Promoting Creative Discovery and Mental Synthesis through Freehand Sketching

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Abstract

Across many domains including, art, engineering, design and technology education, research in freehand sketching is primarily concerned with the development of sketching based activities and the resultant external representations using pencil and paper. The body of literature is primarily based on introspective, observational data, it is anecdotal in nature and as a result it is subject to debate. This paper which is primarily informed by research in cognitive psychology, aims to establish how expertise in sketching ability and creative discovery can be developed and measured in a definitive manner.

The research was carried out as part of a Design and Communication Graphics module at the University of Limerick and involved 124 undergraduate students in their third year of an Initial Technology Teacher Education programme. Following the completion of specific sketching based activities which aimed to develop the ability to mentally synthesise graphical information through the medium of freehand sketching, a creative sketching based task, a design based task and a number of factor referenced cognitive tests were administered. The purpose of the two tasks and the cognitive tests was to establish if students had developed a level of sketching expertise and whether this could be associated with any underlying cognitive factors and performance in creative design based tasks.

The results of the study provide significant correlations between scores in the sketching based task, scores in the design based task and scores in a test which measures Figural Flexibility. These findings can be correlated with research in cognitive psychology (Verstijnen, 1998b) where expertise in freehand sketching is associated with high levels of creativity and the ability to detect novel components in figural combinations through a “restructuring” process.

Based on the results, future work will discuss the development of re-interpretive auxiliary activities which aid in the synthesis of mental imagery within a proposed paradigm. It is anticipated that this paradigm will aid in the development of sketching expertise and the ability to explore analogies necessary to shorten the sometimes frustrating incubation periods experienced in the early stages of problem solving and the design process.

Keywords: Sketching ability, creative discovery, mental synthesis, design, expertise

Introduction

It is suggested, that the externalisation of visual thinking through the medium of freehand sketching is a valuable skill which everybody should be taught (Fish, 2004). However, the value of freehand sketching is open to debate considering the availability of digitised communication tools such as CAD Modelling and the relative ease with which a design can be realised using modern techniques such as rapid prototyping. Considering the emergence
of the digital image culture (Jonson, 2002) it is critical that educators realise the potential and significant benefits of freehand sketching as a tool that aids in the synthesis of mental imagery and creative discoveries.

This paper reports on an element of a research study that is being carried out with undergraduate students of an Initial Technology Teacher Education programme at the University of Limerick. An insight is provided into the development of sketching expertise and the importance of considering related literature in cognitive psychology when designing sketching based activities.

Analysis of the Literature

The body of literature surrounding freehand sketching is predominantly focused on the design of sketching based activities and the resultant external representation of visual thinking. Notable research includes; insights into art education and how children learn to freehand sketch (Duncum, 1988) and Hope’s (2008) fascinating description of her longitudinal observation of children’s use of sketching as a design tool. Other significant work includes Edwards (1989) identification of critical components that must be developed in order to draw well and Lane’s (2010; 2010) “stunning evidence” (Spendlove & Stables2010) that the ability to sketch can be nurtured through specially designed activities.

Complementing the above literature which is primarily focused on sketching activities, the importance of developing the ability to sketch is strongly promoted within cognitive focused research. Fish (2004) describes sketching as being an accessory for the visualising instinct in addition to supporting the conceptualisation of design solutions and creative discovery. Building on the supportive function of sketches, Goldschmidt (2003) highlights the potential of sketching to act as an extension of mental imagery in storing and manipulating images.

Based on this brief discussion of the related literature, one could be persuaded that sketching is indeed a fundamental skill that should be taught in engineering and design based subjects. However as previously mentioned, the majority of the research is based on the design of sketching based activities. The research methods used are mainly introspective and provide causal observational data and systematic descriptions. As a result, the evidence is anecdotal in nature and subject to debate (Verstijnen, 1998b). In order to justify the underlying importance of freehand sketching, a valid scientific argument is required. Research in cognitive psychology with particular reference to mental imagery (R. A. Finke, Shepard, R. N., 1986; 1998a, 1998b) provides significant evidence that sketching is a critical accessory for creative discovery. Exploring this literature forms the focus of the next section.

Sketching and Creative Discovery

The externalisation of student’s visual ideas is made possible through various media such as Computer Aided Design [CAD], measured board drawings, rapid prototyping technology, presentation sketches and physical modelling. However, during the early phases of design, students can experience periods of anxiety and frustration in forming design ideas. Many designers tend to overcome this frustration by using “idea-sketches” which aid in the interaction with mental imagery for creative discovery. They are private in nature (Verstijnen, 1998b) and are sometimes so idiosyncratic they are only comprehensible by the maker (Goldschmidt, 1991).
The reason why artists and designers require externalisation for creative discovery is the subject of debate in research surrounding cognitive psychology. Finke (1990; 1988) reports that visual discoveries in imagery can be reliably induced in every person under appropriate laboratory conditions. In contrast to this, Reed and Johnsen (1975) report that the extraction of novel components is difficult through mental imagery alone and is significantly enhanced through sketching.

