AN INSIGHT INTO THE USE OF PROBLEM-BASED LEARNING WITHIN DISTRIBUTED DESIGN STUDENT PROJECTS

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ABSTRACT
As technology is evolving, the complexity of design projects is increasing. Hence, it is becoming imperative to employ distributed design, which allows people from different academic backgrounds, cultures and disciplines to work collaboratively towards the development of a viable solution to a specific problem.
The objective of this paper is to provide an overview of the experience gained by students while integrating various tools to enhance learning and the utilisation of various elements of a student distributed design project. Students at four different universities across Europe tackled the challenge of finding the optimal way of deploying design, management and engineering expertise with the aim to solve the open-ended problem of designing a more effective and innovative aeroplane seatbelt. Students engaged using different online communication tools in order to share thinking strategies and specific domain knowledge with regard to the use of various design methods, which was essentially problem-based learning. The open-ended nature of the project allowed each team the freedom to have its own unique vision; this enabled participants to explore a range of different tools for various stages of the design process.
This study will provide an in-depth analysis of the experience gained during the design of the aeroplane seatbelt. The project represented a valuable platform for learning due to the exposure to the challenges encountered while working as part of a distributed design team and the familiarity gained on the benefits and constraints of the various design methods employed. The insights presented will form the foundation for the development of a group decision-making framework within the more challenging environment of the EGPR-NARIP 2016 project and real-life problem-solving.

Keywords: Distributed design, problem-based learning, open-ended project, communication tools, design methods, European Global Product Realisation (EGPR).

1 INTRODUCTION

Skill deficiencies are found to have a substantial impact on new product development and business growth. Specific gaps were identified in problem solving and application of theory to real problems [1]. Problem-based projects encourage students to work on a simulated problem that closely resembles a real-life situation in order to gain significant knowledge that is more applicable to reality than the methods employed within conventional learning. Problem-based learning is characterised by leaving students to their own devices in an attempt to foster retention of content, higher order thinking, problem solving skills, self-directed learning and confidence. Several studies have shown that graduates who had participated in problem based learning projects applied problem solving skills much more efficiently in their future workspaces than traditionally taught students; these students had to be trained for an average of a year to reach the same level of proficiency. It was highlighted that this type of learning enhances problem solving skills by as much as 30% when compared to traditional methods [2]. However, it is worth noting the fact that other studies indicate that an increased work load would affect the participants study routines. This effect was observed by Moust *et al.* in the 2005 evaluation of problem-based learning study teams where the students indicated that they enjoyed the format but the increased work load disturbed their customary study rhythm [3].

Distributed teams of skilled individuals are becoming ever more necessary as globalisation increases [4]. There is a particular combination of skills that marks out the engineering graduate of the future and underpins the roles that industry will need such graduates to undertake: firstly, the role of the engineer as a specialist – technical experts of world-class standing; secondly, the engineer as an integrator – operating and managing across boundaries in a complex business environment; thirdly, the engineer as a change agent – providing the creativity, innovation and leadership to shape industry for a successful future [1].
There is a need for multidisciplinary teamwork; the boundary between design disciplines is fuzzy, there is a movement trend from individual product to system development [1]. In order to improve students' expectations of real-life projects and increase their learning capabilities, the global design project of designing a more effective aeroplane seatbelt was conducted. This paper aims at exploring the experiences of three of the six teams that participated in this undertaking. The objective is to demonstrate how distributed environment corroborated with problem-based learning enhances team working practices such as project/time management and communication skills.

2 IMPACT FACTORS ON PROBLEM-BASED LEARNING

Problem-based learning requires students to solve composite and realistic problems that enhance the development of content information as well as problem-solving, rationale, communication, and self-assessment skills [5]. There are several factors that act upon problem-based learning, which shall be discussed in the following sub-sections.

2.1 Educational Background

Educational background can be identified as one of the most significant aspects affecting the task, given that students were enrolled on different courses, as shown in Table 1. This fact meant that each team member had a diverse set of skills, methods and working tools to address the given challenge. This meant that students had to come to an agreement regarding the most appropriate method to apply to each given design stage, which enhanced the problem-based learning. For example, design engineers employ a very iterative design process when compared to mechanical, electrical, aeronautical and industrial engineers who prefer a more linear approach.
Problem-based learning corroborated with open-ended projects represents a novel teaching method within university studies, stimulating students to take responsibility for their own learning and giving participants the opportunity to model a distinctive approach to tackling real-life problems. Characterised by relatively few traditionally taught lectures, problem-based learning enables students to build upon the educational/work background built in previous years. For instance, for one of the participants, the experience gained as part of a group working on the conceptual design of an airliner helped develop a structured approach to tackle the concept generation phase of the seatbelt design project. While focusing on a minute piece of equipment, it was possible to break the design into components in the same way an aircraft design can be split into wings, body, systems, interior etc. With no previous knowledge of morphological charts, the thinking process behind the visualising each of the components pertaining to a seatbelt could be initiated.

