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A TRAINING STRATEGY FOR MANAGING DISTRIBUTED CONCEPTUAL DESIGN WORK

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ABSTRACT
This paper reviews how sketching can support distributed student design teams in the early phases of concept design. When working in the limited communication channels of distributed teams, sketches can form an important way for teams to build a rapport that would otherwise be difficult. This work reviews the performance of ten distributed student design teams made up of participants from Scotland and Malta who were required to undertake a conceptual design task – the design of cardboard packaging for a wine glass. Issues relating to the creation, use and development of sketches were analyzed for a sample of three teams, and correlated to the communication patterns, team satisfaction and quality of output. It was subsequently found that the team who shared the most 'talking sketches', resulted in a higher degree of satisfaction compared to the other teams. Results also suggest that those teams who generated the most 'thinking sketches' developed a more robust design solution. These findings form the basis for a strategy to train students to manage distributed concept design work.

Keywords: distributed teams, sketching, collaboration, conceptual design

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1 INTRODUCTION

The increasing interconnectedness of the world economy continues to drive collaboration across geographical boundaries (Dicken, 2003). In the context of product development, the management of global teams has become of strategic importance (Schilling, 2006). This can bring a number of benefits, including: increased ability to respond to local markets, organizational flexibility to changing environments, and enhanced creativity through a diversity of perspectives (Schneider & Barsoux, 2003). A major barrier, however, is that teams working across distances using computer-based communication media can often suffer from inhibited interaction (Broadbent et al., 1999; Rogers & Lea, 2005). In the concept design phase, when idea generation, development and selection take place (Pugh, 1991), expressive means such as sketching, conversation and gesture are essential for designers to communicate the subtleties of their ideas in a vivid way (de Sausmarez, 1964).

Providing a technologically rich environment is therefore crucial to facilitate the multiple modes of communication used by designers (Wang et al., 2002; Milne & Winograd, 2003). The development of team management frameworks and approaches that take account of technological limitations has historically been a concern in design research (Coates et al., 1999; Mark, 2002). Recent work has however suggested that the technology to support sketching has reached a level comparative to traditional paper based methods, with studies indicating that in face-to-face environments cognitive activities were unaffected by the change of medium (Tang et al., 2011). However, these studies deal with the use of high-end tablet and stylus setups that are not commonplace, and the more common digitizing approaches of using a mouse or scanner are far more limiting in terms of fluency and communication of ideas. We can expect technological environments to continue to mature, but rather than focus on the efficacy of hardware, this work focuses on the types of sketches used by distributed teams and how they affect collaboration.

To this end, it is required that prospective engineering students acquaint themselves with the available technologies used in these scenarios and to acquire the necessary knowledge and skills. Engaging students in hands-on collaborative design work is becoming part and parcel of design curricula (Borg & Farrugia, 2011). When teams are working remotely, the lack of face-to-face contact means that communication and information management strategies are crucial in building successful teams (Nicol & MacLeod, 2004). The digital tools that support communication are, however, orientated towards voice or textual modes rather than drawings and sketches. While a number of shared online sketching tools exist, such as *skrbl* (www.skrbl.com) and *CoSketch* (www.cosketch.com), their use is limited due to the lack of input responsiveness and the asynchronous work patterns that are commonplace for distributed teams. In addition to the rich design information and process thinking that drawings can convey, the gesture and movement manifest in sketchwork also allows for thought and feeling interpretation (Arnheim, 1969). Given its effectiveness in generating, sharing and developing of design ideas, this paper investigates how sketching influences effective distributed student team collaboration and the quality of the design solution.

Within this context, distributed student design teams undertaking conceptual design work were examined. This was achieved through the study of the role of sketching in building rapport, and generating, sharing and developing ideas, in ten student global design teams distributed between Scotland and Malta. In undertaking a detailed review of the functions and effects of teams' sketchwork, this research aims to develop a strategy for training students to manage distributed concept design work, built around the drawings created by the design team.

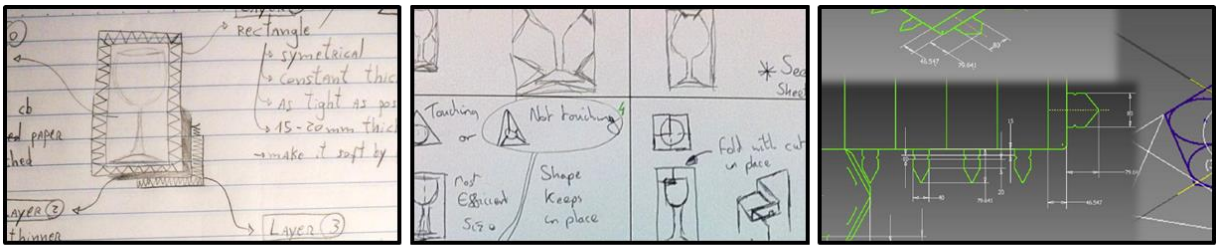
Based upon this introductory section, the rest of this paper is structured as follows. Section 2 highlights the roles of sketching in conceptual design, in particular in design team activities. An overview of the global design project carried out between students in distributed locations is given in Section 3. Key results obtained from this project are presented and analyzed in Section 4, with recommendations for training developed in Section 5. Conclusions are finally drawn in Section 6.

