Title	Fostering creativity in science through design and technology: Pencil holder project
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Fostering Creativity In Science Through Design And Technology: Pencil Holder Project

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Introduction

Creativity is often a misunderstood term. To be creative is not to have a blinding flash of inspiration that has come from nowhere. Many say that a "creative child" is someone who is able to "make something out of nothing". According to research by Koberg, creativity is more likely to be the result of thinking broadly about an issue and giving time to ponder over the problem than just to sit down and find the answer within a minute or even a day.

In recent years, the Ministry of Education in Singapore has been placing a great deal of emphasis on teaching thinking skills in schools. "Thinking School and Learning Nation (TSLN)" was launched in 1997, with the aim of fostering higher order thinking skills (critical thinking, creative thinking and problem solving) among Singapore students. Teachers have been encouraged to teach creatively and to find ways to develop students' thinking skills, including creative thinking, through content instructions in various subjects. The Thinking Programme, aiming to help our students become critical, creative, and self-regulated thinking learners, has since been incorporated as part of the secondary school curricula. Courses in the teaching of thinking have been conducted by the Ministry of Education (MOE), the Singapore Centre for Teaching Thinking (SCTT), and the National Institute of Education (NIE) (Tan, 2000) for teachers at both secondary and primary levels. Fostering creativity among students through science teaching has become a challenge for science educators.

Being able to identify or recognize a problem that can be solved and then find a way to solve it actually is a form of discovery. Problem solving is therefore a unique way of thinking. Moravcsik (1981) has suggested creative thinking in pupils be promoted by using open-ended experimental-based problems. In Design & Technology, students have the perfect opportunity to do this.

Despite the need to foster creative talent in science and technology, creativity is only sparsely discussed in the science education literature (Garret, 1989, 1987; Moravcsik, 1981; Washington, 1971). Creativity and the so called 'creative subjects' are separate areas of the curriculum commonly isolated from science, and usually not thought of as a proper domain in the science curricula (Garret, 1987).

There is a general perception that Asian students are not so creative. Lately, there have been a number of science and technology competitions in Singapore to encourage students to participate in order to display their creative talents. These include the Physics Toy Invention Challenge in Raffles Junior College, the Tan Kah Kee Award, Singapore Young Inventors Award, the Robotic and Solar Car Competitions by the Young Engineers Club in Singapore Polytechnic and others. In most of these competitions, a significant amount of marks is awarded for creativity.

It is unfortunate that many competitions in Singapore draw attention to the final product rather than the process of coming up with the product. Judging is usually done on a specific day by awarding marks on the performance of the product and the design of the product. By doing this, judges do not actually get to see the learning process and struggles that a student goes through. What the judges see is a final product that exhibits some form of scientific concept that would fulfil the judging rubrics. This would indeed have a negative impact on students who actually do not meet the high expectations of the judging criteria but have learnt a lot more than others while coming up with their product.

Rationale for Study

After studying the various problem-solving models, we find that Design & Technology can be a powerful vehicle to allow secondary school students to display their creative talents through solving a problem.

Students embark on a learning journey and go through the design process after which they come up with a product of their interest. During this journey, they will record their thoughts and ideas for solutions in the form of portfolios. In doing so, they will improve their graphic communication skills and also have scope to synthesize ideas for the optimal solution. Also while going through the process, students get to conduct research. Included in their portfolios are Gantt Charts that students create to plan out how much time they will need to spend in prototyping their solutions. The 'O' level rubrics in Design & Technology award marks for process-based learning. It allows for creative thinking by allowing students to design a problem of their choice based on a theme and construct artifacts to their liking and the liking of users of such products. Also while going through the planning stages of their projects, students are required to apply scientific knowledge in the areas of mechanical, structural, electronics and material sciences. Students usually apply the theoretical knowledge they acquire in Physics and apply it into their artifacts. While going through the planning stages, students come up with hypothesis, experiments and models to ensure that their artifacts will function properly. In short, Design & Technology provides an excellent platform to foster innovative and inventive mindsets.

