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Author(s)	Tan Seng Chong Jason and Chen Ai Yen
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## A Case Study of the Teaching of Design and Technology in a Secondary School

Tan Seng Chong Jason  
Fairfield Methodist Secondary School

and

Dr Chen Ai Yen  
Head, Division of Instructional Science  
School of Education  
National Institute of Education/ Nanyang Technological University

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Abstract

Design and Technology is a relatively new subject in the Singapore's secondary school curriculum. This subject calls for a very different approach to teaching and learning by both the teacher and the pupil so as to realise Design and Technology's fullest potential.

Factors influencing the teaching of Design and Technology are many. A disciplined inquiry using the naturalistic inquiry method revealed the importance of teacher's design background, teacher's design knowledge base, teacher's expertise in designing, pupil's attitude and innate abilities in designing in the implementation of a Design and Technology programme.

This paper will present a 'double learning loop process' model of both teacher and pupil in an intense learning relationship. A comparison is made between the pupil's folio after going through the learning process with the teacher and that of a pupil's folio taught in the conventional approach in a school. The fundamental role of drawing/sketching in pupil's design abilities, the understanding of the concept of 'design process-in-action' by both teacher and pupil, and the marking system of Design and Technology affecting both teaching methodology and pupil's performance will be discussed.

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### Introduction

In recent years there has been a growing interest in treating design education as a means of developing problem solving skills among learners. Donald Schon (1987) in his research into professional effectiveness advocates the importance of developing "artistry in practice". He believes that in a reflective practice, learners learn by doing under the guidance of a designer-coach who helps to "frame the situation" or "the problem" in different ways. Through a process of cognitive scaffolding using images and metaphors, the designer-coach

leads the learner to new understanding and a higher level of creativity. The learning process is social in nature even though the three-party interaction involves "the materials of a situation" which may be non-human.

Creative problem solving has also emerged as new emphasis in the Singapore school curriculum. This is related to the development of Singapore as an information society specializing in the creative use of economic and technological knowledge and expertise in a rapidly developing world of innovations.

The central role of the secondary school subject 'Design and Technology' (D&T) features problem solving design activity involving

practical manipulative work which uses a range of materials. This subject has a great role to play in reaching out to the whole population of pupils in Singapore. The teaching of this subject calls for an entirely different approach as compared with the old technical education programme. The implementation of Design and Technology in the school curriculum seemed timely in this post-industrialization era. Design and Technology emphasises creative thinking relevant to solving problems in design.

This paper highlights the findings of a current research work carried out by the writer. The purpose of the research work was to investigate and inquire into the way design process is understood and taught and the many interactions that may occur during the teaching and learning of this process. The questions for the purpose of the research study were initially broad. Simply stated, the grand tour question is "An Inquiry into the Learning of Design and Technology In A Singapore School". Related to it are a number of interconnected questions. But as the study progressed, five major research questions were proposed. They are:

1. Is there a relationship between the teaching and learning of 'design method' and the understanding of the concept of 'design process-in-action' by both teachers and pupils?
2. Is there a relationship between teacher's background in design and the pupil's performance in design and technology?
3. Does drawing/sketching skill (in terms of free-hand drawing/sketching on the assumption that this is evidently reflected in pupil's design folio) have an effect on pupil's design capabilities?
4. Does spatial intelligence (defined in terms of the ability to visualise and doodle) have an effect on pupil's design capabilities?
5. Does the marking system for pupil's work affects both teaching

methodology and pupil's performance?

Literature review was broadly categorised as follows:

- Major Design Practices.
- Studies related to the design process and its implications on design education.
- Studies on visual-thinking or spatial-visualization and its influence on design ability.
- Studies on the role of drawing/sketching in designing and its importance in design ability.

For the purpose of this paper presentation, only highlights of the literature review will be included.

An overview of the design practices

"Knowing that design consists of analysis, synthesis and evaluation linked in an iterative cycle will no more enable you to design than knowing the movements of breaststroke will prevent you from sinking in a swimming pool. You will just have to put it all together for yourself.....

.....The designer, however, has never resembled Rodin's 'Thinker' who sits in solitary meditation, but has in contrast always externalised his thoughts, not only as an end-product in the form of a design, but

as an integral part of the process itself in the form of drawings and sketches. The whole purpose of doodles, sketches or models is to act as a kind of additional memory to freeze and store spatial ideas which can then be evaluated and manipulated. These drawings and models, taken together with interviews with designers and their writings, offer some insight into the thought processes involved in design."

- Lawson (1991)

Design Thinking and/or the thought processes involved in design when one goes through the 'design process', or rather the latter acting as a spring board for further design thinking, becomes a crucial two-way interactive framework which is closely interspersed and interwoven. Researchers of design studies are constantly trying to understand how designers think and in the hope of theorizing design models, propose design methods and apply the understanding to artificial intelligence amongst other interests. As Lawson (1991) put it:

"In order to draw such a map (ie. referring to the design model representing the design process) we must observe the designer in action. One of the difficulties here is that on the whole there is not a great deal of action to be seen, and what there is cannot easily be

understood. True, the designer may sketch or draw profusely but his drawings are by no means totally explicit about what is going on in his head. Unfortunately for those who would wish to draw a map (ie. the model of the design process) therefore most of the route remains hidden, for it is what goes on in the designer's mind which really matters."-Lawson (1991)

This paradoxical situation in a way confirms what Schon (1987) is advocating in what he calls the 'reflective-practicum' whereby architecture student learns designing through the 'studio master or coach' and through the 'planned or practised' rigorous interaction and communication between student and studio master or coach, in the form of 'reflection-in-action' and 'reflection-on-action'. Design learning takes place in such a process, leading to the student internalising in himself/herself an internalised design process. The 'studio' is a common part of the curriculum in any architectural training and it is also used extensively in most school of design for their design students.

Schon (1990), in proposing how a more adequate theory of design might be developed, had based his thesis on a critical analysis of Herbert Simon (1971)'s broad view of design. Simon's design encompasses the making of all varieties of human artifacts and a science of design that Simon characterises as a "science of the artificial." Simon sees design as a 'problem-solving' process.

"To think of designing as 'problem-solving' is to use a rather dead metaphor for a 'lively process' and to forget that design is not so much a matter of adjusting the status quo as of realising new possibilities and discovering our reactions to them."

- Jones (1980)

Apparently, for anyone who had gone through a disciplined course in design and/or with design experience, it is difficult to reject the fact that design is more than just 'problem-solving'. And this, is what Schon's theory has aptly defined as follows:

"..... Designing is seen as a conversation with the materials of a situation within which new trials are often based on LEARNING (writer's emphasis) from earlier ones. It is seen, for the most part, as a SOCIAL PROCESS (writer's emphasis) in which different designers FRAME

THE SITUATION (writer's emphasis) in different ways and learn, when they are successful, to talk across divergent frames. The idea of a designer's repertoire of types, images, and metaphors plays a central role on this perspective, as does the idea of design dilemmas, on whose resolution or dissolution the possibility of problem solving depends."

-Schon (1990)

The theory provides a good framework for discussing, researching and teaching (or coaching in Schon's word) the process of design. It conceptualises the design process-in-action. Many theorists attempting to use design model or method to externalise design thinking for the purpose of guiding and teaching designing showed the common converging thesis. (Bartlett, 1961; Newman, 1966; Asimow, 1962; Archer, 1969; Lawson, 1972; Akin, 1986; Darke, 1978; Rowe, 1987; Lawson, 1990; Cross, 1990). With these theorists, design is looked upon as a cyclical process of iteration whereby mistakes and errors shape proposals of solution based much on experience and knowledge gained in similar situation of designing. Trials and re-trials are a common phenomenon advocated by these theorists and researchers in discussing their model of the design process or the way designers think.

The model of design as rational decision seems to Schon to be incomplete in three main respects namely: i) the idea of a design structure, ii) the idea of learning across episodes of designing and iii) the idea of social process in designing. Schon believes in a more evolutionary design process, that is, the beginning "representation" of initial situation or frame may evolve and may look very different in the "end representation". Simon however advocates the establishment of a basic design structure whereby rational decision process can occur. Also Schon attributes more to the social interaction aspect of each individual's design process rather than the isolated individuals. This conceptual arguments put forth by Schon show a clear direction as to how one should look at the concept of a design process, how such process actually operates and how we could possibly capitalise on this theory to the full advantage of a design education and that as practised in the secondary school. Designing as a process comes with a great many variables and factors. One major factor deals with the basic human intelligences.

".....that design ability is, in fact, one of the several forms or fundamental aspects of human intelligence."  
- Cross (1990)

Cross (1982, 1990) in his papers 'The nature and nurture of design ability' and 'Designerly ways

of knowing', attempted to show that design ability is a multi-faceted cognitive skill, possessed in some degree by everyone. He believes that there is enough evidence to make a reasonable claim that there are particular, 'designerly' ways of knowing, thinking and acting. And as mentioned above, it seems possible to him, to make a reasonable claim that design ability is a form of natural intelligence, of the kind that the psychologist Howard Gardner (1983) has identified as the Theory of Multiple Intelligences (MI).

