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AN APPROACH FOR THE EFFECTIVE UTILISATION OF ENGINEERING DESIGN TOOLS BY MULTIDISCIPLINARY STUDENT TEAMS

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ABSTRACT
Collaborative design practice is becoming more popular as technology makes it easier to communicate ideas with others that are geographically distant. However, there is a challenge as different engineers use design tools which are familiar to them. These design tools usually differ from each other, and that is where the problem arises. With different design tools, engineers may find it much more difficult to share their ideas as well as making the whole process longer, which is highly undesirable. Each year the *University of Malta, City University of London* and *University of Strathclyde* organize a joint collaborative design project, in which engineering with different background and cultures participate. In this paper, the patterns in the use of design tools by students to collaborate with each other are investigated. The main aim will be to suggest an approach, which can easily be utilised by engineering students during collaborative work. The final approach proposed aids in facilitating the collaboration work of the engineering students as well as in promoting collaboration between engineering students.

Keywords: design collaboration, social media, collaborative design, student projects

1 Problem Background

In engineering, collaborative design is usually a double-edged sword. While it is indispensable for engineers who must work together to complete a design problem, it can also be the main setback in the process. If the engineers select the improper design tool, the outcome can be very disappointing, as the desired goals will not be reached [1]. Another challenge that usually arises in design teams is the way that the work is distributed among the designers. To distribute the workload in the most efficient way possible, the project manager or team leader must have some previous experience with the team. Unfortunately, this is not always achievable and thus the project cannot be carried out in the most economical way [2].

It is widely accepted amongst engineering lecturers and educators that collaborative team exercises or projects greatly encourage innovative ideas [3,4]. Studies suggest that globalisation is progressing rapidly [3,4] and hence it is highly beneficial for engineering students to take part in collaborative exercises [5]. These types of exercises and projects are becoming more popular and students are being introduced to firsthand design projects at an early stage [5].

The advantage of online communication technology was highlighted in previous studies. For instance, *Wiki* websites were created for each team of engineering students to create, edit and compile the project [6]. The students who took part in this project found the website very useful and relatively easy to use, meaning that engineering students can benefit from use of online technology to work together [6]. Engineering course projects also enhance the students' cognitive and problem solving ability, thus being better prepared for a dynamic design team with greater responsibility [6]. Systematic design engineering is used in some specific situations hence its applications are limited as it is a theory based on Engineering Design Science [7]. In previous studies, models were created to aid the design engineering teaching stage by proposing guidelines that can be followed by the lecturers [8] but these did not deal with the of collaboration in engineering design in academia . To address this gap, the objective of this paper is therefore to propose an effective design method which can be used in a dynamic design environment, as well as to suggest the most efficient use of online communication tools that can be utilised by engineering design students to collaborate with each other.

2 Methodology

In a multidisciplinary design project organised by the *University of Malta, City University of London* and *University of Strathclyde* groups of students were formed from each of these universities. This project is known as the *Global Design Exercise (GDE).* Every group consisted of students from at least two of the universities mentioned above. The students had the opportunity to get hands on experience of collaborative design in engineering, as this project simulated a real design environment with weekly deadlines and two presentations. The nationality of the students varied and thus each team had a mixture of different mentalities, cultures and ideas. The task given to the students was to design an innovative airplane tray table [9]. This exercise posed a challenge because not only had the students never worked together but also they had different working methods to tackle the design problem.

After all the students finished the GDE successfully, a survey was conducted to investigate the preferred methods of collaboration, in particular to use and complete design tools relevant to different activities of the basic design cycle. A sample of students that participated in the GDE in previous years, were also included, to see if the preferred methods of collaboration changed in the past few years due to a constant increase of usage of social media and online communication [10]. The main aim of the survey was to find out which online means of communication were used by the students to complete the design tools and design activities as well as to investigate the procedure used by the students to complete each of these tools and activities. For instance, Figure 1 illustrates schematically one of the methods used by the distributed team members to complete the QFD. This was done in order to study which means of online communication the students found out to be most useful for each of the design tools and activities. The procedure used by the students to use each design tool was also examined, as this can vary from one design tool to another.

