AC 2010-1212: FREEHAND SKETCHING AS A CATALYST FOR DEVELOPING CONCEPT DRIVEN COMPETENCIES

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Freehand sketching as a catalyst for developing concept driven competencies

Abstract

At a time when concept driven competencies are perceived to be critical in redefining effective technological education, the introduction of Design and Communication Graphics at senior cycle in Irish high schools has broad implications. Students now have the potential to explore applied geometries, integrated with conceptual thinking in addition to developing essential communication skills. As a result, freehand sketching has become an integral facet of all technological subjects.

Action research currently being carried out at the University of Limerick aims to identify a sustainable intervention strategy for the development of concept driven competencies in students of technological education. Core to this is the development of student's ability to freehand sketch what is both perceived and conceptualised.

This paper presents findings of an intervention strategy carried out with a cohort of 124 pre-service teachers of technology education. The study develops participant's ability to engage in higher order symphonic cognition as well as the harmonisation of fundamental communication skills through the medium of freehand sketching.

The approach for the research followed a five phase intervention strategy. An initial pre-instruction covariant exercise was used to measure participants overall communication ability together with their capacity to engage in higher order thinking. Stage one, two and three developed the aptitudes of recognition, enquiry and synthesis through the use of both regular and non-regular geometry embedded in dual purpose activities. Stage four, moving towards conceptualisation, employed a comparative photographic composition as a measure of students previously perceived composition. The final stage centred on an organic composition derived by the students that outlined their ability not only to communicate but also present symphonic aptitudes.

The key findings for this paper are significant in terms of developing a sustainable strategy for teaching freehand sketching in Irish high schools. Instantaneous improvement resulted in participants developing an intrinsic motivation to develop their skills and engage in the activities as autonomous learners. An innovative pedagogical strategy was applied. This facilitated a cohort of thirty participants and incorporated *Pareto's Law* and the *80/20 Principle*. The concept of realising and developing personal styles in the communication of compositions was a novel finding of the research. Relationships between *metacognition* and sketching competencies are discussed with implications for the exploration and development of complex solutions in plane and descriptive geometry.

The paper concludes by highlighting the value of freehand sketching in developing symphonic design capabilities, the implications of this skill in terms of transferability and access of the *physical symbol system* present in the cognitive architecture.

Introduction

The purpose of this study was to further develop and investigate the effectiveness of an intervention strategy which aims to determine how freehand drawing can be applied as a multi-purpose autonomous learning tool in technology subjects in the Irish education system [1].

Previous research carried out at University of Limerick with a cohort of nine participants established that sketching is a teachable skill that can be learned by the majority of people, irrespective of innate ability. It was also evident that the holistic value of learning to sketch using a defined process was far greater than the completed composition. Increased levels of enquiry, recognition of patterns and synthesis between unrelated elements in compositions provided an indicator that there is an underlying cognitive value to this activity which requires further investigation [1]

In order to further develop this previous research, the intervention strategy will now be analysed in terms of developing a pedagogy that will facilitate class sizes up to thirty participants and incorporate the paradigm of *"diminished return"*. In addition to this the transferability of freehand drawing as a critical tool in developing concept driven competencies as well as solving problems in plane and descriptive geometry will be explored.

Teaching and Learning

Deficiencies in engineering education have been exhaustively enumerated in recent years with experts advising educationalists in several areas such as the exploration of real world engineering designs and the development of critical and creative thinking and problem solving skills [2]. In response to this, the development of new and improved methods of teaching and learning has become a universal aim among technological teachers over the past ten years [3]. The introduction of a new suite of technology subjects at senior cycle in the Irish education system has brought about an unprecedented need for a change in pedagogic structures. Fundamental to all of the technological subjects is the development of technological capabilities. Design and Communication graphics has particular importance in developing students ability to *"apply knowledge and skills by thinking and acting confidently, imaginatively, creatively and with sensitivity"* through design and realisation [4].

Craft subjects traditionally derived their educational justification from their contribution to the emotional and physical development of children in preparation for work. Refined curriculum in technology education throughout the world has incorporated a design element that is becoming increasingly recognised for developing intellectual skills in students [5]. As design is a demanding and complex problem solving activity of great economic and social importance, sketching has an integral part to play [6] and a defined pedagogic approach is important to ensure the required abilities are nurtured [1].

In the Irish second level system, teachers are required to facilitate the learning of students who are in one of two possible phases of cognitive development; concrete operational stage or formal operational stage [7]. It is important that teachers recognise what stage of development students are at and structure their lessons at a level that is consistent with or slightly advanced than the students existing schemes. This will facilitate the nurtured process of cognitive growth [8].

Previous research in freehand drawing carried out at University of Limerick found that participants engaged in *"increased levels of enquiry, recognition of patterns and synthesis between unrelated elements"* while constructing various compositions [1]. These increased levels of *"cognitive engagement"* [9] suggest that the participants had developed an *"intrinsic motivation"* [8] to become competent and assimilated different schemes to engage in *"hypothetico-deductive reasoning"* [10]. As a result it can be hypothesised that the participants reached the upper levels of Blooms Taxonomy of Educational Objectives; Analysis, Synthesis and Evaluation [11].

Current research aims to establish how a class size of thirty students can reach the same level of *"cognitive engagement"* and achieve higher results than the original participant group of nine people. Previous testing carried out took fifteen hours to complete [1] but due to timetabling restrictions this will need to be reduced to an eight hour period. The present challenge is to facilitate the cognitive development of these large class groups so that the *"Zone of Proximal Development"* [12] is identified which will in turn enable participants to enter the *"symbolic mode"* [13] of development which leads to *"formal operational cognition"*[7].

In response to the logistical restrictions placed on this study in terms of classroom delivery time and increased participant numbers it is worth analysing *"Pareto's Law",* which is also known as the 80/20 principle [14]. This principle based on the paradigm of *diminished return* has been successfully applied in language courses by Michel Thomas where it was found that the most effective way to teach was to find out what would be most useful to students new to a subject area. Figure 1 illustrates how eighty percent of results would flow from twenty percent effort in a system [15].

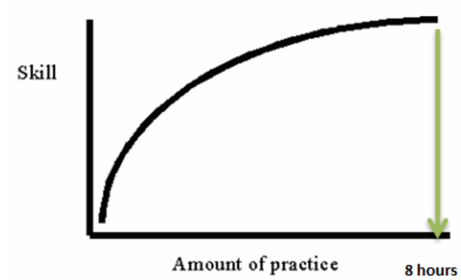

Figure 1 – Illustrating 80/20 Principle

In conjunction with *Pareto's Law* it is important to value the student's ability to think independently and form hypotheses. The time spent on teaching information should be reduced in order to focus on the direct teaching of higher order thinking and the development of *"operacy"* (which is the ability to do things and make things happen)[16]. It can therefore be hypothesised that by coupling *Pareto's Law* and de Bono's view of direct teaching of thinking, a defined structure for facilitating freehand sketching can be established. Twenty percent of classroom time will be spent teaching core principles outlined in the previous study [1] which are critical to learning how to freehand draw. The remaining eighty percent of participant's time will be spent engaging in critical thought integrated with incubation periods that will help dissipate *"functional fixedness"* [17].