Gardner (1983) in his book, *Frames of Mind-The Theory of Multiple Intelligences*, has put forth his view that there are several, relatively autonomous human intellectual abilities or competences. He distinguishes seven forms of intelligence namely: a) linguistic; b) logical-mathematical; c) spatial; d) musical; e) bodily-kinaesthetic;

f) interpersonal; and g) intrapersonal.

Cross (1990) in his attempt to separate design ability as a form of intelligence in its own right has argued that aspects of design ability seem to be spread through these seven forms of intelligence in a way that, seems to him, not always entirely satisfactory. He claims that spatial abilities in problem-solving (including thinking 'in the mind's eye') are classified under spatial intelligence, unlike practical problem-solving ability (including examples from engineering) are classified under bodily-kinaesthetic intelligence. Metaphorically speaking "In this classification, the inventor appears alongside the dancer and the actor, which doesn't seem appropriate" (Cross, 1990). The claims by Cross (1990) however provided a good framework for the use of the Theory of MI for the purpose of this research work. Nigel Cross attempted to match 'design intelligence' against the criteria proposed by Gardner who claims that a distinct forms of intelligence can be judged. The matching by Cross (1990) is summarised as follows headed by the seven criteria against which Gardner's MIs are based:

1. Potential isolation by brain damage.

-The evidence here for design intelligence draws upon the work with 'split-brain' and brain-damaged patients, which shows that abilities such as geometric reasoning, three-dimensional problem-solving and visuo-spatial thinking are indeed located in specific brain-centres. (Cross, 1984; Franco and Sperry, 1985; Sacks, 1985; Bogen, 1969; Wapner, Judd, and Gardner, 1969; Edwards, 1979).

2. The existence of idiots savants, prodigies, and other exceptional individuals.

-In design, there are indeed examples of otherwise ordinary individuals who demonstrate high levels of ability in forming their own environments - the 'naive' designers; (eg. 'Watts Towers' - and environmental fantasy created by Simon Rodia in his Los Angeles backyard between the 1920s and 1950s).

3. An identifiable core operation or set of operations.

-In design, this might be the operation of transferring the input of the problem into the output of conjectured solutions, or the ability to generate alternative solution. (Marples, 1960; Darke, 1979; Akin, 1979; Levin, 1966; Rowe, 1987.)

-work on the automatic generation of design by computer is therefore helping to clarify the concept of design intelligence.

4. A distinctive developmental history, and a definable set of expert, end-state performance.

-There are clearly recognisable differences between novices and experts in design, and stages of development amongst design students. (But a clarification of the developmental stages of design ability is something that is needed badly in design education.)

5. An evolutionary history.

-In design, we do have examples of animals and insects that construct shelters and environments, and use and devise tools. We also have a long tradition of vernacular and craft design as a precursor to modern, innovative design ability (Watts Towers, 1920s-1950s.)

6. Susceptibility to encoding in a symbol system.

-Clearly, in design we have the use of sketches, drawings and other models which constitute a coherent, symbolic media system for thinking and communicating.

7. Support from experimental psychological tasks.

-We only have a few psychological studies of design behaviour or thinking, but aspects such as solution-focused thinking have been identified. More work in this area needs to be done.

Close scrutiny of the above comparisons may not warrant the case for design as a distinct form of intelligence. However, it provides good evidence to meet most criteria and as far as this present research is concerned, it aptly provides or offers, as Cross describes it, "a framework for understanding and developing the nature of design ability." It is not the intention of this paper to argue for 'design intelligence' - as a class of its own but to seriously consider the existence of such forms of intelligences as identified by Gardner and as constructs which are crucial to design education.

The study conducted by the writer, being an exploratory study, examines the effects of spatial intelligence, bodily-kinaesthetic intelligence, personal intelligence, linguistic intelligence and logical-mathematical intelligence on the teaching of D&T and the extent of MI's presence in the context of the D&T subject.

Gardner's multiple intelligences theory has been summarised in several journals namely: Walters & Gardner, 1985; Gardner, 1987a; 1987b; Hatch & Gardner, 1988; Brandit, 1988; Gardner & Hatch, 1989; Gardner, 1990. The detailed matching by Cross (1990) Gardner's criteria for MI is one example of the theory being relevant to the study. Other applications of the MI theory by researchers at school levels are Gardner (1984) and Proctor (1985). The projects ARTS PROPEL, a collaborative project with the Educational Testing Service and Pittsburg Public School System seeks to assess growth and learning in areas like music, imaginative



writing and visual arts (Zessoules, Wolf & Gardner, 1988; Brandit, 1988; Wolf, 1989). Researchers from Harvard Project Zero are now engaged in developing a set of criteria for assessing student achievement in art. Some of the dimensions include presentation, technical quality of project and originality (Gardner & Hatch, 1989).

As mentioned earlier, the framework of MI, as seen from the argument given by Cross (1990), provides a strong supporting role to that of the 'Design Process' theory advocated by Schon (1990) and allows essential constructs like 'geometric reasoning'; 'three-dimensional problem-solving'; 'visual-spatial thinking'; 'naive-designers way of thinking'; 'conjectured-solutions' or 'ability to generate alternative solution'; 'thinking with a pencil' as in the importance of sketches and drawings; and 'learning from earlier trials' to be discussed and brought to light in the design process. By matching the two theories against the teaching of D&T in the Singapore secondary schools, it is hoped that this present study will reveal the essence of such teaching as contrasted to current practice and to answer the research questions raised. It will definitely give a better and clearer picture of the directions to follow in teaching the subject - 'a better way'. Table 1 gives a summary of studies on the role of drawing/sketching in designing and its importance in design ability. Table 2 gives a summary of studies in the area of visual-thinking or spatial-visualization and its influence on design ability.

Table 1 - Summary of studies on the role of drawing/sketching in designing and its importance in design ability

STUDY/YEAR  
MAIN FOCUS  
RESULTS/FINDINGS  
TYPE OF STUDY  
POPULATION

1. Denton 1993

review of the efficient & effective use of design sheets by pupils  
similar phenomena in the Singapore's D&T context ie inefficient &  
ineffective use of drawing/sketching; the 'hows' & 'whys' of  
drawings/sketching seemingly misconstrued by both teachers and pupils  
descriptive  
CDT pupils - U.K. (equivalent of secondary four level pupils in  
Singapore)

2. Galle & Kovacs 1992

to provide documentation of a design process as source material for use  
by others and other focus  
the complexity of design and knowledge were established as 13 themes  
introspective/case study  
the first author

3. Schenk 1991

the role of drawing in the graphic design process  
that drawing: is an intrinsic procedural device; use is highly complex;  
use in managerial task amongst other use; is a vehicle for creativity;  
as visual literacy development; important as part of the design process  
qualitative study  
50 experienced designers; 20 junior designers; 200 designer's drawings

4. Kellett 1990

a documentary analysis of design media in architecture  
shows the selective use of media in the designer's process of design  
and how such use enhance their process and creative moves; the use of  
sketching as a fundamental economical & essential media is also  
demonstrated in the study  
case-study  
Le Corbusier's schematic design and journals for the Carpenter Center  
at Harvard (1963)

5. Garner 1989

relationship between drawing and designing  
that drawing: is vital to thought organisation; is an essential  
component of designerly thought; facilitate creativity; is vital to  
exploration & manipulation of ideas; assist in problem definitions  
case-study  
a wide range of professionals (ceramicists; engineers; architects;  
sculptors; silversmiths; fine artists; graphic artists)

Table 2 - Summary of studies on visual thinking or spatial  
visualization and its influence on design ability.

STUDY/YEAR

MAIN FOCUS

RESULTS/FINDINGS

TYPE OF STUDY

POPULATION

1. Liu 1995

the importance of restructuring shapes in design & the variables  
embedded in such visual behaviour  
four phenomena of seeing shape in design were arrived at and  
implications for design cognition & design computation were drawn from

this experiment

experimental - control group/ qualitative analysis

two groups of subjects: 5 designers & 5 students

IMPLICATIONS: designer's decision making tend to involve drawings of initial stage plus some long term memory/mental images; association of 'visual thinking' process with cognitive model of design; designer's nature to restructure shapes & subshapes in designing; deliberations taken into the design process relate to seeing explicit & implicit subshapes; notion of TRA values vs design & design creativity

## 2. Goldschmidt 1994

the use of imagery by designers in designing being represented through sketching and concept and vice versa; the importance & concept of visual thinking vs sketching as a form of visual thinking that interactive imagery through sketching is a rational mode of reasoning, characterized by systematic exchange between conceptual & figural arguments  
case-study  
a young novice designer from the architecture faculty

IMPLICATIONS: imagery part of visual cognition is one of the mechanisms in generating form, can be amplified by sketching, becoming interactive; underlying trend of systematic visual thinking; powers of visual thinking in education; visual-thinking - interaction with imagery is a rational mode of reasoning

## 3. Schon & Wiggins 1992

on designer's kinds of seeing and their functions in designing that designing is a conversation with materials conducted in the medium of drawing and crucially dependent on seeing (the basic structure of seeing-moving-seeing is an interaction of designing & discovering)  
case study/ qualitative analysis  
7 designers;  
1 student & 1 studio master

IMPLICATIONS: the importance of 'seeing-moving-seeing' structure of the design process; the effect on designer's 'appreciative-system' when she draw-see-and-discover; mental storage of past discoveries triggered to influence new design situation; designing as an educational process; traditional emphasis on drawing in studio reinforced

