The contribution of structural activities to successful design

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Abstract: Examining case studies in design teaching and their analysis, we identify the role of structural activities and other solution searching activities in design learning and problem solving. The case studies follow students working on the same problem under two conditions—one group is taught using traditional face-to-face teaching while the other group is additionally supported by a text-based web board. The design activities of two students were followed in each condition through a semester, followed by in-depth interviews at the end of semester. The results show that cases with above average design work involved more structural activities than the mediocre cases. It also showed that design problem dissections are more organised in the better cases. These successful cases engaged in textual expression of their design solutions. Computer tools for design should therefore support multiple representations of design work.

Keywords: design, CSCWD, learning, text, problem solving, representation.

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1 INTRODUCTION

This research is rooted from the research by Vera *et al.* [1] on the effects of computer mediation on solving architectural design problems in collaboration where results showed that in bandwidth-limited chat-line conditions, participants cut down low-level design exchanges but attempted to maintain high-level design exchanges with similar quantity and quality. These initial studies were extended to consider the role of text in learning [2] in which the role of text in supporting learning in a CSCL context was identified.

The present study further examines the role of text in design learning by taking the study out of the laboratory setting. Here we follow four students through a semester-long design task, two students being taught by traditional face-to-face desk reviews and two having these design reviews supplemented by a web-board-based text communication with fellow students as well as tutor. By analysing the sub-tasks in design undertaken by successful and less successful students, we are able to identify the means in which text supports design exploration. This study then enhances our understanding of the role of computer-supported collaborative design activities.

1.1 Background

In Vera *et al.* [1], the chat-line condition comprised text-based activities between design collaborators under laboratory conditions in which the goal was to examine the support of collaborative activity. Design in non-laboratory conditions, however, is typically considered as a process with visual- and verbal-based activities interwoven. Research in design often considers the respective roles of these two modes in collaboration [3]. Vera *et al.* [1] identified, however, that there was a correlation between the exploration of design problems in text with the degree to which a design problem space is explored. Thus in this research we have introduced a more general class of activities, text-based activities, as an essential part of design learning and studied the effect of supporting text communication using a computer web board. Also, instead of directly introducing the activities of interest in the study, we have examined its role outside a laboratory setting, in a design studio assignment.

Design is viewed as ill-formed problem [4]. In a design process, ideas develop incrementally from an abstract level to a concrete level by moving from a schematic level to a detailed level. This increase in specificity is not of course linear and may progress at different rates in different aspects of the design solution. As designers consider various aspects of the task, design problem will be elaborated and defined in greater detail. At points, a design may reframe a design problem as a set of several smaller sub-problems in order to resolve a particular issue.

Problem solution is affected by problem perception [5]. The uniqueness of design as a problem solving activity lies in the possibility of unlimited number of solutions (its ill-formed nature) in contrast to the well-formed nature of a geometric problem, for example. The range of design solutions presented in a class can therefore vary drastically if students frame their understanding of the problem in different ways. These different approaches to framing will occur at all levels in an architectural design problem, for example, starting from design concept down to floor circulations and building details. In the sequential nature of design exploration, the framing of earlier problems will have an effect on later sub-problems [3].

Fricke [6] has noted that successful designers engage in processes characterised by in part by the extent to which the designer produced variants and assess these together, not discarding choices sequentially. Thus, we set out to identify design processes undertaken by our subjects to identify their use of explorations of design alternatives.

When a design task is treated as a problem-solving situation, exploring multiple solutions at a time to a problem should aid understanding by a novice. Exploration of multiple paths not only enhances the comprehension of a problem but may also suggest the choice of the best solution as a result.

Design can be considered an expert activity [7]. Experts do not propose solutions but work towards them, they chunk the problem in larger pieces. Novices, in contrast, typically work backwards from the desired solution to the problem and chunk the tasks in smaller pieces [8]. Many of the designers have the habit of proposing possible design solutions as soon as having grasped the design problem. This is the practice of experienced designers after they have got used to most of the design procedures and treat them as if they were routine tasks. In this case, designers frame the design tasks and sub-tasks implicitly in their mind, digested them and generate possible solutions. This approach, however, will be inapplicable when designer is unfamiliar to the design problem or when the design problem is so complicated that mere tackling it mentally will be overloading.

Appropriate problem representations can aid the identification of creative solutions [9]. Some representations will be more effective than others [10]. Goldschmidt [11] notes that re-representations of design concepts and solutions are essential to successful design. Such representation allows for concepts to be compared, joined, transformed or interpreted. In studio learning terms, this implies that re-representation supports better understanding of the design problem at hand.