Concept Driven Competencies

The development of cognitive and psychomotor skills in communication graphics, problem solving and critical thinking is a primary aim of Design and Communication Graphics in the Irish second level system. In addition to this, students are provided with an appropriate learning environment where they can plan, organise and present creative design solutions using a variety of skills, techniques and media [4]. Assessment of the subject is in two components: A design assignment (worth forty percent of marks) that assesses students on elements that cannot be readily assessed through the terminal examination that is worth sixty percent of marks.

Core to both components is the development of *"Concept Driven Competencies"*, where students are expected to develop an ability to engage in *"metacognition"*[18] where principles and problems are analysed, solutions are formulated and effects of these are evaluated taking into consideration one's strengths and weaknesses. This in turn, helps develop abilities to problem solve, creatively design, communicate ideas through freehand sketching and apply principles of plane and descriptive geometry to various problems[4].

The philosophy of Design and Communication Graphics promotes creative thinking, discovery and personal decision making and it is clear that these principles are related to design education in all subjects and not just art education [19]. The realisation of this philosophy will see students having a *"high concept"* aptitude of *"symphonic thinking"* which is critical for economies to succeed in the *"Conceptual Age"* [20]. Teaching methods must ensure that students are able to synthesise their abilities to enquire, explore, communicate, manipulate and evaluate information [5].

In relation to freehand drawing, it has been found that a variety of intellectual skills can be systematically developed in order to draw well. The ability to recognise, enquire and synthesise information [1] should be integrated into McKim's model of visual thinking (figure 2) *"when seeing, imagining and drawing merge into active interplay"* [21]. This interplay could involve regular/irregular geometric problems or complex design problems all of which require *symphonic* and *concept driven* competencies.

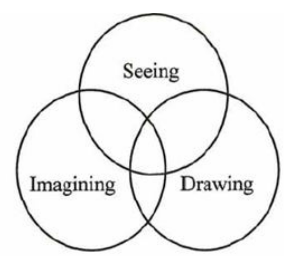

Figure 2 – McKim's model of visual thinking

Cognitive Architecture

The human mind is a remarkable information-processing system that is astonishingly powerful in most instances and yet surprisingly limited in others [22]. The lack of understanding and exploration of how the natural intelligence processes information is a common root problem in science and engineering disciplines that has led to the development of disciplines such as cognitive science, artificial intelligence (AI) and cognitive informatics (CI) [23]. Cognitive psychology concerns human cognition. The capacity to perceive, memorise, think, learn and engage in problem solving is misconceptualised among teachers and educational specialists [22, 24]. In this section an initial overview of the cognitive architecture will be given in order to provide an insight into how students process information.

Given the broad level of abilities that teachers of technological subjects are faced with, it is important to have an understanding of human cognitive potential, its information processing capacities and mechanisms. Human beings receive information through their senses, engage in some form of thought about that information and carry physical action through voluntary muscular movement. Central to the human cognitive architecture are; **sensory systems** including vision, hearing, taste/smell and touch, **central systems** concerning thinking, memory, learning and attention and **motor systems** which include physical and verbal responses [22].

The transfer of physical energy impinging on the human body and conversion into electrochemical activity through special nerve cells called receptors is known as *transduction*. Sensory systems including vision, hearing, taste, smell and touch have complex architectures to complete this initial transduction and further processing of sensory input [22]. Sensory systems are *"informationally encapsulated"* and their ability to classify and process inputs is evidence of the *"modularity thesis"*. That is, a sensory system transforms a class of environmental inputs into outputs that can be used by the central systems [25].

Thinking is a key component of the central system of cognitive architecture. The ability to think is an amazingly flexible, limitless cognitive tool which enables a person to draw conclusions, make plans and solve problems in remarkably diverse domains in everyday life. Thinking can usually be characterised by a focus of attention, inputs from memory and our capacity to learn. Knowledge that is built up in human memory and both cognitive and motor skills are acquired over a life time. Integral to the central system is a *physical symbol system* [26] that contains a set of *"built-in information processing facilities"* that have the potential to acquire an unlimited range of further processes resulting in semantic interpretations of different environments [22]. Evidence of this physical symbol system and its programmable like potential must question the theories of experts in teaching freehand drawing where students are encouraged to use *"right hemisphere"* visual attributes to reduce the influence of the symbolic *"left hemisphere"* [27].

The ability of the cognitive architecture to retrieve information through *"distal access"* [26] of the symbol system, where the processing of one symbol evokes further processing of other symbolic structures, is significant in terms of teaching and learning in technology education. The construction of a mechanism or pedagogic structure to help students maintain, access and transform symbolic structures that are not immediately driven by sensory input or motor output has significant implications and has the potential to transform teaching and learning in areas such as design, problem solving and communication graphics.

Methodology

The approach for this research project involved a five phase intervention strategy which had a participant group of 124 pre-service teachers of technology education at University of Limerick. The participants are studying to teach subjects such as Engineering Design Graphics and Technology to high school students between the ages of twelve and eighteen. The research aimed to further investigate a previous study where freehand sketching was taught to a novice group of participants [1]. The creation of a learning environment and pedagogical mechanism to teach large group sizes of 30 participants in a restricted eight hour time frame was the underlying challenge.

Participants

The participant group consisted of 124 pre-service teachers of which 98.4% were male and the remaining 1.6% female. Figure 3 gives a breakdown of how many participants studied Communication Graphics at second level (high school level) and the level which was studied.

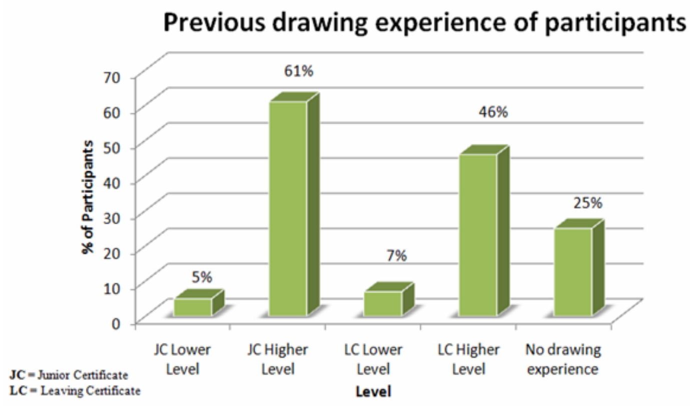

Figure 3 – Previous drawing experience of participants

All participants were required to take part in the activity which was run as an element of an Engineering Design Graphics module specifically for trainee teachers. The study was carried out over a four week period when participants attended classroom sessions for two hours per week. Class times were varied on different days and times throughout the week. Participants rated their own sketching ability prior to taking part in the research with a notable 57% of the group rating themselves as either *poor* or *very poor* (Figure 4).