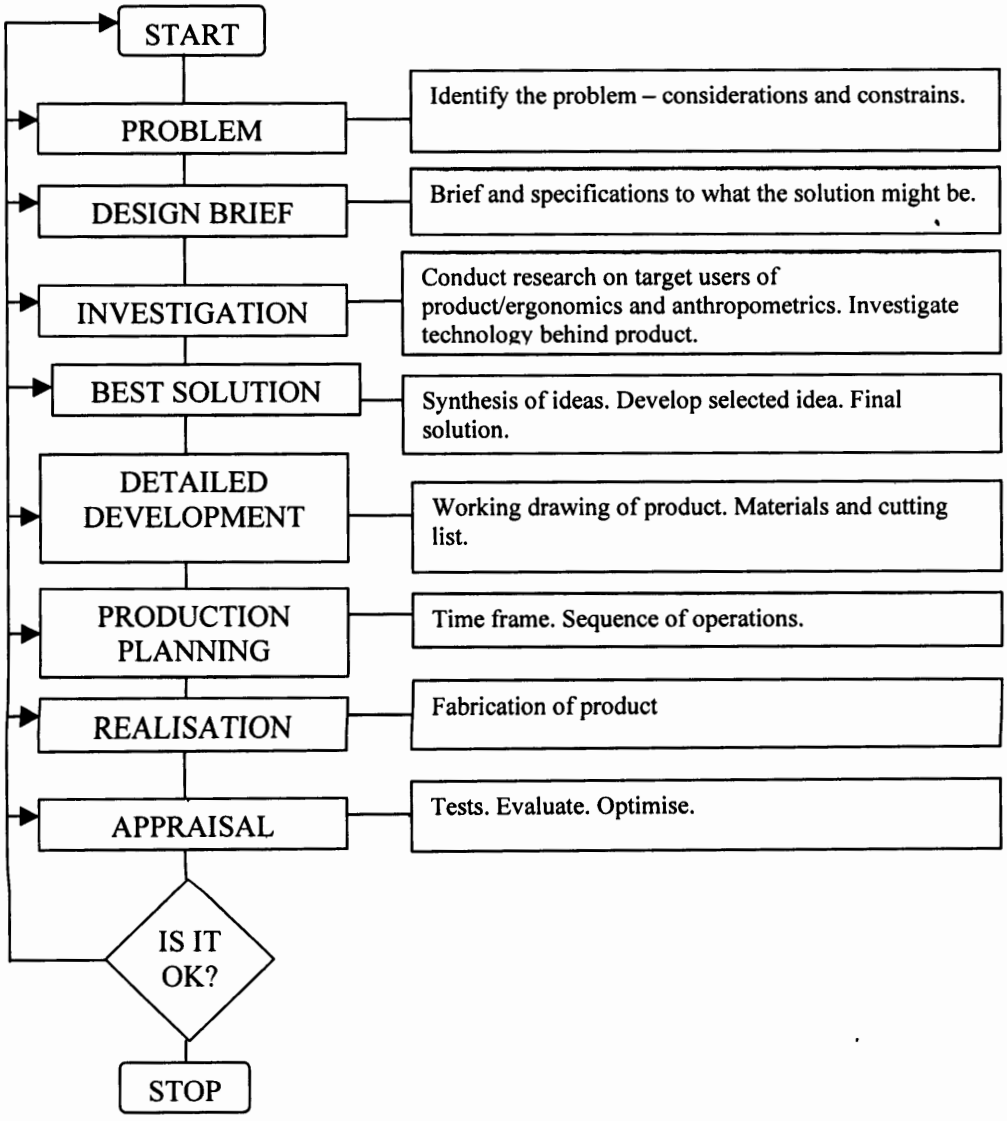
The two major areas of research in this project are:

- To study if creative mindsets can be measured through a student's portfolio and product he / she produces
- To investigate if the creative talents of students taking up Design & Technology can have an impact on the learning of Science

The Design Process in Design & Technology focuses on the approach to solve a problem through several stages. Although these stages are essential in the problem-solving process, it is non-linear.

Methodology – Pencil Holder Project

We tried measuring creativity and design with a group of 25 Secondary 3 students in Greenview Secondary School within the Design & Technology curriculum through a simple pencil holder project. These students are of 15-16 years of age and comprised 9 females and 16 males. We decided to use a similar problem to the one given to NIE trainee teachers for the PGDE (Sec) D&T programme. However, certain modifications have been made to suit the interests of secondary school students. In particular, this project aims to measure the creative talents of secondary school students through a unique set of rubrics based on MOE guidelines. A considerable amount of marks is awarded to the process of coming up with a mini portfolio of about 7-10 pages.



The pencil holder project seeks to ensure that students recognize the need for a housing joint and also allows them to develop their graphic skills as they go through the design process of sketching their thoughts and planned actions in a mini-portfolio. They are to realize their final solution through an artifact, which should be completed in about 4 hours. There are a number of physics principles that they need to recognize in the course of fabricating their prototype, for example, dynamic stability, centre of gravity, and so on. Students should go through the design process as shown above.

Problem Based Learning

In order to spark off interest in the project, we developed a problem situation and students go through the problem based-learning (PBL) approach to come up with the solution.

Through PBL, students build substantial knowledge bases when they form hypotheses, refine and enlarge what they know, collaborate with classmates, articulate their thinking during discussions, and engage in self-directed study. Through this process, students are also made more aware of their cognitive skills.