Reconciling these opposing conclusions surrounding mental imagery and creative discovery, Verstijnen et al. (1998a, 1998b) proposed two forms of processing within mental imagery which are combining and restructuring. “Combining” involves the joining of known components to form a novel whole whereas “restructuring” involves the decomposition of a component into incidental parts, not previously known to exist within the combination (Verstijnen, 1998a). These two measurable processes impose different cognitive challenges.

An example of the difference between “combining” and “restructuring” can be seen when the configuration on the left of Figure 1 is imagined. Reed and Johnsen (1975) proved that people will tend to form a mental image consisting of two isometric triangles as shown in “A”, while the decomposition of the image into other novel components as in “B-D” is very difficult to perform using imagery alone.

Building on the research of Reed and Johnsen (1975) and Finke (1988), Verstijnen et al. (1998b) utilised a “Component Detection Task” and a “Figural Combination Task” to establish the nature of combining and restructuring tasks and the effect of paper-and-pencil support. The administration of the tests was varied by controlling groups (of both novice and expert sketchers), with some being compelled to sketch and others being denied the opportunity. In addition to this, they monitored spontaneous sketching activity and varied the number of novel parts in each configuration.

The results of the experiments concluded that externalisation through sketching has a significant positive effect on the ability to detect novel components in figural combinations through “restructuring”. Interestingly, it was also found that being compelled to sketch can have no additional value in “combining” tasks and that it can even deteriorate performance.
Expertise in sketching and the associated ability to engage in restructuring was also correlated with high levels of creativity. Notably, there was only one major difference between novel and expert sketchers. Novice sketchers performed significantly worse in restructuring novel parts in the administered tests. This provides a valid argument that "restructuring" is a fundamental component of sketching expertise. Exploring the development of sketching expertise will form the focus of the next section.

**Developing sketching expertise**

Previous research carried out by Lane et al. (2010; 2009; 2010) with undergraduate students of Initial Teacher Education, has provided evidence that sketching ability can be significantly improved in novice sketchers through specially designed activities which promote mental synthesis.

The activities were designed to facilitate the progression from "controlled and reflective" to "automatic and reflexive" cognitive processing (Satpute, 2006). In addition to this the activities were designed within a paradigm (Figure 2) which facilitated students in developing an ability to build, manipulate and synthesise graphical libraries. The paradigm aims to promote sketching as a sense making tool which supports the synthesis of mental imagery through activities that progress within an "observation-imagination" continuum (Fish, 1990) and "seeing-as" and "seeing-that" modalities (Goldschmidt, 1991).

![Figure 2](image)

**Figure 2** – Proposed paradigm for promoting mental synthesis through freehand sketching

Notably, there appears to be a relationship between Goldschmidt’s (1991) "seeing-as" and "seeing-that" modalities and the "combining" and "restructuring" processes of mental imagery as identified by Verstijnen (1998b). It could be hypothesised that the "seeing as" modality utilises figural, perceived argumentation similar to the synthesis of known components in the "combining" process, while the "seeing that" modality uses non figural, imaginative arguments to extract novel components not previously considered which is similar to the "restructuring" process.

The underlying research question in this paper is whether, there is a correlation between the findings on expertise in sketching ability within cognitive psychology (Verstijnen, 1998b) and the development of students sketching expertise as a result of the activities designed as
part of this research within the presented paradigm (Figure 2). This will be discussed in the next section.

**Methodology**

**Establishing a level of expertise**

Subsequent to carrying out a series of sketching based activities, the students were given a design based task and a number of psychometric tests from the Kit of Factor Referenced Cognitive Tests (Ekstrom, French, Harman, & Dermen, 1976) (Figure 3). The purpose of these tests was to establish any relationships between cognitive factors, the student’s performance in the sketching based activities and performance in the design based task. The research was carried out as part of a Design and Communication Graphics module taken by all students in their third year of study.

**Factor Referenced Tests**

The tests (Ekstrom, et al., 1976) that were administered include the following:

- **Gestalt Completion Test**: This tests the ability to see a whole picture even though it is not completely shown. The Gestalt Completion Test is part of Elkstrom’s (1976) “Speed of Closure” factor which is the ability to unite an apparently disparate perceptual field into a single concept.

