A Paradigm for Promoting Visual Synthesis through Freehand Sketching

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Abstract

Research (Fish, 2004) suggests that everybody should be taught how to freehand sketch and utilise it as a tool for supporting the visualising instinct. A fundamental shift in philosophy of the technology education system in Ireland towards design driven subjects brought with it a need to develop practising teacher's technological capabilities. This paper is concerned with the exploration and development of freehand sketching as a support tool for visual synthesis and creative discovery during design driven activities.

The fundamental hypothesis tested was whether a set of empirically derived activities ranging from observation to imagination, improved the ability of students with novice sketching ability to develop, manipulate and synthesise graphical libraries through the medium of freehand sketching.

124 students of an Initial Technology Teacher Education programme participated in a journey through the activities as part of a third year undergraduate Design and Communication Graphics module. The study was carried out over a four week period, it involved eight hours of classroom based instruction and the sketching ability of all students was measured pre and post-instruction.
Results from the study reveal a statistically significant increase in student's ability to freehand sketch with notable improvement in their fluency and ability to synthesise concepts and geometries.

Overall, the novel and original activities have a notable effect on student's ability to form, manipulate and synthesise visual information and communicate this through freehand sketching. The model presented has potential to be successively implemented by other teachers in a variety of educational settings and student populations.

Key words

sketching, visual imagery, pedagogy, cognition, design, problem solving

Introduction

The ability to utilise sketches to support and represent cognitive activity is a difficult skill that everybody deserves to be taught (Fish, 2004). The design of appropriate pedagogies that nurture the ability to externally represent conceptual thought through freehand sketching is dependent on educators ability to understand how information is perceived, learned, memorised and conceptualised (Fish, 2004, OECD, 2002).
This paper details part of a research project that was undertaken at the University of Limerick with a cohort of 124 undergraduate students of technology teacher education. The project aims to establish how concept driven, synthesising capabilities can be enhanced using freehand sketching as a supporting medium for the communication of visual mental imagery.

Significant contributions to the body of literature surrounding freehand sketching and graphicacy have been made by the Design and Technology Association researchers as well as other international researchers in recent years. Notable research includes the work of Fish (2004) and his fascinating insight into how sketches support design cognition, Hope's (2008) longitudinal observations of primary school children's drawings during design activities and Storer's (2008) insight into freehand sketching in an industrial design context.

Prior to advancing to the details of this research study it is necessary to consider the underlying factors which influenced its design. These include; a brief overview of the fundamental shift in philosophy of the technology education system in Ireland, an in-depth analysis of the pertinent literature surrounding freehand sketching as well as a summation of the key findings of preliminary pilot studies.

Technology education in Ireland

In response to a rapidly changing global society, which promotes the development of technological capabilities, the Irish government has been particularly proactive in addressing the area of technology education. A complete overhaul of technology based subjects studied at Senior Cycle (typically by pupils ranging in age from 16-19 years), has resulted in the drafting of four new subjects with two of these; *"Design and Communication Graphics"* (DES, 2007a) and *"Technology"* (DES, 2007b) having been implemented in September 2007.

The rationale behind the implementation of these new subjects was to create a fundamental shift in focus from a purely traditional craft based approach to a more creative design based philosophy that still embraces and values the psychomotor craft based emphasis (Lane et al., 2009). The change in focus of the subject area, particularly towards communication and design promotes the utilisation of freehand sketching as a supporting medium for ideation, problem solving and flexible visualisation within design driven tasks as well as tasks involving plane and descriptive geometry.

The process driven, craft based activities that were central to the previous subjects utilised pre-designed and measured working drawings. This meant that there wasn't a need to explore design solutions or problems resulting in little attention being paid to freehand sketching. The implementation of the new subjects and in particular Design and Communication Graphics (DCG) has resulted in practising teachers requiring professional development courses in order to develop their sketching skills. In order to prepare and support teachers to implement the suite of new subjects, a full-time support service known as t^4 was established under the auspices of the Teacher Education Section of the Department of Education and Science.

Commendable work has been carried out by t^4 in providing teachers of DCG with the opportunity to develop their sketching skills as well as making various classroom resources available. During in-service training, teachers were encouraged to explore a range of sketching media and techniques used by industrial designers including *"crating"* and *"primitives"* methods (Storer, 2008), which involved the application of both sketches and annotations. An example of the type of activities which was explored is illustrated in Figure 1.

Building on this notable work carried out by t^4, there is significant evidence to suggest that further exploration and development of teacher's skills is required. A concentrated effort in developing these skills further, will contribute towards meeting the potential of sketching as a support tool for visual thinking in technology subjects. An analysis of recent chief examiners reports, the work carried out by the national subject support service and the related literature reveals the following:

- Subsequent to the inaugural examination of design based tasks in 2009, the Chief State Examiner reported that freehand sketching requires further emphasis, development, and promotion within schools. Pupils appeared to have significant difficulty sketching design solutions and ideas with a considerable number resorting to using measuring equipment and tracing methods (State-Examinations-Commission, 2009).
- The activities which practising teachers engaged in during the stages of professional development reveal a dependence on observational sketching of representations depicting inanimate objects (such as shown in Figure 1). Sole reliance on this type of activity mirrors Arnheim's (1978) *"copycat mentality"*, inducing inhibition, dependence and false security.
- There is insufficient evidence within the activities and resources made available to suggest that sketching is considered a *"sense making activity"* (Jonson, 2004, Kimbell, 2004) and a support tool which stimulates the graphic processing capacity of visual mental imagery (Borst, 2008).

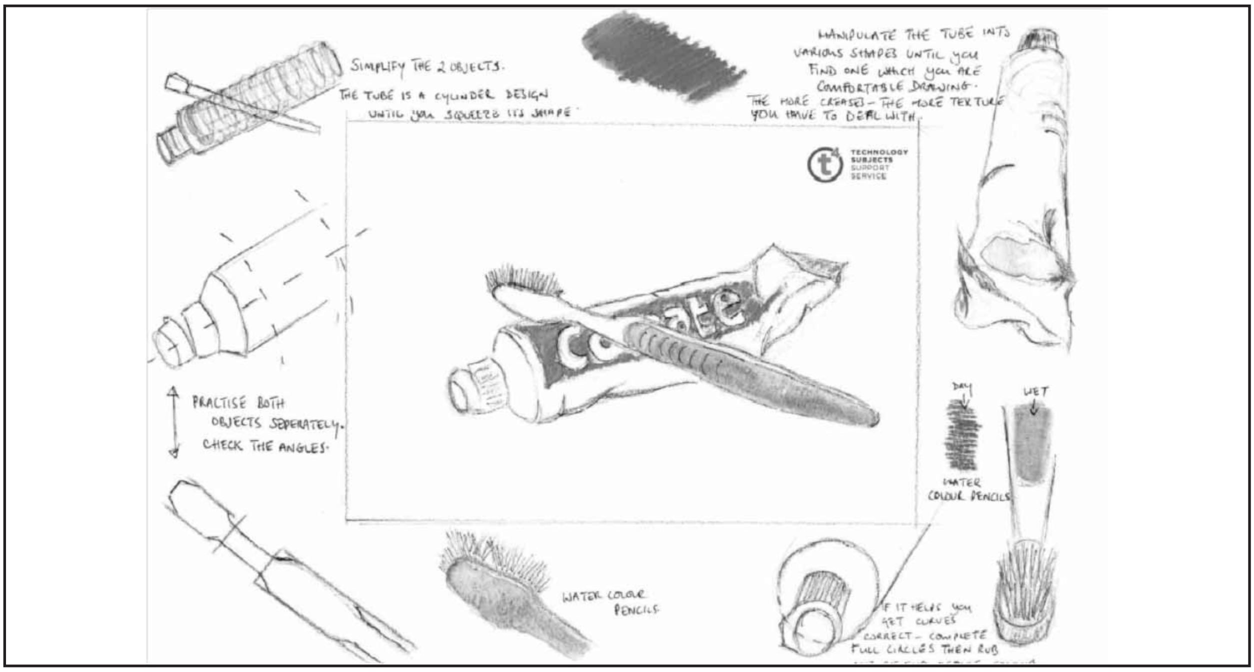

Figure 1. Examples of sketching type activities used to train practising teachers

On reflection, the embracement of freehand sketching within technology education in Ireland has significant potential as a vehicle for the development of technological capabilities. Realising this potential is the focus of research that is being carried out at the University of Limerick. Prior to considering the design of the study it is worth analysing the related literature.

Analysis of the literature

Introduction

A significant and varied body of literature exists surrounding freehand sketching. The shift in philosophy and values of technology education in Ireland and the variance in contemporary methods for developing the ability to freehand sketch, make it difficult to identify a sole piece of research or discipline that can inform the development of freehand sketching ability. Considering this variance, it was deemed worthwhile to explore literature and methods from different areas such as design education, art education, engineering education and cognitive based research in visual mental imagery.
The literature presented in this paper, considers facets such as; the debate surrounding how children learn to draw in art and primary education (Duncum, 1988, Hope, 2008), the industrial designers freehand sketching experience (Storer, 2008) and sketching as a support tool for visual imagery (Fish, 2004, Goldschmidt, 1994).
Given the broad variation in perspectives surrounding freehand sketching it could be considered too complex to delineate. However, there appears to be a convergence within the body of literature that provides a conclusive indicator as to how the skill of sketching can be nurtured. Identifying this convergence will be the focus throughout this section.

Sketching in design education

Sketching is widely considered as a medium for recording the journey through design iterations and communicating design solutions (Schutze, 2003, Storer, 2008, Hope, 2008). Storer (2008) considers the importance of industrial designers becoming experts in sketching despite the emergence of sophisticated CAD software. He presents various sketching techniques that are utilised by industrial designers and considers the importance of building a *“graphical library”* of products and images that can be accessed during design activities (Storer, 2008, p.60). McKim (1972) describes a *“collective graphic memory”*, which is central to his model of visual thinking where seeing, imagining and sketching are synthesised. This memory provides an immediately accessible database for the stimulation of design ideas and is comparable to the Storer’s (2008) *“graphical library”*.

Sketching in art education

Building on the above research in design education it is worthwhile to consider sketching through research in art education. The copying paradigm has been the subject of considerable debate among art educationalists for a number of years. Copying of drawings and paintings has been accused of being restrictive in addition to promoting dependency and false security (Lowenfield, 1975) while inducing a copycat like culture that is detrimental to the development of the human mind (Arnheim, 1978). In contrast to these views, Wilson and Wilson (1977) support the conventional position for drawing where it is claimed that copying is children’s preferred drawing strategy as drawing is a *“conventional sign system”*. Acquiring knowledge of the sign system is imperative as the perceptions that people use everyday are too numerous and complex and cannot be readily converted into graphical images.

Sketching in primary education

Hope (2005, 2008) provides a fascinating insight into her observations of children’s drawings during design based activities. She describes a metaphor for drawing where it is considered as a *“static container”* for design ideas that are taken on a conceptual *“journey”* across a surface (Hope, 2008, p.6). The external representation of existing ideas on a surface creates a building block or container that can be brought on a conceptual journey where the interaction of images and ideas aid in the development of new constructs. Hope (2008) provides an informed breakdown of children’s drawings into six dimensions, including; *“Drawing to Play, Mean, Feel, See, Know and Design”*. All of these dimensions have influenced the design of this study presented in this paper.

Identifying a point of convergence

Prior to analysing other research in freehand sketching it is worth identifying a point of convergence in the literature presented thus far. Exploration of research concerning freehand sketching in disciplines such as design education, art education and primary school education suggests that the process of sketching involves much more than the physical manipulation of a pencil to communicate design ideas. Rather, it is considered a support tool for the communication of mental images that are stored within a “*graphical library”* (Storer, 2008) or *“collective graphic memory”* (McKim, 1972). These are supported by a *“conventional sign system”* (Wilson, 1980), which is utilised during a conceptual *“journey”* (Hope, 2008). Considering that sketching is a support tool for the synthesis of *“visual imagery”*, it is appropriate to analyse the work of Fish (1990, 2004) and Goldschmidt (1991, 1994).

Sketches as a cognitive catalyst

"Visual imagery" is a common term that is referred to within the cognitive focused literature. Visual (or mental imagery) is a unique, *"top-down"* (Borst, 2008) *"graphics processor"* like component of the cognitive architecture, which plays an integral role in processing visual information (Stillings, 1995).

Goldschmidt (1991, p.131) considers sketching as a systematic dialectic between the *"seeing as"* and *"seeing that"* reasoning modalities. The *"seeing as"* modality utilises figural, perceived argumentation while *"sketch thinking"*. In contrast, the *"seeing that"* modality utilises non figural, imaginative arguments to advance the thinking process. Similar to Hope (2005, 2008), Goldschmidt (1994, 2003) considers sketching not only as an activity that enables the communication of visual imagery but also provides the inverse as a feedback mechanism for the unlocking, reconfiguration and synthesis of ideas. This is comparable to Jonson's (2004, p.282) description of sketching as a *"sense making activity"*.