We want to show that:

- The simple problem crafted for this pencil holder project will be the starting point of learning about design process and structural technology.
- The problem is usually a real world problem – students can relate to how designers and engineers have to work hand-in-hand in the real world when dealing with time and material constraints.
- Self-directed learning is primary. Thus, students assume major responsibility for acquisition of information and knowledge. We want them to learn the relevant content knowledge in order to come up with optimal solutions in planning.
- Learning is collaborative, communicative and co-operative. Students can work together in small groups in the first instance and then proceed to display their craftsmanship skills through fabrication of the pencil-holder.
- Development of inquiry and problem-solving skills are as important as content knowledge acquisition for the solution of the problem. The teacher facilitates and coaches through questioning and cognitive coaching. Students should be aware that the design process is a powerful tool that will help them in their problem-solving journey.

Requirements of the Pencil Holder Project

An overview of the requirements for the pencil holder project was shown to the students. They are to complete their designs in mini portfolios during the one week March holidays. Instructions given to them were as follows:

Greenview Secondary School
Design & Technology (6049)
Secondary 3 Express 2004

March Holidays – Assignment

Assignment – Pencil Holder Project

a. You are to complete this mini-project and embark onto making the product very early in Term 2.
b. You are to copy the following and submit your mini-project in the form of plain A4 papers stapled or filed together.
c. The total number of pages should not be less than 7 pages and no more than 10 pages.
d. Your Pencil Holder Mini-Folio Assignment should include the following:
    - **Design Situation**
    - **Design Brief**
    - **Design Specifications** – place them in correct order of importance (show me your understanding of considerations and constrains)
    - **Investigation** of: - Strength of Through Housing Joints, -Suitability of Pine Wood, -Lengths of Various Pencils (Wooden and Mechanical)
    - **Exploration of Ideas** of Pencil Holders (5 Ideas) → Indicate clearly your **Chosen Idea** (Explain Briefly Why You Choose This Idea)
    - **Working Drawing** in First Angle Orthographic Projection of your chosen idea
    - **Production Planning** – sequential steps you would take to make the pencil holder

It is clear to students that they need to sketch their thoughts and action plans within the constraints of 7 – 10 pieces of plain A4 paper. The students at this point may not even know what a pencil holder may look like. However, that is not the main concern of discussion in this project. We would like to have them explore existing pencil holders that are available in the market. This would mean students might have to go out of the classroom and engage in some form of research by either looking up the Internet on pictures of pencil holders or visiting Ikea, MPH, bookstores or stationary shops to get some ideas of pencil holder designs. It is important that the students embark on the design process and learn as much as they can before finalizing their designs.

A few questions we ask ourselves while crafting the project are:

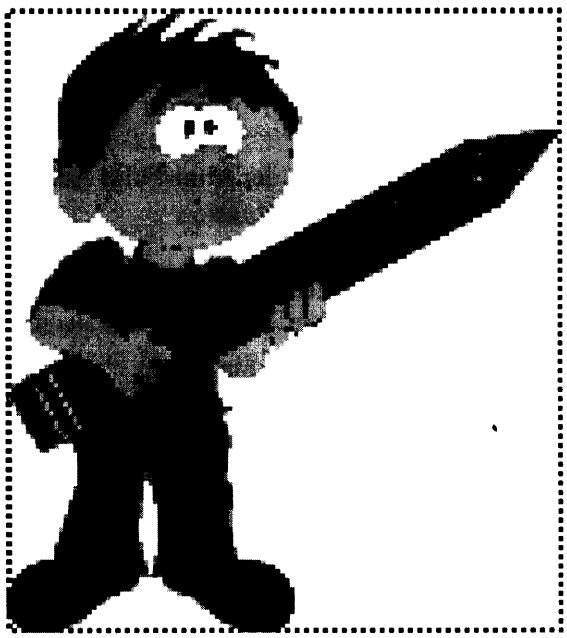
- What do we want the pupils to achieve?
- What folio evidence will illustrate their achievement?
- Have we taught the necessary graphic techniques in order that they can communicate their thoughts and action plans?
- Have we taught them how to carry out these design activities?

As mentioned, we tried to get the Problem/Design Situation as closely as possible to what engineers and designers would do in the real world. The following MTP was crafted in the hope that students can motivate themselves into thinking on their design.

Meet The Problem (Design Situation)

1) Design Situation – The situation will give you a general background to the problem

You are a Designer for a local design company – DESIGN UNLIMITED. You have been asked by your boss to design a pencil holder, incorporating **Through Housing Joints**, to be made of **pine wood** for your clients. Most of your clients are school teachers. However the pencil holders you design are not for teachers but for students on Youth Day.



Your pencil holder will be a prototype model and mass manufactured for 1500 teenage students of about **13-16 years of age** in a particular secondary school.

Engineers in your company have told you that they can only supply one piece of **Pine Wood** of dimensions **(300x70x20)** mm for your prototype model.

