this transition to becoming Product Design Engineers with pride

and the conflicts they experience on the way may actually help to form their professionalism and confidence in their particular multidisciplinary skills, which are distinct from those of their peers on other courses. Both [**7**] (West 2000) and [**11**] (Gale and Linsdell 2003) mention the presence of conflict and its resolution as one aspect of the creative process. West proposes that: 'Innovation is also often caused by conflict. It is diversity of views that generates the friction and energy for innovation. Groups need some grit to fashion pearls'. Gale and Linsdell describe a congruent example of such dynamics in a project where artist and engineers experienced wide diversity of knowledge and approach and had to share this diversity and accept each other's differences before real creative processes could develop and succeed. Learning to become a multidisciplinary professional involves much the same kind of conflict experience and resolution. The author's observations from industry and academia support these findings.

The project represent a substantial challenge to the students and is a significant step up in expected performance level. In rising to this challenge the students have an opportunity to individually synthesize all that they have learnt with their creativity, drive and flair. This is a maturing process and a formative experience, which produces the rounded, multidisciplinary individuals, which are Product Design Engineers. The student centered studio helps to develop the individual confidence which allow the students to succeed in their challenges.

10 PROFESSIONAL QUALIFICATIONS

The PDE MEng course is fully accredited by the Institution of Mechanical Engineers (IMechE). It is worth noting that at the first accreditation in 1991 the IMechE commented that:' PDE brings back the joy and creativity into engineering'. Since then the ImechE have focused more on the technical aspects of the course.

However with the Engineering Council UK inspired UK-SPEC [**12**] having superceeded SARTOR 3 on the 1 March 2004, a much broader basis for awarding chartered or incorporated status has been established. At the introduction of UK-SPEC, Lord Sainsbury of Turville, the Parliamentary Under-Secretary of State for Science and Innovation stated: *'The UK economy depends on improved business performance, which in turn relies to a great extent on the competence of our engineers and technicians. The UK has a proud engineering heritage, but in an increasingly competitive world our engineering competence must reflect the needs of business and industry for astute and experienced creators and managers of technology'.*

Lord Sainsbury goes on to outline a professional code of conduct for engineers, on the basis that engineers have a professional commitment to society, to their profession and to the environment. Specifically that development should not cause problems for safety or health, minimize risk to the environment and encourage worldwide sustainable development.

The primary statement on Chartered Engineer provides the following definition: *'**Chartered Engineers** are characterized by their ability to develop appropriate solutions to engineering problems, using new or existing technologies, through innovation, creativity and change. They might develop and apply new technologies, promote advanced designs and design methods, introduce new and more efficient production techniques, marketing and construction concepts, pioneer new engineering services and management methods. Chartered Engineers are variously engaged in technical and commercial leadership and possess effective interpersonal skills'.*

Whilst significantly broadening the criteria for registration at Chartered and Incorporated level, it is equally clear that the stringent requirements for technical and theoretical expertise remain in force, maintaining a sound foundation for the profession
The strong forging together of engineering competence with innovation, creativity, design, technology, production, construction, marketing, management, technical and commercial leadership, social and environmental commitment and effective interpersonal skills is to be welcomed. This combination is sound and is almost congruent with the multidisciplinary skills set that PDE has endeavored to achieve in our students for a considerable time. The missing elements are those of products and enterprise. Neither Lord Sainsbury or UK-SPEC make use of the words product or enterprise, which is to be regretted, however there appear to be strong allusions to products, enterprise and enterprise culture in both.
The effects of UK-SPEC on course accreditation is as yet unknown, however the close alignment between the requirements for Chartered and Incorporated status with the PDE Curricula would indicate that PDE may be well placed to bring forward the talented, creative and well rounded professionals described in UK-SPEC and hopefully there will be recognition for this at accreditation.

11 THE ENTERPRISE FACTOR

A number of enterprises have been created by PDE graduates:

- SPECK Design, Palo Alto, California 1992
- 4C Design, Glasgow 2002
- Fearsome Engine, Glasgow 2003
- Tierney and Farish, Edinburgh 2003
- Core Design, Glasgow 2004.

Core Design consists of two Y5 MEng students who are the winners of the 2004 Big Idea business plan competition by the Scottish Institute of Enterprise, and the prize provides financial/business advise, IPR protection as well as £5750 towards the business start up costs.
In addition there have been considerable business/industry collaboration in the year 4&5 projects and a number of patent applications and design registrations have been made. With IPR protection, in place commercialization is being pursued in some cases.
Although there is now a greater awareness of the wealth creating power of design and an enterprise culture emerging in society, there remains a large untapped potential for enterprise based on the IP generated in some student projects. For this to succeed there needs to be a more determined and consistent funding of IP protection, commercialization effort and business start up facilities. A PDE/NPD Incubator would be a logical and beneficial development for PDE.

12 CONCLUDING REMARKS

The PDE studio has achieved much in terms of making the learning and teaching of Design Engineering enjoyable and effective as well as giving students a realistic experience of a professional working environment. The significant elements are: Studio practice emulating a professional working style and environment, ownership, motivation and support, process and design tools, folio, a high degree of individual freedom coupled with challenge and appropriate maturity and responsibility, interaction with clients, 3rd party evaluation and reflective practice.

In light of the recently published UK-SPEC, which replaces Sartor 3 the PDE studio is well placed to meet the much broader requirements for professional registration at either Chartered or Incorporated Engineer Standard.
The studio is recognized by students, graduates and industry as a stimulating, supportive, challenging and relevant learning structure/environment that allows time and space for creativity, speculation and reflection and is capable of achieving excellent results.
The changes to the studio learning programme have resulted in consistent overall high quality of achievement by students. There is evidence of significant improvement in individual student performance. Generally the level of student engagement, motivation and enthusiasm has shown a marked improvement. The commercial exploitation of IP generated within PDE could become a beneficial development. Further challenging and interesting developments exist within creativity and innovation, studio learning and teaching, including assessment, advanced design tools and managing the design process.

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