2 SKETCHING IN CONCEPTUAL DESIGN TEAMS

Studies have shown the value of sketches to support design thinking (McKoy et al., 2001; Schutze et al., 2003) and encourage diversity in idea generation (Bilda & Demirkan, 2002). Although concept sketches are commonly accepted as a drawing relating to a product or problem solution, they are useful to clarify further the evolving solutions. Ulrich and Eppinger (1995) define a concept as 'an approximate description of the technology, working principles, and form of the product'. In this

context, concept sketches are typically composed using line, marginal shading, and annotation, and communicate at least one fundamental innovation in the design solution embodied within an overall product context. While a concept sketch might be expected to clearly convey a concept, it has been shown that the ambiguity and indeterminacy of sketches can also be beneficial in stimulating creativity (Purcell & Gero, 1998; Tseng, 2007). Generally, the level of detail and thus reduction in ambiguity tends to occur further on in the design process. In the early stages, however, the situation is much more dynamic. Rodgers et al. (2000), in their work examining the use of concept sketches to track design progress, define a scale of complexity for concepts ranging from 1-5. They discuss *lateral* and *vertical* transformations (Goel, 1995) in relation to conceptual sketches, with lateral transformations denoting an obvious change in thinking or focus and a vertical transformation denoting a more detailed concept embodiment. These can be broadly equated to *divergent* and *convergent* modes of design.

It has been suggested (Cross, 1994; Dorst & Cross, 2001) that shifting between these modes in a flexible way can be beneficial, given the designer's tendency to make 'rapid explorations of problem and solution in tandem, in the co-evolution of problem and solution' (Cross, 2004) rather than follow linear stages. This shifting of attention was the subject of a series of tests conducted by Santanen et al. (2003): participants in brainstorming sessions were prompted to change topics every two minutes through the use of stimuli. The authors reported that this positively impacted the creativity of design solutions produced. Goldschmidt (1991) has made similar observations regarding the sketching, emphasizing the importance of 'shifts in perception' that occur during this activity with regard to creativity and the development of novel design solutions. This emphasis on movement between different types of sketches suggests that effective teams would move between different types of sketches. Eris and Martelaro (2010) analyzed co-located and distributed sketching interactions and found out that requiring designers to take turns whilst sketching can improve participation and collaboration. Van der Lugt (2005) highlights the different roles of sketching in the design group meetings. Based on this study and using Ferguson's taxonomy of sketches (Ferguson, 1992; Ferguson & Forbus, 2002), three categories of sketches for analyzing the work produced by the teams have been identified, namely 'thinking', 'talking' and 'prescriptive' sketches. Examples and definitions of these are given in Figure 1:



Thinking sketches supporting a re-interpretive cycle in the individual thinking process

Talking sketches supporting reinterpretation of each other's ideas in group synchronous and asynchronous activity

Prescriptive sketches *created by CAD by an individual or in a group to capture concepts or enhance access to earlier ideas*

Figure 1: Types of sketches used in the conceptual design phase

All these types of sketches are described as providing access to the team's individual or shared 'external memory' – all the task-related information generated and stored during the project. Given the particular challenges faced by the distributed team in effective communication, sketches potentially provide an important facility to develop team understanding and rapport as well as developing design thinking. This work therefore adopts the *thinking/talking/prescriptive* framework as a basis to examine the role of sketching in distributed design teams undertaking conceptual design work, with a view to utilizing their characteristics for the effective management of project activity.