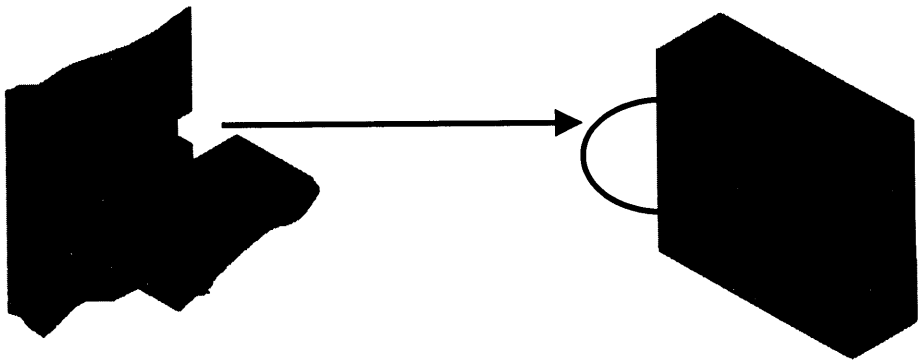
The engineering division of your company is working on a tight schedule and the engineers can only afford **3-4 hours** to work on your prototype design.

You are given exactly one week to come up with a working drawing (in accordance to the 1st Angle Standards) of your proposed Pencil Holder.

Good Luck!

Students know, at this point, that they only have one pinewood piece to work with and that they have a time constraint of 3-4 hours. Furthermore they are to plan their time so that they can spend part of their one-week vacation doing the assignment.

Most of the students do not have much idea though why we chose a housing joint to be constructed in such a project. At this point, they have no experience in cutting a housing joint. They do know however, from Secondary 2 theory, that a housing joint is useful in the construction of a carcase.



Housing Joints Used For Shelves In Carcasses – Knowledge Acquired in Secondary 2

This deliberate shift from their prior knowledge of housing joints used only in carcases and shifting that mindset to look into other possibilities these joints may prove to be useful in instilling creative abilities and attitudes in them. The first step taken towards instilling creative abilities and attitudes would be to allow them to consider possibilities and alternatives (changing and reapplying) on existing ideas.

Guiding Students Through The Design Process

We decided to guide the students through the design process by specifying certain areas that we can assess them on. These key areas that should be described in their design portfolios are:

- Analysis of Theme
- Exploration of Ideas
- Detailed Development
- Production Planning
- Proficiency in Graphic Communications

The following was given to the students to show the key areas within the design process that the students needed to produce in their design portfolios for the pencil holder project:

2) Design Brief – The design brief is a summary statement that clearly states the aim of the design project and in a few words states the kind of thing that is needed. For example. "Design a toy" is not very useful to a designer. "Design a toy for a designer a clearer focus without applying restrictions.

Write a Design Brief for your Pencil Holder

3) Design Specifications – Once you have a clear understanding of the problem, you can work out the specifications for your Pencil Holder. A specification is a list of things that the final design must do. A good specification will list all the important features in order of importance.

Example: "The toy should be painted" does not give the designer enough information. "The toy should be painted a primary colour" is a clear statement without restricting the designer.

Specifications also provide a checklist against which you can review your ideas as you are working. They also give you something against which to evaluate your ideas and your finished product.

Write your Design Specifications for your Pencil Holder

- **Make a list of all the features you need to include in your design.**
- **Place them in the correct order of importance**

4) Investigation

a. Do a bit of reading in your book an look into the advantages of using a **through housing joint** – look into the strengths, suitability, etc
b. Jot down why you think your boss has asked you to make the souvenir out of **Pine wood** instead of other wood (meranti, ramin, etc) – jot down your research.
c. Who will the pencil holders made for? – Do some form of research on comfort levels (Study of **Ergonomics** and **Anthropometrics**) – so that the Pencil Holder would be easy to use.
d. Feel free to do any form of other research to impress your boss that your design will be suitable for the users.

5) Exploration of Ideas

a. The Internet is a powerful tool to get ideas for
b. Do group work. It's always so much easier to sketch just 1-2 ideas and share them with your friends. In return, get their ideas into your folio as well. After all you only need 5. Sketch more if you feel it's going to help.
c. Always bear in mind of your constrains while working on your ideas.

6) Working Drawing – the name says it all → remember its 1st Angle Orthographic Projection.

7) Production Planning:

a. Simply draw a time frame for your engineers so that they can at least try to follow it closely and not lose track of time.
b. Eg: Week 1a (30mins) – Mark out the wood, Week 1b(30 mins) - Cut out Piece A and Piece B. Week 2a & 2b (60mins) – Cut out Though Housing Joints. Week 3a (30 mins) - Drills holes in Pieces A & B. Week 3b (30 mins) – Glue and Assemble the pieces. Week 4a (60mins) – Sand the Pencil Holder – make it smooth and apply finishing.