#### 4. Downing 1992

conversations in imagery; the role that place-imagery plays in the codification & ordering of complex experience in the mind of the designer

an architectural designer's mental imagery of memorable places presents essential information for design inquiry

content analysis/ qualitative study

117 individuals grouped into 3 groups of different experience and level

of training

IMPLICATIONS: designers tend to refer to past experience for new design situation; absence of memory usually in design process attributed to stereotyping syndrome; interaction with memory through imagination during the design process is a natural phenomenon & worthy of theoretical consideration; vitality of imagery generation is not static during the process of design; "image formation-mental imagery adjustment-contextual conditions" is a dynamic act - a process which never stop!; imagery as raw-data for conjectures in design; as building blocks for design; designer's palette of inquiry (past-present)

#### 5. Muller 1989

design discipline & the significance of visuo-spatial thinking that the stimulation of visuo-spatial thinking processes in design education can be strongly encouraged through planned lessons

case study

two pupil's design project and a class

IMPLICATIONS: structuring processes of visuo-spatial thinking in design education in such a way that a dynamic approach to idea representation is stimulated

The above brief overview so far suggests strongly that there seems to be a distinct relationship between drawing/sketching ability and that of design ability. Additionally the spatial/visual aspect or human's spatial intelligence relates much to what he sees and, in the case of designer, the interactive nature of seeing and designing in the "mind's eye". The dynamic cyclical and iterative aspects of the design

process-in-action seem to be the basic phenomenon in designing and observable to a certain extent through interviews, observations and also act as a common platform for analysing the design sketches and drawings in design. Even though majority of the researches carried out were mainly on subjects who were professional designers or students of higher institute of learning, parallel inferences could be drawn as can be seen in the papers presented by Denton (1993) and Chidgey (1990). The basic practice of design is universal and design ability is possessed by everyone (Cross, 1990).

## Method and Procedures

A qualitative study in the form of a few case-studies were involved. The in-depth inquiry into the situation through interviewing of teachers, pupils and studying of important documents like pupil's folio, scheme of work and data drawn from the writer's two-year studies as a participant-observer in a local polytechnic's School of Design was carried out. This research probed the ways teachers perceived design, the way design is being taught generally, and the ways pupils learn the D&T subject, for example, from keeping and developing folios and the interactions that may possibly occur in the D&T environment of teaching/learning. The naturalistic inquiry approach was adopted for this purpose. The research design is based on the naturalistic inquiry

model by Lincoln & Guba (1985) which outlines the design and procedural concept of the inquiry. The steps involve in such an inquiry seem to correspond with the design process analogously in that problem situation interacts with solution and subsolution proposals and iteratively sharpening and honing the solution. Ill-defined problems are constantly re-structured cyclically when new information bears consequence on the problem space evolved (Schon, 1987). The semblance lies in this case in the emergent design driven by situational learning of the content. The difference however is that the designer manipulates and controls under constraints of the information with his design judgement and creates the solution, whereas in the naturalistic inquiry the inquirer reports without any manipulation of the so-called 'solution' in the form of case reports. As Lincoln & Guba (1985) put it: "the salient points of such an inquiry are that no manipulation of the 'natural' setting is implied in any way by the inquirer and there are no prior constraints or limitations placed on the outcomes of the research." Simply stated, the inquirer immersed and engaged himself in the natural setting to understand and discover the reality of that setting. The design started with the problem statement and questions based on the hunches and experience of the writer and the many feedbacks through casual conversation with teachers and pupils in school. Based on the strategies for the naturalistic interview and qualitative methods of data collection, analysis and interpretation, the research questions were operationalized.

A search for a tentative theory from the data and the natural setting follows. The characteristic of a naturalistic inquiry being that no a priori theory could possibly cover and explain the multiple realities of the 'problem-space' to be inquired. The writer allowed the research design to evolve as he builds upon his tacit knowledge through a fairly long process of engagement with the setting. (The setting here refers to the natural context in which the writer was constantly engaged-in in teaching the D&T subject himself, in interaction with his peers, interaction with the teacher-respondents during professional society's meeting and informal 'chit-chat-outing' sessions.) The research also evolve through opportunity to examine a wide spectrum of pupils' work, interviews carried out in the pilot and main studies, seminars, dialogue with a Cambridge examiner, a two-year participation in a coursework on Design, the actual implementation of the learning-teaching-learning cycle between the writer and pupils, and the on-going literature review. All these provided a good grounding for the conceptual framework which responds to the contextual values while the study is being formed.

With the guiding operationalized research questions, data were collected purely by qualitative means. The data obtained was mainly gathered through prolonged observations, in-depth interviews with the teacher-respondents and the pupils taught by the them, collection of field notes, documents, informal peer debriefing and from participants of a local polytechnic's part-time design course. The main study's data come from the actual implementation of learning and teaching the D&T subject by the writer himself. Field notes were written on pieces of A4 size papers as supplementary data to the fully audio recorded interviews and journals were kept in a diary format.

Extensive data was also obtained from two opportune occasions attended by the writer in late 1993 and early 1994, a seminar by a renowned professor from U.K. and a dialogue-session with a Cambridge examiner. Pupils' folios were used as a main source for data analysis. Pupils' Folios from the 1995 'N' and 'O'-levels examinations were also used as

supporting evidence for the main study data analysis.

A pilot study and a main study were carried out. Formal interviews were conducted for the pilot study. For the pilot study two teachers and three pupils taught by the teachers were interviewed. Interviews were fully recorded on audio tapes for the creation of verbatim reports and data analysis. Each interview lasted about 1-1½ hours.

The main study calls for a totally different re-focusing of approach to the research design through a learning-teaching process engaged-in by

the writer himself. A teaching programme for a class of 33 Normal Stream pupils based on the insights gained through observations of how design was taught in a tertiary institution and based on review of design related literature was carried out. Seven pupils from a class of 33 were identified to go through what the writer called "coach-pupil" learning-teaching partnership.

This is based on the idea of Schon's "studio master-student" studio approach in the training of architects. However modifications were made with emphasis on "teacher learning-teacher teaching-pupil learning" cyclical process. The critical dialogue between the researcher (ie the writer) and the pupil from the reflexive journal and the pupils' folios were used as a main exposition for data analysis and findings.

### Findings, Data analysis and Discussion

The naturalistic inquiry method is used to capture the complex interaction of multiple views, multiple perspectives and perceptions, and diverse factors in the D&T environment. The methodology has enabled the writer to understand the complexity of the situation and the struggles of D&T teachers in their teaching. It has shaped and reshaped the initial hunches and feelings of the writer pertaining to the nature of D&T in the Singapore context.

The research questions were therefore reconstructed as the focus of the study shifted from teaching Design and Technology to learning the subject. Initial research questions such as 'why do teachers consider practical skills important?' or 'are the teachers teaching designing in the right perspective and approach?' or 'do the teachers understand the concept of Design and its Process?' were reconstructed. This is done as new information and insights are gained during the inquiry. The focus becomes that of the learning of D&T and understanding the entire process of learning the subject.

The inquiry now centres on examining the learning of Design and Technology as a process of learning for both the writer and his pupils in two different learning contexts. The first is associated with the experience and insights gained in a two year part-time design course. The second is related to a Secondary Four D&T class in a particular Singapore school. The two learning processes which can be described as a double learning loop, are intimately intertwined.

From the interviews of teacher-respondents and pupils in the pilot study, a number of concerns and issues emerged. The pilot study data were analysed and categorised according to the responses. The initial concerns and issues were grouped under 15 headings including: D&T objectives, drawing, weaknesses of D&T, teacher's knowledge, syllabus,

training, competence, complains, pupil's knowledge, designing skills, strengths of D&T, pupil's intelligence, distinction grades, pupil's

profile, and teaching. Based on these groupings the writer attempted to categorise the concerns, issues and idiosyncratic responses at this early stage of the study into the following four areas:

- (1) Teacher's prior training,
- (2) Teacher's knowledge in Design and in Technology,
- (3) Perception in Design teaching and learning,
- (4) Importance and role of pupil's folio.

The responses from pupils pertaining to the seemingly troubling folio work were looked into by inspecting their Secondary Four's 'O'-level folios. The initial observations of the pupil's folio were based purely on the writer's own teaching experience. Comments were totally qualitative in nature. It was not the intention to have quantitative comparison of the folios as this could become very subjective and meaningless in the context of the research study. Initial comparison made between the three pupils' folios are as follows:

- i) All folios were very neatly done up like a formal 'type written' technical report.
- ii) Drawings were very neatly ruled and drawn.
- iii) The folios are A4 in size.
- iv) A table of contents showing the various sections according to the order required by the 'O'-level examination paper was included in each folio.
- v) Folio sections were arranged in orderly fashion, clearly defined between sections and at times with section dividing page.
- vi) Each folio was about 100 page thick.
- vii) Drawings were fully coloured throughout the folio, using either markers or colour pencils.
- viii) Analysis of topic was very meticulously done with numerous pictorial illustrations for the purpose of surveying the theme given and for the purpose of identifying problems to be solved.