Interestingly, Goldschmidt (2003, p.81) describes two essential components of sketching. Firstly, it is important that sketching is a fluid activity, which does not give spare attention to the production process. The second component (which is optional) concerns the command of orthogonal projection, which enables the precise communication of an object based on mathematical rules. Similar to Goldschmidt (2003), Fish (1990, 2004) emphasises the important role that *"visual imagery"* plays in the early stages of visual invention and sketching. Fish (2004) describes sketching as a support for the visualising instinct. It is an intermediate between descriptive and depictive representations and conveys implicit information. He further expands on this intermediate nature by explaining how sketches contain depictive drawings mixed with descriptive notes and labels. Notably, this was also detailed by Jonson (2004) where ideation was described as a dialogue between visualisation and language.

Fish (1990, p.120) also makes a clear distinction between sketching from observation and sketching from memory/imagination. While sketching from observation, the visual information can be constantly refreshed by analysing *"vivid perceptual snapshots"*, whereas sketching from memory and imagination requires the generation and manipulation of more abstract mental images which mimic perception.

A definition for sketching

Based on the analysis of the research it is considered worthwhile to construct a definition for sketching, which synthesises the pertinent literature in addition to informing the design of the research study. The definition is as follows: *"Sketching is a, sense-making tool which supports the synthesis of visual imagery".*

In order for the potential of sketching to be maximised in design and technology based subjects, it needs to be considered as a tool, which supports the communication and exploration of design ideas in addition to supporting the manipulation and synthesis of visual imagery. Considering this, it is worth constructing a paradigm for sketching, which supports the modalities of *"seeing as"* and *"seeing that"* (Goldschmidt, 1991, 2003) within the *"observation"* to *"imagination"* continuum (Fish, 1990). This paradigm is illustrated in Figure 2.

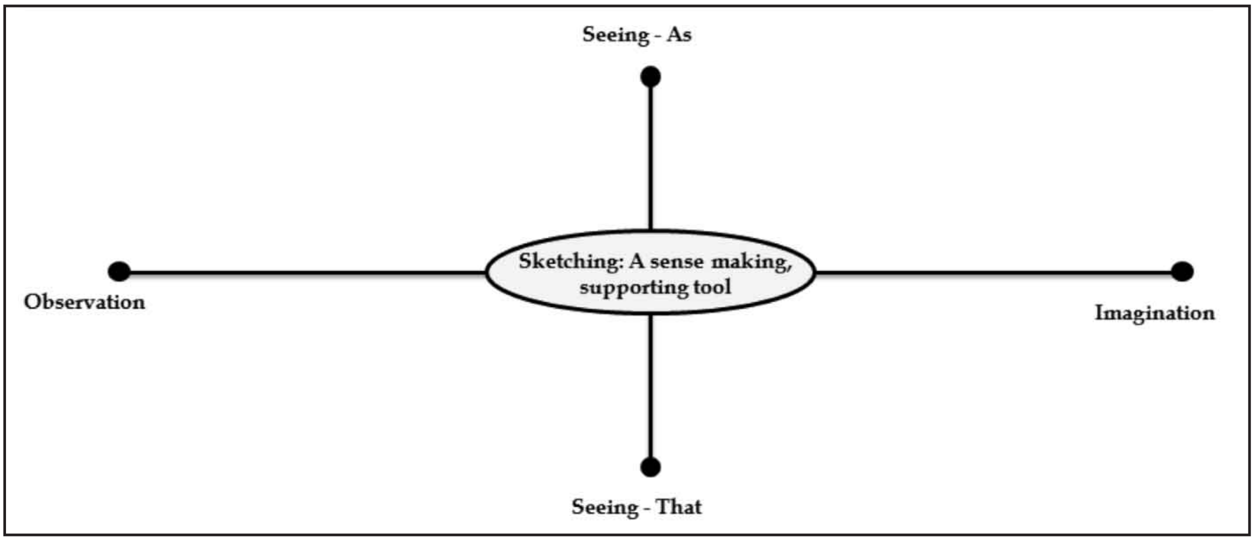

Figure 2. Establishing a paradigm for sketching

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Methodology

Background

The paper so far has presented the need to develop the skills and expertise of practising teachers of technology education in freehand sketching. However, the logistics involved in organising a large sample of practising teachers to volunteer in a research study over a number of weeks were considered impractical. It was decided that a Year 3 group of students who are part of a specialised Initial Teacher Education (ITE) programme for technology education, would provide the representative sample required. The reasons for this are as follows:

- The students graduated from the previous system of technology education at second level, which didn't prioritise or promote the ability to freehand sketch.
- The students had previously received little or no formal instruction in freehand sketching at third level. Therefore, there was an increased chance that a significant number of students could be categorised as novices.
- All students had completed a six week period of teaching practice in a secondary school in Year 2 and could closely relate to the sketching related anxiety experienced by Ö teachers.

The research was carried out with a cohort of 124 third year undergraduates and it was implemented as part of a Design and Communication Graphics module, which is a core area of study for the students. Previous graphics modules studied by the students focused on building fundamental psychomotor drawing skills in addition to developing an understanding of core geometric principles involving defined problems in plane, solid and descriptive geometry. The focus of the third year module is to enable students to bring their understanding of geometric concepts and principles on a journey, which explores ill-defined geometric problems within a design driven environment.

The aim of the research study was to establish how students with novice sketching ability can utilise their knowledge of and ability to manipulate and synthesise geometry while developing their ability to visually communicate this through freehand sketching. This will be further discussed in the section *'Design of the Study'*. Prior to considering this, it is appropriate to describe the key findings of preliminary pilot studies carried out within the confines of Initial Teacher Education (Lane et al., 2009, 2010c).

Summary of preliminary pilot studies

Before carrying out the study presented in this paper, a number of preliminary pilot studies were carried out at the University of Limerick. The purpose of these studies was to establish the critical factors and milestones that necessitate the journey towards expertise in freehand sketching. Previously, Lane et al. (2009, 2010c) describes preliminary studies that provide a significant indicator that sketching is a teachable skill, which can be developed by people with novice sketching ability. Two pilot studies were carried out with small groups of 6-8 students. The main findings of these studies are as follows:

- It was found that development of sketching skill along the *'observation-imagination continuum'* could be facilitated by novel activities that include: Reflection, Recognition, Enquiry, Transfer, Enlightenment, Journey, and Unification. These will be detailed in the next section.

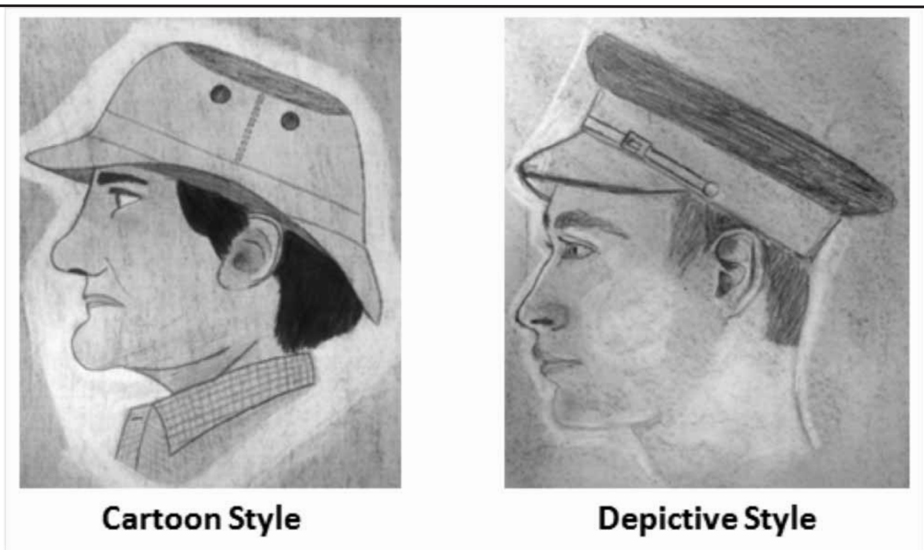

Figure 3. Variation in sketching styles

- The utilisation of ICT including data projectors, PowerPoint applications, and visual presenters can benefit the students sketching and learning experience in a large class environment.
- A three-dimensional (3D) to two-dimensional (2D) conversion device was designed and applied (Lane, 2010a, p.8). This develops pupil's knowledge of the principles of the picture plane as well as alleviating the anxiety of sketching a physical 3D object.
- There appeared to be a significant variation in student sketching styles (Figure 3) with evidence of cartoon style drawings with minimal detail in addition to depictive, almost real life representations.

Students

124 student teachers of technology education participated in the research project ranging in age from 21-36. The cohort had only two female students (which is a typical ratio for technology teachers in Ireland). 53% of students had studied *"Technical Drawing"* at senior cycle (the final phase of second level education) while the remaining 47% never took the subject before entering university.
During the first year of their undergraduate degree, the students were given some instruction on technical sketching. This involved the communication of artefacts in first and third angle orthographic projection in addition to isometric, oblique and perspective projection using grid paper. Examples of the type of artefacts sketched by the students are shown in Figure 4.

Mapping the journey

The design of the study is informed by the presented literature (with particular emphasis on the *'observation-imagination'* continuum) and the findings of the previous pilot studies (Lane et al., 2009).

It is worth considering Goldschmidt's (2003) two components for sketching skill, which are fluency and knowledge of orthogonal projection. Given the students competency (albeit using measuring equipment) in utilising the orthogonal projection system to communicate information and the limited amount of instruction they received in freehand sketching as a design driven tool, it is clear that the design of the study should concentrate on the *'fluency'* component.

Similar to any complex cognitive, perceptual or motor skill, developing the skill of freehand sketching requires both an appropriate pedagogy and sufficient amount of practice (Stillings, 1995). Both of these are critical in achieving a high degree of fluency (Goldschmidt, 2003) or *"automatic processing"* (Satpute, 2006). Development of this fluency requires a carefully designed pedagogy that nurtures the skill of sketching, beginning with *"controlled"* and *"reflective"* activities and progressing to activities that are *"automatic"* and *"reflexive"* in nature (Satpute, 2006, Stillings, 1995). Considering this *"controlled"* to *"automatic"* progression, Wilson's (1977) conventional position for drawing, Fish's (1990) distinction between sketching from observation and imagination and the novice sketching ability of the students, it is appropriate to focus the design of this study around the paradigm that was presented earlier (Figure 2). The design of the activities will facilitate the journey between sketching from observation and sketching from imagination. It is anticipated that the activities will initially be slightly biased towards the *"seeing-as"* modality but

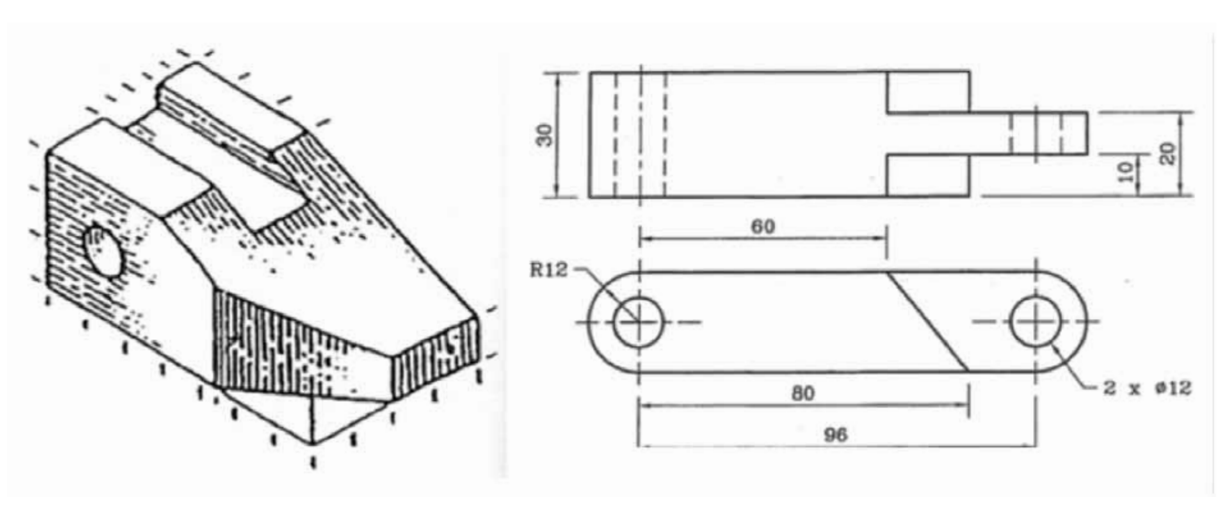

Figure 4. Examples of technical sketching activities

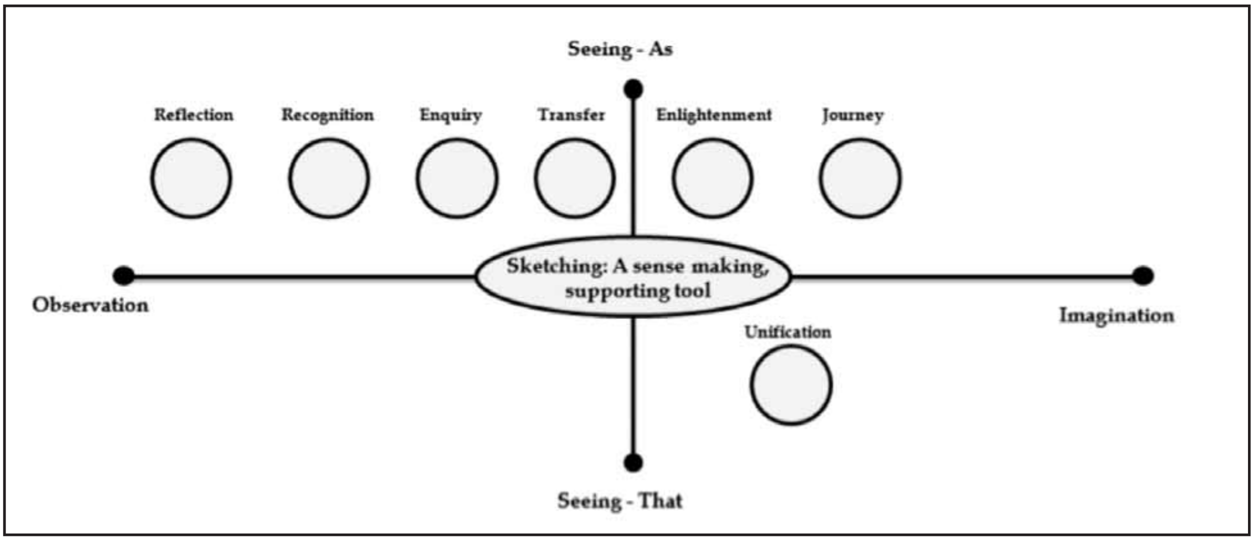

Figure 5. Progression through the proposed paradigm

this will aid in the development of a *"collective graphic memory"* (McKim, 1972) for the subsequent exploration of the *"seeing that"* modality (Goldschmidt, 1991, 2003).