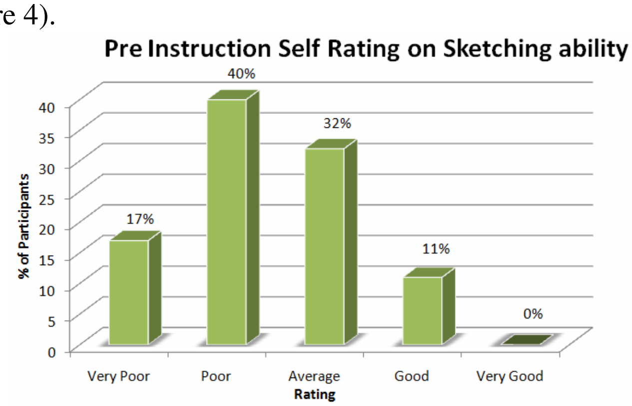

Figure 4 – Participant pre-instruction self rating on sketching ability

Design Procedure

The strategy was broken into five stages which were all unique, yet complementary activities that had specific learning outcomes. The activities were strategically devised to develop critical cognitive attributes in the participants using a pedagogic structure that facilitated the independent exploration of learning. Instruction was given in a restricted timeframe of eight hours with appropriate incubation periods of one week.

Pre-Instruction Activity

In order to determine whether participant's ability to sketch improved throughout the study, it was necessary to have a pre-instruction activity. This acted as a covariant in relation to the final composition at the end of the study. Participants were given a 45 minute timeframe to draw their self portrait. A mirror, felt pens, pencils and erasers were provided and participants were given no limits in what they communicated.

Stage 1 – Recognition

Previous research carried out (Lane & Seery, 2009) has shown that when students are given an inverted drawing of irregular geometry, it can be drawn accurately by analysing and communicating the geometries when placed beside the original composition (Figure 5).

Figure 5 – Perception proof Exercise (Lane & Seery, 2009)

Analysis of the above approach resulted in an improved method being devised that will enable participants to develop additional attributes and this has implications for teaching large class sizes.

The revised approach for the recognition exercise involved 124 participants completing a composition which consisted of both regular and irregular geometries in a lecture theatre during a twenty minute time period. Rather than drawing an original composition at a scale of 1:1 (figure 5) and having the original directly alongside each participant, it was decided to present a composition on a screen measuring 4 meters across and 3 meters down.

Each participant was given a blank A4 sheet which consisted of an equally spaced grid of twenty four squares. Using a data projector and a PowerPoint presentation each grid of the composition was revealed with set time intervals (Figure 6). Participants were required to analyse the geometry in each grid and communicate this on their own sheet.

The following learning outcomes were critical to this activity:

- The ability to perceive and recognise the different geometries
- The ability to scale what was perceived on the large screen on to an A4 sheet
- The ability to realise the relationships between different geometries within each square and between different squares

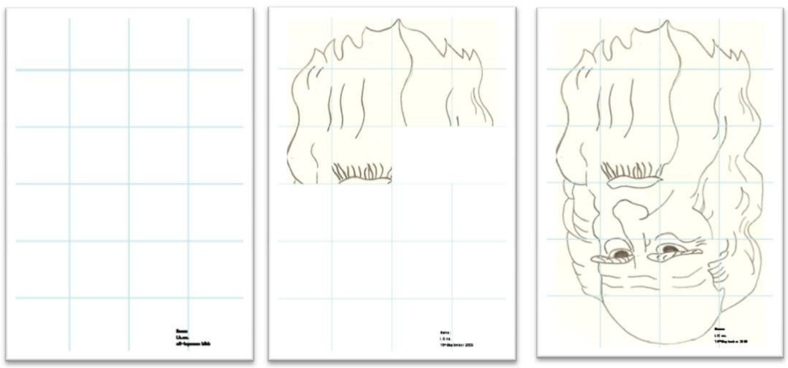

Figure 6 - Illustration of slides from PowerPoint presentation used for perception proof exercise

Stage 2 – Enquiry

A perception enhancement exercise was used to develop participant's ability to graphically represent a 3D composition on a 2D picture plane. Previous research found that the use of a floating picture plane which had to be balanced on the composition being communicated proved difficult for participants and was a source of unnecessary anxiety [1]. This needed to be addressed as the physical manipulation of the picture plane should be carried out quickly and without any difficulty in a classroom of thirty students. The picture plane shown in figure 7 was designed to address the previous issues. It is a standalone device which can be assembled and disassembled quickly by students of all ages and can be manufactured easily in most engineering rooms.

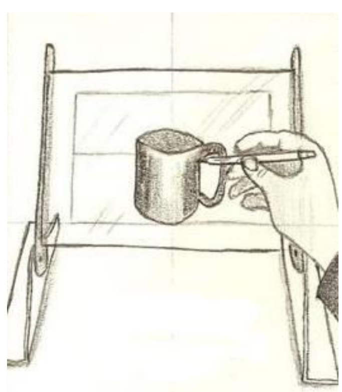

Figure 7 - Drawing on the picture plane

In order to help develop *"design thinking"* [28] and autonomy in participants, it was decided that a brief was given that required the creation of a unique and imaginative composition that included the participants' hand and any other material they wished.

The following learning outcomes are integral to this activity:

- The ability to utilise previously developed skills from the perception proof exercise
- The ability to compose a physical composition that is creative and intrinsically motivating to draw
- The ability to draw accurately in perspective and understand the principles of the picture plane in relation to its position and the position of the spectator
- The ability to analyse a composition in detail to realise the intricate geometries and values that determine the *gestalt* in the completed drawing
- The ability to evaluate the sketched composition and make changes to help further improve

Stage 3 – Transfer

It was found previously that the ability to recognise different values in a composition and represent these on paper was a difficult concept to understand and carry out [1]. The current research project aimed to overcome this problem by engaging participants in a *Merging* activity that harnessed the skills that were developed in the previous two activities and developed new abilities to recognise and communicate different values in a composition along with the skill of sighting.

Selection of the composition that the participants would sketch required careful thought. It needed to contain both regular and irregular geometry, have a variance in the values that were represented, be interesting and related to technology education, be applicable to a learning environment of thirty participants and possible to complete in a thirty minute timeframe.

The composition shown in figure 8 was used for this activity. It was felt that this particular drawing satisfied all the requirements stated in the previous paragraph. In the context of teaching a large class size this exercise is deemed suitable for the following reasons:

- The composition can be shown to the whole class using a data projector and screen
- The concept of physically sighting the composition can easily be explained through a step by step instruction from any location in the room
- It is possible to question participants on key areas such as proportionality and relationships between geometries as well as different values in the composition because everybody is looking at the same screen

Figure 8 - Value realisation activity

The following learning outcomes are critical to the *merging activity*:

- The ability to analyse the composition and select a suitable piece of geometry which will act as a basic unit
- The ability to determine the overall size of the participants own composition by selecting a suitable scale for the basic unit
- The ability to apply the sighting technique to determine the relationships between the geometries within the composition. **Note:** The technique is applied using an extended straight arm and pencil as a measurement tool. By extending the arm at a set distance the participants are autonomously creating an imaginary picture plane which all geometries are projected to
- The ability to communicate the geometry using a pencil and eraser
- The ability to evaluate the sketched composition and make any alterations (as in previous activities)
- The ability to understand how the picture plane has now become abstract and imaginary
- The ability to determine the most suitable position for the imaginary picture plane

Stage 4 – Enlightenment

Previous research involved a space enlightenment exercise [1] that introduced participants to the concepts of using the sighting technique to determine an imaginary picture plane. Examples of participants work from this previous study are shown in figure 9.