Table 1. Participating student teams' composition

Gender	Group 1	Group 2	Group 3
Females	4	3	2
Males	6	7	8
Course			
Mechanical Engineering	1	1	1
Aeronautical Engineering	1	0	0
Electrical & Electronic Engineering	0	1	1
Industrial Engineering	3	4	4
Product Design Engineering	2	3	2
Innovation Management	3	2	2

2.2 Culture

Culture can manifest itself in the characteristics of organisational structures. It operates at organisational as well as national levels. The focus of the culture in this case is on the design teams. Working in multi-national teams increases the diversity of cultures, hence diversity of thoughts, experiences, and ideas. While conducting the project, it was discovered that culture does not represent an obstacle to cooperation; on the contrary, given the professional environment, teams tried to develop their own code of behaviour, meeting etiquette and basic rules and procedures, and, by adhering to them, they achieved a seamless project experience, at least from an organisational point of view. The only minor drawback of multi-cultural teams is the presence of a language barrier, which makes communication slightly more challenging; however, this can also be seen as an advantage, as students enhance their problem solving skills in order to overcome the barrier.

2.3 Team Dynamics

In a professional environment the dynamics of a team can affect anything from the profitability of the company to its reputation. The definition of team dynamics states that it is the unconscious, psychological forces that influence the direction of a team's behaviour and performance. They are like undercurrents in the sea, which can carry boats in a different direction to the one they intend to sail [6]. Team dynamics have a significant effect on the team's behaviour and performance. Factors that influence it include personalities and working relationships within the team, the operation strategy, and its organisation. Good dynamics in a distributed design team can bring the best out of individual members which in turn will improve efficiency and performance, while bad dynamics can lead to demotivation and conflict preventing the achievement of the common goal.

A fine balance between skills, personalities and management must be achieved in order to attain an effective team. An ideal team member would display social skills such as flexibility, understanding, reliability, commitment, openness, etc. These skills often do not come naturally, hence adaptation is crucial. The fact that the project is distributed geographically only presents a greater challenge for the students to overcome, since members' interactions are limited and, in many cases, more formal. The fuzzy front end nature of the project meant that specifications were not rigid, which led to various interpretations. This is where team dynamics play an essential role, as students must communicate their ideas, give constructive criticism and make non-biased decisions so as to reach a common consensus on which direction to take the project.

Leadership characteristics in new product development teams affect the learning, knowledge application and subsequently the performance of teams. Selected team managers were faced with the challenge of structuring and allocating tasks. In this situation, personality plays a vital role. For example, if a manager needs one mechanical engineer but has three to choose from, he might rely on personality to make the final decision, possibly putting the more proactive person in a more active role and getting the other two to help him. However, this approach is not always the most constructive, due to the fact that the engineer's pro-activeness might exceed his technical ability. In problem based learning, the manger gains the capability to see the bigger picture, discipline, structure the process and utilise intuitive thinking skills.

2.4 Distributed Design

Given the distributed nature of the project, it was important to understand that coordination is crucial to achieving a fully integrated solution. Coordination refers to skills, actions and tools used for communication and information storage.

Teams observed that the main factor that contributes to the realisation of the distributed design process is diverse knowledge that is essential in a design project. Shared design expertise need to be managed at distance, thus multiple universities across Europe need to manage the process. An example could be CAD drawings provided mostly by mechanical and industrial engineering students, who have the skill set necessary to complete the task. These students need to constantly exchange information with their teams, such as dimensions, materials etc. in order to ensure adherence to specifications.

