Examining Learning in Multiple Settings
Using a Linkograph to Examine Design Learning

Kvan Thomas and Gao Song
Department of Architecture, The University of Hong Kong, Pokfulam, Hong Kong

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Abstract: We use linkographs as a means to examine single and double loop learning within three designed settings. Two types of learning are dynamic processes related to design process. The linkograph is a technique to examine the inter-connective pattern of design moves. Extending our previous analysis of design communications, we investigate the extent to which Schön’s design process consisting of “framing-moving-reflecting” can be identified in communications. The linkographs identify learning loops, the results support prior findings that distal text based communication, although less extensive, is richer in design exchanges; here richer learning is also identified.

1 INTRODUCTION

Face-to-face communication is assumed to be the preferred context for collaborative design. With the introduction of computer and Internet technologies, online remote settings are becoming more broadly adopted. Distal designers cooperate by means of asynchronous, semi asynchronous, or synchronous design and communication tools. Earlier studies on the effects of these new tools on design and learning performance have generally focused on individual learning but we note that collaborative teams must engage group learning as well. Organizational learning has been identified as the process of improving group performance through better knowledge and understanding (Fiol and Lyles 1985). In this paper, we argue that the methodology for understanding learning can be employed as an indicator to examine the impact of different design tools on the process of design teams operation and learning. In this experiment, we asked postgraduate students to use different communicational media in designing and examined the communication protocols recorded during their design activity. These protocols were analysed statistically and the results reported in Kvan and Gao (2004). Here we analyse the same protocols by means of linkographs to identify connectivity in design ideas. We identify measures for the richness of the linkographs and analyze two organizational learning loops (single and double) in the design process.

The impact of collaborative technologies on design practical and educational process improvement have been studied in recent years. Experimental studies show
that textual supported distal design environment not only can engage designers in designing, but also improve design performance. Gabriel and Maher (2000) found that designers successfully engaged in design issues using chat-line communication. In an earlier study (Kvan and Gao 2004), the authors noted that the use of text may facilitate reflective thinking during design. We found that the chat-line facilitated students in engaging in more framing activities. The studies conducted in design studio demonstrate semi-asynchronous and asynchronous design tools contribute to better design results and performance. Compared to traditional design studio settings students can produce more design ideas when using Web-board the semi-asynchronous design tool (Kvan, Wong, and Vera 2003). Lahti, Seitamaa-Hakkarainen, and Hakkarainen (2004) identified that an Internet environment could help design team to engage more intensive collaboration and produce better design products in the end. These papers have not, however, examined the nature of the design process in different conditions to understand whether the complexity or richness of the design conversations is influenced by the medium of communication.

2 LEARNING AND THE DESIGN PROCESS

We teach design in the studio context to enable students to learn the tacit knowledge essential to professional work. In the studio, students normally discuss their design ideas with their colleagues and tutors (Cuff 1991). In this research we start with the assumption that practice is a collaborative activity; hence it is important to support team learning in addition to individual learning.

2.1.1 Learning Loops

The purpose of learning is knowledge acquisition and application. There are many ways of learning. Vygotskii (1978) analyses three methods of learning that deal with the interaction between learning and development. In the three methods, the concepts of learning and development are different. The first is that learning is simply to use the product of development. In this approach, “learning is a purely external process that is not actively involved in the development”. Development is the degree of mental maturation allowing people to conduct this learning process. The second method is that learning and development occur immediately, or simply saying that learning is development. The process of learning completely interweaves with the process of development. “Learning and development coincide at all points in the same way that two identical geometrical figures coincide when superimposed.” The third is that the learning process stimulates and pushes forward the maturation of development. The two processes are inherently different but related. Development is the process of mental maturation; while learning is also a developmental process.

Vygotskii notes that it is this latter aspect that higher education engages. Due to individuality in learning, not every student can master all aspects of learning. Biggs (1999) identifies two levels of learning, academic learning (high-level engagement)
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and non-academic learning (low-level engagement). When students engage in the high-level form, they can relate and apply their knowledge, reflecting and theorizing their learning. When students engage in the low-level form, they engage in activities of memorizing, notes taking and recognizing. Biggs indicates that students with high-level engagement need less help from teachers than those students with low-level engagement.

Vygotskii (1978) developed a model called the “zone of proximal development” that addresses differences in learning:

It is the distance between the actual development level as determined by independent problem solving and the level of potential development as determined through problem solving under adult guidance or in collaborative with more capable peers.

Developing this concept, Doolittle (1997) classifies two stages of learning, early learning and late learning. Early learning relies on assistance and only can use the product of development, while late learning need no assistance and can apply and theorize what has been learnt, thus pushing forward development. The transition from early learning to late learning involves cognitive development through the constructive interaction between teachers and students. Both stages of learning are correlating with Biggs’ two levels of engagement.