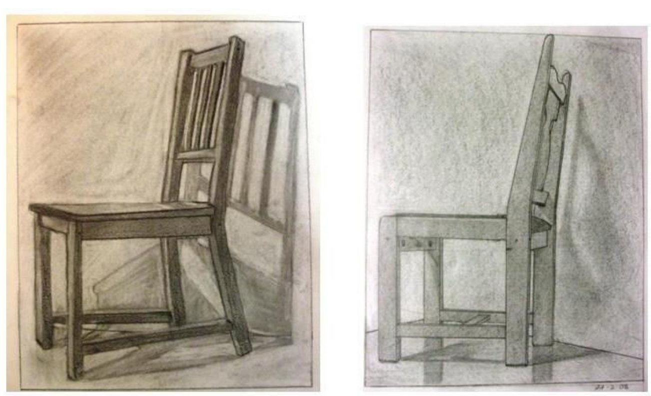

Figure 9 - Space Enlightenment exercise (Lane & Seery 2009)

The space enlightenment exercise has been analysed in terms of applicability for the current research and the following conclusions have been made based on previous findings [1]:

- **Area for development:** The sighting equipment used in the previous research involved a measuring gauge that participants claimed was a source of anxiety due to its difficulty to manipulate, comprehend and apply.
- ✓ **Improvement**: The revised sighting technique using an outstretched arm and pencil will be used. This was applied in the Merging activity (Stage 3).

- **Area for development:** Drawing an artefact such as a chair will not fully enable participants to engage in *metagcognition* and *higher order thinking*. The geometries are excessively regular and the participants already have developed their ability to sight.
- ✓ **Improvement:** Participants will be presented with a selection of furniture that are of regular geometry along with a selection of soft toys which are irregular and varying in texture. Participants will be required to set up a composition in groups of six people (figure 10). The composition needs to be creative and stimulating to draw.

- **Area for development:** The space enlightenment exercise that was used in previous research [1] involved drawing a physical composition that was perceived and a feature that was sketched from memory. It was found that sketching the feature from memory was very beneficial and engaged participants on a higher level of thinking in contrast to the physical object which remained.
- ✓ **Improvement:** A photographic composition exercise will be applied that will challenge the participants on a higher cognitive level by requiring them to draw the composition from memory.

Figure 10 - Setup of classroom for photographic composition exercise along with some configurations which participants created

The photographic composition exercise (figure 10) aims to satisfy the following learning outcomes where participants will be able to:

- Create a suitable configuration and decide the most appropriate seating position to view the geometry
- Analyse the requirements for the activity and decide what critical geometry is recorded. Critical information will include geometries, values, shadow/shade, and textures within the composition. The use of thumbnail sketches and annotations will be encouraged

- Apply previously used skills to sight and relate geometries to each other within a timeframe of 25 minutes.
- Analyse the critical information that was recorded and engage in critical thought to remember the previously perceived composition on completion at home
- Evaluate and critique the completed composition and make any changes if necessary (as in previous activities)

Stage 5 - Synthesis

A *conceptual challenge* activity aims to harness the abilities developed in previous activities to culminate in a composition that is creative and a large part of which is drawn from imagination. Previous research found that participants (figure 11) had positive feelings, a sense of confidence and satisfaction through engaging in this particular activity [1].

The sole alteration that will be made to this activity from the previous study is the requirement of an increased level of conceptual thought and creativity as it is felt participants are competent to attain a high level. This composition will be used as a covariant in measuring the level of progression from the pre-instruction composition.

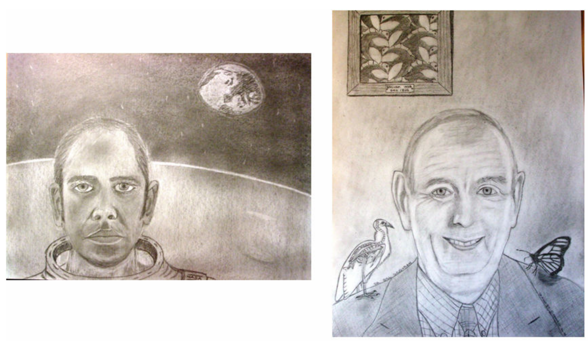

Figure 11 - Selection of Conceptual Challenge compositions [1]

The conceptual challenge activity has the following learning outcomes where participants will be able to:

- Develop a conceptual theme for the composition and determine the position of the critical geometries.
- Synthesise previously developed skills to communicate a creative composition.
- Evaluate the completed composition and critique their personal development.

Findings

In this section the results of all stages of the methodology are detailed. Results include both qualitative and quantitative data in addition to compositions completed by participants. Questionnaires were given to all throughout the four weeks and these measured participant level of performance in activities, the value they placed in the activities and areas that they feel need improvement.

Pre-Instruction Activity

Participant results in this activity are very similar to previous research carried out at University of Limerick with the following observations:

- 75% of participants expressed difficulty accurately communicating facial geometries
- 63% found it difficult to resist the temptation to draw child like faces which are very much symbolic in nature
- 85% experienced periods of anxiety and frustration.

Examples of some participant pre-instruction compositions are shown (figure 12):

Figure 12 - Selection of Pre-Instruction Compositions

Stage 1 – Recognition

A selection of compositions from the Perception Proof Activity is shown in figure 13 below:

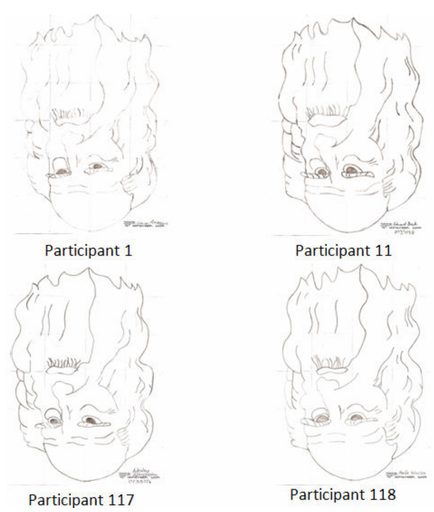

Figure 13 - Selection of Perception Proof Compositions

Figure 14 illustrates the participants self ratings for their performance in the Perception Proof activity along with the value they placed in the activity.