Figure 1 displays the distributed design scheme, which is a systematic approach employed by the participating teams in order to optimally utilise students' skill sets and strengths within a virtual environment. This helped students solve the given problem by having a structured methodology to follow. Firstly, tasks needed to be identified in order to be able to allocate the most proficient resource for solving the given assignment. Solutions brought forward were then evaluated in order to agree on

whether it can be implemented or needs further development. The cycle is reinitiated to develop the solution further if needed or to begin with a new task. This scheme can be implemented throughout the project within any of the design phases.
The effectiveness of the scheme is highly affected by the communication capabilities of the team within the distributed environment; finding the right balance between synchronous and asynchronous communication. Throughout the project, it was noted that synchronous communication allows for a more fluid exchange of ideas; however, it presented the potential of deviating from the task being conducted. On the other hand, asynchronous communication provided more comprehensive documentation and in-depth ideas; however, using this communication, it was sometimes unclear if ideas were grasped by the whole team. Information transmission and storage proved essential for effective organisation when communicating asynchronously.

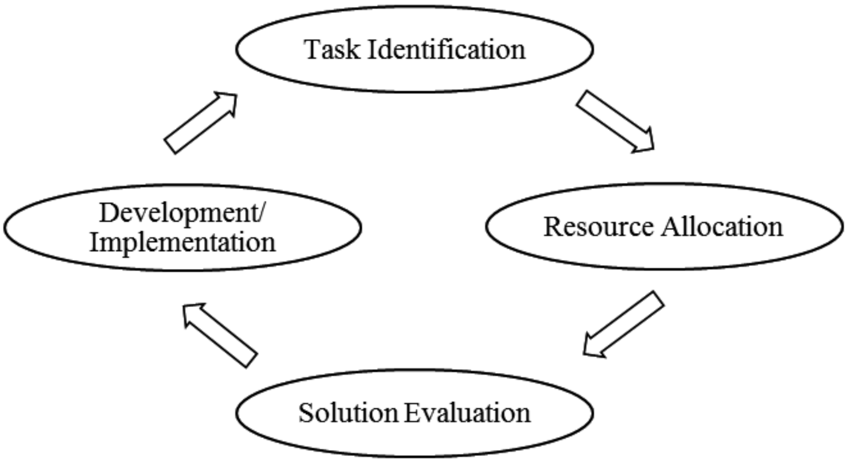

Figure 1. Distributed design scheme

3 CASE STUDY

The aim of this section is to explore the various interpretations of the open-ended problem of re-designing a more effective aeroplane seatbelt. The approaches employed by three different student teams as well as the outcomes shall be compared in order to be able understand how problem-based learning within the distributed design project impacted on the educational experience.

3.1 Research

All three teams felt that the project highlighted how essential the research phase is to the successful development of a new, effective and innovative product. This phase sets the benchmark to follow for the rest of the project. Various tools were used in order to lay out the requirements and constraints related to the product. All three teams employed qualitative methods such as mind maps and requirements lists, while only one team used quantitative methods such as product design specification (PDS) and quality function deployment (QFD). The lack of extensive market research meant that the final constraints lists of all groups were not as comprehensive as they should have been. Teams felt that time constraints at this stage led to a vague statement of the need which, in turn, led to a vague understanding of the product to be designed, which decreased the feasibility of the final solution.

3.2 Concept Generation and Selection

The concept generation phase allowed teams to explore various tools such as 6-3-5 brainwriting[1], synectics[2], morphological charts[3] and SCAMPER[4]. One of the teams relied heavily on the systematic

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[1] Group structured brainwriting technique.
[2] Problem solving methodology that stimulates thought processes of which the subject may be unaware by using analogies and metaphorical information exchanges among seemingly unconnected elements.
[3] Table based on the function analysis of the desired product.
[4] Concept generation method that asks questions about existing products, using the following seven prompts: substitute, combine, adapt, modify, put to other purposes, eliminate and reverse.

approach of the morphological chart. On the other hand, the other two teams used a combination of all other methods, which proved to increase innovation and enhance creativity by allowing participants complete freedom in their approach.

At least five concepts were generated by each of the teams; however, the groups employed different approaches for concept evaluation and selection. Team 1 relied on surveys for the ratings of the functions of each concept, while the other two teams focused on the technical versus economical diagram. Even with the appropriate concept evaluation tools, teams were not able to select the most appropriate concept. At this stage, none of the teams used quantitative methods like quality function deployment in order to assess how the concept fits the specifications; this meant that the specifications of the selected concept did not meet the stringent regulations imposed by the aviation industry.