3 GLOBAL STUDENT DESIGN PROJECT

The Global Design Project was a combination of synchronous and asynchronous design work between fifth year Product Design Engineering and postgraduate Global Innovation Management students at the University of Strathclyde and second year Mechanical Engineering students at the University of Malta. The learning objective was to introduce tools and practices necessary to complete the design of

an artefact in a distributed environment. The hands-on experience highlighted the real issues of sharing and communicating sketched design information with technological constraints.
The project brief required the distributed team to collaborate on the design of cardboard packaging for a wine glass. The design requirements included: construction solely from cardboard; no adhesives used in the construction of the packaging; and minimizing components for ease of assembly. The packages were assessed on three aspects: the wine glass had to survive transportation from Scotland to Malta/ Malta to Scotland and a 2m drop test impact. The packages were then weighed, with the lightest package winning.
Teams were expected to utilize a technological set-up consisting of a shared workspace (*Google+*) and videoconferencing (*Skype, Polycom*) to facilitate teamwork. They were also free to access any additional tools that they identified as suitable for support. By the end of the project they were required to have a CAD model of the finished design. The project timeline was as follows:

- *Week 1* - Introduction, icebreaker, discuss brief, review design tools.
- *Week 2* - Problem definition
- *Week 3* - Concept generation
- *Week 4* - Concept selection and development
- *Week 5* - Prototyping and detailed development
- *Week 6* - Finalization and exchange of models
- *Week 7* - Submission of documentation and delivery of project presentation

4 RESULTS

Quantitative and qualitative data collection methods were used. Teams presented their development work for assessment and were asked to maintain logs of their communications and information records. These have been used to build a context for the design work which was generated and exchanged by the teams. At the end of the exercise, a questionnaire was distributed to obtain feedback on how the students perceived their experience.

4.1 Presentations

On reviewing the material generated by the teams, it was decided to focus on just three to examine the work more closely. Teams 4, 7 and 9 were selected for the quality of their documentation (not necessarily the quality of their design work). Qualitative data collected during the delivery of the presentations by these three teams is summarized in Table 1.

Table 1 – Qualitative data collected during the presentations of the project

Team no.	**Qualitative data concerning:**	
	Concept selection & modelling	**Communication & data sharing**
4	• The *6-3-5 method* was used to develop ideas, although it was found that it gravitated towards a more informal brainstorming. • The final concept was selected without the use of decision matrices; the teams just met for a 3.5hr videoconference session and decided then. Each team member voted for three concepts from a total of approximately twenty concepts and combined ideas from the shortlisted concepts. • Consistent use of CAD to model ideas. • Prototypes were constructed for all the shortlisted concepts. The teams experienced difficulties in sourcing comparable grades of cardboard.	• Videos were employed to share and explain concepts. • *Skype* was used during concept generation. The teams experienced technical problems when using *Skype* and *Google+* from the University premises. Thus, Skype sessions were carried out from home without video streaming. • Teams shifted communication tools depending on design stage.
7	• The teams employed separately the *6-3-5 method* to generate ideas. Then each team selected two to four concepts to develop further. A prototype for two concepts shortlisted by each team, was also	• *Google Drive* and *Facebook* were the primary media to share information.

	generated to help them decide on the candidate solution concept. • The teams presented detailed rationale on the selection of concepts. They did not use decision tables to select the final concept but discussed in one meeting. • To develop the cardboard packaging, the teams utilized *Packmage* software. • They carried out the drop test before sending the packed wine glass by postage.	
9	• The teams carried out separate group sketching activities. • The teams focused on a few specific concepts. They did not use decision matrices to select the final concept; the decision was taken during a videoconferencing discussion. • The teams experienced difficulties in sourcing comparable grades of cardboard. • The teams used *SketchUP* to model their concepts and later on *Autodesk Inventor* to outline the development pattern of the package design. • The teams reflected well on design practices and noted the challenges involved.	• The teams used *Polycom* and *Skype* to communicate. Few technical problems were encountered at university premises; however the teams still carried out videoconferencing sessions at home. • *Google Drive* was used to share information.

4.2 Communication and data logs

Logs of their synchronous communications, for example, *Skype* and *Polycom* videoconferencing and telephone conversations, were plotted (see Figure 2). These show that Teams 7 and 9 followed a similar pattern through the project in terms of increasing their synchronous contact around the middle phase where idea generation, concept development and selection were taking place. Team 4 followed a more unpredictable pattern and included a peak slightly later in the design conceptualization process.