Design

The design of the study is illustrated in Figure 5 and will now be described. It is derived from the paradigm that was proposed in Figure 2. In order to maintain clarity, this illustration will be presented as each phase of the design is described.

Significance of the paradigm

Considering the broad range of subjects that embrace freehand sketching, it is logical to suggest that the related literature in the area could provide appropriate models to inform pedagogies that promote sketching as a sense making tool for creative discovery. However, literature in freehand sketching tends to be anecdotal in nature, it is largely based on observational findings and as a result it is subject to debate (Verstijnen, 1998). The proposed original and novel paradigm (Figure 5) aims to harness research in sketching practice with research in cognitive psychology in order to develop a scientifically informed model, which can be used in designing pedagogies that utilise freehand sketching as a thinking tool for conceptual journeys across multiple disciplines.

Phase 1: Reflection activity

Purpose: The purpose of this phase (Figure 6) was to immerse students in a reflective activity, which promoted the exploration of relationships and forms within a physical composition and the communication of these using

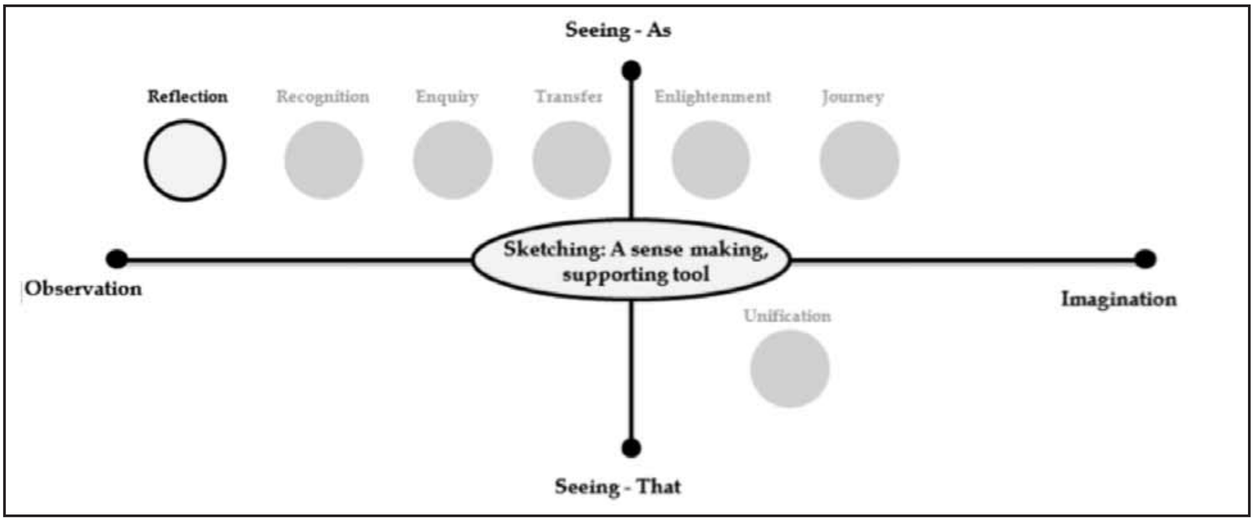

Figure 6. Phase 1 – Reflection Activity

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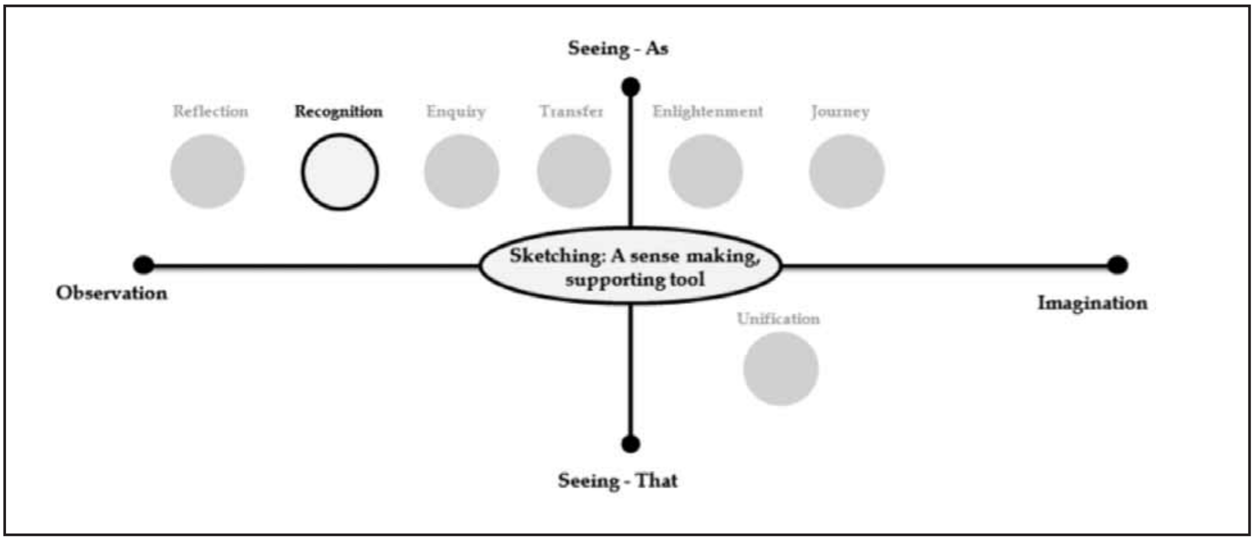

Figure 7: Phase 2 – Recognition activity

Figure 8. "Revealing" the geometry in the recognition activity

regular and irregular geometries. Students were given a mirror and asked to communicate their self portrait. The activity wasn't governed by any time restriction or other criteria.

Objectives: In keeping with the reflective nature of the activity, the students were asked to rate their level of sketching ability subsequent to sketching their self portrait. Prior to rating their sketching ability, students were required to retrospectively analyse their own sketch. This promoted students to critically assess their own ability and identify any strengths or weaknesses in their ability to sketch. The data from the Reflection activity was later used as a comparator with the data from the Journey activity in order to identify any areas of student development.

Phase 2 – Recognition

Purpose: The purpose of the recognition activity (Figure 7) was to promote a level of *'controlled, reflective processing'* resulting in the communication of a composition which was revealed on to a large screen using a PowerPoint presentation (Figure 8). The activity aligns with Wilsons (1977) conventional position on drawing where *'copying'* other images is considered as a fundamental stepping stone in learning to draw.

Objectives: The critical outcomes of this short fifteen minute activity were that students develop the ability to perceive, recognise, scale and synthesise relationships between presented 2D geometries. In addition to this, the activity will instil a sense of confidence and self-belief in students, which is critical to success in the subsequent activities.

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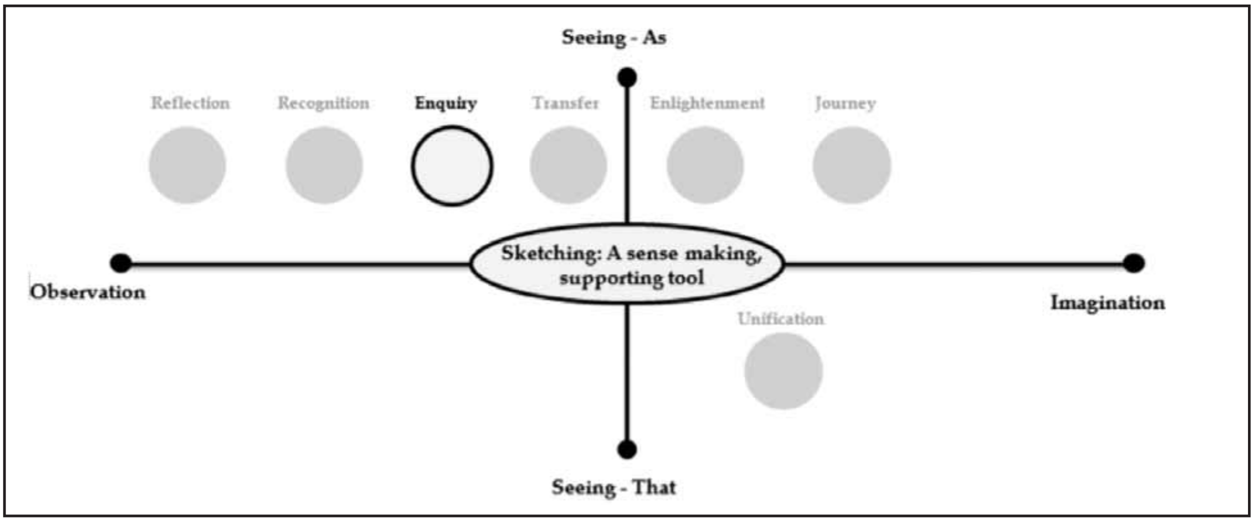

Figure 9. Phase 3 – Enquiry activity

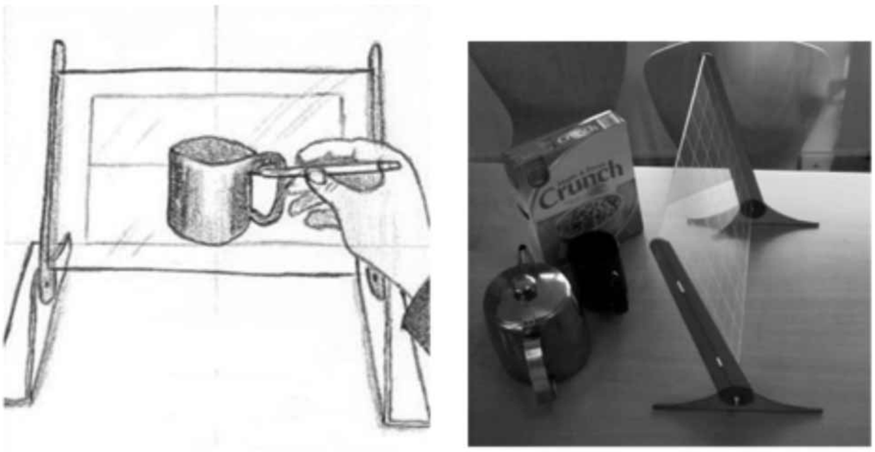

Figure 10. Utilising the 3D to 2D conversion device

Phase 3 – Enquiry

Purpose: This activity involves the construction and communication of a physical 3D composition. It is intended that the activity has a *“controlled, deliberate”* phase and an *“automatic”* phase (Stillings, 1995).

The controlled phase involves the use of the 2D to 3D conversion device (Figure 10) to enquire into the geometry of the physical composition while contemporaneously projecting the image on to the flat 2D plane. The automatic phase involves the translation of the image drawn on the picture plane to paper. This phase should almost be *“maximally automatic”* (Stillings, 1995) as it is similar to the activity in Stage 1 – Recognition.

Objectives: After completing this 45 minute long activity, it is intended that the students will be able to accurately communicate a physical composition through a perspective sketch. Students will be able to experiment with various forms, geometries and configurations. This is comparable with Hope’s (2008) dimensions of *“Drawing to Play”* and *“Drawing to Mean”*.

Phase 4 – Transfer

Purpose: The purpose of the 30 minute transfer activity (Figure 11) is to define observational sketching as an automatic process. The picture plane now becomes imaginary as the 2D to 3D conversion device is discarded. Students are presented with an image, which is projected from a data projector (Figure 12) and they are required to communicate what they perceive.

