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USING ENGINEERING DESIGN TOOLS IN MULTIDISCIPLINARY DISTRIBUTED STUDENT TEAMS

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ABSTRACT
Collaborative design practice in distributed student teams is becoming more popular as technology makes it easier to communicate ideas with others that are geographically distant. However, a challenge for students is to use design tools which they are not familiar with. These design tools usually differ from each other and engineers may find it much more difficult to share their ideas. This could make the whole design process longer and less successful. Each year the *University of Malta*, *City University London* and *University of Strathclyde* organise a joint collaborative design project, involving engineering students with different disciplines and cultural backgrounds. In this paper, the patterns of use of design tools by students to collaborate with each other are investigated. Based on survey results of students, this paper proposes an approach which can be utilised by engineering students to enhance collaboration in multidisciplinary distributed design teams.

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

1 PROBLEM BACKGROUND

Information computer technology has facilitated the collaboration of different product development stakeholders located at different places around the globe. Collaboration in product development brings along a number of advantages such as sharing of expertise and improving the product performance metrics, particularly a reduction in the time-to-market. At the same time, such a collaboration poses a number of challenges as it typically involve people of different backgrounds, cultures and working practices. In addition, if the engineers select an inappropriate design tool, the outcome can be very disappointing, as the desired goals may not be reached [1]. Another challenge that usually arises in design teams is the way that the work is distributed amongst the designers. To distribute the workload in the most efficient way, the project manager or the team leader must have some previous experience and knowledge about team members. Unfortunately, this is not always achievable and thus a project may not be carried out in the most efficient 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 firsthand to 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, indicating 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 collaboration in engineering design in academia. Therefore to address this gap, the objective of this paper is to propose an approach which can be used in a dynamic design environment involving distributed teams of students.

2 BACKGROUND TO THE GLOBAL DESIGN EXERCISE

In a multidisciplinary design project organised by the University of Malta (UOM), City University London (CUL) and University of Strathclyde (UOS), distributed design groups were formed of a number of students from each of these universities. This eight-week project, known as the *Global Design Exercise* (GDE), takes place in the winter semester. The teams comprised two to three mechanical engineering students from UOM, two to three mechanical engineering students from CUL and four to six Product Design Engineering/ Global Innovation Management students from UOS. The participating students were from different educational levels, some were in their third year of their studies while others were in their fourth or fifth year. In addition, the nationality of the students varied and thus each team had a mixture of different mentalities, cultures and ideas. All students however, had taken study-units related to engineering design tools, engineering design methodologies and Computer-Aided Design. The students collaborated both synchronously and asynchronously for eight weeks, using a range of communication tools, in order to develop designs for an airplane tray table that would make it easier to eat a meal while at the same time increasing the functionality of the table tray. *Doodle* was the main tool used by the distributed student team members to schedule meetings. 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 (one on the progress made towards the fourth week and a final one on the design solution). This exercise posed a challenge because the students never worked together face-to-face as an entire team.

3 METHODOLOGY

After the students finished the GDE successfully, a survey was conducted to investigate the preferred methods of collaboration, in particular to use and complete a range of design tools. The aim of the survey was twofold; (i) to investigate the procedure used by the students to complete each of these tools (for instance, Figure 1 illustrates schematically one of the methods used by distributed team members to complete the Quality Function Deployment - QFD) (ii) to find out which online means were used by the students to utilise the particular design tool.