Assessing Different Components In The Design Process

We want the students to take their design folios very seriously. They could capture their thoughts, reflections and learning in terms of notes and drawings in the folio. The folio should show a meaningful record of their plans, progress and achievements. Design folios should reflect a variety of approaches and design problems should be tackled and recorded in different ways. Folios will often illustrate the student's strengths and individual interests in terms of graphics, annotation, and technical and aesthetic expertise. A good folio will have depth and will not be superficial. Also a good folio will support and reflect the production of a good quality final product. Frequently a well-made, nicely finished product is supported by a meaningful and realistic folio

Rubrics for Assessment

The following is a set of rubrics we designed from the MOE guidelines.

Part A - Mini Design Folio Components (60 Marks)

	Analysis of Theme (10 Marks)	**Marks**
a)	Design Situation	/ 2
b)	Design Brief	/ 2
c)	Design Specifications	/ 6
	Exploration of Ideas (10 Marks)	
d)	5 imaginative ideas with annotations & indication of chosen idea	/ 10
	Detailed Development (25 Marks)	
e)	Investigation of Through Housing Joints	/ 5
f)	Ergonomics and Anthropometrics Investigations	/ 5
g)	Working Drawing - First Angle Orthographic Projection	/ 5
h)	Exploded Diagram of Pencil Holder	/ 5
i)	Cutting List	/ 5
	Production Planning (10 Marks)	
j)	Time Frame	/ 2
k)	Sequence of Operations	/ 8
	Graphic Communications (5 Marks)	
l)	Clear graphic presentation and details	/ 5
	Total Marks For Design Folio =	**/ 60**

Part B - The Artifact (40 Marks)

	Creativeness & Inventiveness Of Proposed Solution (15 Marks)	**Marks**
a)	Check Against Specifications	/ 5
b)	Aesthetics & Technical features quality	/ 5
c)	Sound In Most Aspects & has good features	/ 5
	Workmanship (15 Marks)	
d)	Precision and accuracy - mastery of most aspects, refinement to detail	/ 5
e)	Ability to demonstrate skills in cutting through housing joints	/ 5
f)	Ability to apply finishing (lacquer) that will protect and enhance the artifact	/ 5
	Evaluation (10 Marks)	
g)	Test against specifications	/ 5
h)	Modifications/ Learning points communicated throughout process. Suggestions for further improvements.	/ 5
	Total Marks For Artifact =	**/ 40**

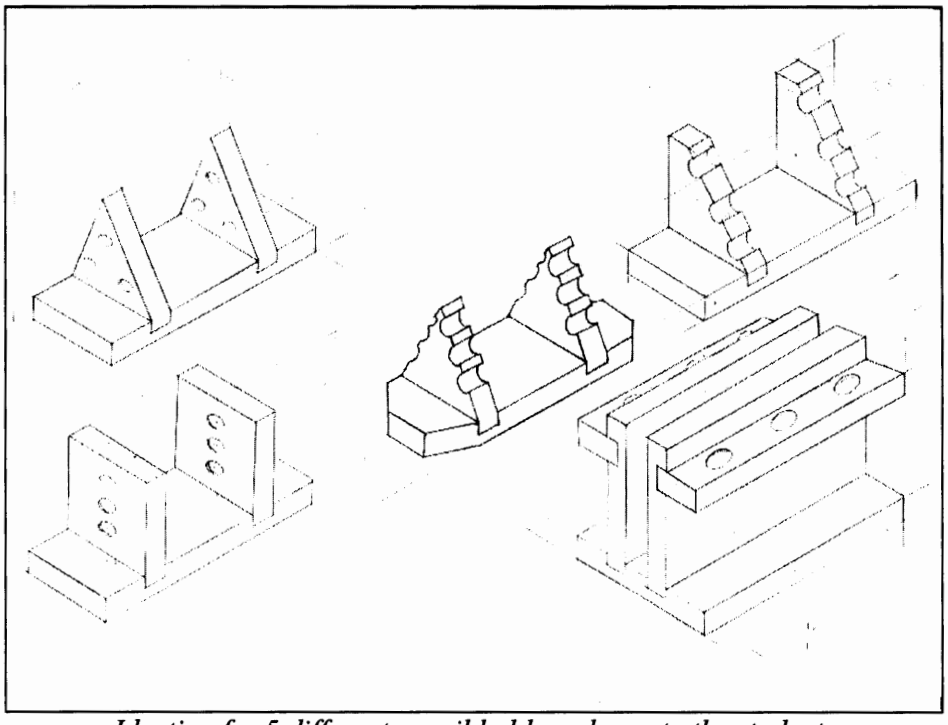
Evaluation (Process & Product)

We set an oral presentation for students to comment on their pencil holders. It is important here that we listen to what they have to say about their products. We would want them to test the pencil holders against specifications and ask them to recommend further improvements. We want them to cite what went wrong during planning/ fabrication process. Some questions that are of interest include:

- What are their learning points in this project?
- Were they being too ambitious?
- Did they think that 3-4 hours was actually a lot of time?
- Did the planning help them?
- Should we ask them to re-do the project:
  a. What parts of the design process will they improve on?
  b. Will they still chose the same design?
  c. Will they be more involved in producing a good design folio?
  d. Why?