It has been noted that different design strategies will affect the design process and hence the product [12]. Some strategies are more appropriate for a particular situation than other strategies. Strategies are not universally successful and must be adapted to the problem at hand. Thus, learning about design will be more successful if the student can be made aware of their design strategies and can develop techniques of working that support exploration.

2 METHOD

With these ideas in mind, we have analysed design activity to identify structural activities, that is, those activities in which the designer re-expresses a problem in an organised and systematic way, manipulating ideas using programming languages, standardized symbols, flow diagrams, written languages or mathematical symbols. Textual activities are therefore a subset of structural activities. The authors believe that structural activities, e.g. elaborating a conceptual idea with text, mark explicit problem framing. Such re-presentation of the problem aids understanding and thus learning of design.

There is no standard way of conducting analysis on design activities. One of the very usual methods is utilizing the think-aloud protocol, which was first introduced for the investigation of problem solving in cognitive psychology. Nevertheless, there is contention as to whether intentional verbalization can truly reflect the internal cognitive processes of the designers and whether it will affect the process itself during the task [13]

Furthermore, most design activities research uses a specifically contrived standard task for the subjects to solve. These tasks are intended to be appropriate for subjects and feasible within the time available in the experiment [14]. Design processes typically recorded on audio or videotape and transcribed.

This study employs neither the think-aloud protocol nor the standard task approach. We are especially interested in learning in real design studio settings and have chosen therefore to utilize a case study approach in order to capture the most out of the activities in real design learning situation. In order to capture problem-framing activities, we divided the observed design tasks into sub-tasks according to the way it was tackled by the design students. This process was carried out for each of the cases.

Our primary interest in this paper is to examine the ways in which students approach design and the support they receive from computer-supported communication during their design activities. To this end, we examine the mode in which students frame a design task or sub-task. Hence we have examined the role of structural activities such as diagrams and text-based activities in the process. The relationship between design quality and dissembling pattern of a design problem was investigated also.

2.1 The design studio

In this study, we followed individual students in a design studio project. We selected architectural students in the second year of study as they have some basic architectural knowledge but yet have to refine and enrich their understanding of the field. The design studio project of interest was a one-semester project to design a fire station in Macau. Students could choose between four alternative sites, all of which were on the coastline. The major components of the fire station had to be implemented from designed components manufactured off-site. The design brief called for a five-bay appliance room for six vehicles, a drill tower, a dining room, barracks and a boat shelter standing in part on land and in part on the water.

We employed a multiple-case approach to this study in which architectural students in the University of Hong Kong participated. In order to follow replication logic in the case selection process, we monitored the performance of two design studio groups, comprising about 10 students each, for over two months in the design studio project. One design studio group was taught by a studio tutor in the common manner of desk reviews [4]. The other group was taught in a similar manner with communication with the design tutor supplemented by a computer-based bulletin board (Webboard by O'Reilly Associates) in which they posted messages and queries about their design investigations. The design tutor responded to all queries daily and encouraged students in the group to participate in online collective discussions about their design work.

2.2 Recording activities

The activities of the students in these two groups were monitored continuously by the research team, this monitoring consisting of periodic interviews and noting of each individual's activities in logs of studio progress each week. Design tutors assessed the performance of the students in the normal manner. Using these assessments, we identified two classifications of students, type A and type B. Those who were considered to produce good design work were labelled type A. In this classification, the students demonstrated steady and above-averaged performance in the semester in studio sessions and their resulting work were selected for display in a public exhibition held at the end of the semester. Type B cases were students producing mediocre design work; these students demonstrated below-average performance in the semester in most of the studio sessions, the design works were subject to significant criticism in many studio sessions and their resulting projects were not assessed highly.

For the purposes of this case study, we have reported on four students, two of type A and two of type B. After subjects were identified, records of their respective design activity throughout the semester were verified by in-depth interviews of 40–70 minutes. All interviews were tape recorded and processed accordingly together with the logs of studio activity.

2.3 Analysis

Data from these four cases were mainly the logs of design accumulated throughout the project, supplemented by recorded interviews. These data were coded using to two schemas.

A task segmentation schema was used to dissect the design process according to the way it was framed by subjects and design processes were segmented according to the sub-tasks involved. For instance, if a student designs the floor plans of a building by first designing the functional massing diagrams and then floor plans afterwards, this part of design will be segmented into two parts.

Segmentation charts of the four cases were coded and major design activities involved in each sub-task were illustrated. An activity-based schema was utilized to code the design logs in order to reveal the nature of methods employed to frame and to tackle a design task or sub-task. This activity-based model was similar to Akin's activity-based model [15] but we supplemented this by coding first to identify the searching for design alternatives and also to note steps at which the student engaged in re-representation of the situation to enhance understanding. These latter we called 'structural' tasks as it involved restructuring the problem situation.