In the field of organizational learning the learning style is divided into two levels or two cycles (Argyris and Schö 1996; Fiol and Lyles 1985). Low-level learning is identified by Argyris and Schö as single loop learning and high-level learning as double loop learning. The difference between single and double loop learning is located at the degree of inquiry. When people engage in single loop learning, they limit their inquiry between “problem setting” and “problem solving”. The strategy they adopt leaves the value of a theory of action unchanged. In this type of activity, professionals engage in routine, repetitive work. By contrast, double loop learning is considered a high level activity that encompasses change the value of theory-in-use.

"In this type of organizational double-loop learning ... they do so through organizational inquiry that creates new understandings of the conflicting requirements – their sources, conditions, and consequences – and set new priorities and weightings of norms, or reframes the norms themselves, together with their associated strategies and assumptions."

(Argyris and Schö 1996, 25)

Single loop learning includes action strategy and its consequences, whereas except both elements double loop learning has governing variables, which give direction to other two actions. Figure 1 describes the process of these two learning loops.
2.1.2 Design Learning and Design Process

The design process has been identified as a learning process (Cross 1980; Schön 1985). Through engaging in designing, designers learn about a design problem and know more about it at the end than in the beginning (Cross 1980). This characteristic of designing is called as “reflective conversation with the situation” consisting of framing, moving and reflecting (Schön 1985). It is through learning-by-doing that students understand and comprehend design problems and abstract theories from the design process. Schön’s contribution to design learning and its application in examining design protocols using the three actions has been discussed elsewhere (Kvan and Gao 2004). An important contribution in Schön’s work is to identify that we not only need to teach students how to solve design problems but also, more importantly, how to identify problems. The concept of the inquiry of both learning loops therefore is very similar to the idea of framing in that they provide the guidance of designing or learning for further actions. From this, we suggest that a design process that moves from framing through reflection, then on to other activities and then returns to engage in further framing and reflection may correlate to a learning loop. Thus, although we do not claim that learning loops are directly reflected in the encoding, the revisiting of an idea may indicate engagement in learning. Connecting the conclusion made from last paragraph, we adopt the concepts of two learning loops as indicators to examine design learning under different design environments.

3 CODING SCHEMA

Learning loops are tacit and not easily identified; statistical analysis of protocols cannot identify such learning. To identify developmental steps in designing, therefore, we have used the graphing technique of linkographs to track the development of design ideas. Developed by Goldschmidt (1990), the linkograph is a tool to encode design activities by identifying interlinked design moves by way of a systematic triangular web. We then analyze the resulting graph using graph theory to distinguish the graphs. Table 1 illustrates the definition of terms adopted in this paper. These terms are used to measure this triangular web. Some of them are same with the terms used by Goldschmidt; others derive from the domain of graph theory.
### Table 1 The definition of terms

<table>
<thead>
<tr>
<th>Name</th>
<th>Abbr.</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Links</td>
<td>L</td>
<td>The number of linked design moves in a component; the larger the diameter of a single component, the more extensive a design thought.</td>
</tr>
<tr>
<td>Index</td>
<td>I</td>
<td>A process or a portion of it is the ratio between the number of links and the number of moves that form them (Goldschmidt 1990).</td>
</tr>
<tr>
<td>Component</td>
<td>C</td>
<td>One unit in which all design moves are inter-linked; the larger the number of components, the more fragmented the design session.</td>
</tr>
<tr>
<td>Diameter</td>
<td>Di</td>
<td>The number of linked design moves in the largest component in one setting; the larger the diameter of a single component, the more extensive a design idea.</td>
</tr>
<tr>
<td>Depth</td>
<td>De</td>
<td>The largest number of nodes linking two discrete design actions in a component and hence describes complexity of relationships between design actions.</td>
</tr>
</tbody>
</table>

Table 2 explains the definition of the elements used in a component and their legends. We considered the metric of the index inadequate to compare the complexity and richness of design activity manifest in our protocols. This study therefore introduces the following metrics to describe the results as displayed in a linkograph. Figure 2 illustrates an example of one component. In this component, the number of links is thirteen the number of moves is fifteen, thus the index would be 0.87; the diameter is fourteen and the maximum depth is two.