Looking at the work done by the pupils, it is without doubt that the pupils put in lots of time and effort painstakingly compiling their folios. A lay person like the writer's school principal could also share the same sentiments when she was interviewed during this pilot study:

"A boy taking the D&T certainly has a broad and enriched outlook to situations. I admire their... what you call it... their folio. Painstakingly done."

[Time consuming? - the writer asked.]

"That's why it fails to attract because people are not prepared to spend the time doing this folio. But if your heart and sweat and your interests are there, you don't mind hours of drawing. The first year I really went through with teacher TA (one of the teacher interviewed by



the writer) and I thought it was fantastic. I myself would not be able to do it. That the thinking process, that it reaches the final stage of the product, is very good training."

- School Principal, Nov. 1992.

Hence the sentiments of the pupils were shared by a lay person who knew very little about D&T. However her remarks on 'the thinking process' provoked much reflections on the writer's part when he continued with his literature review. The ideas of thinking process, design thinking and design process became more and more pressing and meaningful as the research progressed. With new insights into other researcher's work on design processes and how designers think (Rowe, 1987; Lawson, 1991) the pilot study's data helped to gain more insights into the nature of the learning problems faced. This new understanding in turn influenced the writer's inquiry focus in the main study.

The D&T scheme of work was reviewed and compared with two other schools' schemes of work. The following observations were made:

- i) The proportion of time allocated for lessons on design and on technology was 40% for design and 60% for technology.
- ii) Topics and assignments for technology to be taught each week were clearly stated with details of topics to be taught.
- iii) Topics for design were skimpy and purely itemised according to folio contents and only showed the structure or sections to be included in the folio.

The pilot study provided a good starting point for the main study. The data collected raised more questions listed below than answers.

- 1) What really constitutes the knowledge base for D&T teachers?
- 2) Are the D&T teachers able to appreciate design or are they merely mechanical facilitators of the subject?
- 3) Are the D&T teachers teaching design or technology, or technology as product perse?
- 4) How to teach designing?
- 5) Is the training programme for D&T teacher adequate?
- 6) What depth of syllabus should the D&T teachers go into?
- 7) What is the pupil competency level for design?
- 8) Can designing be learnt or taught?
- 9) Is the folio serving its purpose as a record of the pupil's thinking and visualization of a design?
- 10) Is there anything wrong with the way folios are being developed?
- 11) What is the role of skill training in D&T?

The above questions generated from the pilot study and the literature review helped to direct the focus for the main study. The questions set forth in the pilot study seemed sufficiently broad to elicit some data for the study of the teaching and learning of Design and Technology. Since teaching and learning are inseparable processes, the folio was chosen as a good document to tell a story about the teaching

of design, the guidance given by teachers and the pupils' thinking and learning. However, the pilot study was limited to views and opinions about the teaching and learning of Design and Technology. It did not reveal the nature of Design and Technology, nor the process of learning and the role of design in the technological process. The satisfaction with the results of the pilot study stimulated a shift in the focus of research. The main study therefore concentrated on learning the design process in a Design and Technology course.

The pilot study had given a good indication of the concerns and issues involved in the teaching and learning of D&T in the school. The main study looked into the entire process of learning about design and the design process by the writer who, in turn, tried to impart the knowledge and skills acquired to his pupils. Further understanding of how the design process evolved was gained through the learning and implementation stages initiated by the writer.

The strategy adopted for the main study is different from that of the pilot study. The research findings were based on the data collected from a 5-month project work carried out in conjunction with a local polytechnic. As a participant-observer (Lincoln & Guba 1985), the writer was, in fact, engaged simultaneously in two settings, as a learner in an institute of tertiary education and as a teacher in a secondary school. For a period of two years, the inquiry focused on the five research questions mentioned at the outset of this paper. These five questions were incorporated into the 5-month project work.

The same questions were looked into at the participating school. The

methods of teaching design and using studio master-student coaching were carried out with the Secondary Four Normal Academic pupils. In view of the requirements prescribed by the Cambridge Examinations Syndicate, the formal class lessons conducted did not deviate much from the conventional approach. Design elements and tools to assist in creative thinking like mind-mapping and brainstorming were introduced to the pupils formally. As the teaching progressed, periodic feedbacks were given to pupils in the form of written comments on how to improve their work. Like previous years, the pupils would seek to consult the writer. A handful of pupils with greater interest towards the D&T subject were more consistent in seeking advice. The writer took this opportunity to observe and work more closely with this group of pupils. It was the intention of the writer to observe more closely the pupils' studio work.

The cyclical process of teacher's understanding of the various design component as learned from the design course in the local polytechnic was operationalized as theory into practise. More specifically, it is the implementation of the process of teacher-learning to coach

student(s), teacher-coaching-in-action, and teacher-learning from pupils. In implementing the process, it seemed that the writer's own understanding and teaching of Design and Technology had been enhanced.

Formal lessons planned were carried out. Discussion as a class on problems faced by class members was encouraged. This added on to the dimensions of social interactions in class to enhance designing activities. Periodic written feedback to the pupils on their progress and performance of their design works was carried out via a pre-printed Test Form. A total of four tests were carried out. These tests act as a device to push pupils to observe deadlines. In view of the limitations and constraints, it was observed that some pupils could respond well to the sketching/drawing lessons given this short period of training and a few seemed to respond well to the planned study. The majority of the pupils still tended to follow the conventional way of designing and handling of the design folio as taught by previous year's D&T teacher. Pupils were encouraged to discuss their work personally with the writer. The necessity for one-to-one coaching was emphasised to the whole class. However it was observed that 6 to 7 pupils followed closely the writer's attempt to coach the class in designing. For the purpose of this main study, 14 pupils out of the 33 pupils were initially selected which were later narrowed down to 7 pupils. Selection was based on their response to the drawing program, their attitude in wanting to come back after school to seek advice and clarification, and their ability to produce reasonable 3-D sketches. One particular pupil who was weak in his ability to sketch was selected in view of his very positive attitude and willingness to learn and the fact that he was also a school prefect. (The detailed plan and implementation of the main study are not discussed here.) Seven pupils were very consistent and keen to discuss their design work with the writer. This was usually conducted after school hours. The seven pupils' designs were constantly changed to improve on details and functions. Pupils were told not to throw away their old design ideas. They were told to compile all folio sheets no matter how trivial ideas or sketches might seem to be. Rejected ideas and changes need to be kept for reference. On the average, each pupil had gone through about three to five cycles of designing to arrive at a reasonably acceptable design solution. Due to differences in design problem identified by the pupils, the writer was constantly thinking ahead of the pupils and reflecting on how best to guide the seven pupils. Interventions were exercised at every crucial stage of the pupils' design cycle. Whilst maintaining the conventional approach in teaching D&T in every cycle of the pupils' work, the writer intentionally put the pupils into the

cyclical process of iterating their design solutions. The design model thus shadows each cycle of work throughout the entire design process.

Two pupils P1 and P2

Out of the seven pupils, two pupils P1 and P2 were selected for the

purpose of this main study. Their folio extracts were taken for detailed analysis. P1 and P2 happened to design a coin sorting device and their works were selected to show the different outcomes of their designs after going through the designing process with the writer. The following works were selected for the purpose of this research data analysis:

- a) Pupil P1 - a coin sorting device
- b) Pupil P2 - a coin sorting device
- c) one number 1995 G.C.E. 'N'-level Examination Folio
- d) one number 1995 G.C.E. 'O'-level Examination Folio

#### Case 1 - Pupil P1

##### Pupil P1's work

P1 has designed a coin sorting device cum coin box. When the theme 'Sorting' was given to him in the beginning of the year, the very first reaction from him and some of his classmates was to design something to sort coins. This is a very common phenomenon in the D&T class year in and year out. However P1 was guided like many others according to the subject requirements as spelt out in the syllabus and examination criteria. P1 managed to produce a 80-page folio up to the working drawing stage at the point of time of this research study. He was still in the process of doing his production planning, realisation of artefact and evaluation of artefact. A detailed extracts of his folio is taken for data analysis labelled as PG16 to PG66. A few pieces were left out which were not considered important to a complete view of the process P1 had gone through. P1 managed to invent a coin-sorting device which works perfectly well despite the constraints in time, knowledge, and contextual factors affecting the research study. P1 showed interest in sketching/drawing works and showed marked improvements in his sketching ability through the exercises given in the class.

Dialogue between the writer (JT) and pupil (P1) during P1's design process.

The writer, denoted as R in the extracts of the folios and JT in the reflexive recall of the discussion with pupil P1, remembers vividly what transpired between the pupil P1 and himself for he had guided P1 very closely through his journey in designing his coin sorting device. As a matter of fact, his pages of folio work come alive when one reads through them. This helps to recall much of the dialogue between the writer and the pupil. Looking at the folio is like having a dialogue with the pupil at work. The crucial discussion that occurred in the steering of the pupil P1's design process in action was illustrated as quotations, categorised with reference to the folio extracts for analysis purposes. This demonstrates a process whereby the writer, being a participant-learner himself, learns and drop hints along the way to guide the pupil P1 when he faces difficulty or when the writer realised the need for re-designing or improvements.

[A total of 51 extracts (PG16 to PG66) from pupil P1's 80-page folio and 46 extracts from pupil P2's 50-page folio (A6-AA51) were used for data analysis. Only sample of P1's extracts and the recorded dialogue is shown below.]