- **Surface Development Test**: This tests the ability to imagine or visualise how a piece of paper can be folded to form some kind of object. The Surface Development Test is part of Elkstrom’s (1976) “Visualisation” factor which is the ability to manipulate or transform the image of spatial patterns into other arrangements.

- **Form Board Test**: This tests the ability to tell what pieces can be put together in order to form a certain figure. The Form Board Test is also part of the “Visualisation” factor as previously described.

- **Toothpicks Test**: This examines the ability to make different patterns out of squares outlined by toothpicks. The Toothpicks Test is part of Elkstrom’s (1976) “Figural Flexibility” factor which is the ability to change set in order to generate new and different solutions to figural problems.

- **Storage Test**: This tests the ability to plan in as many ways as is possible how objects can be stored in a given space. The Storage Test is also part of “Figural Flexibility” factor as previously described.
• **Elaboration Test**: This tests the ability to think of a number of ways to add detail to a design. The Elaboration Test forms part of Elkstrom’s (1976) “Figural Fluency” factor which is the ability to draw quickly a number of examples, elaborations or restructurings based on a given visual or descriptive stimulus.

**Assessment of performance in sketching based activities**

The development of student’s skills in the novel and original activities designed by Lane et al. (2010; 2010) within the proposed paradigm (Figure 2) was evaluated by a team of independent subject and non-subject specialist assessors using an online survey.

The team of assessors ranked levels of:

- **Improvement** from pre-instruction to post-instruction
- **Likeness** between a profile photograph and the post-instruction composition
- **Creativity** of the post-instruction compositions (Figure 4). Note this paper is only concerned with the creativity score. The reason for this is that the ability to carry out restructuring as well as high levels of sketching ability are associated with high levels of creativity (Verstijnen, 1998b).

![Figure 4 – Participant work presented on the online survey](image)

**Design Based Task**

Subsequent to completion of the sketching based activities, the students were given a design brief where they were asked to “Design and model a personal device/artefact that will enhance the quality of life for an elderly person”. This brief was strategically devised so that students had to first of all identify some problem with a contemporary device or artefact for the elderly. Once the design problem was identified the students were required to explore a range of design ideas using appropriate media prior to modelling their chosen solution. Students were not instructed to use any particular medium for externalising and communicating their design ideas.

Earlier in the paper, it was highlighted that Verstijnen et al. (1998b) found that there was a positive correlation between expertise in sketching skill, creativity and success in restructuring activities. Therefore the student’s performance in this design task was able to
provide an indication as to whether there is any association with the creativity scores in the online survey for the sketching based activities or any of the factor referenced cognitive tests.

The student design portfolios were also examined in order to determine the amount of sketches (if any the students completed and whether this impacted on scores obtained in design tasks. The number of sketches were categorised as follows:

1. None (no sketches)
2. Minimal (between 1-3 sketches)
3. Moderate (4-7 sketches)
4. Significant (8 or more sketches)

Results

The results in the factor referenced cognitive tests, the creativity scores (assessed by independent judges) in the sketching based activities and the scores in the design based task will be presented in this section.

Factor Referenced Test Results

The results of the factor referenced cognitive tests are illustrated in Figure 5 and Figure 6 and tabulated in Table 1. The results presented are marked out of a total of 100. Each test is marked according to specific criteria in the Kit of Factor Referenced Cognitive Tests (Ekstrom, et al., 1976). Interestingly, students scored highest on the Gestalt Completion test and scored lowest on the Toothpicks Test.

<table>
<thead>
<tr>
<th>Test</th>
<th>N</th>
<th>Mean</th>
<th>Standard Deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gestalt Completion</td>
<td>124</td>
<td>73.85</td>
<td>12.31</td>
</tr>
<tr>
<td>Toothpicks</td>
<td>124</td>
<td>37.89</td>
<td>20.31</td>
</tr>
<tr>
<td>Elaboration</td>
<td>124</td>
<td>53.60</td>
<td>16.54</td>
</tr>
<tr>
<td>Form Board</td>
<td>124</td>
<td>60.49</td>
<td>20.04</td>
</tr>
<tr>
<td>Storage</td>
<td>124</td>
<td>61.53</td>
<td>15.72</td>
</tr>
<tr>
<td>Surface Development</td>
<td>124</td>
<td>69.74</td>
<td>30.10</td>
</tr>
</tbody>
</table>
Sketching Based Activity Results

A selection of student’s pre-instruction (Reflective Activity) compositions and post-instruction (Journey Activity) compositions is shown in Figure 7. As discussed earlier, the independent assessors used these sketches to determine scores for creativity.
The independent assessors rated the level of creativity in each student’s post-instruction sketch along a ten point “semantic differential scale” (Cohen et al. 2007) with “no creativity” at the lower end of the scale and “significant creativity” at the upper end of the scale. Figure 8 illustrates the results of the creativity scores from the online survey with a mean score of 68.5.