Objectives: By completing this activity, students will be able to decide a suitable position for the imaginary picture

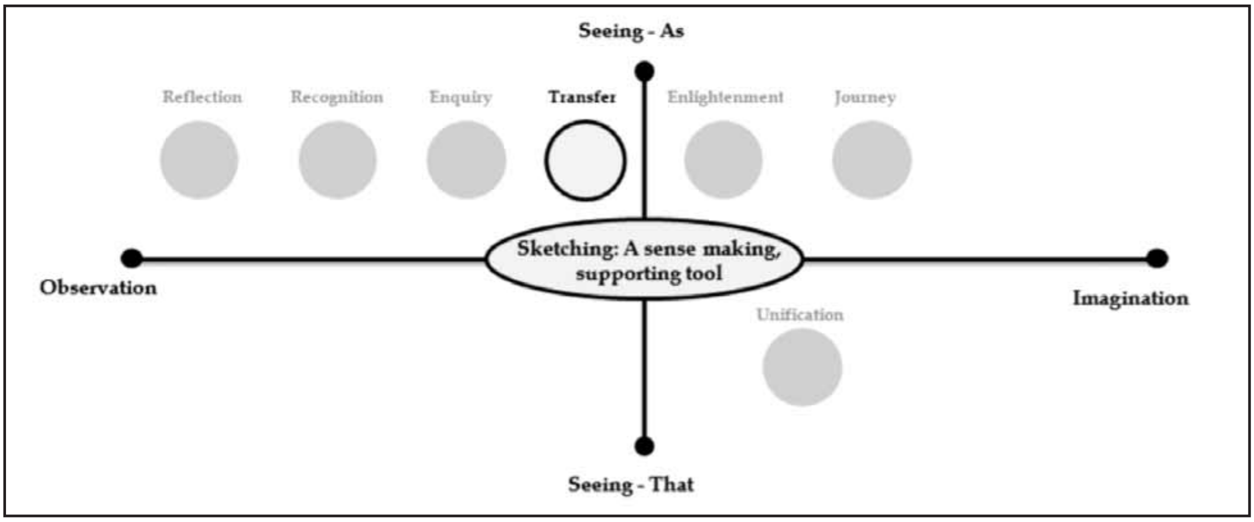

Figure 11. Phase 4 – Transfer activity

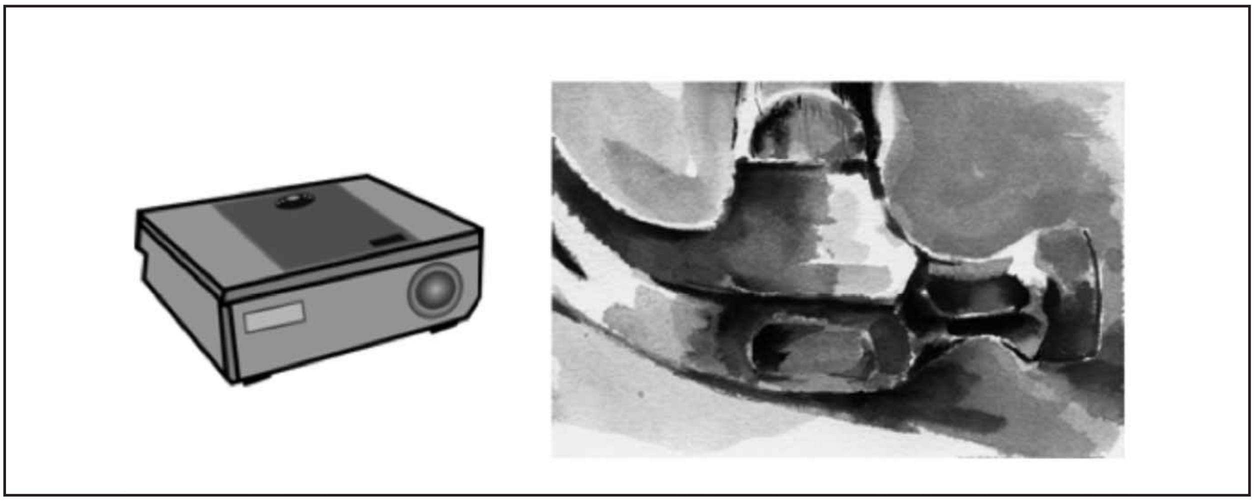

Figure 12. Transfer activity – observational sketching as an automatic process

plane (which will determine the scale for their composition), communicate relationships and values and apply a sighting technique that is consistent and accurate.

Stage 5 – Enlightenment

Purpose: The Enlightenment activity is a critical point of transition in the *'observation-imagination'* continuum. Students are required to setup a composition comprising of both regular and anomalous artefacts which include soft toys, tables and chairs. The activity aims to stimulate student's ability to create images (or visual imagery) of the composition in their minds eye. In order to facilitate the development of this *'visual imagery'*, students were allowed to record ten critical pieces of geometry through annotations or sketches. These acted as a stimulus for the communication of the composition at home by the students.

It is important to note that the activity was carried out in a strictly controlled environment (Figure 14) where no student had any means of digitally recording the composition. Photographs were taken of each student's incomplete sketch as well as their exact view of the physical composition. These were used as a comparator along with the completed sketch at the end of the study.

Objectives: By completing this activity, the students will be able to; apply previously developed skills, manipulate and synthesise both the critical information that they recorded (through sketches and annotations) and their *'visual imagery'* to sketch the composition from memory.

Stage 6 – Journey

Purpose: The Journey activity facilitates further progression along the *'Observation-Imagination'*

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continuum where sketching should be almost an automatic skill with a high degree of *'fluency'* (Goldschmidt, 2003). Students are immersed in an activity where they are required to imagine themselves in a conceptual environment and sketch this using their previously developed skills.

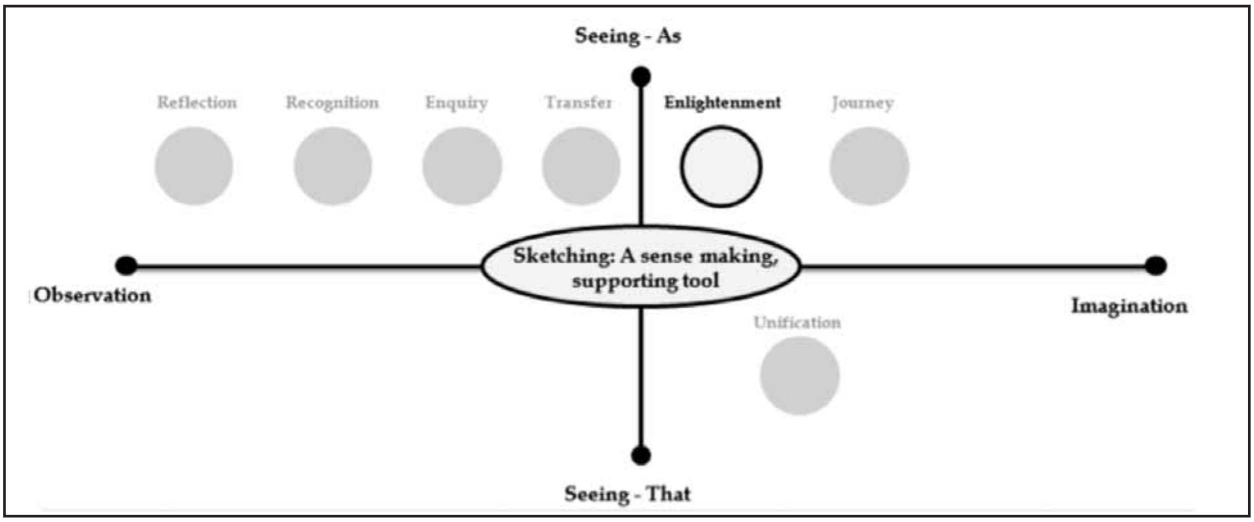

Figure 13. Phase 5 – Enlightenment activity

Figure 14. Classroom activity during the enlightenment activity along with some compositions

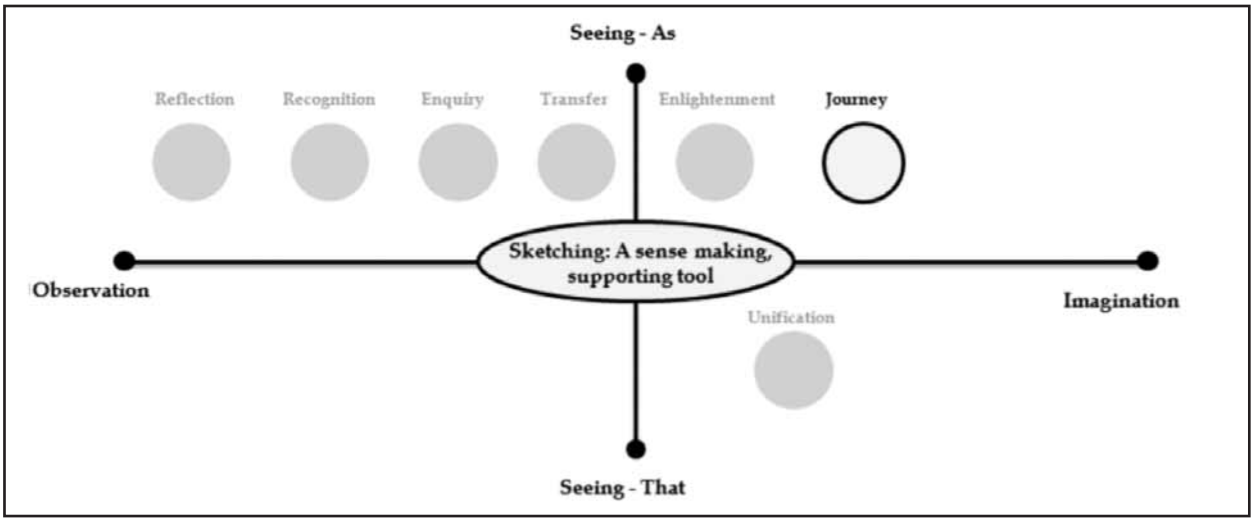

Figure 15. Phase 6 – Journey activity

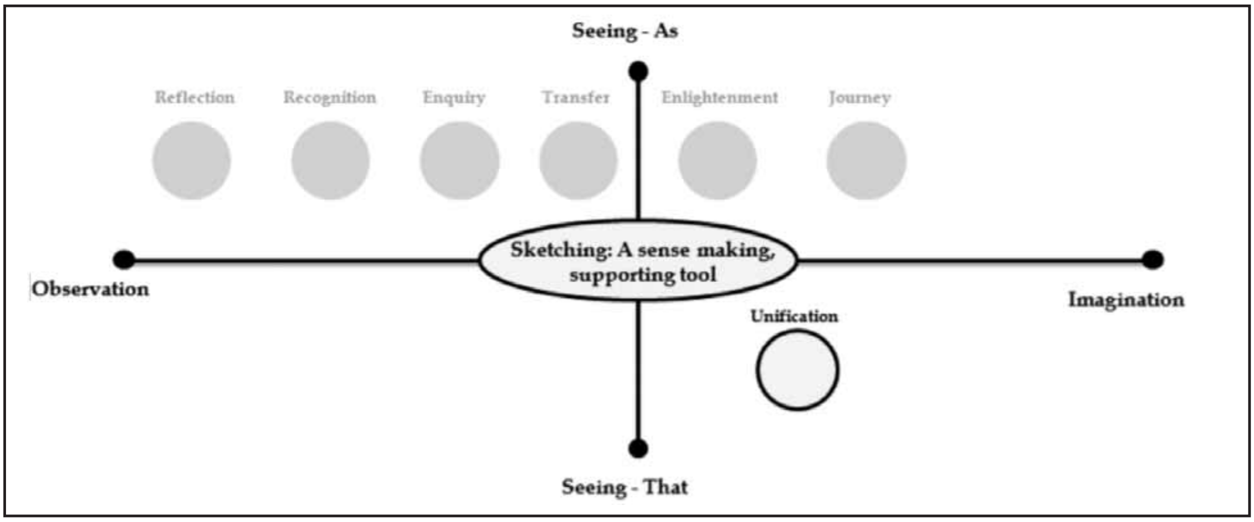

Figure 16. Phase 7 – Unification activity

Objectives: As this activity is a culmination of the previous five stages, students will be able to use visual imagery in addition to any popular media to sketch their own unique composition.

Stage 7 – Unification

Purpose: Considering the application of sketching as a *"sense making"* (Jonson, 2004) exercise that utilises a *"graphical library"* (Storer, 2008) of geometric symbols, it was appropriate to devise an activity (Figure 16), which promotes this with particular emphasis on exploring problems in plane, solid and descriptive geometry. Throughout the study, students were presented with a number of defined geometric problems, which they explored through sketching.

Objectives: Through freehand sketching, students will be able to build on their skills base and ability to make sense of geometric problems and principles. Exploration of these regular geometries will enable the students to develop their ability to modify, reconfigure and synthesise their graphical library for future access.