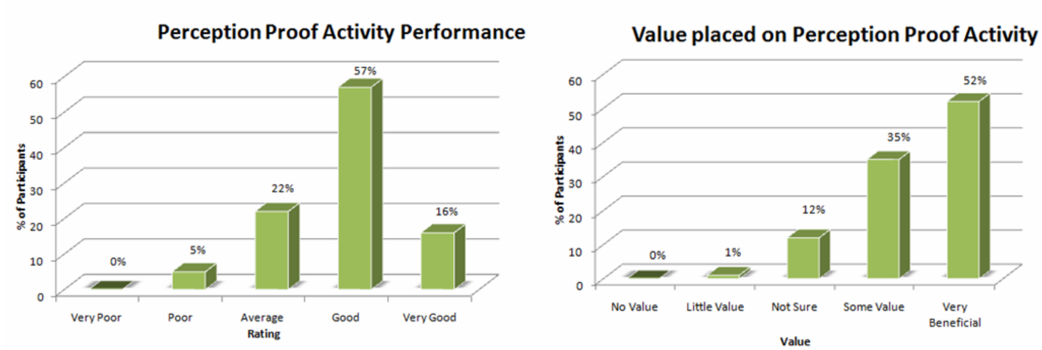

Figure 14 - Participants Ratings on Performance and Value

Stage 2 – Enquiry

A selection of compositions from the Perception Enhancement Activity is illustrated in figure 15.

Figure 15 - Selection of compositions from Perception Enhancement Activity

Figure 16 illustrates the participants self ratings for their performance in the Perception Enhancement activity along with the value that placed in the activity.

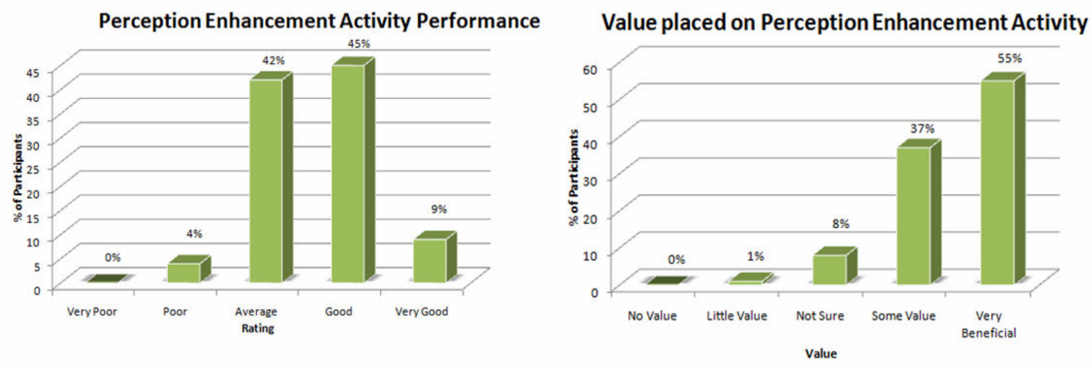

Figure 16 - Participant ratings on performance and value

Stage 3 – Transfer

A selection of compositions from the Merging Activity is illustrated in figure 17.

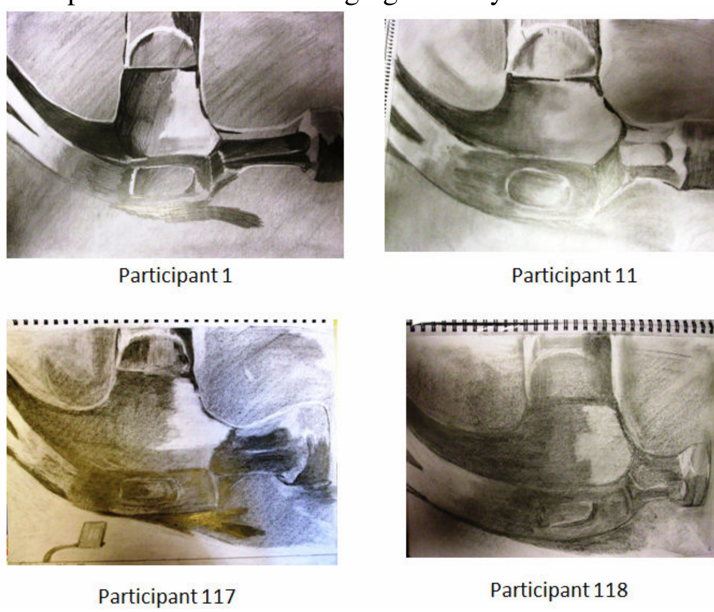

Figure 17 - Selection of compositions from Merging Activity

Figure 18 illustrates the participants self ratings for their performance in the Merging activity along with the value they placed in the activity.

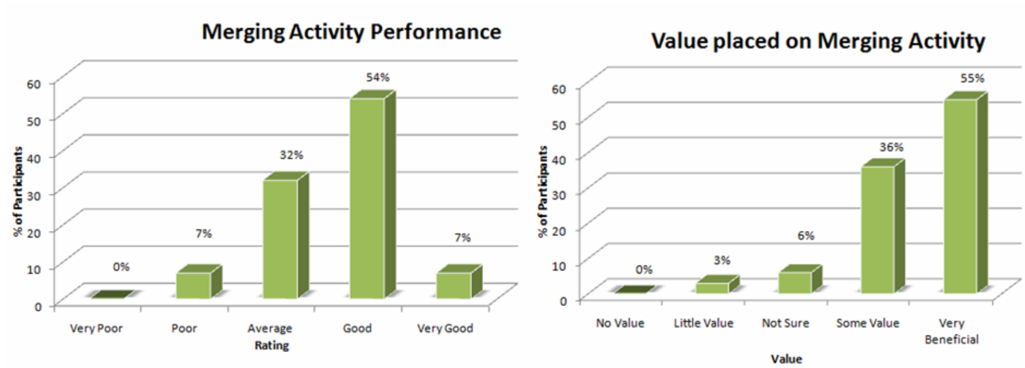

Figure 18 - Participant ratings on performance and value

Stage 4 – Enlightenment

A selection of compositions from the Photographic Composition Activity is illustrated in figure 19. The smaller compositions are photographs of the physical composition that participants took using the researchers' camera and photographs of the participants work at the end of the twenty five minute timeframe prior to completion at home through memory.