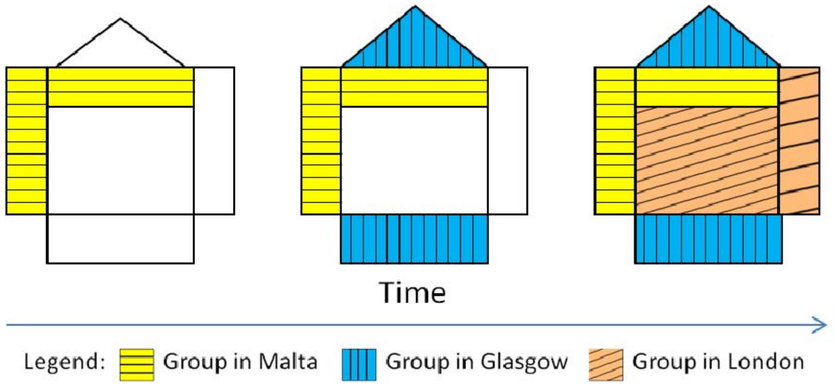

Figure 1. One of the methods used by some of the students to complete the QFD

The survey was structured in two sections reflecting the aforementioned objectives. The design tools considered were categorised to reflect the three main design activities as follows: (i) problem analysis tools covering QFD, product design specification (PDS) (ii) synthesis tools covering morphological chart (MC), brainstorming sessions (BS), Sketching (SK) and (iii) solution analysis and evaluation tools encompassing CAD, DFX, screen matrix (ScrM), scoring matrix (ScoM) and decision matrix (DM). Five key procedures that students follow to work on these tools were identified and included in the survey. These procedures are mentioned later on. The on-line means to complete these tools and which were considered in the survey comprised social media (e.g. *Facebook*), cloud computing (e.g. *Dropbox*), e-mails, *Whatsapp* and *Skype*. To investigate any significant relationship between the design tools and the procedures, a table was employed in the corresponding survey question. The same applies for the relationship between the design tools and the on-line communication means. Participants had to tick cells in these two tables. To ease accessibility by students located in three different countries, the survey was launched on-line. Fifteen GDE students, coming from different design teams at UOM, CUL and UOS, volunteered in the study.

4 RESULTS

The results of each question are analysed both analytically as well as statistically by performing a *Chi*-Square test for each set of tabulated data (a significance level of 0.05 was taken for all *Chi*-Square calculations). The results reveal that to complete QFD and the PDS, the majority of the students preferred to work on a design problem with their co-located team members, thus facilitating communication (69.23% and 53.33% respectively, see Table 1). To complete sketching and brainstorming, 64.29% and 50% respectively, opted to work together as a whole team simultaneously. It was also found out that 60% of the students preferred to have a single person from the team to work on the CAD model (see Table 1). When the *Chi-Square* test was carried out, the p-value obtained for the procedures used to complete problem analysis and problem synthesis tools was 0.716 and 0.161 respectively, hence no level of significance resulted. On the other hand, when the *Chi-Square* test was carried out for the results on the methods used to complete the solution analysis and evaluation tools, 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 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. This reflects that a joint decision by all members of the distributed design teams was deemed important, in particular to select the final concept of the table.

Table 1. Results on procedures employed to complete the design 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 etc.)	Members in the distributed team work together simultaneously	Other
QFD	0%	69.23%	15.38%	7.69%	23.08%	0%
	0	9	2	1	3	0
PDS	0%	53.33%	6.67%	13.33%	33.33%	6.67%
	0	8	1	2	5	1
MC	7.14%	57.14%	21.43%	7.14%	14.29%	7.14%
	1	8	3	1	2	1
BS	0%	21.43%	21.43%	14.29%	64.29%	0%
	0	3	3	2	9	0
SK	7.14%	14.29%	21.43%	28.57%	50%	0%
	1	2	3	4	7	0
CAD	60%	26.67%	13.33%	6.67%	6.67%	0%
	9	4	2	1	1	0
DFX	8.33%	66.67%	16.67%	16.67%	8.33%	0%
	1	8	2	2	1	0
ScrM	0%	57.14%	0%	14.29%	50%	0%
	0	8	0	2	7	0
ScoM	0%	57.14%	0%	14.29%	42.86%	0%
	0	8	0	2	6	0
DM	7.14%	50%	0%	21.43%	50%	0%
	1	7	0	3	7	0

The *Chi-squared* test performed on the data depicted in Table 2, revealed that there is no significant relationship between the types of problem analysis tools and the online means employed to complete them (p-value = 0.383). In this case, the most common means of communication used were *Facebook* and *Skype*. The reason for this is attributed to the highly versatile nature of these online tools. By using the latter, students can convey their ideas better through gestures 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 a very good feature as they also 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. In fact, for design synthesis tools *Facebook* was used as well, but *Skype* resulted to be the most popular. For brainstorming 93.33% of the participants used *Skype* as the tool to communicate their ideas. *Dropbox* was also used significantly to complete the morphological chart and to store the sketches generated. Cloud storage was useful for design synthesis – for instance respondents highlighted that the original morphological chart can be uploaded and each team member can edit and add ideas to the same chart, instead of having multiple files. Regarding the solution analysis and evaluation tools, the use of *Facebook* and *Skype* was also very consistent. Similarly, the use of cloud storage proved to be very popular. The results of the *Chi*-Square test show that there is no level of significance between the use of design tools and the online means employed.