Findings

The results of the study will be presented in this section. The data are predominantly graphical with some critical quantitative and qualitative results presented also. Sketches for ten students will be presented for the Reflection and Journey phases. The journey of four students will be followed throughout all the activities. These students were selected based on their perceived significant level of improvement through the paradigm and their performance in pre-instruction and post-instruction

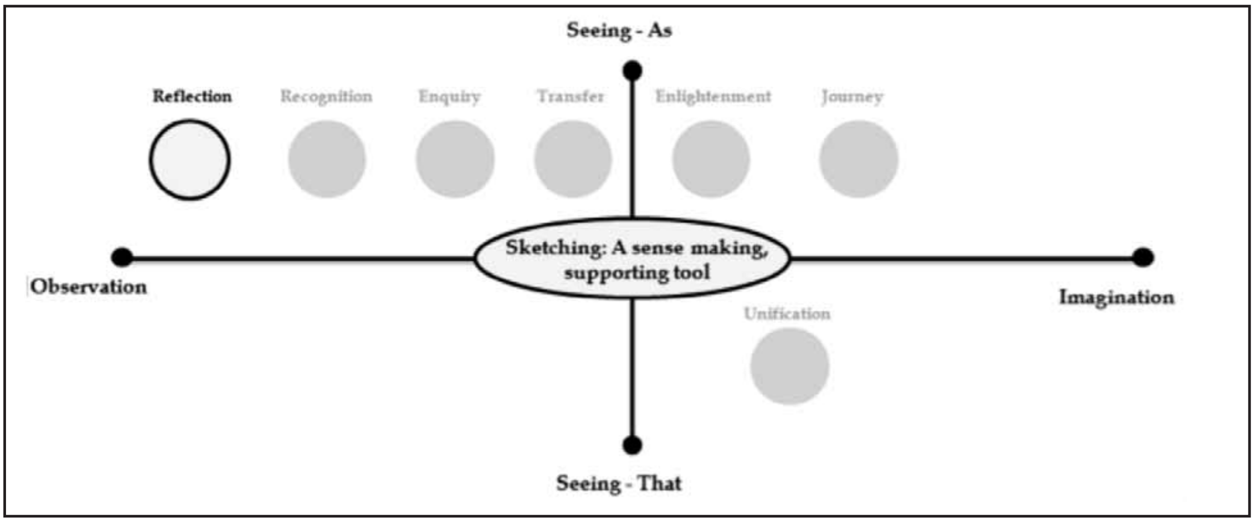

Figure 17. Phase 1 – Reflection activity

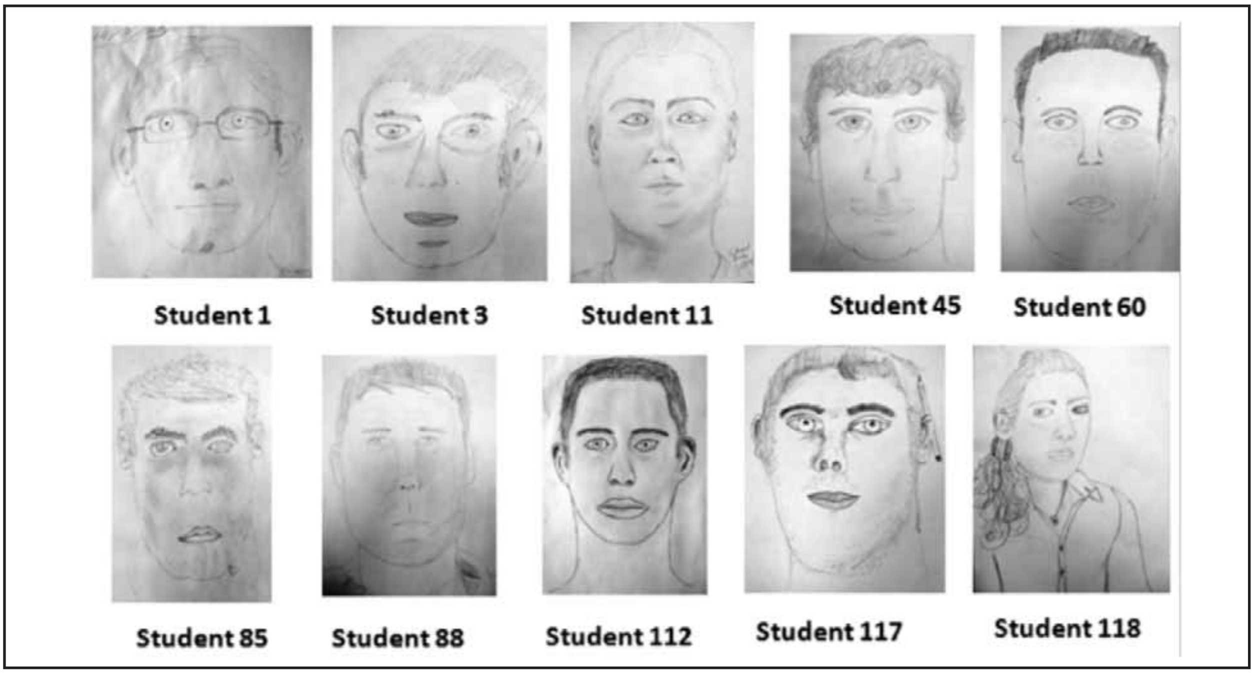

Figure 18. Selection of reflection compositions

psychometric tests, which measured various cognitive factors including visualisation and figural flexibility (Ekstrom et al., 1976). Analysis and discussion of these psychometric tests and their correlation with expertise in freehand sketching has been reported by Lane et al. (2010b) but is outside the scope of this paper.

Phase 1: Reflection

Examples of some Reflection compositions are shown in Figure 18. These were used as a diagnostic tool for the students as well as a comparator with the Journey compositions in order to measure any development in students sketching ability.

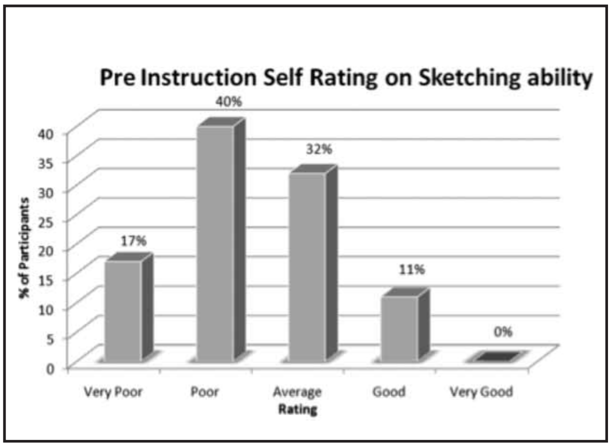

Figure 19. Student self-rating of sketching ability prior to instruction

Notable findings

- After completing the activity, students were asked to rate their level of sketching ability. 57% of the cohort rated their ability as either *'poor'* or *'very poor'* (Figure 19).
- 75% of students expressed difficulty representing the forms and geometries that were unique to their own face.
- 80% of students found that they were unable to position the geometries accurately and struggled with identifying relationships between different features.
- 85% of students claimed that they experienced periods of anxiety and frustration.
- 67% of students stated that they had problems in rendering their composition to communicate 3D form.

Phase 2 – Recognition

A selection of compositions from the Recognition activity, which was presented in the lecture theatre using PowerPoint, is shown in Figure 21.

Notable findings

- 87% of students considered the activity as having significant value.
- 73% of students felt that their performance in the activity was either *'good'* or *'very good'*.
- At the end of the activity, a very positive atmosphere among the students was observed with some students claiming that they never realised they could possibly draw as well as they had done.
- Analysis of the 124 compositions revealed that 100% of

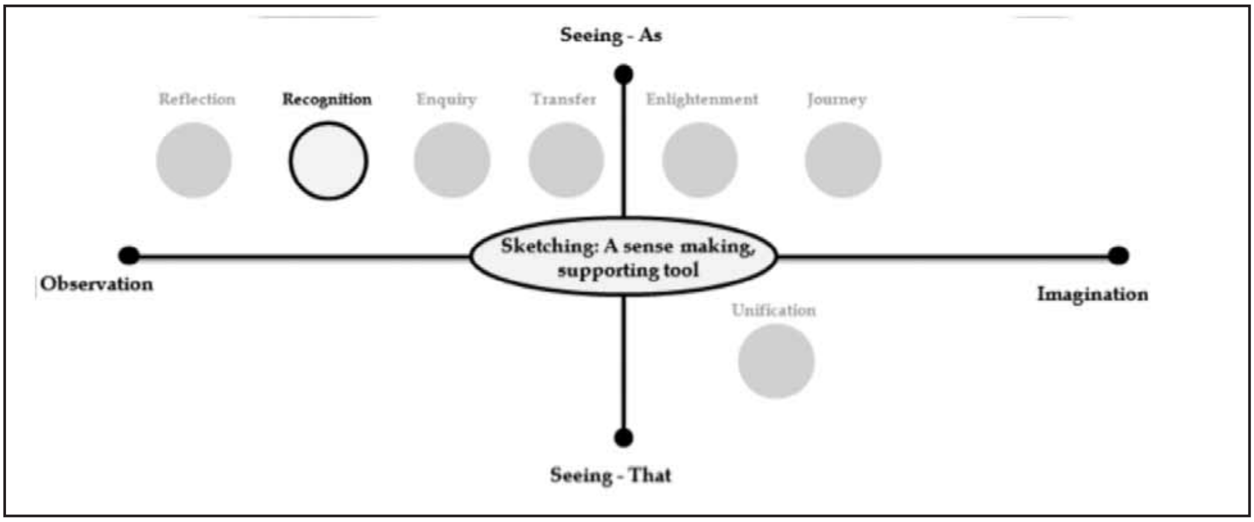

Figure 20. Phase 2 - Recognition

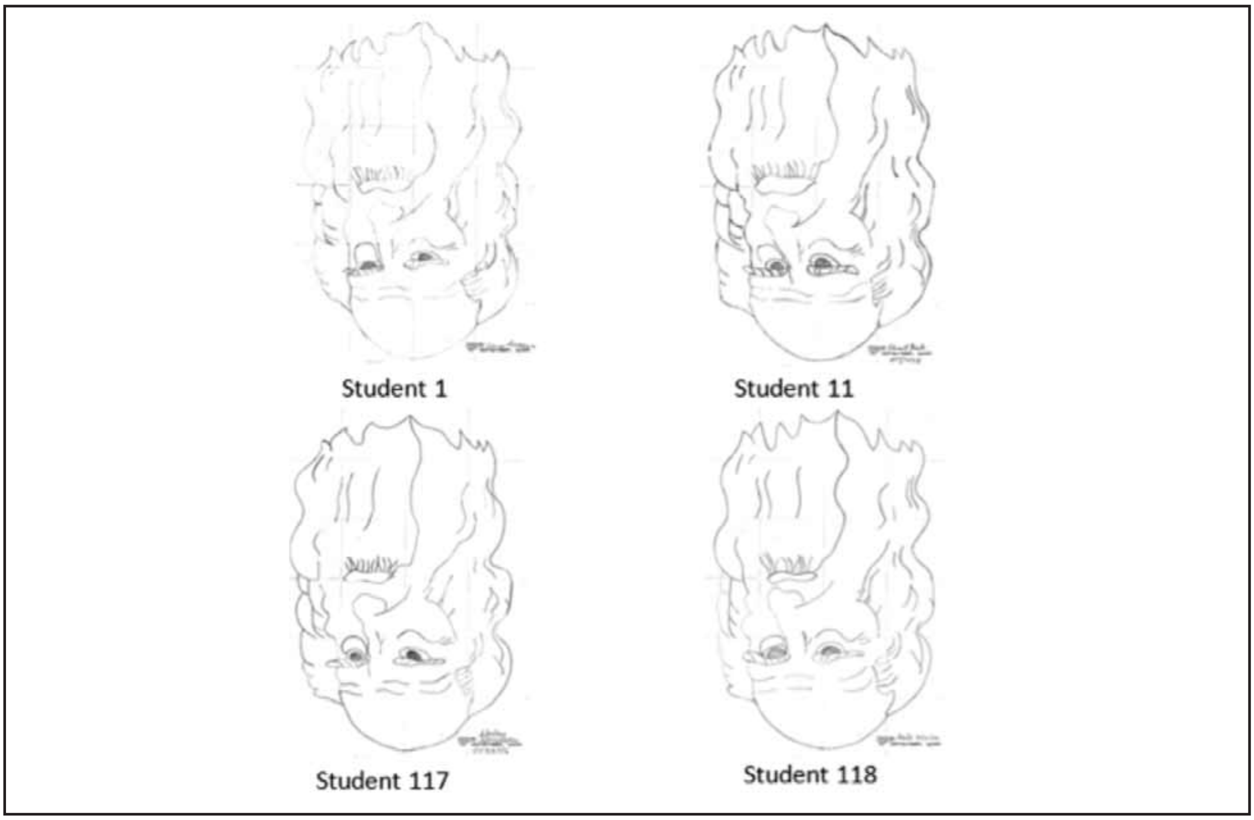

Figure 21. Selection of compositions from the recognition activity

the students completed the activity within the fifteen minute timeframe with a notable similarity between all compositions.

Phase 3 – Enquiry
A selection of compositions from the Enquiry activity is illustrated in Figure 23. Varying levels of creativity is evident in the compositions and students effectively communicated the physical composition utilising the 3D to 2D conversion device.