Administration of Project

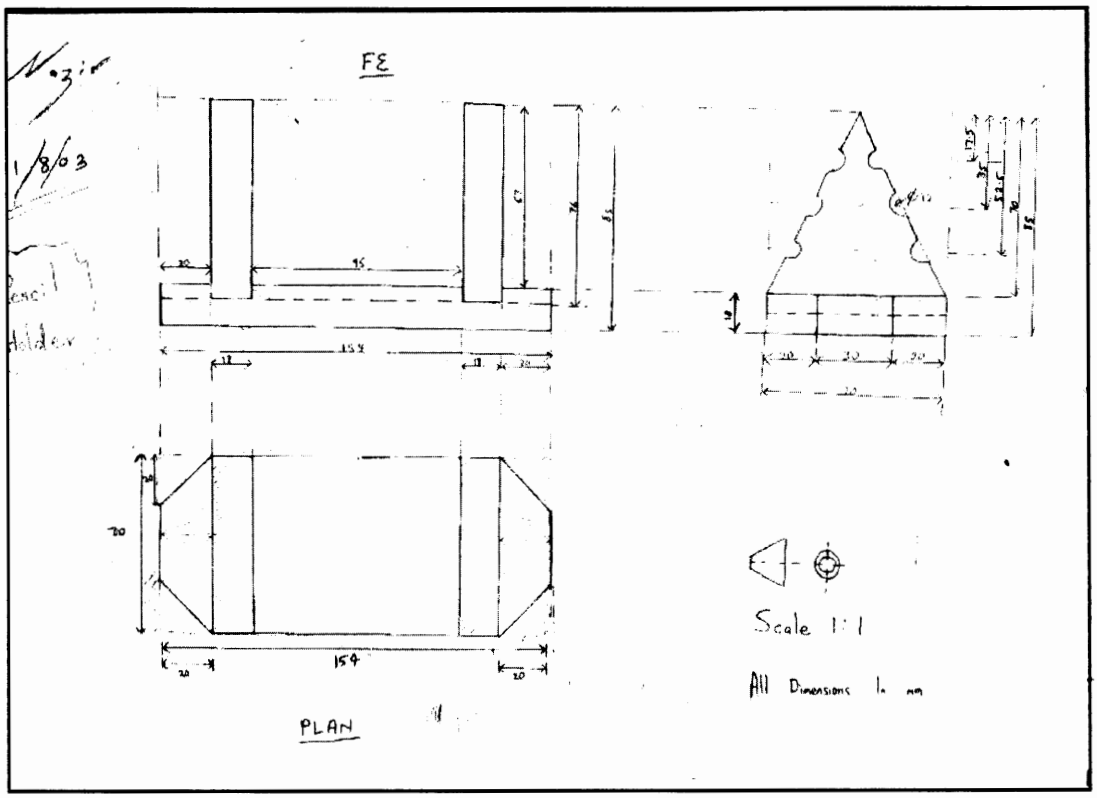
The project started of at the end of Term 1 just before the March holidays. Students were given the March Holidays Assignment, which comprised of 3 pages. These students had one week to manage their time in coming up with the design plan for production. During the time when we mentioned to the students about the project, we showed an example of what some stages of planning may look like. A sample of ideation was shown as follows:



Ideation for 5 different pencil holders shown to the students

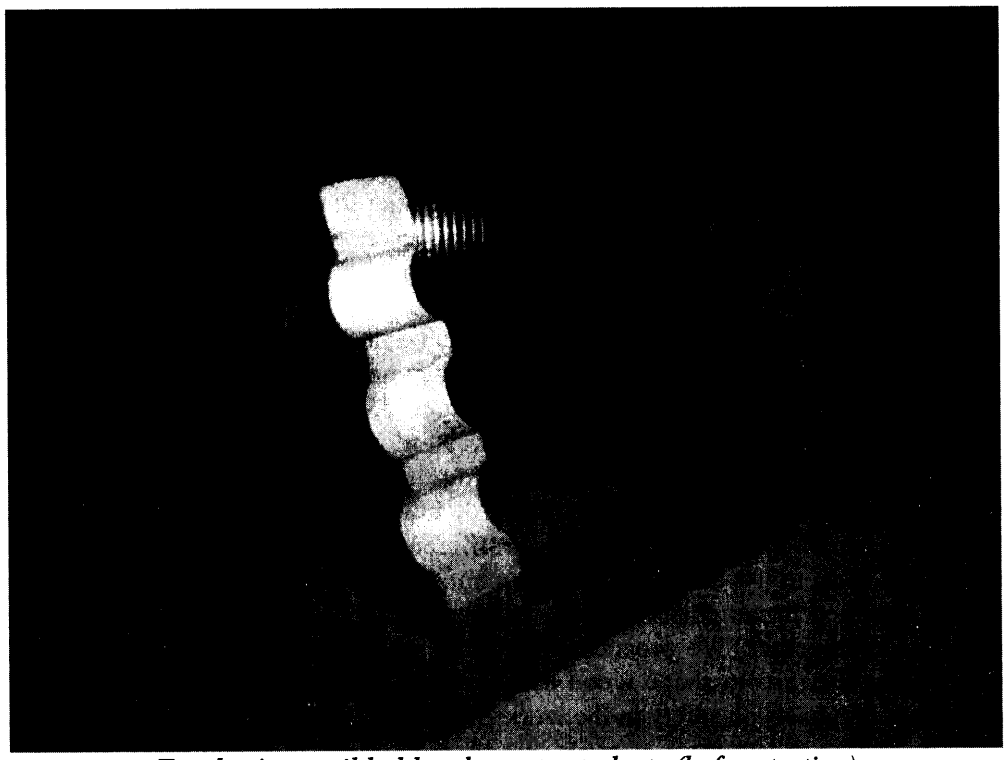
Students were made to note that it would be better for them to sketch a few ideas and put them into a single page rather than many pages. This would trigger them to synthesize the ideas to come up with the optimal design. Furthermore, students were instructed to annotate their ideas to reflect their thoughts on the design.

They were also advised to come up with working drawings to show how they want to go about marking out the wood form the given piece measuring 300x70x20 mm. An example is shown to them:

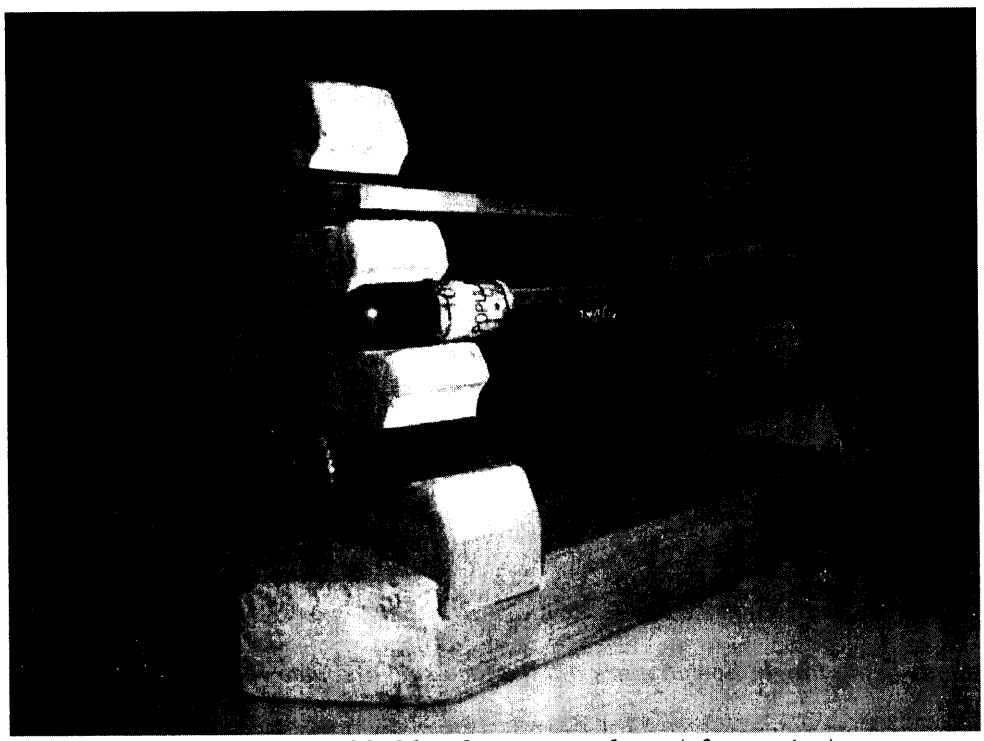


Working drawing (1st Angle Orthographic Projection) shown to students

A sample of the final product was also shown to them. We did not want to structure their minds as to what a pencil holder should look like. As such, we only showed them just one sample and the rest is up to their 'creativity'. We asked students to comment on the designs of our pencil holder. There are many design setbacks that appear in our pencil holder. Many of the students were very honest and gave strong feedbacks that our pencil holder could only hold long pencil, and after testing, could only effectively hold up 4 pencils effectively without allowing them to roll off. This is an important part to kick off their interest in the project. We allowed them to comment and discuss areas of improvements of existing pencil holders.