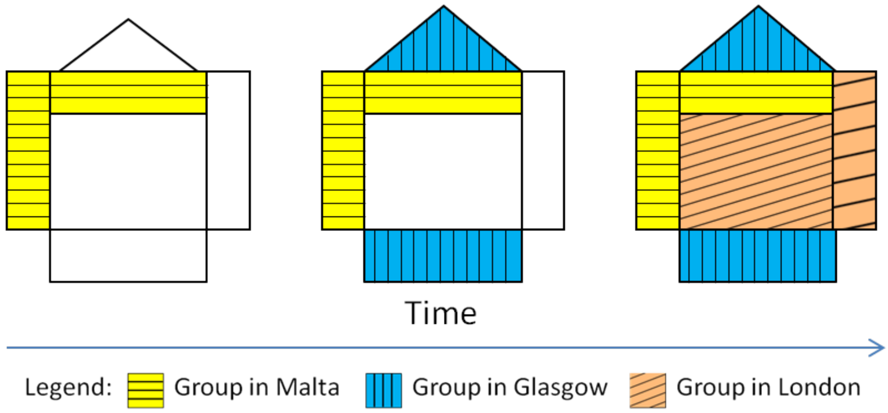

Figure 1: One of the methods used by some of the students to complete the QFD

3 Results

From the forty-two surveys sent, fifteen replied. From these replies, seven were from the *University of Malta*, seven from the *University of Strathclyde* and one from *City University London*. Although not all the students responded, most of the replies were from different teams. In this section, the results of each question will be analysed both analytically as well as statistically by performing a *Chi-Square* test for each set of data (a significance level of $\alpha = 0.5$ was taken for all *Chi-Square* calculations). The aim is to investigate the relationship, first between the means of communication and the design tools, and secondly between the procedures used by the students to complete the various design tools. The first set of questions asked the participants about the communication means used to complete the design tools. For the results collected in the first question (see Table 1) the p-value was 0.383, which means that that there is no significant relationship between the types of problem analysis tools (including the Quality Function Deployment and the Product Design Specification) and means of communication used. The most common means of communication used for the problem analysis tools were *Facebook* and *Skype* as they were used by over 60% of the students at this part of the design cycle. The reason for this may be due to the highly versatile nature of these online social media. *Skype* is a very powerful and useful tool when it comes to collaboration as the students can interact with each other audio-visually [11]. By using this software, students can convey their ideas better through gesture and improved way of conversation, both of which are an essential part of a design process [5]. *Facebook* is also a very dynamic social media tool, where each team in the design exercise formed a *Facebook* group and students could share their ideas there. It also facilitates messaging, as the participants could post an idea and receive feedback from the rest of the team. Instant messages are also appealing as they cater for the fast upload of photos, hence if a sketch was done, a photo can be taken and uploaded on the *Facebook* group or sent as a message to the members in a matter of seconds. The second question treated design synthesis tools (see results in Table 2, p-value = 0.86). For these design synthesis tools *Facebook* was used as well, but *Skype* was the most popular. For brainstorming 93.33% of the participants used *Skype* to communicate their ideas. *Dropbox* was also used significantly to complete the morphological chart and for sketching. Cloud storage (such as *Dropbox* and *Google Drive*) was useful during this stage as the original chart can be uploaded on this cloud storage and each team member can edit and add ideas to the same chart, instead of having multiple files.

Table 1: Results on communication means used to complete problem analysis tools

	Whatsapp	Facebook	Google Drive	Email	One Drive	Dropbox	Box	Video chat e.g. Skype	Other
Quality Function Deployment (Q.F.D.)	14.29%	64.29%	42.86%	21.43%	0.00%	42.86%	14.29%	64.29%	7.14%
	2	9	6	3	0	6	2	9	1
Product Design Specification (P.D.S.)	20.00%	60.00%	33.33%	20.00%	6.67%	33.33%	20.00%	66.67%	0.00%
	3	9	5	3	1	5	3	10	0

Table 2: Results on communication means used to complete design synthesis tools

	Whatsapp	Facebook	Google Drive	Email	One Drive	Dropbox	Box	Video Chat e.g. Skype	Other
Morphological Chart	6.67%	40.00%	33.33%	13.33%	13.33%	40.00%	20.00%	66.67%	0.00%
	1	6	5	2	2	6	3	10	0
Brain Storming	26.67%	46.67%	13.33%	6.67%	6.67%	20.00%	6.67%	93.33%	6.67%
	4	7	2	1	1	3	1	14	1
Sketching	13.33%	53.33%	26.67%	13.33%	13.33%	40.00%	20.00%	46.67%	6.67%
	2	8	4	2	2	6	3	7	1