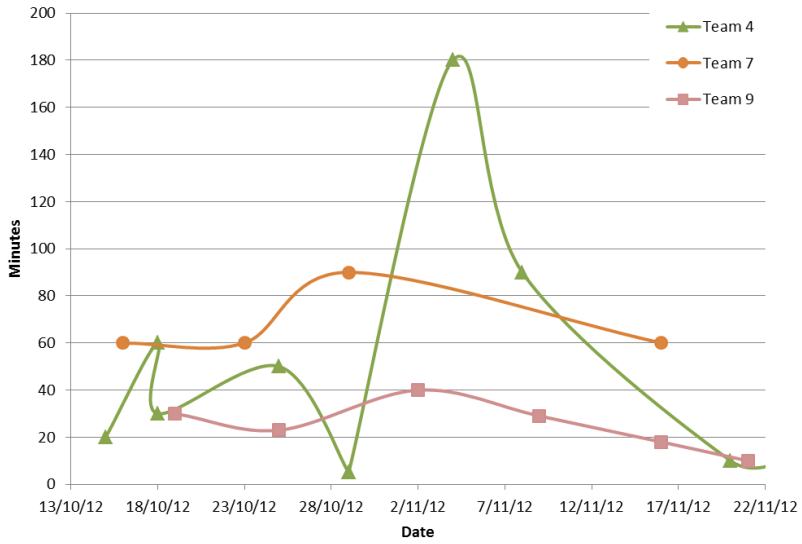


Figure 2: Frequency of synchronous communication for teams 4, 7 and 9

The information media used by the three teams were reviewed based on the teams' logs (Figure 3). These show that Team 4 emphasized the use of photographs, relating to model making and prototyping. Team 7 had a higher number of documents which mostly related to preparation of final project documentation. Team 9 had a balanced set of documents of which sketches were the most common. The output generated by the three teams is illustrated in Figure 4. It was found that Team 4 had the best balance of different sketch types – there was evidence of both talking and thinking sketches being used to help develop the concept and iterate towards a robust solution. Team 7's work

was more ‘talking-focused’ and as a result the team reached a strong consensus but their design lacked rigour and responded poorly to the conditions of transportation. Team 9 on the other hand was dominated by thinking sketchwork. The fact they spent least amount of time in synchronous communication showed a lack of collaboration across the team. While a detailed solution that addressed the safety aspect was developed, it was over-engineered and lacked perspective on the overall aims of the project.