### Table 2 Elements and their legends in a component

<table>
<thead>
<tr>
<th>Name</th>
<th>Abbr.</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Framing</td>
<td>F</td>
<td>Identify a new design problem;</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Interpret further from design brief.</td>
</tr>
<tr>
<td>Moving</td>
<td>M</td>
<td>Proposed explanation of problem solving, a tentative solution.</td>
</tr>
<tr>
<td>Reflecting</td>
<td>R</td>
<td>Evaluate or judge the explanation in Moving.</td>
</tr>
<tr>
<td>Node</td>
<td>N</td>
<td>A symbol links two design moves</td>
</tr>
</tbody>
</table>

A previous study coded the protocols using Schön’s model of framing, moving and reflecting and identified that the number of problem framing activities by using chat-line to communicate is less than the number of communication in face-to-face modes but that remote communication is proportionately richer in framing activities (Kvan and Gao 2004). Statistical analysis shows there is significant difference of design activities when remote setting compared to both co-located settings. Designers seem to transform and reconstruct frames more efficiently in online
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remote setting. To examine the implication further, we have represented the encoding using linkograph to examine the connectedness of frames, moves and reflection throughout the design sessions.

![Linkograph Example](image)

**Figure 2** An example of a component

3.1 Goldschmidt’s Linkograph and Schön’s “Framing-moving-reflecting” Model

Goldschmidt developed the linkograph to represent design chunks and test design productivity. Design chunks represent the organization of reasoning and group together moves which are interconnected in the act of design exploration. The design moves in her study are the reasoning actions, which can be compared to Schön’s three design activities. Using the protocols in which we have previously encoded designs actions using the F-M-R model, the linkograph reveals the interconnected actions and thus the depth of an idea. In addition to representing connectedness by the graphs, we identify double and single loop learning by way of combining an encoding of the design protocol using Schön’s design process and representing the encoding by means of the linkograph. By this technique, the pattern of a design process can be visualized holistically.

3.2 Validation

A significant way of validating the effectiveness of a network on collaborative learning is to ask what effect it has upon the design process (Eason and Olphert 1996). They emphasize usage scenario as an important indicator to analyze the impact of proposed system. One strategy of this scenario is to videotape the iteration process between the interaction of user and proposed system thus the impact on organizational task can be concretely analyzed. The protocol analysis adopted in our experiments belongs to this method. Other ways to evaluate the validity is to discriminate the outcomes and the degree of users’ satisfaction (Andriessen 1996). By integrating the above means with the characteristics of our experiments, we selected two methods. One is to measure the satisfaction of users by way of a questionnaire and the other is to measure the validation of coding scheme we adopted from Schön (1985) and Goldschmidt (1990). Schön’s coding scheme has been tested in a pilot study and modified to improve its reliability (Kvan and Gao 2004). Previous study demonstrates that using chat-line based communication tools has raised the proportion of problem framing. Thus according to Eason and
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Olphert’s usage scenario, this data prove the validation of chat-line remote setting in design session. Goldschmidt’s technique has been used twice to examine the inter-relation between design activities and finally made a consensus. The results of the questionnaire present most of students agree that they could easily draw and express design ideas through drawing and communication by using different tools.

4 RESULTS AND DISCUSSION

Using Goldschmidt’s (1990) index, the description of largest component in each protocol in setting was measured and the mean of these numbers calculated. From this measure, we see that the largest mean index number is obtained for the digital co-located setting. The measure of the index, however, does not inform us of the breadth of the complexity in the design activity. To identify this, we have employed the three standard graph descriptors introduced in the section above, component, diameter and depth.

Table 3 compares the mean value of total number of components and diameters across the three settings; and their ratio. For each metric we have shown the mean of each across the six protocols recorded in each setting. The first column shows the mean value of the number of component in each setting. The mean of component in remote setting is much less (5.8) compared to paper (26.8) and digital based co-located settings (13.5). The next row presents the mean value of the number of link. By comparing the mean value of link among the three settings paper co-located setting contains largest number (238); remote setting has 81; and digital co-located setting has 188. We assume that if fewer components occur while richer links found, then leading to design complexity. In other words, the ratio of link and component (ML/MC) is an indication of the design productivity. The ratio in digital co-located setting is the highest (14.90), next is remote setting (13.96) and the last is paper co-located setting (8.88).

<table>
<thead>
<tr>
<th>Setting</th>
<th>Component Mean</th>
<th>Component SD</th>
<th>Link Mean</th>
<th>Link SD</th>
<th>Ratio (ML/MC)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Remote setting</td>
<td>5.8</td>
<td>2.79</td>
<td>81</td>
<td>21.40</td>
<td>13.96</td>
</tr>
<tr>
<td>Paper co-located setting</td>
<td>26.8</td>
<td>10.76</td>
<td>238</td>
<td>49.86</td>
<td>8.88</td>
</tr>
<tr>
<td>Digital co-located setting</td>
<td>13.5</td>
<td>5.5</td>
<td>188.8</td>
<td>74.01</td>
<td>14.90</td>
</tr>
</tbody>
</table>

Table 4 describes the index metric of the largest components among the three settings and three largest components in each setting. In each design session we choose the largest component, thus totally six components in each setting. The first three columns compare the mean value of total link; mean value of the numbers of
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moves; and index. Results indicate the mean value of total link and the mean value of numbers of moves in paper-based co-located setting is the highest (85.7; 121); next is the remote setting (59.7; 61); and in digital based co-located setting the mean value of total link and moves are 87 and 93.3. When comparing the value of index it shows digital co-located setting holds the largest number (1.12); remote setting is the next, which is 1.07; and paper-based co-located setting is 0.71.