For the results of the design evaluation tools the p-value = 0.993. This time the use of social media and online cloud storage was more widely spread amongst the eight options. Still, the use of *Facebook* was very consistent, as *Skype* decreased slightly in popularity. *Dropbox* and *Google Drive* proved to be very convenient means of cloud storage. The result of each *Chi-Square* test carried out for the other two sets of data, also show that there is no level of significance between the use of design tools and means of communication. A valid and possible reason for this result is that not everyone was familiar with all the means of communication. Hence, the reason why the data was spread amongst the eight different means of communication. The design tools and the procedure employed by the students to complete them is analysed next. From the first two sets of data analyzed, it resulted that the majority preferred to work on a design problem within the local team, thus facilitating communication. To complete the sketching and brain storming, 64.29% and 50% respectively, opted to work together as a whole team simultaneously. From Table 3, it was found out that 60% of the students preferred to have a single person from the team to work on the CAD model. After an analytical approach to the gathered data, the *Chi-Square* test was carried out for each table. The p-values for the data gathered on the procedures used to complete problem analysis and problem synthesis tools was 0.716 and 0.161 respectively, hence no level of significance resulted between the procedure and the design tools being used. On the other hand, when the *Chi-Square* test was carried out for the results presented in Table 3, the p-value was found out to be 0.001. This means that there is a level of significance between the procedure used and the design tool. The two most common and widely used procedures were those that involved either the local team working together or else the whole team working simultaneously. The communication means used by the students in the 2014 project were compared with those used by the students in 2010. No significant difference was found, a very valid reason may be that online tools such as Skype and Facebook were already widely used by most stdents.

Table 3: Results on the procedures followed to complete evaluation tools

	One member in a team does all the work	Members in the same local team (e.g. Malta) work together simultaneously	In steps, one person at a time (same local team)	In steps, one person at a time from the distributed team (e.g. one from Malta, one from UK)	Members in the distributed team work together simultaneously	Other
CAD Modelling	60.00%	26.67%	13.33%	6.67%	6.67%	0.00%
	9	4	2	1	1	0
DFX	8.33%	66.67%	16.67%	16.67%	8.33%	0.00%
	1	8	2	2	1	0
Screening Matrix	0.00%	57.14%	0.00%	14.29%	50.00%	0.00%
	0	8	0	2	7	0
Scoring Matrix	0.00%	57.14%	0.00%	14.29%	42.86%	0.00%
	0	8	0	2	6	0
Decision Matrix	7.14%	50.00%	0.00%	21.43%	50.00%	0.00%
	1	7	0	3	7	0

The above results were analysed thoroughly and a pictorial model was created to help students carry out collaborative design work. This model consisted of suggested means of communication and procedures to carry out different design tools. When this model was finished, the students that replied to the survey were asked to make part of as small focus group to give initial qualitative feedback about this model. Three students accepted to take part in this focus group, one from *City University of London* and two from the *University of Malta*. The response was quite positive as the students highlighted the fact that using such model, less time is spent allocating each task to the team and local teams. Most of the students agreed that it was a good idea to include *Skype* in all of the stages in the model, because problems that arise while tackling that particular task can be solved by meeting on a video call and thus clarify the issue. One of the students suggested that instant messaging using applications such as *Whatsapp* might also be useful to organise a group meeting at a short notice. These type of applications where not included in the model as they were only used by a small percentage of the students as it can be seen from the example in the Tables 1 and 2. In order to improve the model, a suggestion was made to increase the number of times the whole group would meet as well as to increase the number of brainstorming sessions throughout the duration of the project. These are both very viable comments but during the GDE, some teams were struggling to find a date and time when all of the members could join for an online video meeting. After this suggestion the number of times when the whole group meets was increased to include the most important stages of the design cycle, where it s very important that the entire group weighs in to reach a better solution. These stages are brainstorming, sketching and decision matrix.