SAMPLE DIALOGUE:

P1's folio extract: PG16

P1:"Sir do you think this slide can work?"

JT:"Why do you need such a slide in the first place?"

P1:"This will help the coins to enter this box here..." (referring to sketch circled 'A')

JT:"But how does your coin sorter works? Aren't you going to look into this important feature first? I think that is the most important aspect of your design."

P1:"Well I think I like this slide. It kind of helps the coin slides down faster into the box so that it can travel further to the last compartment."

JT:"Oh I see. But isn't it kind of odd? Lets not worry about this go and think up your coin sorting device first. That is more crucial."

P1:"Yah this is my coin sorting device (pointing to the diagram with the word 'slant'), I have discussed with my friends. Three of us used the circle template and it works. Sir we are first to find out."

JT:"Are you sure?"

P1:"Yah we just tried out and the 10 cents coin can drop into this hole here."

JT:"I tell you what go home and use a card board test it out with different size coins. You will be surprised that it may not work at all. Meanwhile go and think about may be a few more other possibilities. Your coin sorting device may go in this line (JT sketched on P1's folio - sketch circled B)."

P1's folio extract: PG17 to PG19

P1:"Sir I have come out with these designs."

JT:"Oh that's interesting. At least now you have more varieties. What is this (PG17/2)?"

P1:"This idea..... inspired by one of the artefacts in workshop. Is like a chimney."

JT:"But I think your coin sorting device may not work. Have you tested it?"

P1:"Yah sir the other day in class we tried out on a the circle template and it works."

JT:"But I told you to make a simple maquette and test it with different size coins. Have you done that?"

P1:"Uh..... no sir."

JT:"There you are.... I still feel that it may not work. Go, go and test it out."

SAMPLE EXTRACTS:

## Analysis of P1's folio (PG16 to PG66)

Attempts were made to reconstruct the meaning behind P1's folio work, through the interaction the writer had with P1 during the course of P1's design work. A few key guidelines were emphasised to P1 and constant reminders given to him regarding the general expectation of the folio as a working platform for exchange of ideas, discussion and development of design ideas. In view of that P1 was told to be very sensitive to devices commonly used by past year pupils. These devices were used by pupils to "enhance" their folios so as to get good marks. P1 was told that this might be counter productive and non-essential to the learning of design. Things like colouring of all sketches or drawings, doing up elaborate borderlines, all drawings neatly ruled, all discussion neatly type-written and the strict adherence to the

stages of the folio were discouraged. P1 was reminded that there is a place for colouring and there is a place for enhancing the looks of his design. Neatly ruled drawings only go to the presentation or technical drawings. P1 was told to use his folio extensively when he is thinking of his design or when he wants to discuss with the writer or friends. He was also constantly reminded of the design model he needs to fall back on as a guide when developing his idea. P1 attempted to make a maquette of his artefact using mounting board as a modelling material. The work of the maquette is not reflected in the folio. The maquette seemed to help P1 a great deal in understanding dimensions and in highlighting problems overlooked during the paper-based design work. This is not usually practised in the conventional approach to teaching D&T in school.

The analysis has shown a very interesting cycle of design P1 had gone through in arriving at the solution. A total of seven stages were "teased" out from P1's folio as follows:

Stage 1 (PG16 to PG42):

First attempt of coin-sorting device after going through the conventional model of design method. - [cycle 1]

Stage 2 (PG43 to PG46):

Invented a feasible coin-sorting device. - [cycle 2]

Stage 3 (PG47 to PG48):

Refinement of coin-sorting device to a practical-workable level. - [cycle 3]

Stage 4 (PG49 to PG50):

New overall form was 'born' (a model was made out of mounting board to test out the feasibility of the design.)

Stage 5 (PG51 to PG56):

Sorting device - form compatibility design and further refinement. - [cycle 4]

Stage 6 (PG57 to PG59):

Designing of internal coin-collectors' container and refinement.

Stage 7 (PG60 to PG62):

Finer details of dimensioning arrived at resulting in material list PG63 - [cycle 5, final]

Basically it was observed that P1 was on his own in controlling his own design activities, with the stages in the design model shadowing his folio details. The writer's intervention was exercised at each crucial stage of P1's design process as reflected in PG16, PG19, PG42, PG43, and PG45 (not shown here). The writer was constantly reconciling his own thoughts with the many pupils' design problems and solutions and P1 being one of them. The intervention was partly based on what P1 had produced progressively and the writer's constant reflection on the problem when he was at home, at work and everywhere. A few obvious points pertaining to the outcome of the folio of P1 are that:

- no borderline is used,
- colours were used as and when needed,
- developmental drawings were drawn free-hand except for a few illustrations of joints, the final and working drawings drawn to scale,
- evidence of writer's advice in the form of sketches,
- and- evidence of P1's usage of sketching as a design tool to think and explore his ideas.

Case 2 - Pupil P2

Analysis of P2's folio (A6 to AA51)

P2's work is not as detail as P1's. However he had also gone through some transformation from his initial raw idea to a final, more acceptable and workable solution. The stages which he had gone through

can be categorised as follows:

Stage 1 (A6 to A11):

Initial idea of sieving device and consideration of coin container to details of materials to be used for construction. - [cycle 1]

Stage 2 (A12 to A14):

Review and re-design of coin sorting device with collectors for coins looked into.

Stage 3 (A15 to A21):

A new form and device attempted with details and exploded views. - [cycle 2]

Stage 4 (A22 to A28):

Another attempt of re-designing to refine the form. - [cycle 3]



Stage 5 (A29 to A36):

Final design of device and form arrived at with details. - [cycle 4]

P2 had gone through about four cycles of designing to arrive at the final acceptable design solution. Given more time, finer improvements could have been made to improve the design. Similarly, it was observed that P2 was on his own in control of his own design activities with the stages in the design model shadowing his folio details. P2 however was not very detailed in each cycle as compared with P1. The writer's intervention was exercised at each crucial stage of P2's design process as in A9, A12-15, A24 and A28/29 (not shown here). The writer's experience with P2 was exercised in guiding P2 towards a more viable solution. The intervention was carried out in a neutral setting with reasoning challenged to P2 each time the writer felt that P2's design was not acceptable. P2 was henceforth allowed to challenge his own design ideas and slowly sharpen his design through the four cycles of his design process. A few similarly obvious points pertaining to the folio of P2 as reflected in P1 are that:

- no borderline is used,
- colours were used as and when needed,
- developmental drawings were drawn free-hand except for a few illustrations of joints, with the final and working drawings drawn to scale,
- evidence of researcher's advice in the form of sketches and- evidence of P2's usage of sketching as a design tool to think and explore his ideas.

Case 3 - 1995 `N'-level and `O'-level Examination Folios

Two folios, 1995 `N'-level and `O'-level Examination Folios, were used for the purpose of data analysis in this study. Sample of the extracts from the `N'-level Examination Folio is shown below:

SAMPLE EXTRACTS

SAMPLE EXTRACTS cont.....

Analysis of 1995 `N'-level Examination Folio (N1 to N20)

Extracts of the folio are labelled N1 to N20 (see sample extracts above). The purpose of this analysis is not so much for comparing quantitative grades as this would be of no meaning in the context of this study. The grades broken down to stages as reflected in the



syllabus and followed closely in the pupil's folio are subjective and the marking system has evolved around this basic set criteria.

The folio can be divided into the following stages:

Stage 1 : N2 to N6 (Exploration of ideas)

Stage 2 : N7 to N9 (Development of selected idea)

Stage 3 : N10 to N17 (Further Development of selected idea)

Stage 4 : N18 to N20 (Working Drawing, Presentation Drawing, Material List)

From the above stages of work the following aspects can be identified:

(A) Physical Aspect

1. - The folio is very neatly done up.
2. - All writings are painstakingly type written and pasted on every page although this may not be typical of all folios but it was commonly observed that neatness in writing is emphasised.
3. - All drawings are very neatly drawn using ruler and geometrical equipment.
4. - All drawings are fully rendered/coloured.
5. - Special font treatments are given to the main title of each stage.
6. - Special device used to highlight write-up.

(B) Design Aspect

1. - No evidence of discussion with teacher or others although this undoubtedly will occur in the pupil-teacher interaction. Good information may be lost.
2. - Approach seemingly is one directional or one cycle affair to reach a final solution.
3. - Selected idea from stage 1 and final solution in stage 4 show minimum transformation and changes.
4. - Idea exploration was seemingly produced without 'generative' train of thoughts shown.
5. - Development of mechanism like gear systems were carefully and neatly drawn to show available possibilities and to show that pupil had made choices and decisions in selecting such system.
6. - Fairly elaborate and detailed design of idea in stage 3 (Further Development). Idea was developed in piece meal, isolated parts, for example, the toy car was divided into 6 different parts for form design considerations. From the principles of design point of view, this would be a gross error for there seems to be no consideration for total or holistic form design.
7. - Joints were developed by showing types of screws, carcase joints and adhesives very neatly presented (N17), seemingly to show that the pupil is making decision of the choice of joints for his design.
8. - Overall the folio is very much contrived without showing the real development of the design through certain design process.
9. - Much precious time could have been spent wastefully in the detailing of the folio than in 'real designing' work.

