Simulation Action Learning (SAL):
A Methodology for Teaching Design Thinking

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Abstract

Problem-based learning (PBL) is now regarded as being one of the most noteworthy innovations in the area of education for the professions. The approach had its beginning in the education of medical students but has since been adopted in many other disciplines such as engineering, and has become part of mainstream pedagogical thinking. Recently there has been a body of literature on the subject of using simulation-based learning (SBL) as an enhancement of PBL. However, much of the current literature largely confines simulation-based learning to computer applications such as games. Nonetheless some scholars have emphasised that simulation-based learning is a *technique* not just a *technology*. Consequently, this ongoing work aims to make a contribution by transferring the simulation concept to engineering education. The paper proposes the idea of simulation-action learning (SAL) as an enhancement of PBL to distinguish it from computer simulation. It outlines how this approach is being implemented to inculcate Design Thinking in a capstone module of a Mechanical Engineering Product Design Stream.

Keywords

Design thinking, product design, pedagogy, PBL, SBL, simulation-action learning.

1. Introduction

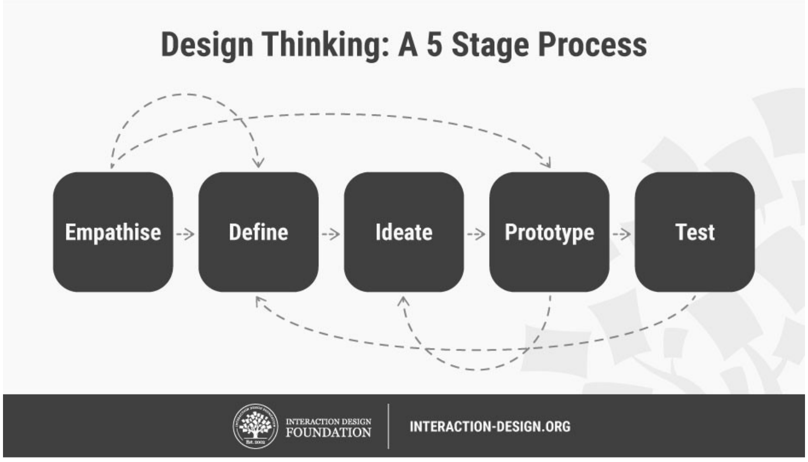
Some scholars of Design Thinking argue that design is difficult to learn and even more difficult to teach (Dym, Agogino, Eris, Frey, & Leifer, 2005). Previously Boud and Feletti (1998 p.1) had argued that “problem-based learning (PBL) is the most significant innovation in the area of education for the professions in many years”. The focus in this type of learning is to provide the students with problem scenarios so that they can learn through a process of action and reflection (Savin-Baden, 2003). PBL had its beginning in the medical field but has since been adopted in many other disciplines and become part of mainstream pedagogical thinking. Currently there is a nascent body of literature that advocates using simulation-based learning (SBL) as an enhancement of PBL. In the literature, the concept of SBL is almost completely restricted to the field of computer applications. However, this paper argues that the practice of using simulation in the learning process is a *technique* rather than just a *technology*. Consequently, it proposes the novel concept of simulation-action learning (SAL) to distinguish it from the term SBL associated with the computing disciplines. The work describes an empirical study of SAL currently being implemented in a capstone module of a Mechanical Engineering Product Design Stream. This paper builds on Design Thinking (Cross, 2000, 2011; Eppinger, 2001; Ulrich & Eppinger, 2004) and proposes to enhance the methodology by directly interfacing and simulating a real-life design interaction for the students.

The paper proceeds as follows. First the background literature in the areas of design thinking, problem-based learning and simulation-based learning is reviewed. Following this the methodology and the research approach is discussed. Finally conclusions and recommendation for future work are proposed.

2. Design Thinking

Design Thinking is as old as civilisation but formulation of design as a formal process is of more recent origin. For example Alfred North Whitehead, the British mathematician, logician and philosopher once remarked that the greatest invention of the nineteenth century was *the invention of the method of invention* (Chesbrough, 2003 p.22). The modern formulation of Design Thinking is often traced to the seminal publication by Herbert Simon of *The Sciences of the Artificial* (Simon, 1996). According to Cross (2011) design is a journey to explore and discover something new; but it is a complex journey. Furthermore he points out that coping with uncertainty is a key aspect of design ability and contends that if you prefer "the certainty of structured well defined problems you will never appreciate the delight of being a designer" (ibid. p. 148). The importance of a design team in the modern complex environment is stressed by Cross who describes design as "as a shared social process" (ibid. p. 20) that is essentially episodic involving lots of "skirmishes with the problem at hand" (ibid. p. 21). Citing designer Gordon Murray that design is "1% inspiration and 99% perspiration" (ibid. p. 74) and that very often people at the beginning have a great idea and then they lose interest when making progress becomes challenging. Furthermore Gedenryd (1998 p.28) argued that "classic methods of reasoning in problem solving are inappropriate in design". The Design Thinking model proposed by the Hasso-Plattner Institute of Design at Stanford (d.school, 2017) consists of five stages: Empathise, Define (the problem), Ideate, Prototype, and Test shown in figure 1.