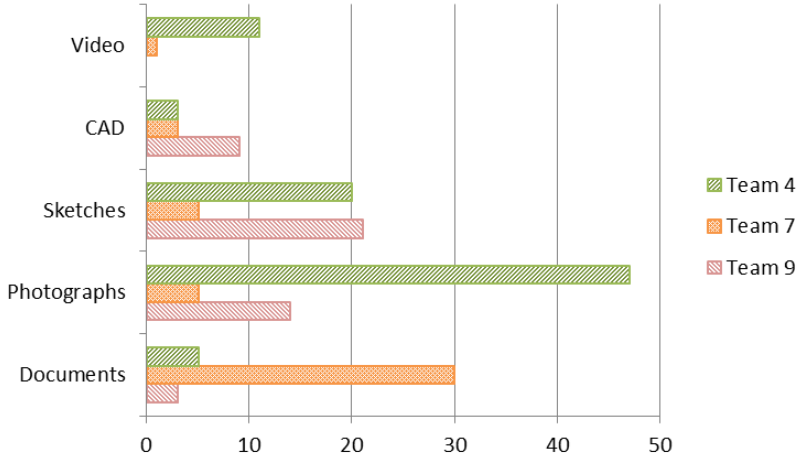


Figure 3: Information media for teams 4, 7 and 9

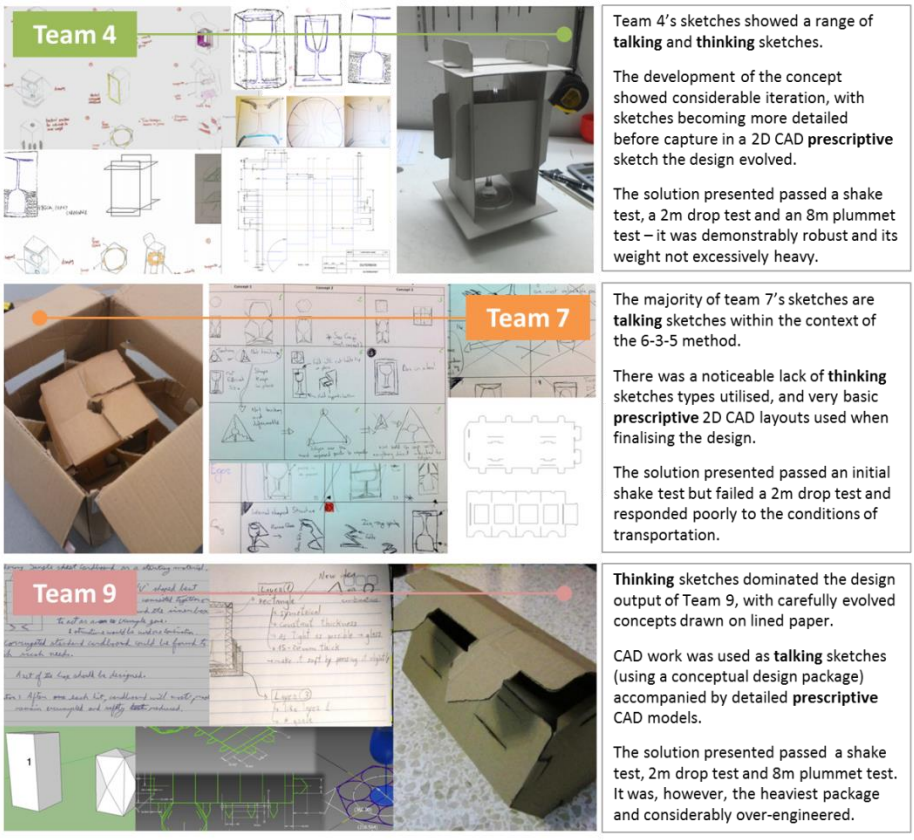


Figure 4: Sample output including sketchwork and final concepts

4.3 Questionnaire

All students were asked to provide feedback on their experience of the project. A Likert Scale was employed addressing key questions in relation to satisfaction, including the project’s structure, content, learning experience, teaching and outcome. Open ended questions were also employed to collect qualitative data. The results obtained by the teams in the distributed location 1 in Scotland (*DL1*) and the distributed location 2 in Malta (*DL2*), are illustrated in Figure 5.

A two sample t-test, performed on the two sets of data revealed that for each of the four questions asked there is no significant difference between the mean rating scores obtained by *DL1* and *DL2* teams ($p < 0.05$). This result indicates that there is coherence as regards to the project's satisfaction exhibited by the two distributed teams. Comments collected from the questionnaire also evidence this result. In particular the best aspects of the project, which were commonly reported by the two sets of teams, included the experience gained of working and communicating with foreign students, the design and prototyping hands-on experience and exposure to different design techniques and ideas. On the other hand, it was commonly reported that more time was required for prototyping. Students also had better expectations from the tools they employed for video conferencing and for data sharing.

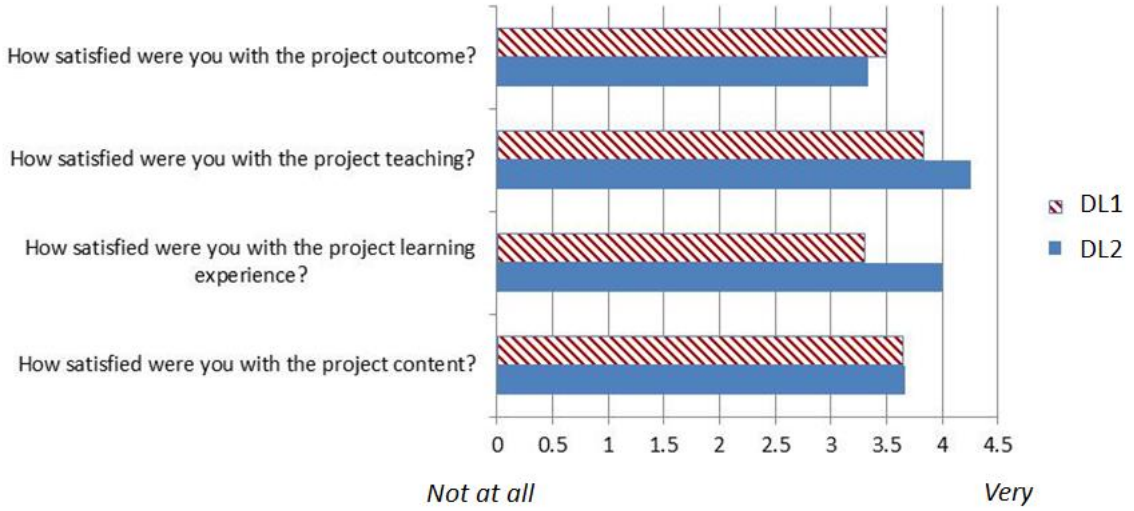


Figure 5: Survey results obtained by DL1 teams in Scotland and DL2 teams in Malta

5 ANALYSIS

The analysis section is presented in two parts: firstly the characteristics of sketches in the distributed design project are reviewed with reference to the literature, and then a new strategy for the distributed management of concept design is outlined.