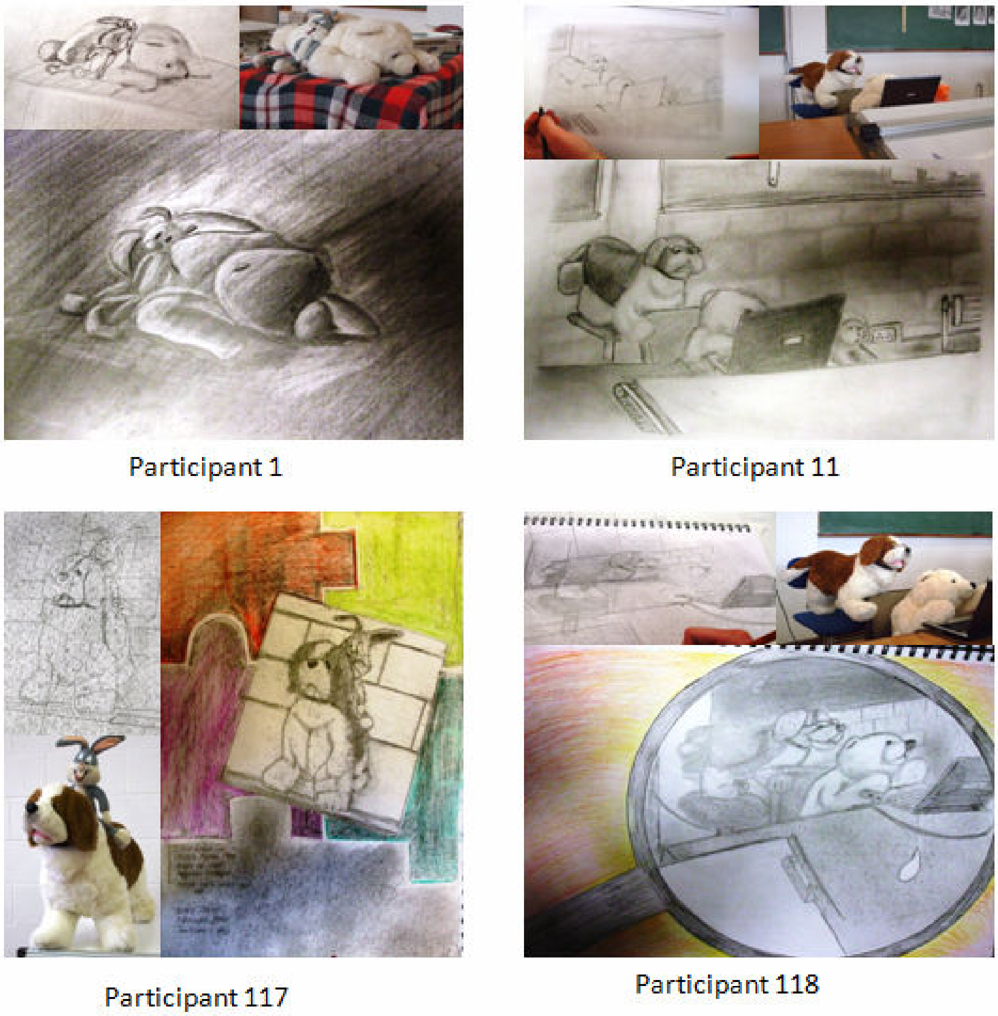

Figure 19 - Selection of participant compositions along with incomplete work prior to completion from memory

Figure 20 illustrates the participants self ratings for their performance in the Photographic Composition activity along with the value they placed in the activity.

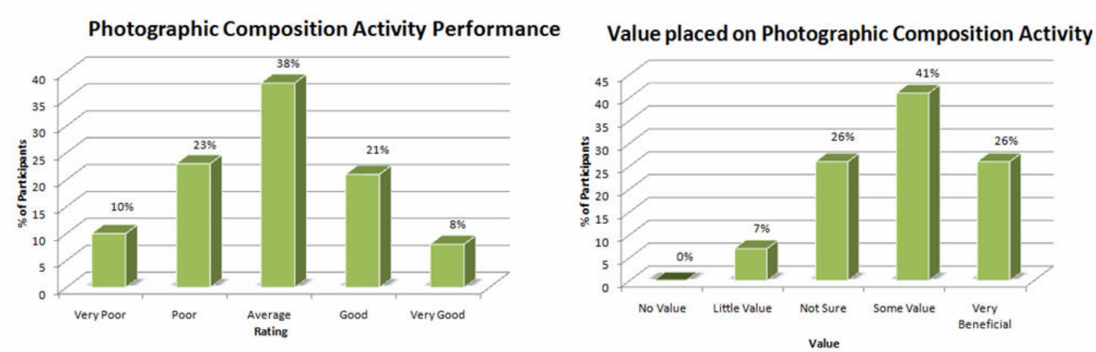

Figure 20 - Participant ratings on performance and value

Stage 5 – Synthesis

All compositions from the Conceptual Challenge Activity along with the pre-instruction composition are illustrated in figure 21 and figure 22.

Figure 21 - Participant compositions for Conceptual Challenge activity in addition to the pre-instruction composition and profile photograph

Figure 22 - Remaining participant compositions for Conceptual Challenge activity in addition to the pre-instruction composition and profile photograph

Figure 23 illustrates the participants self ratings for their performance in the Conceptual Challenge activity along with the value they placed in the activity.

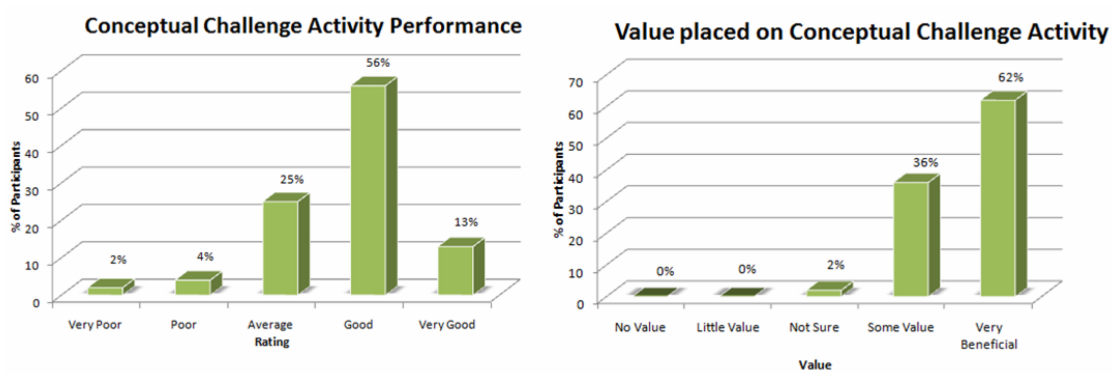

Figure 23 - Participant ratings on performance and value

Figure 24 illustrates the overall effect of the study in terms of participant progression.

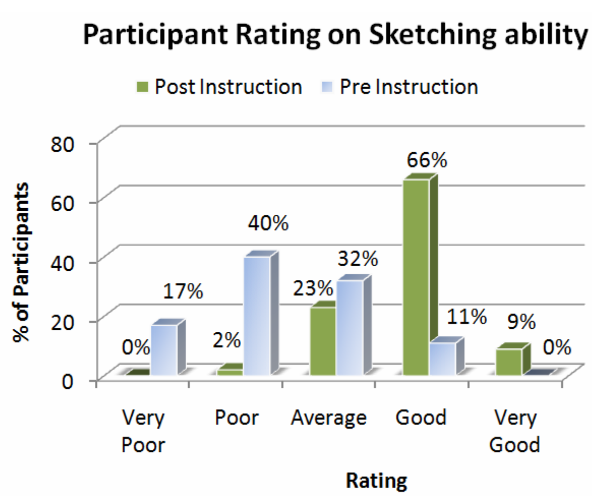

Figure 24 - Participant ratings of pre and post instruction sketching ability

The holistic value of the activities in terms of developing the ability to communicate through freehand sketching is illustrated in figure 25.