Table 2. Results on the on-line means used to complete the three categories of design tools

	Whatsapp	Facebook	Google Drive	Email	One Drive	Dropbox	Box	Skype	Other
QFD	14.29%	64.29%	42.86%	21.43%	0%	42.86%	14.29%	64.29%	7.14%
	2	9	6	3	0	6	2	9	1
PDS	20%	60%	33.33%	20%	6.67%	33.33%	20%	66.67%	0%
	3	9	5	3	1	5	3	10	0
MC	6.67%	40%	33.33%	13.33%	13.33%	40%	20%	66.67%	0%
	1	6	5	2	2	6	3	10	0
BS	26.67%	46.67%	13.33%	6.67%	6.67%	20%	6.67%	93.33%	6.67%
	4	7	2	1	1	3	1	14	1
SK	13.33%	53.33%	26.67%	13.33%	13.33%	40%	20%	46.67%	6.67%
	2	8	4	2	2	6	3	7	1
CAD	7.14%	42.86%	28.57%	7.14%	0%	28.57%	14.29%	35.71%	14.29%
	1	6	4	1	0	4	2	5	2
DFX	8.33%	50%	33.33%	16.67%	0%	50%	8.33%	50%	8.33%
	1	6	4	2	0	6	1	6	1
ScrM	0%	42.86%	50%	14.29%	7.14%	35.71%	21.43%	57.14%	0%
	0	6	7	2	1	5	3	8	0
ScoM	0%	42.86%	50%	21.43%	7.14%	35.71%	21.43%	42.86%	0%
	0	6	7	3	1	5	3	6	0
DM	7.14%	50%	50%	21.43%	7.14%	35.71%	14.29%	50%	0%
	1	7	7	3	1	5	2	7	0

From the data collected in Table 2, a bar chart was generated to pictorially illustrate the use of the most popular on-line means, namely *Facebook*, cloud computing (consisting of *Dropbox* and *Google Drive*) and *Skype*, during the different design activities. From Figure 2, it can be observed that the use of cloud computing increased sharply towards the last stages of the design process. This was expected as in the last design stages the number of design information generated (particularly CAD files) increases. Figure 2 also suggests that the use of *Facebook* and *Skype* was very consistent throughout the different design activities.

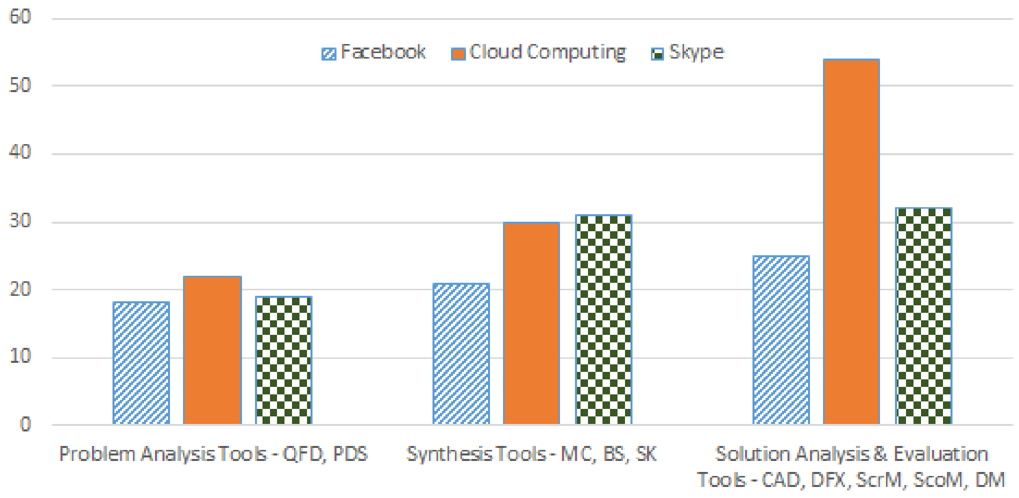

Figure 2. Most common on-line means used to complete different design tools

5 PROPOSED APPROACH

Based on the survey results obtained and preliminary qualitative feedback obtained by a focus group, made up of one CUL student and two UOM students, an approach was devised for distributed student team work (see Figure 3). The original model was improved by including *Skype* in all of the stages of the model, since problems that arise while tackling that particular task can be solved by meeting on a video call and thus clarify the issue. In addition, with respect to the original model, the meetings of the whole group were introduced at critical activities during the design process, particularly the brainstorming, sketching and compiling of the decision matrix. With reference to the model, it is recommended that during problem analysis each local team works independently on the QFD and PDS. *Facebook* and *Skype* are proposed to share information in this regard. At the end of the problem analysis activity a review meeting is held between the whole team members. This serves as a checkpoint for the team (e.g. in the case of the problem analysis to check that all the important design specifications are listed in the PDS). The same applies for the other two main design activities.