3.3 Embodiment Design and Prototyping

Embodiment design presented teams with the challenge to detail the selected concept to such an extent that it could be prototyped or represented in augmented reality. This phase was mostly led by mechanical and industrial engineering students, who were more proficient in the use of computer aided design software. As teams comprised students from different universities, various software packages were employed. This meant that it was necessary to convert all virtual representations of components to a compatible format, so that the final product could be assembled. All teams felt that this was a challenge to overcome, but a valuable exercise of coordination and technical ability. This was a stage in the project that closely resembled the difficulties that tend to arise in real-life distributed design.

The educational background and the open-ended nature of the project allowed students to prototype according to their previous experience. For example, the electrical and electronic engineering student in Team 2 established a functioning electronic system for sensing if the seatbelt was fastened correctly, while in Team 1 the mechanical and aeronautical engineering students focused on the mechanical aspects of the prototypes, by producing a more detailed lock/release mechanism. The influence of product design and innovation management students was felt greatly in Team 3. This resulted in a very innovative product; however, it lacked functionality. It would be worth noting the fact that, while in the other phases the balance between technical and soft skills was more inclined towards the latter, technical skills were prevalent throughout embodiment design and prototyping.

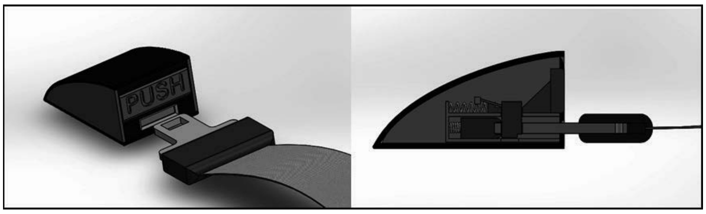

Figure 2. Team 1 – Final Seatbelt Design

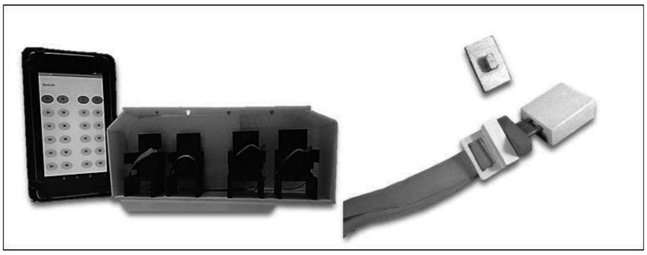

Figure 3. Team 2 – Final Seatbelt Design

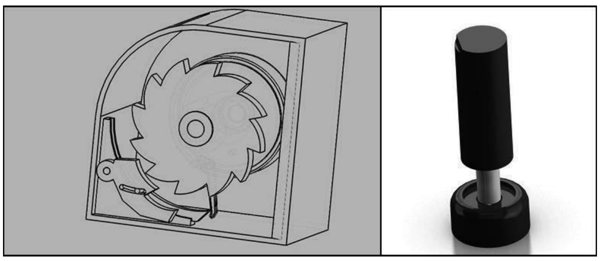

Figure 4. Team 3 – Final Seatbelt Design

4 CONCLUSION

The project of designing a more effective aeroplane seatbelt as part of a distributed design team represented a valuable platform for learning. The exposure to the challenges that arise while working through the fundamentals of the engineering design process highlighted some limitations that cannot be avoided due to the distributed nature of the project. However, the advantages of working within a distributed team far outweigh these limitations due to the diversity of knowledge available from the team members with different backgrounds. It was observed that the educational background of students highly impacted upon the engineering design process followed, which affected the final solution. It is therefore critical that appropriate task allocation is conducted within multi-disciplinary teams.

The fuzzy front end nature of this project meant it was open for individual interpretations. Due to that, the research phase had a great impact on the direction of each team for tackling the problem. This, corroborated with the fact that all teams felt pressure due to time limitations, caused insufficient research that led to impractical solutions. Therefore, it was shown how vital research is to the success of any project. Although time constraints may have caused ineffective solutions, students felt that their learning curve increased by obligating them to efficiently organise themselves in a limited time frame. This endowed the improvement of project management, communication, and self-directed learning skills.

Motivation plays a central role in students' working productivity. Participants felt that the major factor which affected their motivation was that the project was scheduled to conclude with embodiment design. This aspect combined with the strict time constraints disturbed participants' usual study patterns. Finally, working in a distributed environment enhances team working practices for solving problems however the right balance between the intensity/complexity of the task versus the students' motivation is crucial for attaining the optimal learning experience.

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