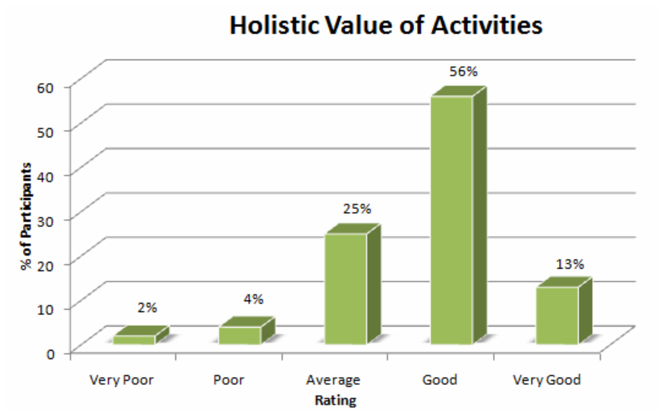

Figure 25 – Participant ratings of holistic value of activities

Both graphs in figures 24 and 25 illustrate data that the participants submitted at the end of the research study. In addition to this participants were asked to select areas of freehand sketching that they would like to develop further in their future study. The results are shown in figure 26.

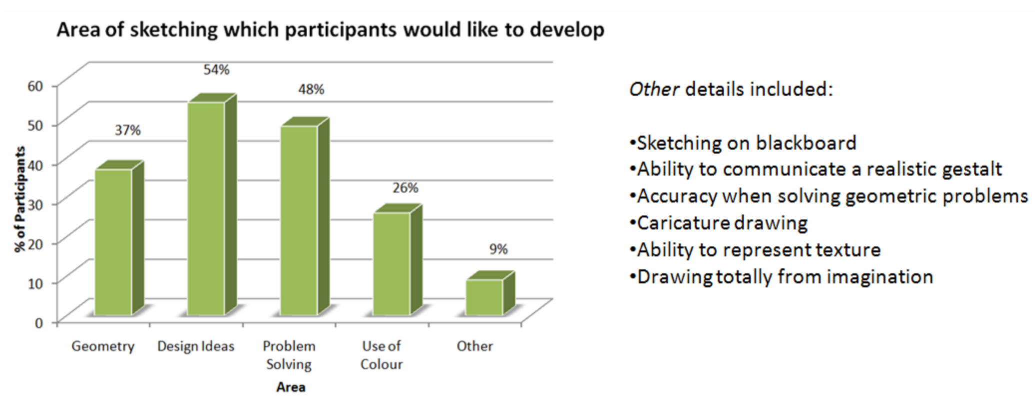

Figure 26 - Areas which participants wish to further improve

The module in which this research study was carried out is twelve weeks in duration. Key areas that are studied by participants are integral to plane and descriptive geometry and are as follows:

1. Principle and auxiliary planes of reference
2. Projection of cubes and tetrahedrons
3. Ellipse, parabola and hyperbola as sections of a right cone
4. Derivation of focal point, focal sphere, directrix and eccentricity in conic sections
5. Intersection of right and oblique solids and their surface development

Participants were required to apply their developed sketching skills to communicate concepts and principles for the problems encountered. A selection of these is illustrated in figure 27.

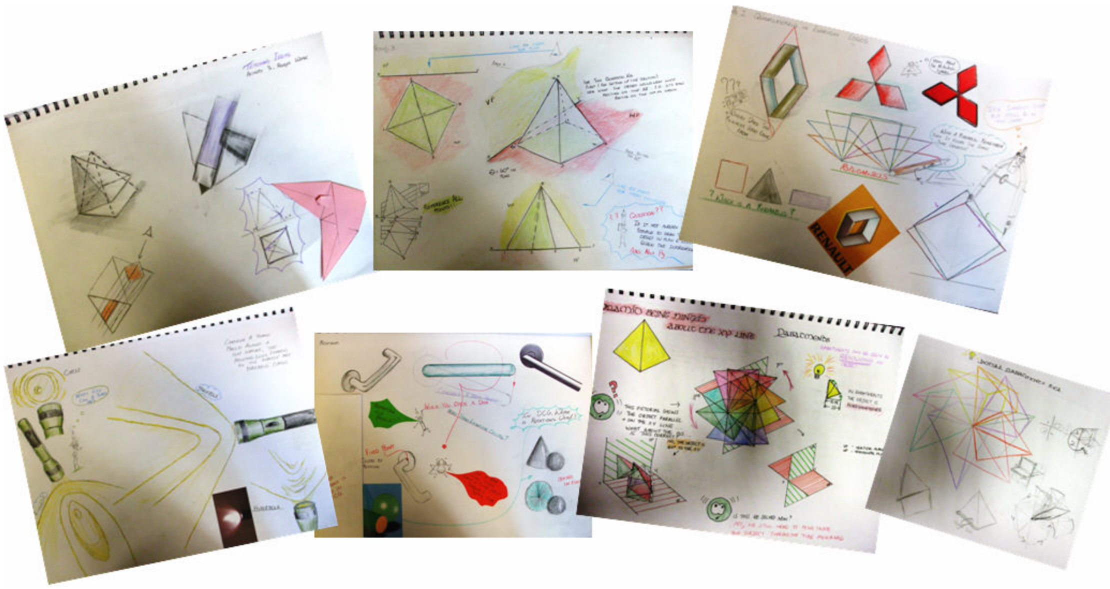

Figure 27 - Selection of participant work based on plane and descriptive geometry

Discussion / Conclusion

This section discusses the results where, the main aims were to determine if the strategy applied by Lane & Seery [1] could be further applied in a large classroom setting with thirty participants in a restricted timeframe of eight hours. The transferability of the developed abilities to problem solving in plane and descriptive geometry and design communication integrated with a pedagogy that coalesced with the principle of *Pareto's Law* will also be explored.

Effectiveness of Strategy

Analysis of participant ratings for the holistic value (figure 25) of the activities throughout the course of the study shows that 94% had a positive experience with 69% rating the value as either good or very good and 25% as average. It can be hypothesised from this finding and observations made that the majority of participants:

- Engaged and were motivated to take part in the activity
- Valued the activities in terms of their personal and holistic development
- Appreciated the planning and preparation involved in addition to the level of teacher interaction
- Found the learning environment and equipment that was applied of benefit and value

The ***Perception Proof*** activity (stage 1) was extremely successful with 87% of participants rating the activity as beneficial or very beneficial) and 95% rating their performance as positive (figure 14). The effectiveness of the strategy in terms of engaging 124 participants in a lecture theatre over a twenty timeframe with outstanding results is very promising. It was an apt activity for inducting participants to the study and this was evident in comments made where participants stated *"I now* *believe that I can learn to draw"* and *"I never thought I could sketch like this... has given me so much confidence and can we do more of these activities?"*.

Analysis of participant ratings for the ***Perception Enhancement*** (stage 2) activity indicate that it was very beneficial with 92% of participants stating that it was either beneficial or very beneficial and 96% positively rating their performance (figure 15). Applicability of this in a classroom consisting of thirty students is very suitable with evidence of increased levels of enquiry, recognition of patterns and synthesis between geometries in the composition. Significant holistic value was evident by giving participants autonomy to set up their composition in an imaginative and creative way, while realising the position and importance of the picture plane.

Positive feedback for the ***Merging*** activity is evident. 91% of participants rated the value as beneficial or very beneficial and 93% rating their performance as average, good or very good and this is forward-looking (figure 18). Considering that the activity is a development from previous research [1], it can be assumed that its applicability in a large class situation and its learning outcomes are achievable and of notable benefit in terms of development of perceptual and communication abilities.