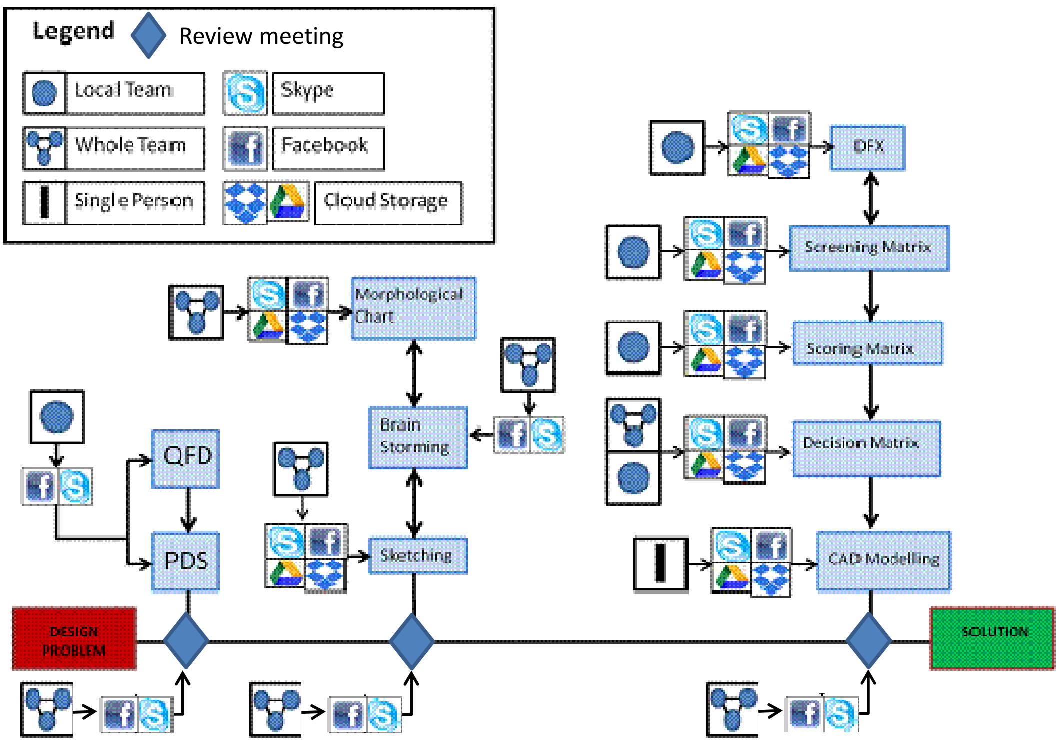

Figure 3. Proposed working approach for distributed teams of design students

The design synthesis activity is characterised by meetings held between members of the whole team, using *Skype* and *Facebook*. It must be mentioned that this model does not rule out asynchronous communication means such as e-mails. *Dropbox* and *Google Drive* are the suggested means to share information (e.g. sketches and morphological charts). In the design solution analysis and evaluation activity it is proposed that the DFX, screening matrix, scoring matrix and decision matrix are conducted primarily by local teams. It is only for the decision matrix that the whole team members are involved. In any case, the information generated can be shared by cloud computing for members of the whole team to access at any time. This shall lead to a faster consensus between all team members to select the final working principle, than if the whole team members had to meet using *Skype* to provide their collective input to fill in the other matrices.
The three focus group members were asked to assess the proposed approach by rating a number of statements using a 5-point Likert scale. Key findings were that students expressed a neutral opinion on the idea of using this model in future projects and on its effectiveness (in both cases an identical mean rating score of 3.4 was obtained). The main reason attributed to this lies in the fact that the opinion expressed is based on the students' impressions rather than on hands-on experience in using the model.

6 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 is to propose tools for distributed design as shown in Figure 3. The proposed approach could provide a roadmap for design educators to guide engineering design students on how to best use the design tools together with on-line tools at different stages in a distributed design context. Such an approach would facilitate collaborative design exercises between students. However, future work is required to test the validity of the approach by using control and experimental groups and test the efficiency of the approach, particularly in terms of the number of ideas generated between the distributed team members in a stipulated timeframe and the time taken to decide on the optimal design solution.

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