## Analysis of 1995 `O'-level Examination Folio (010 to 024)

The 1995 `O'-level Examination Folio extracts are labelled as 010 to 024 (extracts not shown in this paper). The folio can be divided into the following stages:

Stage 1:010 (Exploration of ideas)

Stage 2:011 (Further development)

Stage 3:012 to 020 (Detailed development including construction methods)

Stage 4:024 (Working Drawing)

From the above break down it could be observed very clearly that pupils

conduct similar approach to presenting and using the folio for designing as in the case of `N'-level folio. However the difference between an `O'-level folio and a `N'-level folio lies in the details, ability to draw better drawings, and ability to be more descriptive in nature. Depth of design and iterative nature of design is seemingly not reflected. It is more like reporting than designing. Overall, folio seems gaudy with many decorative devices. Exploration of ideas seem wide ranging but generative nature from which these ideas came from seem lost. Common phenomena as observed in the `N'-level folio discussed above are reflected here too, although the two folios were from two very different schools in Singapore.

## CONVENTIONAL WAY OF TEACHING D&T FOLIO IN SCHOOL

The teaching of D&T folio in school is basically carried out with teachers following closely the stages as spelt out in the marking criteria by Cambridge namely Analysis of Brief, Design Specification, Design Ideas, Design Development, Final Design, Production Plan, and Evaluation. Pupils being guided by these stages are required to present their design approach according to this sequence. Folios of pupils are thus compiled and compartmentalised into chapters of the stages. Pupils are equipped with design ability in a fairly structured manner. Discussions between pupils and D&T teachers on their design problems definitely go on in the school environment. To what extent such teaching and learning interaction is being honoured by the teachers and taken as a very crucial part and parcel of design learning environment is not evident in the pupils' folio work nor with teachers interviewed by the writer. It must however be mentioned that pupils are learning, to a certain extent, design and are equipped with certain aspects of design ability through the way D&T is taught in school. This study however had shown another major aspect of the way D&T can be taught. As a matter of fact it is happening inevitably in view of the nature of the subject. It is the intention of this study to show the importance of teachers' coaching-learning (being the major aspect of the teaching/learning environment) which will result in the pupil's

design abilities and potential being stretched to the fullest.

The importance of presenting the folio in the stages as mentioned above is very much emphasised

and also being used as a framework to teach D&T in school. Teachers interviewed on the way they teach D&T will undoubtedly share the following view points (these view points are sampled from the verbatim reports of interviews conducted by the writer):

"I think er... the text book has quite a good way lah. Basically they teach about the stages in design, you know the `PRIME'. So we start off by teaching them the stages, and then the factors and then teach them that..."T8E

[Any other teaching aids which you use? - the researcher asked]

"I mean I will show other students' work. I think that's about all lah. The folio, I will pass around.....  
.....Again student's folio"T8E

"For this particular topic, (referring to teaching of design) yes of course...er... past year's folio (laugh)"T7E

"Yah, make use of the very good folios from past students."T3

"Using sample copies. We do use that... sample copies. That means

those that had been handed up before."T2

It is logical and easy for teachers to use past year folios as teaching aids to guide and teach the pupils. Pupils will inevitably follow closely the format of how `a design folio' ought to be done and teachers will advocate that for it follows closely the marking system. The format of the stages has, throughout the years, emerged as `the' design process taught to the pupils.

## Conclusion

The in-depth inquiry has shown a very clear evolution process of the teaching of D&T by the writer in a secondary school. The resultant data is strictly descriptive and interpretative in nature. After experiencing a teaching-learning process consisting of `reflection-in-action' cum `reflection-on-action' `student-studio master' environment (Schon, 1987), and as a `participant-observer' (Guba & Lincoln, 1989) in a local polytechnic and with other practitioners of the subject and specialist officers since the writer started teaching D&T in early 1990, certain patterns of recurring

themes and ideas seemed to emerge and a tentative grounded theory is proposed. The amount of data generated from both the pilot study and the main study has begun to show in detail the factors contributing to the effective teaching of D&T and indicating some patterns in the process of design in-action in both teacher and pupil, the characteristics of pupil's design ability and the potential for improvement through the cyclical design process, the pupil's visual/spatial ability being enhanced through the doodling and sketching process, the teaching approach adopted by the writer to internalise the design process in the pupil, and the on-going learning process of the writer in engaging himself with the pupil's design process. All the categories of data with emergent patterns have been classified into four themes related to the learning of Design and Technology:

- (1)Teacher's design knowledge and expertise in relation to externalising any design model as a teaching tool.
- (2)Sketching and drawing abilities of pupils.
- (3)Pupil's spatial intelligence and its relation to design ability.
- (4)The effect of the assessment system on the performance of both teacher and pupil design approaches.

Theme 1: Teacher's design knowledge and expertise in relation to externalising any design model as a teaching tool.

Teacher's design knowledge and expertise play a fundamental role in the teaching of D&T in school. The research has shown the concurrent learning of design knowledge and the externalising of design process by the writer through the coaching of his pupils in a "teacher learning - teacher coaching - pupil learning - teacher learning" dynamic cyclical approach to design. The constant purposively cyclical design approach exercised by the writer as reflected in pupils P1 and P2's folios follows a constructionist approach to the shaping of the design problem and design solution. This is supported by many studies into a designer's way of thinking and working on problems which are described as cyclical in nature, iterative in approach and many times irrational (Schon, 1987 & 1990; Cross & Cross, 1995; Stolterman, 1994; Galle & Kovas, 1992).

"Design problem and design solution evolve in parallel, mutually influencing each other. Mutual dependencies hold between aspects of the design..... Solutions often evolve through a propose-criticize-amend cycle."

- Galle & Kovas, 1992

The contrasting evidence reflected in the data has shown the rich evolving cycle of the pupil's design process in-action whereby pupil P1

had gone through seven stages or five cycles of design and P2 had gone through five stages or four cycles of design.

The design model shadows this process of design with pupil and teacher who continuously learn from mistakes, dilemmas or problems faced in the midst of designing. This is confirmed by Schon's conceptual theory of a design process whereby he sees designing as a conversation with the materials of a solution and whereby designing takes place in the trials and new trials based on the learning from earlier ones (Schon, 1990). The writer being a coach to the pupil is constantly engaging himself in the pupil's design process and consciously 'scaffolding' the pupil's approach in bringing him through the whole cyclical process of designing and re-designing. Purposive intervention at each crucial stage of the pupil's design cycle becomes an important move to bring a pupil to another level or vantage point especially when pupils are 'stuck' and do not know what to do.

The design process evolving from the teacher-pupil relationship uses the constructionist approach although the present conventional way of teaching D&T seems to have adopted the technical rational or scientific approach (Dorst & Dijkhuis, 1995). From experience and observations, it is fairly clear and natural and even inevitable that certain discussion and interaction must go on between teacher and pupil, especially in the teaching of a design-based subject. In what ways all these interactions can be captured and enhanced becomes an important aspect of the present study.

The development of the pupils in D&T can thus be seen as subjecting the pupils to two major phases of teaching/learning consisting of the formal lesson of understanding design method, principles in design, design tools, technology and design method, and the operationalization of the design method by the pupils themselves. The latter becomes the main context in which either pupils see or fail to see the essence of design-in-action. It is thus an important major aspect of the whole D&T education to internalise in each individual pupil their own process of designing. This has been observed by Chidgey (1990), Mann (1992) and in Schon's reflective practitioner (Schon, 1987). Pupil becomes an apprentice to the teacher as in Schon's studio master-student relationship. Through the teacher's expertise in knowledge related to design and his ability to constantly reflect on the whole process of learning-teaching-learning, the teacher is able to internalise in each pupil his/her own approach or process in design. This has also been confirmed by the writer's observations and knowledge acquired in the polytechnic. In trying to understand the theory of such rigour in acquiring expertise from the lecturers, the writer had critically and intentionally subjected himself through the constant interaction and discussion relating to design problems. The insights gained through this designing-in-action further enhances the writer's understanding of the whole design process and thereafter his ability to operationalize it with the pupils in the secondary school. Understanding this major

aspect is no doubt important but other areas contributing to the success of this are equally important. A pupil's design ability is grossly influenced by his ability to externalise his thought or imagery process in a quick and acceptable physical form. This could be in the

form of an object like a model or in the form of sketches and drawings. The latter being the most essential and common tool used by designers of all professions. It is also the most economical modelling tool. The importance of such ability will be discussed in the second theme that follows.

## Theme 2: Sketching and drawing abilities of pupils.

Sketching and drawing abilities is no doubt universally recognised as an important component in designing. It will definitely be taught in any design based programme. This research however has shown that the importance of such abilities is far beyond that of communicating ideas, presenting ideas and production of construction drawings. The ability to sketch and to draw has been validated by many

researchers as a way of definitely promoting visual thinking between mind and paper in an interactive nature (Goldschmidt, 1994; Schon & Wiggins, 1992; Schenk, 1991). When one compares the sketches and drawings produced by pupils P1 and P2 with that of the two G.C.E. 'O' and 'N'-level Examination Folios, the latter may seem to have produced better drawings. However, the effective use of sketching as a tool for modelling and exploration or manipulation of ideas is not exercised. This phenomenon has also been confirmed by Denton (1993) that it does occur in many United Kingdom D&T students' folios.