The ***Photographic Composition*** activity was a novel activity introduced for this study which had clear learning outcomes in terms of challenging participants and pushing the boundaries for their cognitive development in a restricted timeframe. However, participant ratings of 67% in terms of value and 67% positive ratings (figure 20) for performance indicate that the activity is not as beneficial as the previous three stages. Observations and participant concerns highlight a lack of total understanding on what was required and an overwhelming factor in terms of progressing from sighting a 2D composition to a 3D composition. Based on this, it can be hypothesised that a prerequisite activity needs to be developed that will enable *"distal access"* of the *"physical symbol system"* [26] through communicating more regular geometries from memory which will then lead on to the photographic composition activity.

Analysis of participant ratings for the ***Conceptual Challenge*** activity has positive implications. 98% of participants rated the activity as beneficial or very beneficial while 94% rated their performance positively (figure 23). The level to which participants engaged in the activity is very promising and it is obvious that the assimilation of developed skills into a conceptual activity was a source of motivation and reward for participants.

Implications for Teaching and Learning

Sketching is an integral tool in the design process, for communicating concepts and ideas in addition to recording and sharing relevant design information [29]. It can be hypothesised that the applied strategy, developed a critical set of abilities in participants that caused them to engage in *metagcognition"* [18] and higher order cognitive development [7]. An understanding of the cognitive architecture [22] contributed to a deeper insight into how participants think and was instrumental in devising a pedagogic structure based on the *"80/20 principle"* and *"Pareto's Law"* [14]. The application of an eight hour strategy coupled with incubation periods of one week proved successful when integrated into a forty hour module that allowed participants to transfer their skills into solving problems in plane and descriptive geometry (figure 27).

Based on participants ratings of their pre and post instruction compositions (figure 24), it can be categorically concluded that a significant level of improvement was attained by 96% of participants. This is reinforced by visual comparison of pre and post instruction compositions together with profile photographs (figures 21 & 22). Further development of sketching skills to improve the ability to communicate design ideas (54%) and problem solving in plane and descriptive geometry (48%) (Figure 26), indicate that there is significant need for the development of approaches that synthesise and advance sketching abilities.

Summarising the implications of the strategy in terms of integrating freehand sketching skills with problems in plane and descriptive geometry and design communication, the participants are now able to:

- Engage in *metagcognition* and *symphonic thinking* to apply core skills in solving problems in areas of communication graphics while adding to a repertoire of *concept driven competencies*.
- Retrieve information through *"distal access"* of the *"physical symbol memory"* to communicate geometry from short and long term memory in conceptual activities.

Future Research

1. The development of an assessment technique that will measure the level of improvement in participants from the pre-instruction to post-instruction stages.
2. Further analysis of the transferability of developed abilities in design communication and problems in plane and descriptive geometry with particular reference to the *physical symbol system* [26].
3. As spatial visualisation skills are important for success in engineering [30], evaluation of participant's spatial abilities pre and post instruction needs to take place to establish if improvement is occurring contemporaneously.

Bibliography

1. Lane, D., Seery, N., Gordon, S., *The Understated Value of Freehand Sketching in Technology Education.* Engineering Design Graphics Journal, 2009. **73**(3): p. 10.
2. Felder, R.M., Woods, D.R., Stice, J.E., Rugarcia, A., *The Future of Engineering Education. II Teaching Methods That Work.* Chem. Engr. Education, 2000. **34**(1): p. 14.
3. DES. *Minister Hanafin launches new Technology Subjects Support Service*. Archived Press Releases 2006 [cited 2009 8th January].
4. DES, *Leaving Certificate Design and Communication Graphics Syllabus*. 2007, National Council for Curriculum and Assessment: Dublin.
5. Kimbell, R., *Design Education: The Foundation Years*. 1986, London: Routledge & Kegan Paul plc.
6. Schutze, M., Sachse,P.,Romer,A., *Support value of sketching in the design process.* Research in Engineering Design, 2003. **14**(2): p. 9.
7. Piaget, J., Inhelder, B., *The Psychology of the Child*. 1969, New York: Basic Books.
8. Snowman, B., Biehler, R., *Psychology Applied to Teaching*. 11 ed. 2006, Boston: Houghton Mifflin.

9. Cohen, L., Manion, L., Morrison, K., *A Guide to teaching Practice*. 2005, London: RouteledgeFalmer.
10. Evans, C., Kakas., C., *Hypothetico-deductive Reasoning*, in *International Conference on Fifth Generation Computer Systems*. 1992, ICOT. p. 9.
11. Bloom, B.S., Engelhart, M.D., Furst, E.J., Hill, W.H., & Krathwohl, D.R., *Taxonomy of educational objectives: The classification of educational goals. . Handbook 1: Cognitive domain* 1956 New York: David McKay.
12. Vygotsky, L.S., *Annals of Dyslexia.* Springer, 1964. **14**(1): p. 2.
13. Bruner, J.S., *The culture of education*. 1996, United States of America: Harvard College.
14. Koch, R., *The 80/20 Principle: The secret to success by achieving more with less*. 1998, New York: Doubleday.
15. Solity, J., *The Learning Revolution*. 2008, London: Hodder Education.
16. deBono, E., *The Direct Teaching of Thinking as a Skill.* The Phi Delta Kappan, 1983. **64**(10): p. 6.
17. Adamson, R.E., *Functional fixedness as related to problem solving: a repetition of three experiments.* Journal of Experimental Psychology, 1952. **44**(4): p. 4.
18. Flavell, J.H., *Metacognition and cognitive monitoring: A new area of cognitive-development inquiry.* American Psychologist, 1979. **34**(10): p. 6.
19. Green, P., *Design Education: problem solving and visual experience*. 1974, London: B T Batsford Limited.
20. Pink, D.H., *A Whole New Mind*. 2006, London: Cyan Books.
21. McKim, R.H., *Experiences in visual thinking*. 1980, Boston, MA: PWS Publishers.
22. Stillings, N.A., et al, *Cognitive Science: An Introduction*. 1995, London: MIT Press.
23. Wang, Y., *On Cognitive Informatics.* Brain and Mind, 2003. **4**(2): p. 17.
24. OECD, *Learning Seen from a Neuroscientific Approach*, in *Understanding the Brain: Towards a New Learning Science*. 2002: Paris. p. 9.
25. Fodor, J.A., *The modularity of the mind*. 1983, Cambridge, MA: MIT Press.
26. Newell, A., *Pysical symbol systems*, in *Cognitive Science 4*. 1980. p. 135-183.
27. Edwards, B., *Drawing on the Right Side of the Brian*. 1989, New York: Putnam Publishing Group.
28. Welch, M.L., H.S., *Teaching sketching and its effect on the solutions produced by novice designers*, in *IDATER*. 1999: Loughborough University.
29. Lau, K., Oshlberg, L., Agogino, A., *Sketching in Designs: An analysis of visual representations in the product design process.* Engineering Design Graphics Journal, 2009. **73**(3): p. 6.
30. Sorby, S.A., Baartmans, B.J., *A Course for the Development of 3-D Spatial Visualization Skills.* Engineering Design Graphics Journal, 1996. **60**(1): p. 8.