**Figure 8 – Creativity scores in sketching based activities**

### Design Brief Results

The design briefs were assessed by the academic responsible for the module and the scores are illustrated in Figure 9 below where there was a mean score of 54.7% recorded.

**Figure 9 – Design Brief scores**

The number of sketches that were produced in students’ design portfolios is presented in Figure 10. The mean number of sketches that students produced was 2.5 per portfolio.
A selection of the types of sketches typically produced by students is shown in Figure 11. Colour and annotations were generally used in sketches. It is notable that the majority of sketches are representational in nature and do not tend to be abstract or have the idiosyncratic appearance of “idea-sketches”.

The relationship between scores in the design based task and the number of freehand sketches produced by students was investigated using Spearman’s Rank Order Correlation (Cohen, 2007). There was a medium, positive correlation between the two variables, $\rho = 0.390$, $n = 117$, $r < 0.01$ (2-tailed) with high scores in the design task associated with a high number of freehand sketches.

**Correlating the results**

The relationship between creativity scores in the sketching based task (as measured by specialist assessors), scores in the design based task and the scores from the psychometric tests (as measured by the Kit of Factor Referenced Cognitive Tests) were investigated using
Spearman’s Rank Order Correlation coefficient. Significantly, three notable correlations were found and these are presented in Table 2.

Table 2 – Spearman Rank Order Correlations between measures of Creativity in sketching based activities, Design based task scores and Storage Test scores

<table>
<thead>
<tr>
<th>Variable</th>
<th>1</th>
<th>2</th>
<th>3</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Creativity scores (Sketching based task)</td>
<td>-</td>
<td>0.302 **</td>
<td>0.356 **</td>
</tr>
<tr>
<td>2. Design based task scores</td>
<td>-</td>
<td>-</td>
<td>0.249 **</td>
</tr>
<tr>
<td>3. Storage test scores</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

** $p<0.01$ (2-tailed)

Discussion

Prior to discussing the results it is worthwhile to consider once again the findings in cognitive psychology in relation to expertise in freehand sketching. As described earlier in the paper, Verstijnen et al. (1998b) found that expertise in sketching can be associated with high levels of creativity and the ability to perform “restructuring” tasks. The focus of this paper is to establish if the findings of Verstijnen et al. (1998b) can be correlated with the work of Lane et al. (2010; 2009; 2010) and the results presented in the previous section.

The correlations presented in Table 2 provide substantial evidence that the sketching activities designed within the proposed paradigm (Figure 2) have a significant positive effect on developing expertise in sketching ability. The three variables presented in Table 2 can be triangulated, proving that there is a significant correlation between scores in the sketching tasks, design based tasks and the storage test. It is notable that the storage test forms part of Elkstrom’s (1976) factor of “Figural Flexibility”. This factor gives an insight into the ability to change set in order to generate new and different solutions to figural problems. This is very similar to Verstijnen’s (1998b) “restructuring” process where novel components are detected in figural patterns.

However, further analysis of the results provides an indication that there is room for considerable development within the proposed paradigm for promoting mental synthesis and expertise in freehand sketching (Figure 2). It is notable that students scored lowest on the “toothpicks test” which like the “storage test” is part of the “Figural Flexibility” factor (Ekstrom, et al., 1976). If expertise in “restructuring” and freehand sketching is to be developed, it is considered that students should score high in both the “storage test” and the “toothpicks test” as these are both part of the “Figural Flexibility” factor.

On reflection, the paradigm (Figure 2) from which the sketching based activities were derived is biased towards the “seeing-as” modality, which was earlier compared to the “combining” process (Verstijnen, 1998b). In order to align more closely with the ability to engage in “restructuring” (Verstijnen, 1998b), activities within the “seeing-that” modality are required. These auxiliary type activities (Figure 12) will include tasks such as “Brainsketching” (van der Lugt, 2002) and it is envisaged that these will promote students to re-interpret and restructure graphical information, aiding in the further development of sketching expertise.
Conclusion

On reflection, there is significant evidence within the findings to suggest that expertise in sketching ability can be developed and measured scientifically. Analysis of the results provides a notable indicator for the future development of sketching based activities within the proposed paradigm (Figure 12). As sketching provides the analogies necessary to shorten the periods of frustration experienced in the early stages of the design process, future research will focus on the development of auxiliary, re-interpretive type activities which promote “restructuring” (Verstijnen, 1998b) and creative discovery.

Bibliography