Notable findings
- 92% of students found that the activity had significant value.

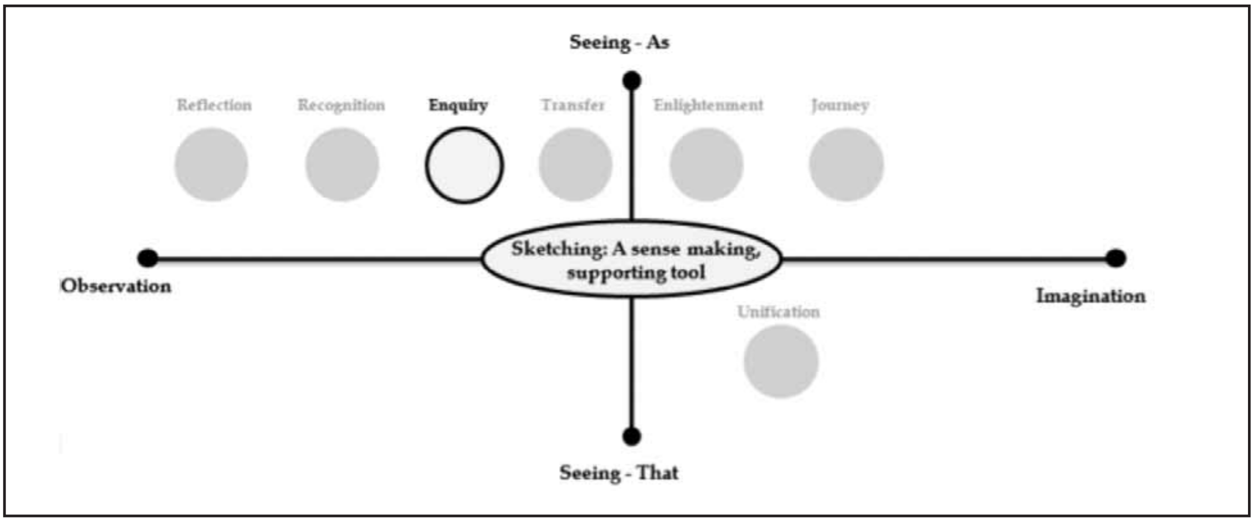

Figure 22. Phase 3 – Enquiry activity

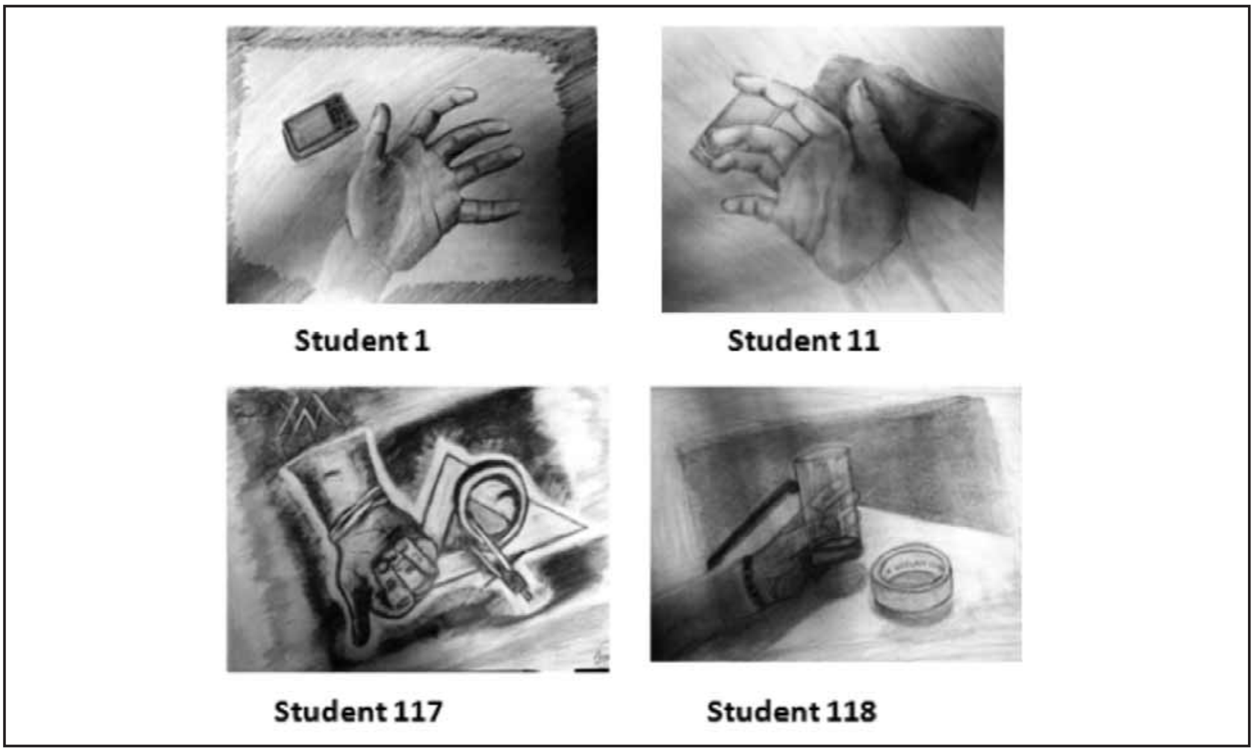

Figure 23. Selection of compositions from enquiry activity

- Only 4% of students claimed that they performed poorly during the activity while 54% claimed that their performance was either *'good'*or *'very good'*.
- Throughout the activity, it was observed that 25% of students struggled to understand the purpose of the 3D to 2D conversion device and its potential to aid in the enquiry and recording of intricate geometries within their compositions.

Stage 4 – Transfer
A selection of compositions from the Transfer activity is illustrated in Figure 25. Progression of previously developed skills is evident in addition to developed abilities to communicate values and synthesise relationships without using the 3D to 2D conversion device.

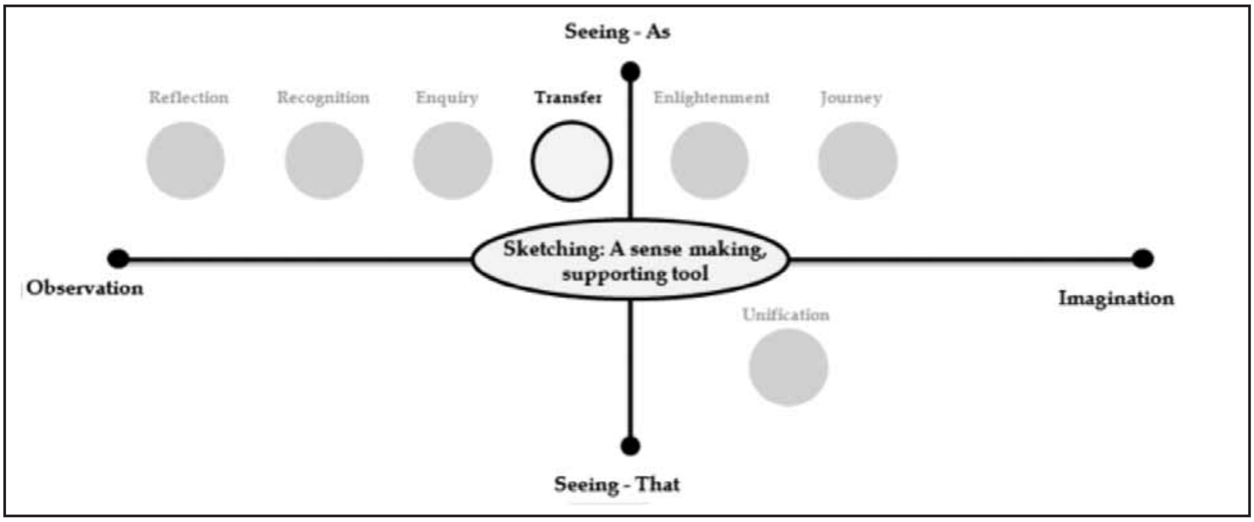

Figure 24. Phase 4 – Transfer activity

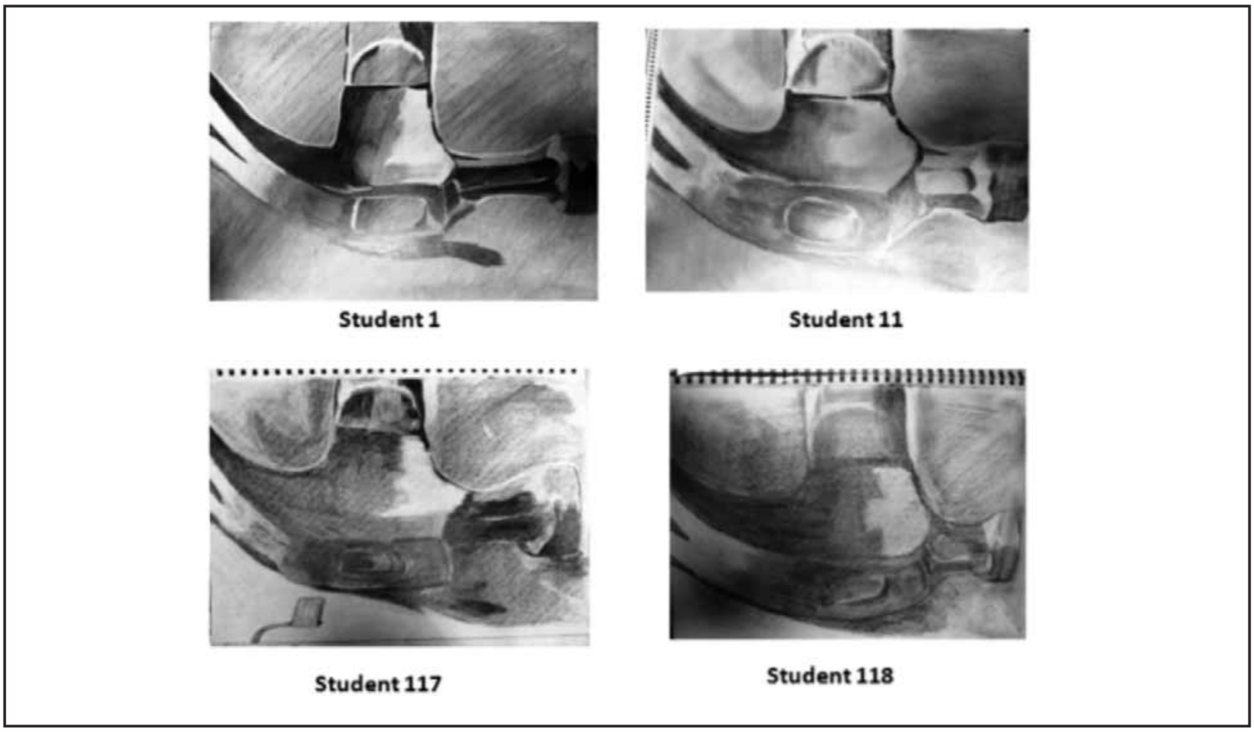

Figure 25. Selection of compositions from transfer activity

Notable findings
- 91% of students placed significant value in the activity.
- Only 7% of students considered their performance in the activity as 'poor' while 61% rated their performance as *'good'* or *'very good'*.
- During the activity it was observed that 75% of students applied sighting techniques using an extended arm and pencil for measuring relationships between geometries while 25% preferred to analyse the same solely by perception.
- In contrast to the recognition compositions the compositions for the transfer activity reveal unique decision making by students in relation to the size of their composition on the A3 sketch pad, rendering styles and line type communication.