5.1 Characteristics of sketches in distributed design

Through the quantitative and qualitative analysis of the project, a number of key insights have been inferred regarding the role of sketches in distributed design work:

Sketches provide clarity

The barriers of communication are the greatest challenge facing distributed teams, and sketches provide a medium for teams to exchange rich design knowledge and information. Van der Lugt (2005) emphasizes the role of sketches in creating the external memory of the team, and the different types of sketches all help to contribute towards a shared understanding of the design problem, potential design solutions and strategies to agree on a solution. By externalizing design thinking, everyone is able to contribute and access a more neutral and objective forum in the advancement of shared goals. All of the teams were required to provide clear prescriptive CAD sketches to overcome discrepancies in workshop technologies and access to materials and deliver identical prototypes, with Team 4 showing particular adeptness in revising and reviewing their design. This resulted in a well resolved design that comfortably passed the design tests. These prescriptive sketches are not necessarily created in CAD, but are simply drawings constructed for clarity wherever decisions are made in the design process.

Sketches engage the team

The forming of distributed teams can be a socially inhibited situation. By introducing sketches to the team, this can provide a useful point of discussion to engage the various members of the team. This type of engagement can also be achieved asynchronously, with individuals generating ideas individually and presenting them to their team mates for review, or undertaking shared online sketching sessions. It is possible to adapt existing idea generation techniques to account for this type of activity. Roy and Kodkanir (2000) developed a tool that adopted the 'gallery method' in such a way

that a distributed team was able to share sketches and incrementally add new ones to the evolving grid. A tool such as this helps harness the power of sketches to formalize integration of the team. While Team 7 used a structured idea generation approach, it was conducted at either side of the distributed team rather than together. While the team achieved a good level of rapport, it could have been enhanced further by a cross-location approach.

Sketches help achieve consensus
The incremental exchange of talking sketches, where the workings of a concept are being explained and demonstrated, is typical of concept design and important in obtaining agreement across the team. Indeed, good brainstorming practice (Kelley & Littman, 2001; Kelley, 2006) relies on non-critical and supportive development of others' ideas. Team 7 showed a preference for talking sketches, which resulted in a high degree of consensus and satisfaction across the team, as demonstrated by their qualitative feedback comments. However, their concept suffered from a lack of rigour in analysis. While talking sketches can help build rapport across the team, robust mechanisms are still required for objective design reviews.

Sketches focus creativity
Working in technologically rich environments, there are a number of distractions associated with the management of the team and logistics of information exchange. It has been suggested that sketching can assist in allowing the team to focus on creativity and spend less 'cognitive load' on worrying about technology and driving things like CAD (Carkett, 2004). Of the teams examined in detail, Teams 4 and 9 created the most sketches and their solutions were the most successful in testing. This pattern was, however, observable across the class. These internal sketches act as stimuli and support further idea generation within the team (Goldschmidt & Smolkov, 2006). Team 4 in particular showed evidence of this – the exchange of sketches evidenced an evolution of their design, ensuring the final solution was well refined.

5.2 A training strategy for the distributed management of the concept design phase

Based on the review of the design project and associated literature, Figure 6 summarizes the emphasis of different sketches during the concept phase in a distributed design environment, and hence our recommendations for a preliminary strategy for training students in this respect:

- *Use prescriptive sketches to ensure clarity* – Prescriptive sketches take on an additional importance in the distributed team to ensure there is shared understanding in the different team locations. Increased frequency of milestones where sketches review and capture the current design status provide a means to ensure coherence across the team. This means that rather than just key milestones, such as at concept evaluation or prototype build, a series of mini-milestones result in the generation of sketches that are exchanged and signed off. It could even form an agenda item at synchronous meetings. The generation of this sketchwork adds to the external memory of the team and provides a clear basis for further progression.
- *Use talking sketches to help engagement and achieve consensus* - Sketches can be an effective way to maintain team rapport and morale through the project. By insisting that sketches are used to augment both synchronous and asynchronous communication, rich knowledge and information is shared across the team. This provides a focus on the shared creative effort. The incorporation of fixed goals for the number, type and nature of sketches delivered through the project may seem onerous but would ensure progress in this regard. For example, when engaging in instant messaging, provision of sketch facilities for thinking sketching (and the expectation that a prescriptive sketch is produced at the end of it) ensured communication is more vivid for those directly involved and more accessible to the rest of the team.
- *Use thinking sketches to enhance creativity* - When robust creativity tools are implemented in a form suitable for distributed design, for example an asynchronous 6-3-5 session or a brainstorming session with clear rules to account for time delay, the team focus rests on ideas rather than communication barriers. It is therefore important to consider the team organizational framework that will allow a focus on 'thinking sketches' and the generation of new design ideas.

6 CONCLUSIONS

This paper has reviewed the use of sketching by distributed student teams during the concept design phase. By categorizing three sketch types and reviewing how they were used by teams in a design project, a number of insights regarding the management of distributed student teams have been presented. In particular this paper contributed a preliminary strategy for training students effectively in managing concept design in a distributed environment phase. This strategy is characterized by the use of prescriptive sketches to ensure clarity, talking sketches to help engagement and achieve consensus, and thinking sketches to enhance creativity. It is concluded that sketching is a fundamental tool for all design work, and it is hoped that design educators implement this strategy in their curricula.