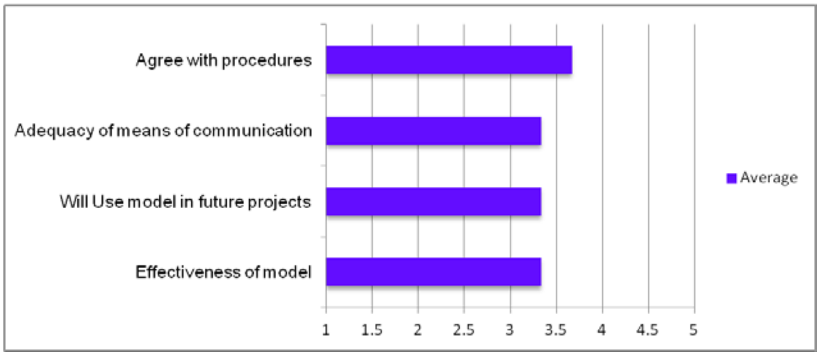

Figure 2: Focus group results showing the average student rating

From the student's feedback, these three stages are the most important stages that the whole group should meet together using online video calls (for the case of GDE) and decide on a final solution as a team. The bar graph in Figure 2 represents the rating given by the students to the pictorial model that was created. Overall, the average rating of the model for each criterion was 3.42. Based on the indicative results obtained in this study, an approach for the effective utilisation of engineering design tools by multidisciplinary student teams is proposed, as illustrated in Figure 3.

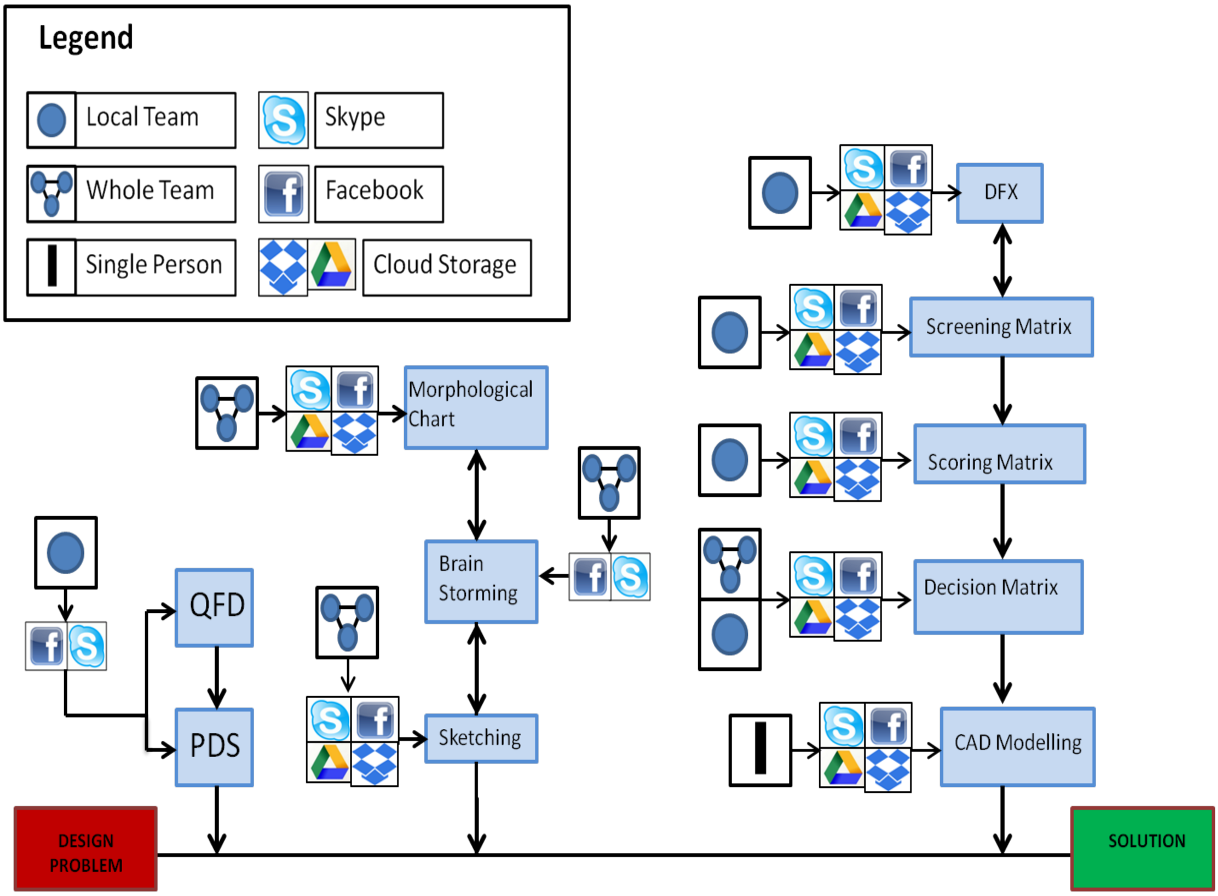

Figure 2: Proposed approach to effectively use design tools by distributed students design teams