Phase 5 – Enlightenment
A selection of compositions from the Enlightenment activity is illustrated in Figure 27. The smaller composition in the top left hand corner of each students work is the

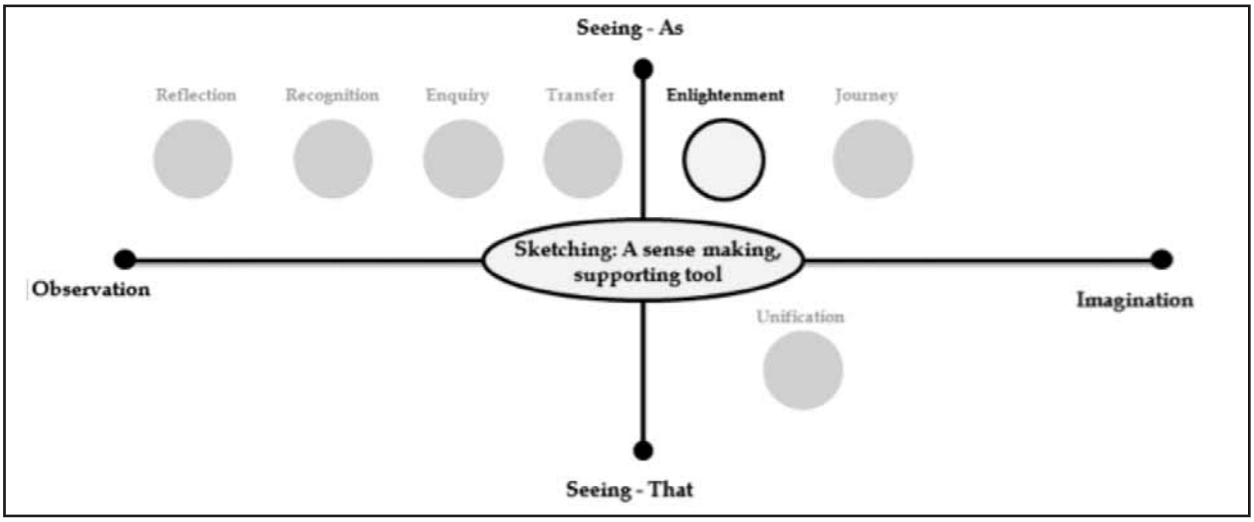

Figure 26. Phase 5 – Enlightenment activity

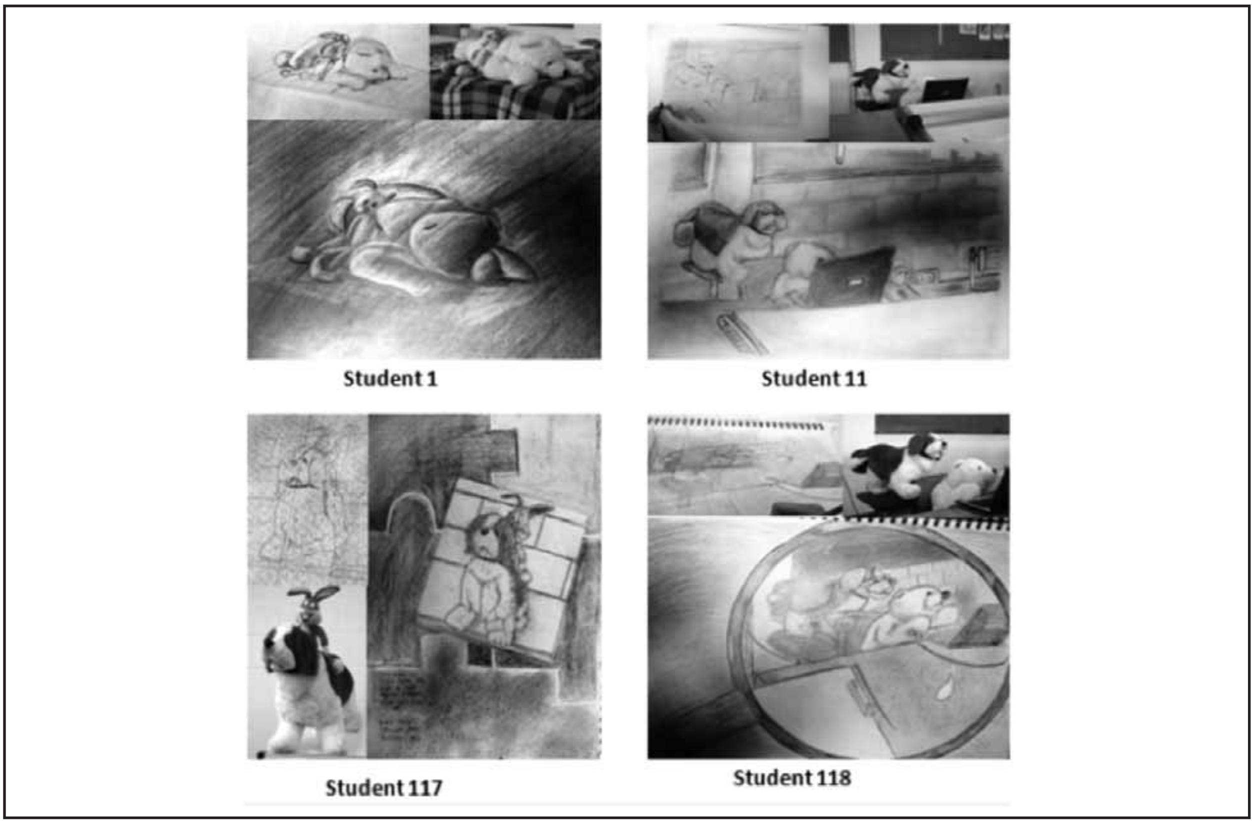

Figure 27. Selection of student compositions along with incomplete work prior to completion from memory

incomplete perceived sketch after the 25 minute timeframe. The composition was completed at home (bottom sketch) by stimulating, modifying and externally representing visual imagery. The photograph in the top right allows a comparison to be made between the final composition and physical composition.

Notable findings

- 67% of students placed significant value in the activity.
- Notably, 33% of students rated their performance as either *'poor'* or *'very poor'*.
- A significant variance was observed in the physical configurations formed by the students. Some groups displayed very imaginative possibilities while other

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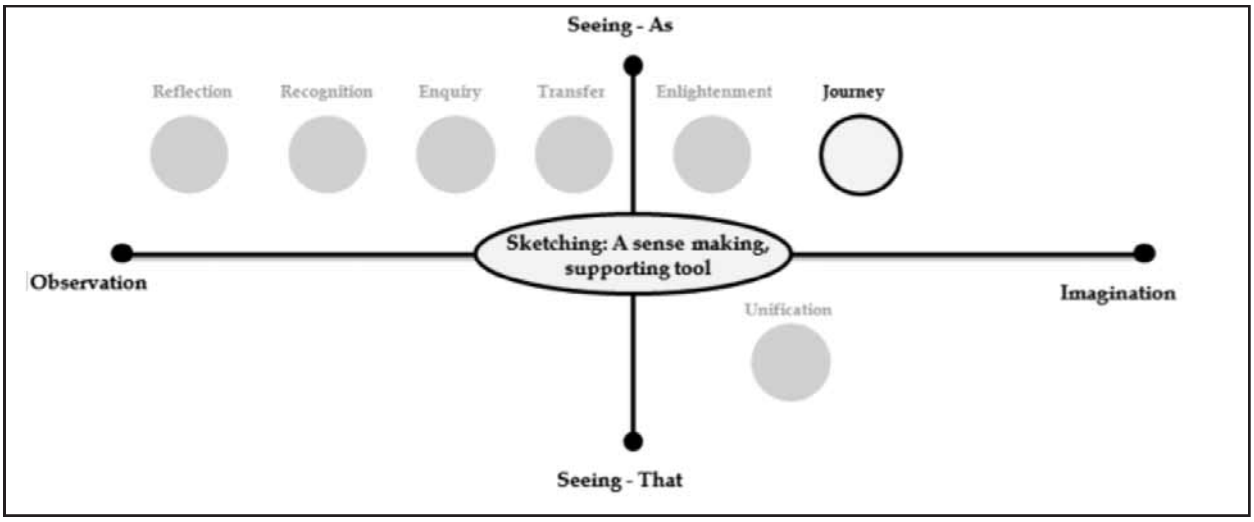

Figure 28. Phase 6 – Journey activity

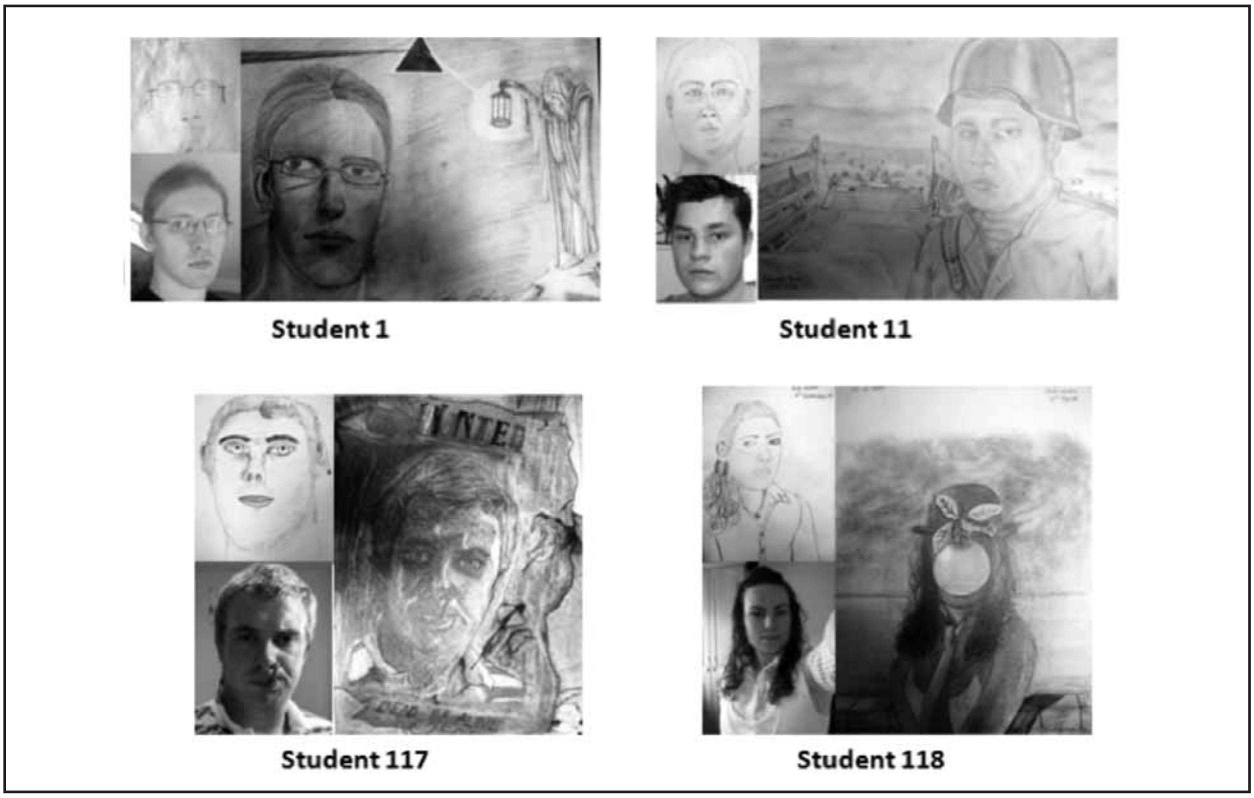

Figure 29. Student compositions for journey activity

groups seemed content with setting up the physical compositions in a simple, easy to remember configuration.

- Unique approaches for communicating critical information (thumb nail sketches and annotations) are also evident in the completed sketches indicating variance in student's ability to recall, manipulate and synthesise visual imagery.

Phase 6 – Journey

Compositions from the Journey activity are illustrated in Figure 29 and Figure 30. The pre-instruction Reflection composition and student photographs are given to enable a comparison to be made with the Journey composition.

Notable findings

- 98% of students placed significant value in the activity.

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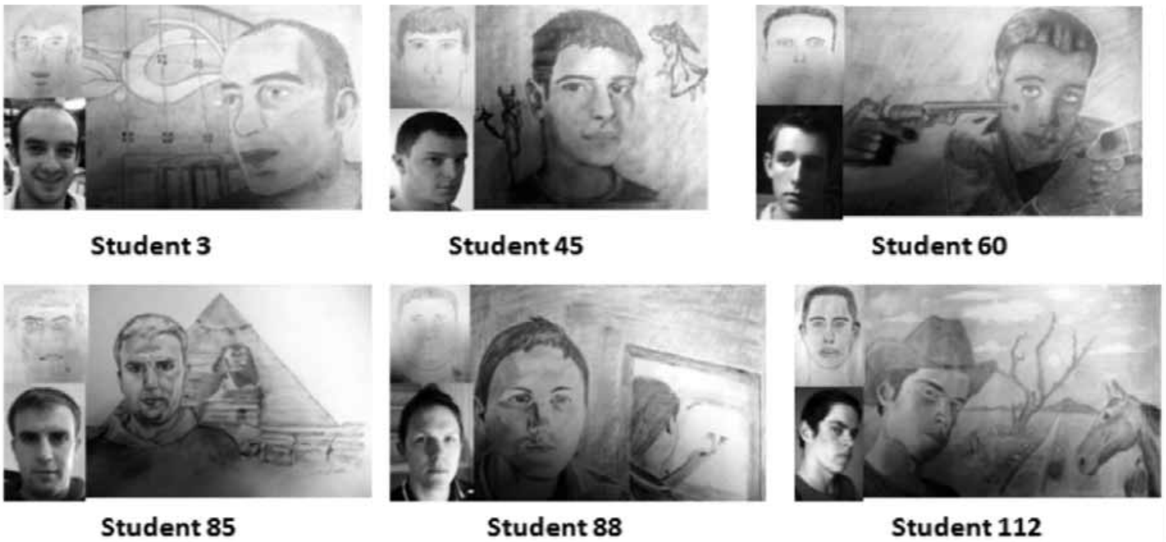

Figure 30. Remaining student compositions for journey activity

- 69% of students rated their performance as either *'good'* or *'very good'* while only 6% rated their performance as *'poor'* or *'very poor'*.
- Fluency in sketching skills is evident in addition to creative expressions of the students integrated into a conceptual theme.
- There is increased evidence within the compositions of an alignment between student's ability to manipulate and synthesise visual imagery and communicate this through their developed ability to sketch.

Phase 7 – Unification

A selection of the sketches from the Unification activity is presented in Figure 32.