Figure 1 : The 5 Stages in the Design Thinking Process (Dam & Siang, 2017)



In the area of information systems the paper by Hevner *et al.* (2004 p.75) provides "a concise conceptual framework and clear guidelines for understanding, executing and evaluating design science research (DSR)". Furthermore March and Vogus (2010 p.196) argue that design is fundamental to the management disciplines as managers "are engaged in the design and implementation of business systems aimed at improving organisational performance" .

3. Simulation as Learning

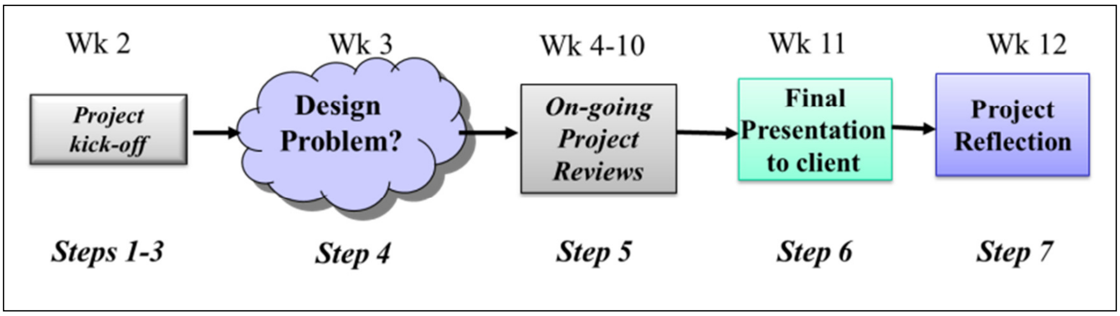
The Oxford dictionary definition of simulation is as follows: to “imitate the appearance or character of” (ODE, 2006). While the entry does refer to computer modelling as an application of simulation, I will use the broader definition to argue that the etymology of the word implies a much wider concept than that of computer modelling and the digital learning debates (Eck, 2006; Prensky, 2001). Recently there has been a body of literature in the field of medicine on the subject of using simulation-based learning (SBL) as an enhancement of PBL (Cant & Cooper, 2010; Lateef, 2010; Steadman et al., 2006). PBL had its origins in 1968 in a medical program at McMaster University in Canada and subsequently was adopted in other disciplines such as engineering (Smith, Sheppard, Johnson, & Johnson, 2005). Its influence on medical education and training is supported by the fact that Stanford has a Center dedicated to its study (CISL, 2016). Simulation is being used to increase nurse’s self-efficacy and skills (Fadale, Tucker, Dungan, & Sabol, 2014) while a review of simulation-based learning by Cant and Cooper (2010 p. 3) concludes that simulation “using manikins is an effective teaching and learning method when best practice guidelines are adhered to”. In the area of surgery simulation-based learning models attempt to replicate an environment similar to real life surgical situation (Khunger & Kathuria, 2016). Importantly for my argument, Lateef (2010) emphasises that simulation-based learning is a *technique* not a *technology* designed to “replace and amplify real experiences with guided ones, often "immersive" in nature, that evoke or replicate substantial aspects of the real world in a fully interactive fashion”. Consequently, this paper proposes to make a contribution by transferring the simulation concept from medicine to engineering education in a similar way that PBL migrated from medicine to engineering. Recently the topic of simulation as a learning experience has emerged in the management literature where for example Lu *et al.* (2014) found that students considered SBL to provide a richer learning experience than conventional methods such as lectures. They also proposed that SBL addressed the increasing criticism with the management literature on the relevance of much educational pedagogy in the field. In the area of teaching entrepreneurship to management students the role of the teacher changes from that of a presenter to that of a “coach” (Cadotte, 2014) which is also adopted in this engineering study. Deegan *et* *al.* (2014) in their paper on the role of simulation-based learning environments (SBLE) in public management curricula, proposed out that it addresses the genre of “wicked problems” and complexity which Lindblom (1959) had examined a few decades ago .

4. Methodology Employed

The product design module taught to the mechanical engineering students can be described in a number of steps which are presented in figure 2 together with the high-level timeline (note that the timeline is indicative and can vary from project to project).

Step 1: The lecturer makes contact with an industry based partner to establish possible projects in advance of the commencement of the term. This includes the incubation start-ups such as the Innovation Hubs (2017) and also local small and medium sized companies (SME) and large multi-nationals with a research capability. Partners have also included not-for-profit enterprises.

Figure 2: High Level Module Roadmap



Step 2: The lecturer meets with the client to further explain the pedagogical approach and to clarify requirements and deliverables. This is an important stage in developing a relationship with the practitioner at the beginning of the three month interaction. However it is worth stressing that work for the practitioner is kept at a very reasonable level given their busy workload.