4 Conclusions

This paper has investigated the patterns in the use of design tools by students in engineering design to collaborate with each other. The main contribution of this paper consists of the approach depicted in Figure 3. It provides a roadmap for engineering design students to use the design tools together with communication tools at different stages of the design process in a collaborative working environment.

Such an approach contributes to facilitate collaborative design exercises between students. The usefulness of such an approach was further enhanced by including some of the suggestions made by the students in the focus group. Given the small sample size, future work is required to test the validity of the approach by conducting a comparative study.

References

[1] Lopez-Mesa B. , Thompson G. 2003. Exploring the need for an interactive software tool for the appropriate selection of design methods. In: *ICED (International Conference on Engineering Design), 19-21 August 2003,* Stockholm. Sweden: Luela University of Technology. ICED03-1118.

[2] Coates G. ,Duffy A.H.B. , Whitfield R.I. , Hills W. A Methodology for prospective operational design co-ordination. In: *ICED (International Conference on Engineering Design), 19-21 August 2003,* Stockholm. Newcastle: University of Newcastle, ICED03-1147.

[3] Siddique Z. 2012. Beyond hands-on-learning-fostering creativity in student competitive teams. In: *International Design Engineering Technical Conferences & Computers and Information in Engineering Conference IDET/CIE 2012, 12-15 August 2012,* Chicago. Oklahoma: University of Oklahoma, DETC2012-71021.

[4] Hurdelbrink K. , Doyle B. , Collins D. , Evans N.N. , Hatch P.A. , Ingram T. , Kucinskas J.W. , Moorhead-Rosenberg Z. and Siddique,Z. 2011. Enhancing Experiential Learning in Collaborative-Competitive Student Design Teams. In: *International Design Engineering Technical Conferences & Computers and Information in Engineering Conference IDET/CIE 2011, 28-31 August 2011,* Washington, DC. Oklahoma: University of Oklahoma. DETC2011-48648.

[5] Wodehouse A. , Farrugia P. and Grierson H. and Borg J.C. 2013. Sharing digital sketch work for distributed concept design. In: *19th International Conference on Engineering Design (ICED13),* Seoul, South Korea, ICED13/132.

[6] Moore J.P. , Williams C.B. , Paretti M.C. 2011. Using Wikis as a Formative Assessment Tool for Student Engineering Design Teams. In: : *International Design Engineering Technical Conferences & Computers and Information in Engineering Conference IDET/CIE 2011, 28-31 August 2011*, Washington, DC. Virginia: Virginia Polytechnic Institute & State University. DETC2011-48310.

[7] Ernst Eder W. 2010. Case Study in Systematic Design Engineering – Trapeze Demonstration Rig. In: *International Design Engineering Technical Conferences & Computers and Information in Engineering Conference IDET/CIE 2010, 15-18 August 2010,* Quebec. Ontario: Royal Military College of Canada. DETC2010-28065.

[8] Vargas Hernandez N. , Davila Rangel D. 2010. Improving Engineering Design Education: From Skills to Educational Objectives. In: *International Design Engineering Technical Conferences & Computers and Information in Engineering Conference IDET/CIE 2010, 15-18 August 2010,* Quebec. Texas: University of Texas at El Paso. DETC2010-28955.

[9] City University London, the University of Malta, and the University of Strathclyde. 2014. Global Design Project brief.

[10] Statista. 2015. *Number of global social network users 2010-2018.* [Online]. [Date accessed: 13th February 2015]. Available From: http://www.statista.com/statistics/278414/number-of-worldwide-social-network-users/

[11] Asay M. 2008. *Skype: The ultimate collaboration tool?.* [Online].[Date accessed: 13th February 2015]. Available From: http://www.cnet.com/news/skype-the-ultimate-collaboration-tool/