3 RESULTS

Data is presented here as counts of sub-tasks exhibiting particular attributes. Analysis of the data shows that type A students engaged in more sub-tasks than students type B in which searching of alternatives was a priority (Table 1). This agrees with the findings of Fricke [6].

In this coding, however, we notice that much of the work undertaken by our students was not accounted for. In particular, following on our earlier work in the use of text [1], we noted some students employed text more often as a mode of problem representation than others. Upon coding for the use of text we noted that successful

Table 1

Case Type	*Alternative searching*
A1	6
A2	8
B1	1
B2	2

Table 2

Case Type	*Use of text*
A1	4
A2	5
B1	2
B2	2

students engaged in greater use of text, whether they had access to a web board or not (Table 2).

Having identified this, it became apparent that some students were engaged in re-representation of the problem at a particular moment. We called this re-representation a *structural activity* and identified that it occurred in seven modes:

1 Use of analytical diagrams
2 Diagrams with detailed annotations
3 Calculations and analysis worked out on paper
4 Textual elaborations of requirement information
5 Textual elaborations of design problems
6 Textual elaborations of design concepts
7 Textual elaborations of design procedures

In these, four modes employed text extensively. Coding the subtasks in this manner identified that students who engaged regularly in structural activity tended to be more successful (Table 3).

Thus, successful students not only engaged in the search for alternative solutions but also re-represented the problem understanding by engaging in structural activities (Table 4).

Student A1 exhibited this behaviour most clearly. From the pattern of segmentation, we can see a clear and systematic pattern of design process flow as the student approached design tasks carefully throughout the design studio. There was minimal overlapping (intersection) of design sub-tasks on activities.

4 DISCUSSION

In this study we have identified some of the working processes of successful design students. These students exhibit the behaviour identified by Fricke, i.e. the examination of more design alternatives, replicating one of the behaviours of a successful student.

In addition to engaging in searching of alternatives, we have also identified that these students engage in more textual activity, as noted in earlier laboratory studies of design collaboration. In order to identify how these textual expressions contribute to design, we have, in this study, introduced the concept of 'structural activity' as an act of re-presenting or restructuring conceptual ideas. We have found that students employ textual representations as an important component of structural activity. Structural activity is found to be important, as, through the act of re-representation, it appears that students have come to explore the solution space more extensively.

Table 3

Case Type	*Structural activity*
A1	5
A2	7
B1	2
B2	3

Table 4

	Activity	
Case Type	*Structural*	*Alternative searching*
A1	5	6
A2	7	8
B1	2	1
B2	3	2

Successful students have engaged in significantly more structural activity than less successful. These re-representations appear to aid the students in seeking better solutions, as suggested by Mumford [10]. This supports the proposals by Newell and Simon [5] and Eisentraut [12] that certain representations are more favourable for problem perception and solution seeking. In this study, we have identified that the representation of the interim problem formulations can be successfully supported by textual expressions.

The key effect of structural activities on design quality was its influence on problem representation for the designers. These structural representations, e.g. bubble diagrams, tree diagrams, calculations and elaborations were effective as they are better representation for some of the design subtasks. The extent to which such structural activities are of assistance to a student appears to vary, but the apparent connection between undertaking such activities and success is strong. This is due to wording or other issues such as attitude affect people's understanding of them and led to construction of different problem representations.

From our findings here, text is a substantial component of structural activity. The two students who engaged in structural activity employed text as a mode of re-representation. This reinforces the findings under laboratory conditions that students using text explored more design alternatives. In a design studio setting the finding has been confirmed.

4.1 Implications for collaborative design support

Design collaboration can be supported through creating an environment for design, providing the equipment and tools to support appropriate multiple design representations and encourage alternate design approaches. Prior research suggested that supporting textual exchange was beneficial to collaborative activity. This study suggests that such representation is beneficial for individual work as well.

Text-based activities can support some of the exchange of design ideas. This research and similar ones on design problem representation may be a way to seek a clearer picture and a better support of collaborative design. After acquiring more knowledge on framing patterns of design problem and supporting activities for respective design subtasks, we will be able to support design learning through promoting design strategies and skills of choice during relevant practices phases.

If successful designers engage in structural activity (i.e. re-representation of design understanding) and if text plays a major role in such activity, collaborative design systems need to support effective structural representation, including text and not only graphic, audio or video, at all stages of design investigation and representation.

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BIOGRAPHICAL NOTES

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