By isolating the largest component in the three settings for investigating we find that digital co-located setting contains the largest number of diameter (164); the greatest depth is 5. The remote setting holds the largest number of greatest depth (9) though the diameter of it is less than that of digital face-to-face environment that is 83. The largest component in paper-based setting has 132 diameter and 7 of the greatest depth.

Table 4  Index metric of the largest components among three settings

<table>
<thead>
<tr>
<th>Setting</th>
<th>Total link Mean</th>
<th>Total link SD</th>
<th>Number of moves Mean</th>
<th>Number of moves SD</th>
<th>Index Mean</th>
<th>Index SD</th>
<th>The largest one in each setting</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Diameter (Depth) 1</td>
</tr>
<tr>
<td>Remote setting</td>
<td>59.7</td>
<td>16.81</td>
<td>61</td>
<td>17.25</td>
<td>1.07</td>
<td>0.32</td>
<td>83 (9)</td>
</tr>
<tr>
<td>Paper-based co-located setting</td>
<td>85.7</td>
<td>36.45</td>
<td>121</td>
<td>25.20</td>
<td>0.72</td>
<td>0.32</td>
<td>132 (4)</td>
</tr>
<tr>
<td>Digital based co-located setting</td>
<td>87</td>
<td>49.78</td>
<td>93.3</td>
<td>54.73</td>
<td>1.12</td>
<td>0.05</td>
<td>164 (4)</td>
</tr>
</tbody>
</table>

1. The depth in parentheses indicate the depth of the component with largest diameter.
2. The diameters in parentheses indicate the diameter of the component with greatest depth.

As described above, a component is a unit of inter-connected design moves, which represents the process of the development of design ideas. We observe that remote setting has far fewer components, that is, far fewer discrete design threads are developed which then are abandoned and not continued; designers appear to engage in more limited exploration of a problem. In addition, the remote setting exhibits the greatest depth among components. From this, we observe that purposeful design activity is more often engaged in the remote setting. This suggests that initial ideas developed and recorded in the remote setting, where a chat line is employed, are more persistent while in the paper-based setting the idea is developed sequentially. Although digital co-located setting has the largest number of diameter and the highest value of ratio, the depth is only five even less than paper-based co-located setting. This implies that the design ideas raised in digital co-located setting are not re-visited or re-modified as often as those raised in other two settings.
CONCLUSION

This paper has introduced the use of linkographs to measure protocols in an effort to characterise the richness and complexity of design activity and represent double and single loop learning. We have applied three new measures, components, diameter and depth, as metrics of richness and adopted the idea of Goldschmidt’s index. We have demonstrated that these measures correlate with findings derived in earlier papers using statistical measures. The conclusion is that the discussions of design activity in chat lines can be measured to be richer in design complexity than those taking place face to face. Goldschmidt (1990) notes that “design productivity is related to the generation of a high proportion of design moves rich with links”. In her paper, Goldschmidt developed an index as a measure of the percentage of linked moves. She proposed that the higher linkage value is an indicator of greater interconnectedness in design moves. In this figure, we observe that the pattern of design activities in the remote setting are richly interlinked as suggested by the considerable interconnections in the design activities; framing activity in this setting appears to have an impact on later moves. In co-located setting, however, many design moves are isolated and disconnected. Thus, the remote setting seems to support better design productivity than co-located settings.

Argyris and Schön (1996) propose two factors to define single and double loop learning. One factor is the level of aggregation of single loop learning. It is assumed that “single loop learning at one level of aggregation stimulates double-loop learning at all levels.” The other factor is to investigate the relationship between learning products and learning processes. They argue that except the product of organizational learning, the values and norms governing process need to be concerned in that those indicators are essential for “improving its (organizational learning) performance and restructuring the values that define improvement.” Double loop learning is therefore represented in the form of consistently re-evaluating design values or ideas during design process. In the remote setting the number of components is smallest and depth is the highest implying that double-loop learning is more evident compared to both co-located settings. Remote setting in this experiment is synchronous distributed design environment by adopting the chat-line communication. Chat-line allows designers to record their design process in text format might contribute to design idea maintenance and re-evaluation thus fostering double-loop learning to occur.

REFERENCES


Exercising Learning in Multiple Settings