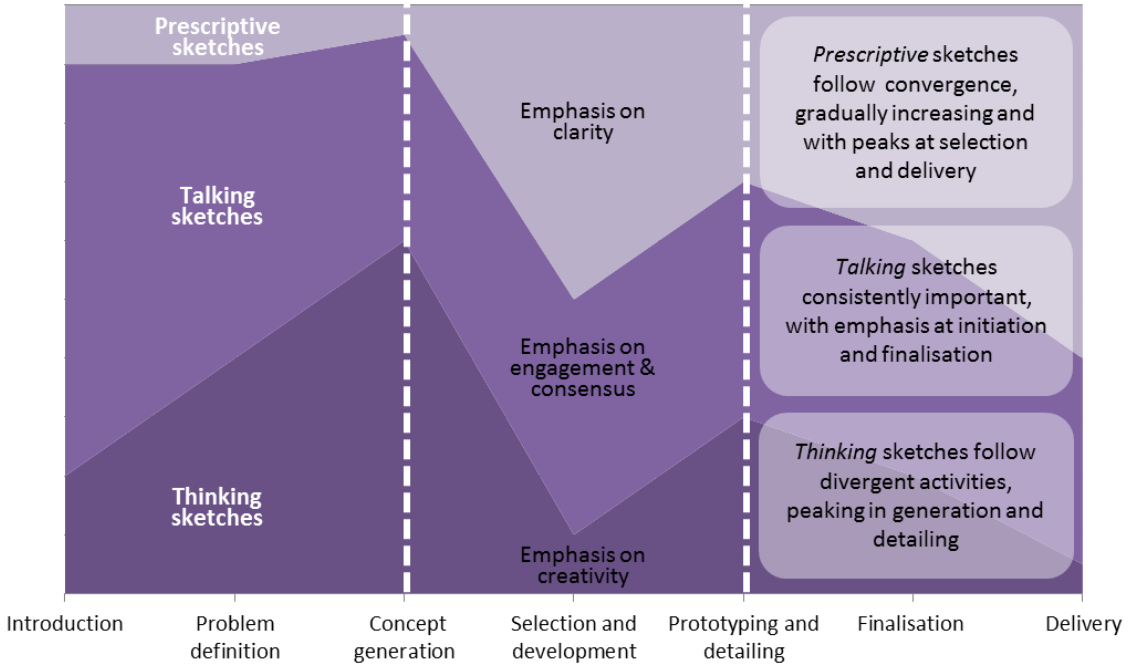


Figure 6: The use of different sketch types through the concept design phase

REFERENCES

Arnheim, R. *Visual Thinking*, 1969, (University of California Press, Berkeley, CA).

Bilda, Z. and Demirkan, H. An Insight on Designers' Sketching Activities in Traditional Versus Digital Media. *Design Studies*, 2002, 24, 27-50.

Borg, J.C. and Farrugia, P.J. Mapping Design Theory into Industrial Applications: Best Practices from Malta, in *Proceedings of DesignEd Asia* Hong Kong, China, 2011, pp. 281-293.

Broadbent, J.A., Cross, N., Rodgers, P.A., Huxor, A.P. and Caldwell, N.H.M. Design Support Using Distributed Web-Based Ai Tools. *Research in Engineering Design*, 1999, 11, 31-44.

Carkett, R. 'He's Different, He's Got 'Star Trek' Vision': Supporting the Expertise of Conceptual Design Engineers. *Design Studies*, 2004, 25, 459–475.

Coates, G., Duffy, A.H.B., Whitfield, R.I. and Hills, W. A Methodology for Design Coordination in a Distributed Computing Environment, in *Proceedings of International Conference on Engineering Design ICED 99*, Munich, Germany, 1999, pp. 673–678.

Cross, N. *Engineering Design Methods, Strategies for Product Design*, 1994, (John Wiley & Sons, Chichester, UK).

Cross, N. Expertise in Design: An Overview. *Design Studies*, 2004, 25 (5), 427-441.

de Sausmarez, M. *Basic Design: The Dynamics of Visual Form*, 1964, (The Herbert Press, London, UK).

Dicken, P. *Global Shift: Reshaping the Global Economic Map in the 21st Century*, 2003, (SAGE Publications, London, England).

Dorst, K. and Cross, N. Creativity in the Design Process:Co-Evolution of Problem–Solution. *Design Studies*, 2001, 22 (5), 425-437.