The extracts of pupils P1 and P2's folios have shown their quick and effective use of sketches to generate ideas be it discussion with the writer or on their own. The main emphasis here is speed and spontaneity in doodling and sketching. Clarity to convey ideas and provision for discussion are sufficient. Pupils do not waste precious time in unnecessary decorative work of their folios which do not directly engage their thinking process. Close linkage between purpose of sketches and drawings with the design solutions is ensured. From the folio extracts it could be observed that pupils P1 and P2 were initially fearful of doodling and making quick sketches. Their confidence was gained through the continual practice of sketching and drawing in class. This could be seen as evolving progressively in the two pupils' work, especially in the latter halves of their folio extracts. If given time and training, the pupils will be able to acquire higher order sketching and drawing skills. Drawing is vital to thought organisation. It is an essential component of designerly thought. It facilitates creativity and is important to the exploration and manipulation of ideas and assists in problem definition (Garner,

1989). This research has shown and confirms this notion through the two pupils' work. The relationship between pupil's ability to draw and pupil's spatial/visual intelligence is closely knitted.

"... that drawing: is an intrinsic procedural device; use is highly complex; is a vehicle for creativity; as visual literacy development; important as part of the design process."  
- Schenk, 1991

This brings us to the third theme of our discussion.

Theme 3: Pupil's spatial intelligence and its relation to design ability.

Spatial or visual ability of the two pupils P1 and P2 is demonstrated again very clearly in the way generative sketches were made during the designing of their solutions to the identified problems. Progressive

changes in their design doodling and sketching illustrate their mental spatial ability in-action. Idea representations were demonstrated strongly showing the way new ideas were attempted and arrived at. The fact that the 'O' and 'N'-levels folios have shown good, neat and detailed drawings made by the pupils confirmed the very nature of the pupil's spatial ability. This is proof of the integration of visuo-spatial thinking processes being deliberately built into the D&T curriculum as planned lessons is obvious from the way folios were written or produced. Certainly visuo-spatial thinking processes exist when pupils attempt to draw much of the drawings nicely as shown in the examination folios. The contrasting sketches produced by Pupils P1 and P2 and that of the examination folios as mentioned in Theme 2 above make one wonders whether the latter has any true effect on the pupil's visuo-spatial thinking process. As Schon & Wiggins (1992) put it: "...that designing is a conversation with materials conducted in the medium of drawing and crucially dependent on seeing (the basic structure of seeing-moving-seeing is an interaction of designing and discovering)". This calls for manipulation of visual thoughts and interacting with the doodling or sketching that one is engaged in. This supports the very nature of the pupils' result after going through the close supervision by the writer. However, as mentioned, if given ample time for training the pupils in the area of visualization, much more might have been achieved.

The overall execution of such a D&T programme however depends not only on teacher's knowledge and expertise in designing, his ability in understanding the concept of design process-in-action, his ability to learn himself and simultaneously engaging his pupils in the learning and internalising of the design process but also the crucial aspect of how teachers assess their pupils. This will bring us to discuss the



next theme.

Theme 4: The effect of the assessment system on the performance of both teacher and pupil design approaches.

The way the 'O' and 'N'-levels pupils present the folio work confirms clearly how such work is being developed. Teachers and pupils are conditioned by certain assessment system from Cambridge which may or may not be correctly interpreted and implemented. As can be seen from the two examination folios presented, the structure or format of the works shows the following pattern of lay-out:

1995 'N'-level Examination Folio:

Stage 1 : N2 to N6(Exploration of ideas)

Stage 2 : N7 to N9(Development of selected idea)

Stage 3 : N10 to N17(Further Development of selected idea)

Stage 4 : N18 to N20(Working Drawing, Presentation Drawing, Material List)

1995 'O'-level Examination Folio:

Stage 1 : O10(Exploration of ideas)

Stage 2 : O11(Further development)

Stage 3 : O12 to O20(Detailed development including construction methods)

Stage 4 : O24(Working Drawing)

It is the practice of many, if not all, schools in Singapore to follow closely to the marking system or marking criteria for D&T. In their attempt to do so, the examiners or teachers invariably stereotype and

structure pupils' design work so as to relate to the marking criteria as spelt out in the syllabus. A close study of the syllabus pertaining to assessment however shows that there is no definite instruction to compartmentalise marking of pupils' folio-work according to the contents of the marking criteria namely analysis of topic, design brief and specification, exploration of ideas, detailed development, selected solution, production planning and evaluation. These can be seen clearly in the above two folios' stages of work. There may or may not be an interpretation error in exercising the marking system locally but it is not the intention of this research to critically analyse the assessment system. However it must be mentioned that this system has definitely imposed certain constraints on how designing was taught and on the pupils' performance in D&T. Chidgey (1990) has pointed out in his paper that such phenomenon has been observed in the United Kingdom schools whereby great differences were observed in pupils seriously engaging in designing activities on the one hand and teachers worrying



about what ought to be presented for assessment purposes on the other.

## REFLECTIONS ON RESEARCH PROCESS & FINDINGS

The naturalistic inquiry method of research adopted is inductive and involved a continual shifting of research focus as hunches developed and new insights were gained. This could be observed in the major shift of the research focus from teaching Design and Technology to learning the subject. The nature of the study, adopting the methodology of the naturalistic inquiry, thus allows the hypothesis to emerge over the process of data collection, grounding the developing theory in the data itself. 'Grounded Theory' as Weingand (1993) put it is when substantive theory building is viewed from the perspective of 'grounding' the hypotheses in qualitative data, it can be defined as 'grounded theory'. This study is an attempt by the writer to engage himself in the intellectual rigour of a qualitative research methodology to develop a grounded theory based on the natural context of the teaching of D&T in a Singapore school.

The way D&T was taught by the writer in the school, on the surface, may not be seen as of any great difference from any other D&T teacher. This is so for many D&T teachers do engage themselves in discussion with their pupils whenever problem crops up as mentioned earlier. However, the understanding of the way the design process evolved and the careful and planned pacing of the various interventions by the writer made for a distinctive difference in his approach. The way the writer learned design and the process of designing, the way he conducted his teaching of D&T and the way pupils learned through the process reflected much of the conceptual model defined in the research work. The dynamism of the various major variables contributing to the design-like environment surfaced very strongly in the data collected from the main study. Pupils P1 and P2 were eventually able to accept and understand the rigour of the design process imposed on them. They not only intellectually gained the rigour in tackling design problem but were also

able to invent a 'coin-sorting' device cum coin box on their own. As pupil P1 put it:

".....thou I was told to change my design several times, I found I have gained valuable experience. Discussion with Mr JT has helped the development of my design."

The findings of this study are based on the experience of the writer teaching his own class of D&T pupils. Though the sample involved may be small, many of the research questions have been answered as seen in

the following findings:

(1) A D&T teacher not only needs to understand what is design perse, but he also needs to practice and understand the fundamental principles of the rigour of design process-in-action.

(2) Failing to involve oneself in the process becomes a great handicap to bringing pupils through the process competently. Pupils may be left with the design method not being fully operationalized. The teaching of D&T will eventually be very mechanical in approach. This will definitely make a significant difference to the pupil's performance.

(3) It can be inferred from the findings that in the current practices, D&T could have been taught with great emphasis on the final outcome of the product that is the artefact. This could be due to two major contributing factors that the emphasis of marks is on a well finished product and that teachers being overly concerned with pupils' seemingly weak performances in realizing an artefact may tend to attribute practical skills being crucial to pupils' ability in designing.

(4) It is apparent that teaching of D&T is not just a chalk-board based lecturing process but is more of a coach-pupil consultative relationship process. This calls for rigour, intense and two way learning process of teacher and pupil in-action. As Mayall (1978) put it:

"Design is a highly sophisticated activity and is becoming increasingly so..... Design cannot be taught in the sense of listening to lectures and passing examinations. It is essentially a subject to be learned by doing, and moreover by doing under the guidance and leadership of good designers."

(5) Going through a course on design may be the essential and logical training a D&T teacher ought to commit oneself to but the understanding of the learning-teaching phenomenon as shown through this research study would result in a full implementation of the D&T programme.

(6) The concurrent learning and understanding of the principles in design and the design process itself by the teachers and pupils will definitely enhance pupils' designing competency and for that matter the pupils' verbal, visual and intellectual intelligence (Gardner, 1983) through the rigour of the design process-in-action. The research study shows the impact on a small group of Normal Stream pupils who, though not academically inclined, had risen to a higher level of design capability. Their verbal, visual, mathematical, and social intelligences are definitely enhanced through the interactive process of "teacher-pupil, pupil-pupil, and pupil-paper" on-going actions. The latter could be seen in the rich design process reflected in their folio extracts. The folio extracts also reflected the transition stage of the pupils from the conventional approach of handling the folio to the new creative problem-solving approach. However, it must be mentioned that the process should not be deemed as only naturally

evolving from teacher-pupil's engagement in a design task as evidenced in pupils doing a nice looking folio. The fundamental principle of the effective transfer of design knowledge must be radiating in one form or another from the coach as a guide (that is the D&T teacher) and most important of all the coach as a reflective practitioner (Schon, 1987).