Step 3: The practitioner completes a short description of the design problem (see figure 2) and sends it to the lecturer to review. This draft design brief is made available to the students via Moodle (an on-line eLearning application). The lecturer meets with the class and presents an overview of the module learning outcomes and the structure of the project as well as assessment criteria and expected project logistics. Then the class is divided into project teams (normally three students per team) and they review the draft design problem and prepare for a meeting with the practitioner on the following week.

Step 4: The class project teams meet the practitioner (who assumes the role of a real-world client) face-to face. The client presents the design problem to the class verbally with more detailed description than in the design brief. This provides an opportunity for the class to get a more in-depth view of the clients thinking and to put themselves in the client's shoes (Leonard & Rayport, 1997). Also the project teams have time to question the client based on their initial week long research into the problem domain. At this stage a date will be set on which each project team will present their design solution to the client at the end of the semester Also issues like Intellectual Property (IP) are discussed at this point and in some cases the students are asked to sign a non-disclosure agreement (NDA).

Step 5: Each week the project teams present a status of their work to the lecturer who in this type of pedagogy acts as a coach and advisor rather than the conventional lecturing mode. The project teams work on the design problem during the semester using academic and industry standard product design methodologies (Cooper, 2001; Eppinger, 2001; Ulrich & Eppinger, 2004). The project teams initially complete a detailed project plan in the form of a Gantt chart before undertaking the main task of concept generation.

Step 6: The class project teams present their design solutions to the client and lecturer through oral presentation and a project report. Distribution of marks is the responsibility of the lecturer who, however, takes into account feedback from the client on the quality and relevance of each project. The project deliverables include such items as: a set of working drawings, computer-aided design (CAD) models and/or renderings. An artefact such as a mock-up of the design in cardboard or other materials is encouraged but not mandatory. This early development of an artefact is now sometimes called preto-typing in the literature and it is also referred to as "fake it before you make it".

Step 7: Reflection and feedback from the students is built into the module review process. In the week 12 class of the module each student is required to do an assessment of their own contribution to the project. The rationale used for this is based on the lecturer’s experience (twenty years as an engineering practitioner) of having to complete end of year reviews. This feedback is important for the lecturer who is continually endeavouring to improve the module content and process year-on-year. Each team project is assessed and the same mark given to all students in a project team with 10% of the module marks for the presentation and 20% for the report and 10% for the individual review. Typical project assessment criteria include: Innovation, Technical Content, Feasibility, Teamwork, Construction of an Artefact and the Presentation of the project. This section has outlined the process used to simulate a real-life design experience for undergraduate mechanical engineers in their final year product design stream. Now I will describe some of the conclusions resulting from the work.

5. Conclusions

Design thinking is having an increasing impact not only on the world of product design but on a wide variety of disciplines as far afield as IT, Business, Education and Medicine (Dorst, 2011). This paper provides an example of using student-client collaboration in the teaching of Design Thinking to Mechanical Engineering final year students. There were a number of learning experiences in this study: by the students; by the lecturer and the industry partner. Additionally, the act of writing of this paper provided a reflective learning experience for the author. The module structure, described here, has embedded Design Thinking in the GMIT department of Mechanical/Industrial Engineering. Working directly with an industry-based client is a novel pedagogical approach that fosters Design Thinking and behaviour among the students. Furthermore key stakeholders in industry have been persuaded to engage in the learning process. Reaction to the project was positive as the students appreciated the opportunity to work in a *simulated* environment similar to what they would encounter in industry. Students were particularly pleased that their work might be implemented in a real-world product and not just be archived as another class project. The current literature largely associates simulation-based learning to computer applications such as games. However, this paper disagrees with Chang *et al.* (2008) who identify SBL as solely computer based, and argues that role playing by students interfacing with technology start-ups can also be regarded as “simulation” in a wider sense. This study is set against the background painted by Gavin (2011) which I will quote here:

> Engineering education is in a state of flux, with universities facing requirements from industry to develop graduates with a wider skills base, while at the same time a revolution in the availability of information is changing the way that students learn (p. 547).

To address this, I propose the concept of *simulation-action learning* (SAL) for engineering students as an enhancement of problem-based learning and the empirical evidence presented in this paper supports this argument. It also contributes to the what Gattieab *et al.* (2011 p.521) call the cultivation of engineering education “as a complex system that will prepare students to think critically and make decisions with regard to poorly understood, ill-structured issues”.

6. Future Work

The pedagogical process outlined above was initially developed through projects carried out with start-up companies in the Innovation Hubs. The next step is to trial the simulation process in a large company and a project is currently being carried out in conjunction with Thermo King (2017), which was established in Galway, Ireland in 1976 and presently employs over 500 people. The Galway subsidiary is now the headquarters of Ingersoll Rand's Europe, Middle East, India and Africa (EMEIA) region. Originally set up as a manufacturing location, it has recently added Research and Development of the next generation of truck and trailer refrigeration units to its Galway capabilities. The opportunity to complete a project in a real life product development environment, albeit in a controlled manner, has the potential to be a very beneficial learning experience for the final year students and help prepare them for their future careers. It is hoped to report on this project in future academic publications.

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