Notable findings

- There was notable evidence of the application of different sketching media and techniques within students work.
- Students communicated an ability to utilise their understanding of geometric principles and concepts in exploring design ideas.

Post Instruction Findings

At the end of the study, the students were asked to rate their level of sketching ability. This data was used as a comparator with the self-ratings taken during the Reflection phase. Figure 33 illustrates this data in the form of a graph.

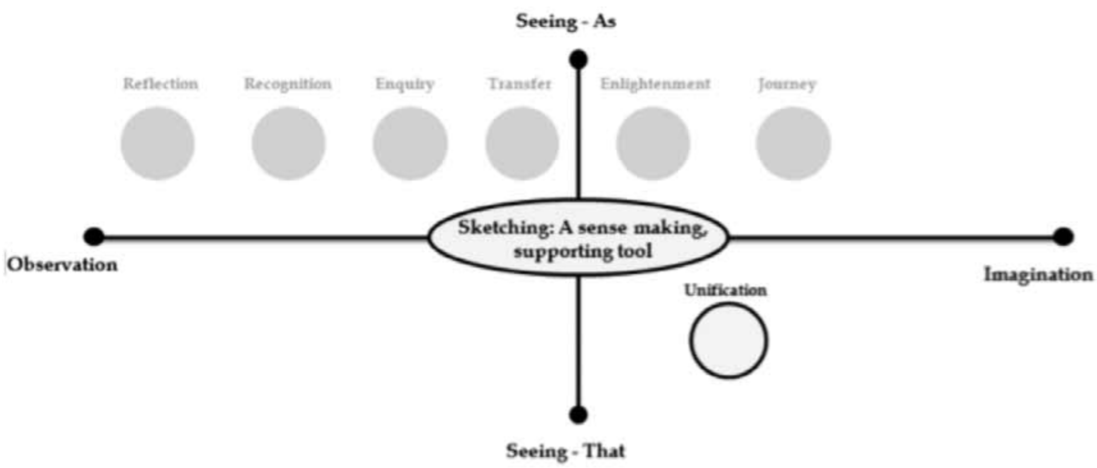

Figure 31. Phase 7 – Unification activity

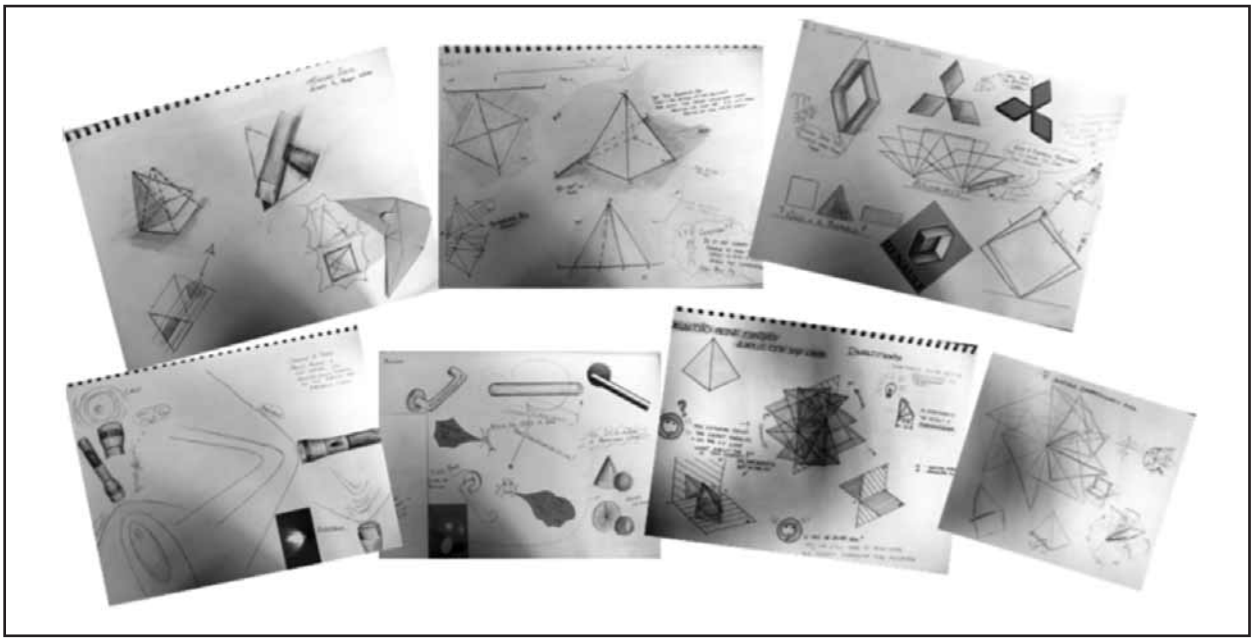

Figure 32. Selection of student work based on plane and descriptive geometry and the design task

A paired sample t-test was conducted to evaluate the impact of the intervention on student's ratings at Reflection phase and at post-instruction. There was a statistically significant increase in student performance ratings with $p < .001$ (2-tailed).

Other notable data

At the end of the study, students were given the option of providing additional comments on the set of activities, which was presented to them. Students who commented were generally very positive. Typical comments included the following:

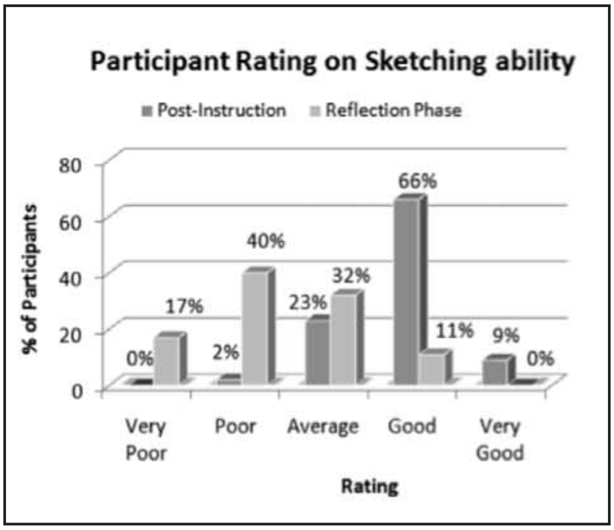

Figure 33. Student ratings of pre and post instruction sketching ability

- Student 6: *"Sketching exercises were class [colloquial Irish speech meaning "mind-blowing"]. I really enjoyed them and feel that my sketching ability greatly improved."*
- Student 12: *"Very worthwhile and enjoyable. This is an essential skill."*
- Student 16: *"I really enjoyed this part of the module but I found the Enlightenment activity very difficult."*
- Student 33: *"I feel that these sketching activities deserve a module of their own."*
- Student 49: *"I found the sketching exercises very worthwhile and gave me much more confidence in my sketching ability."*
- Student 60: *"These sketching activities have been the most enjoyable part of technical graphics that I have studied at college."*
- Student 124: *"These activities greatly helped me to redevelop and enhance a skill I had long forgotten and I really appreciate being able to sketch to a decent level once again."*

Discussion

It is worth emphasising that the findings within this study are based on the exploration of a novel and original paradigm, the design of which was built on contemporary literature surrounding freehand sketching. The students *'journey'* (Hope, 2008) through the paradigm involved the progression from observation to imagination (Fish, 1990) within *'seeing-that'* and *'seeing-as'* modalities (Goldschmidt, 1991, 2003).

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Analysis of the student compositions and pre and post instruction self-ratings suggest a significant improvement in student's ability to formulate, manipulate and synthesise perceived geometry and visual, mental images. Evidence of this is particularly notable in the *'Journey'* compositions (Figure 29 and Figure 30). This cognitive development was underwritten and derived from the completion of the specially designed sketching based activities within the paradigm. This is a novel and original finding considering that the study was carried out in a restricted time period of four weeks with only eight hours of classroom based instruction.

It is also notable that students placed significantly less value in the *'Enlightenment'* activity in comparison to the other activities within the paradigm. As the perceptual buffer is removed during the *'Enlightenment'* activity, this may be an indication that student's felt uncomfortable with drawing from memory. This requires further exploration and analysis in future studies.

If this model for teaching freehand sketching is to become an international standard there are several changes that could be made, which will significantly enhance its potential. These will be discussed in the next section and are informed by the findings of the study presented in this paper in addition to the body of literature relating to freehand sketching.

Reflections within the paradigm

On reflection, the progression within the proposed paradigm (Figure 3) is significantly enhanced by the devised activities however; some critical observations have been made. The seven activities greatly facilitated controlled, reflective and deliberate sketching. Considering that there was a notable increase in the fluency (Goldschmidt, 2003) of students sketching ability in the latter stages there was increasing evidence that the sketches were precious and of value to the students. This was particularly evident during the Enlightenment activity where the perceptual buffer (physical objects) was taken away and students expressed difficulty and less satisfaction with their performance compared with other activities.

The *'preciousness'* of student's sketches and their intent on clearly communicating their compositions is of particular interest and is evident throughout all the compositions within the findings with particular evidence in the Journey activity. Notably, Goldschmidt (1991) describes sketches as sometimes being so idiosyncratic that they are only comprehendible by the person that made them. This idiosyncratic element appears to be missing and undervalued in the students work.

On reflection, future studies will incorporate a number of auxiliary intermediate sketching activities (Figure 34), which will promote unpremeditated mark making and creative thought during incubation periods. These will aid in the progression through the seven primary phases. An example of a type of activity that could be applied, involves group work using an idea generating *'Brainsketching'* (van der Lugt, 2002) technique, which utilises sketching as the primary means for recording ideas.

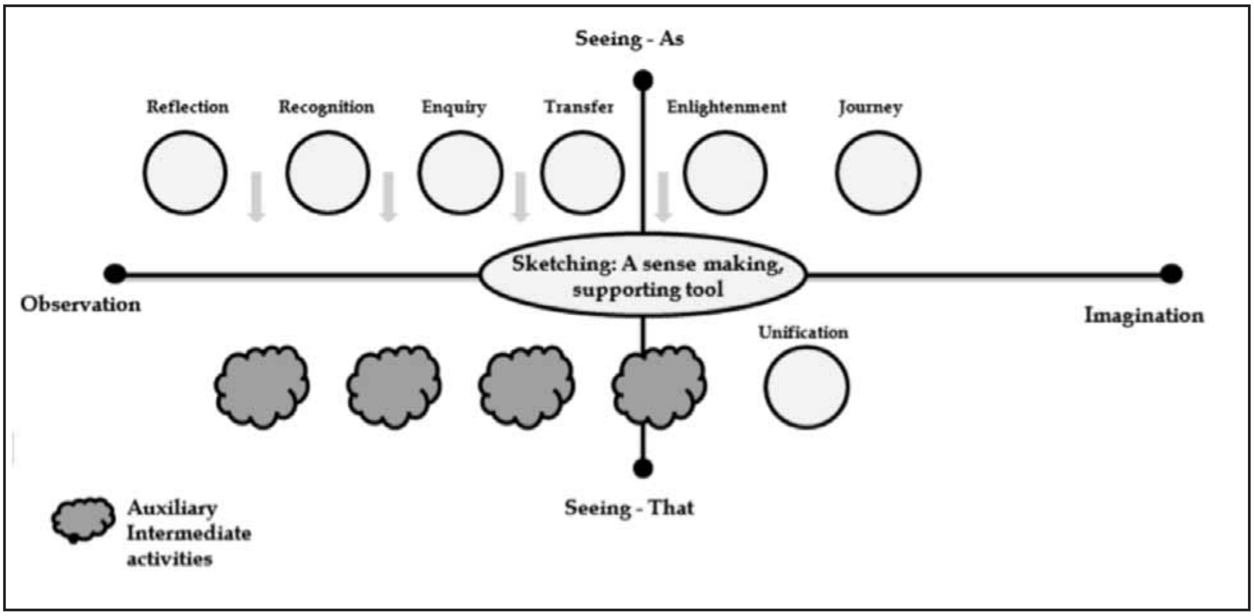

Figure 34. Enhancing the proposed paradigm

Through these auxiliary activities, the students will build on the *"seeing-that"* modality (Goldschmidt, 1991, 2003). The randomness and creativeness of the activities will facilitate the recording and relating of ideas as well as building on and exploring an immediately accessible database or "collective graphic memory" (McKim, 1972). Further analysis of these phases will form the basis of future work.

Conclusion

The purpose of this study was to provide an indicator as to whether the development of sketching expertise is possible through activities within the proposed paradigm. There is significant evidence within the results that suggest the proposed paradigm facilitates the development of concept driven capabilities.

However, it must be noted that these findings are based on student's feedback and independent observations and as a result they may be subject to debate. Future research will utilise observational frameworks to analyse student's technological approaches (Stables, 2008) during the sketching based tasks. In addition to this, visual and verbal protocol analysis (Middleton, 2008) will be utilised to analyse the cognitive actions of students as they sketch and psychometric tests will also be applied as an alternative measure of cognitive development.

It is anticipated that this paper has provided a significant indication that freehand sketching is much more than a psychomotor skill linked to external representations on paper. Rather, it is a highly complex cognitive skill, which can significantly support the formation, manipulation and synthesis of visual thinking and creative discovery. It is expected that future research relating to the proposed paradigm, will contribute further to the body of literature surrounding 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.

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