(7) The understanding of the rigour of the design process and the coach-pupil relationship being made known to the pupils involved at the beginning of any such design activity becomes essential for effective teaching and learning of design in D&T.

(8) It is evidently shown that folios taught in the conventional way seemed to be very restrictive and stereotypical. The efficient and effective use of the design sheets, that is the folio, will be lost if wrongly emphasised (Denton, 1993). Visualization and thinking through designing and using the folio as a medium is crucial in designing. This becomes part of the basic supporting structure for the whole design process.

(9) Practical skill training is undoubtedly important in any design and realisation programme for this also impacts, to a certain extent, design considerations. However it is not an "all must" know, crucial knowledge unless extensive assessment is made on this. If this is the case, then emphasis on designing and the intrinsic gain in design education will be lost. "Design-design process-technology-technology process-product" is a framework whereby emphasis must be clear. A good design will ultimately evolved and a quality product produced when one emphasises and correctly practises the teaching-learning process of designing.

#### ANSWERS TO THE FIVE MAJOR RESEARCH QUESTIONS

(1) Is there a relationship between the teaching and learning of 'design method' and the understanding of the concept of 'design process-in-action' by both teachers and pupils?

The strong intertwined process-in-action demonstrated thus far cannot be overemphasised. To understand 'design process-in-action' is to put into practise the coach's own process in designing and paralleling that of the pupil's infancy stage of design process. Teaching just 'a design method' is different from teaching-in-action the 'design method' to operationalize it for both teacher and pupil. Whilst the teacher is learning together with his pupil about the problem situation, the teacher 'scaffolds' the pupil's design ability as he spirals up together with the teacher. The teacher is creating an environment, ie Collins (1989)'s cognitive apprenticeship environment (Chen, 1996), conducive to the transfer of the design process. It is an "invitation to dialogue" (Chen, 1996).

(2) Is there a relationship between teacher's background in design and the pupil's performance in design and technology?

Every individual, be it teacher or pupil, has a certain degree of innate design ability.

"Design ability is possessed by everyone: Although professional designers might naturally be expected to have highly developed design abilities, it is also clear that non-designers also possess at least some aspects, or lower levels of design ability. Everyone makes decisions about arrangements and combinations of clothes, furniture, etc."

- Cross (1990)

The design background of a D&T teacher cannot be just that of his innate ability. It is thus crucial for him to enhance this ability through a certain discipline of practice before design teaching can be based on any fundamentally sound design principles. As can be seen from this research, the 'O'-level and 'N'-level folios showed that pupils are able to design. Closer scrutiny of their work will tell a story of how pupils are being guided to achieve the final product. Certain forms of designing have definitely taken place. What performance then do we expect the pupil or even the teacher to achieve

in the D&T subject? This research study thus showed the significant relationship between teacher's background in design (as in the writer himself after going through the rigorous learning-teaching-learning process in designing) and the pupil's performance (what are we actually assessing them?) in Design and Technology.

(3) Does drawing/sketching skill (in terms of freehand drawing/sketching on the assumption that this is evidently reflected in pupil's design folio) have an effect on pupil's design capabilities?

Although the sample chosen is very small, the results demonstrated by the pupils could be significantly observed through their works. Freehand sketching and doodling enhances design creativity and one's visual thinking (Kellett, 1990) is an up and coming focus in the design research field. Many researchers have confirmed the fundamental role of drawing/sketching in designing and its importance in design ability (Goldschmidt, 1994; Galle & Kovacs, 1992; Schenk, 1991). In the context of Design and Technology, drawing/sketching skill is very important to the successful implementation of the programme

(4) Does spatial intelligence (defined in terms of the ability to visualise and doodle) have an effect on pupil's design capabilities?

Howard Gardner's multiple intelligences (1983) theory is applicable in

the D&T environment especially when pupils are expected to visualise and verbalise their design solutions. The pupil's dialogue with his teacher, if sensitively structured or paced by the teacher, maps Gardner's multiple-intelligences in almost all aspects. Social, intra- and inter- personal intelligences revolve around the studio environment. Logical-mathematical intelligence and bodily-kinaesthetic intelligence are also involved in the pupil's work when he attempts to design and construct. Judging from the progressive change in the drawing and sketching activities in pupils P1 and P2, we could say that the pupils' spatial abilities were enhanced through the period of treatment and their design abilities improved as evident in their folios.

(5) Does the marking system for pupil's work affects both teaching methodology and pupil's performance?

This question is aptly answered in the findings and discussion. The writer was also a victim of the marking system when he first started teaching D&T. Pupils were constantly guided along the marking system in an attempt to help them do better in their results. Pupils may ultimately get good results but the ability to design may not be significantly challenged in its right direction. This is confirmed in the present research study.

#### IMPLICATIONS OF THIS RESEARCH STUDY

(1)The design background of D&T teachers is thus vital to the successful implementation of the design education if any `designerly' performance is expected out of the D&T pupils. Design background constitutes not just the declarative knowledge but the rigour of the procedural knowledge in-action. This may imply a totally different emphasis to teaching design education in a teacher education course and a different approach to teaching D&T in schools.

(2)Effective implementation of coach-pupil or studio master-student concept of teaching and learning however must be carefully planned and executed for this "teaching and learning process can easily go wrong" (Schon, 1987).

(3)Scheme of work may have to be adjusted or revised to accommodate the practice of sketching/doodling and drawing and the structured lesson to take into consideration the development of pupils' spatial-visuo ability.

(4)Apparently, the educational value of Design and Technology in the current school situation is seen as one suited to the less academically inclined. Workshop skills and production seem to be the forte of this group of pupils. This research study however has shown the tremendous

potential of getting the pupils to exercise their intelligences as spelt out in Gardner's multiple-intelligences. The fact that the pupils taught by the writer in 1996 were all Normal Academic pupils, yet were able to show the intellectual rigour in going through the design-process in-action and developing significantly good design solutions contradicted the assumption of their lower abilities as compared to that of the Express pupils. If taught in an approach suggested in this research work, the latter group of pupils may benefit even more extensively from appropriate design education and D&T will not be just another craft subject.

(5)The positive approach in internalizing and externalizing the whole process of design through the teacher-pupil relationship will greatly enhance the intellectual well being of both teacher and pupil in design. The 'burnt out' syndrome of teachers may be an obstacle to such a practice for it is definitely much easier to teach pupils using the conventional approach. Extensive on-going training and upgrading of teachers whilst in practice cannot be avoided. D&T is just like any other academic subject or profession whereby training and re-training must be on-going to help the practitioners keep up with the development of technology.

(6)The effect of learning design using a method proposed in this research could be of paramount importance to the pupils' future careers in engineering, designing, architecture, education or any other professions. The process of design, if grounded in each individual, will definitely benefit the pupils in different ways in their lives.

This study has brought to light issues and concerns relevant to the teaching of Design and Technology. Although the study concentrates only on a particular Singapore school with a small sample, the insights gained could be applied generally to the general teaching of Design and Technology. The main concern is the understanding of the double-learning loops of teacher and pupil in carrying out a particular design task and the interacting process between teacher-pupil and materials. The success of such a double-learning loop depends very much on the understanding of the teacher and pupil and on how willing a teacher and his/her pupils are prepared to come into such a relationship. It also depends very much on the teacher's design background, teacher's design knowledge base, teacher's expertise in designing, pupil's attitude and innate abilities in designing, time frame to allow for such events to happen and, last but not least, the strong commitment of both teacher and pupil to see the importance of learning design through such a double learning loop process.

The importance of enhancing pupil's spatial/visual intelligence and the role of sketching/drawing in pupil's design ability cannot be overstated.

It is hoped that this research study will provide a sampling of insights into the nature of how Design and Technology is being taught

and how it can be taught. Pupils doing 'well' in designing will be placed in a good position when they embark on their tertiary education.

They will bring proper recognition of D&T as a subject in tertiary education. And the answer to question such as 'Do our pupils really know designing?' will be a resounding 'yes'!

Last but not least, as this is a pioneering study of its kind in the Singapore context, it is hoped that this inquiry will be the first of many more research works to be carried out in the area of Design and Technology. Ample opportunities are available for disciplined research work in this area.

#### FINAL REMARKS

It must be emphasised that this research study looks into the design aspect of the D&T subject in a Singapore secondary school context. The importance of design has been clearly stated at the outset of this paper and emphasis could be drawn from the many research studies reviewed. For the purpose of this research study, the technology part of the subject was taught by another teacher. So if the writer were to teach the latter, the process may have to take into consideration the level of technical materials. This the writer had attempted minimally when discussing with pupils. For future studies, the technological aspect of the subject area may have to be looked into in detail.

This research also revealed the emerging so-called "Double Looping Learning - Model" as shown in Figure 1. The "Double Looping Learning - Model" intertwined with the different levels of technological know-how move to higher levels of difficulty as both teacher and pupils work closely together. The teacher learning-teaching in a teaching environment, spirals through the different levels of knowledge in technology, scaffolding along with him/her the pupil through this process of design. The different level of technological know-how will have to be incorporated in future studies.

This sums up the case study of the teaching of Design and Technology in a secondary school.

"Double-Looping Learning - Model"

Figure 1

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