Eris, O. and Martelaro, E. A Comparative Analysis of Sketching Interactions of Designers in Co-Located and Distributed Environments, in *Proceedings of Proceedings of Design Thinking Research Symposium – DTRS8*, Sydney, Australia, 2010, pp. 149-162.
Ferguson, E.S. *Engineering and the Mind's Eye*, 1992, (MIT Press, Cambridge, MA).
Ferguson, R.W. and Forbus, K.D. A Cognitive Approach to Sketch Understanding, in *Proceedings of AAAI Spring Symposium on Sketch Understanding*, Menlo Park, CA, 2002, pp. 67-72.
Goel, V. *Sketches of Thought*, 1995, (MIT Press, Cambridge, MA).
Goldschmidt, G. The Dialectics of Sketching. *Creativity Research Journal*, 1991, 4 (2), 123-143.
Goldschmidt, G. and Smolkov, M. Variances in the Impact of Visual Stimuli on Design Problem Solving Performance. *Design Studies*, 2006, 27, 549-569.
Kelley, T. and Littman, J. *The Art of Innovation*, 2001, (Profile Books, London, UK).
Kelley, T. *The Ten Faces of Innovation: Strategies for Heightening Creativity*, 2006, (Profile Books, London, UK).
Lugt, R.v.d. How Sketching Can Affect the Idea Generation Process in Design Group Meetings. *Design Studies*, 2005, 26, 101-122.
Mark, G. Conventions and Commitments in Distributed Cscw Groups. *Computer Supported Cooperative Work*, 2002, 11, 349–387.
McKoy, F.L., Vargas-Hernández, N., Summers, J.D. and Shah, J.J. Influence of Design Representation on Effectiveness of Idea Generation, in *Proceedings of DETC'01: ASME 2001 Design Engineering Technical Conferences and Computers and Information in Engineering Conference*, Pittsburgh, PA, 2001, pp. 9-12.
Milne, A. and Winograd, T. The Iloft Project: A Technologically Advanced Collaborative Design Workspace as a Research Instrument, in *Proceedings of International Conference on Engineering Design*, Stockholm, Sweden, 2003, pp. 315-316.
Nicol, D.J. and MacLeod, I.A. Using a Shared Workspace and Wireless Laptops to Improve Collaborative Project Learning in an Engineering Design Class. *Computers & Education*, 2004, 44 (4), 459-475.
Pugh, S. *Total Design*, 1991, (Addison-Wesley, Reading, UK).
Purcell, A.T. and Gero, J.S. Drawings and the Design Process: A Review of Protocol Studies in Design and Other Disciplines and Related Research in Cognitive Psychology. *Design Studies*, 1998, 19 (4), 389-430.
Rodgers, P.A., Green, G. and McGown, A. Using Concept Sketches to Track Design Progress. *Design Studies*, 2000, 21 (5), 451-464.
Rogers, P. and Lea, M. Social Presence in Distributed Group Environments: The Role of Social Identity. *Behaviour & Information Technology*, 2005, 24 (2), 151-158.
Roy, U. and Kodkanir, S.S. Collaborative Product Conceptualization Tool Using Web Technology. *Computers in Industry*, 2000, 41, 195-209.
Santanen, E.L., Briggs, R.O. and Vreede, G.-J.d. The Impact of Stimulus Diversity on Creative Solution Generation: An Evaluation of the Cognitive Network Model of Creativity, in *Proceedings of 36th Hawaii International Conference on System Sciences (HICSS'03)*, Big Island, HI, 2003, pp. 1-10.
Schilling, M.A. *Strategic Management of Technological Innovation*, 2006, (McGraw-Hill, New York, NY).
Schneider, S.C. and Barsoux, J.-L. *Managing across Cultures*, 2003, (Pearson Education, Harlow, England).
Schutze, M., Sachse, P. and Romer, A. Support Value of Sketching in the Design Process. *Research in Engineering Design*, 2003, 14, 89-97.
Tang, H.H., Lee, Y.Y. and Gero, J.S. Comparing Collaborative Co-Located and Distributed Design Processes in Digital and Traditional Sketching Environments: A Protocol Study Using the Function-Behaviour-Structure Coding Scheme. *Design Studies*, 2011, 32, 1-29.
Tseng, W.: The Influences of Unstructured Ambiguous Figures in Ideation and Interpretation. International Association of Societies of Design Research, Hong Kong, China (2007)
Ulrich, K.T. and Eppinger, S.D. *Product Design and Development*, 1995, (McGraw-Hill, New York, NY).
Wang, L., Shen, W., Xie, H., Neelamkavil, J. and Pardasani, A. Collaborative Conceptual Design-State of the Art and Future Trends. *Computer-Aided Design*, 2002, 34, 981-996.