Teacher's pencil holder shown to students (before testing)



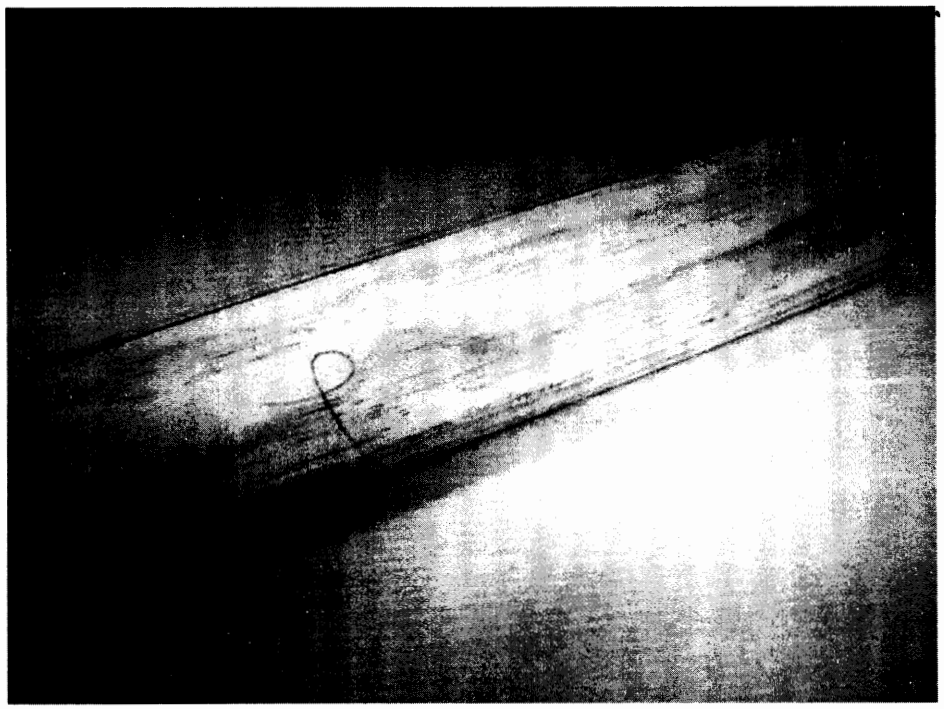
Teacher's pencil holder shown to students (after testing)

Their folios were checked once school re-opened on the first week of Term 2. Students proceeded with the fabrication of their mini pencil holder on the beginning of the following week.

Technical Skills Learnt From This Project

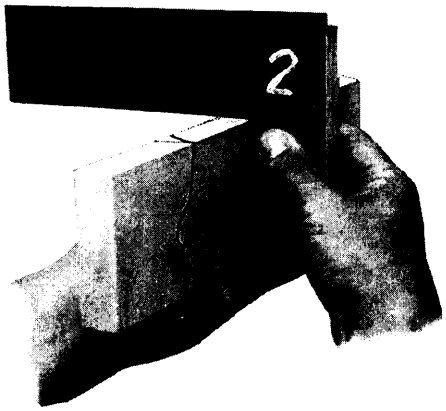
During the first week of Term 2, they were taught skills in marking out the face side and face edges of a piece of pinewood. We proceeded to teach them the different types of wood available and lessons on wood processing.

Students embarked on the pencil holder project in week 2 using the knowledge acquired from week 1.We started off by allowing them to have hands-on experience in marking out their pieces of pine wood. They were initially taught to check for squareness of the wood pieces using the steel rule and try-square. This was followed by teaching them marking out techniques on the face sides and face edges using the marking knife. Students were then taught how to use the smoothing plane to cut their wood to size. We then moved on to teach them the use of a marking gauge to set different depth levels for their housing joint. We also taught them to use tenon saws to cut a housing joint and pare a housing joint using a wooden mallet and firmer chisel. Finally they were taught skills in using the PVA glue to stick two pieces together. We proceeded to revise their knowledge on drilling holes on wood and using the rasp to shape wood as we went along. Throughout the lessons, there was a constant emphasis on safety in the workshop.

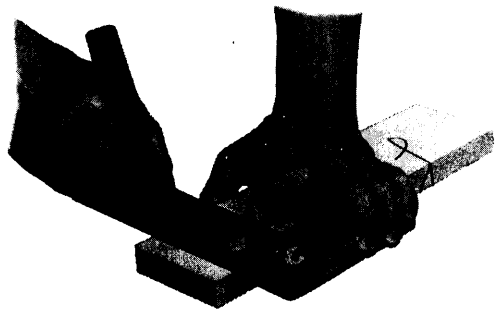


Students being taught how to mark out the face side and face edge on their pine wood

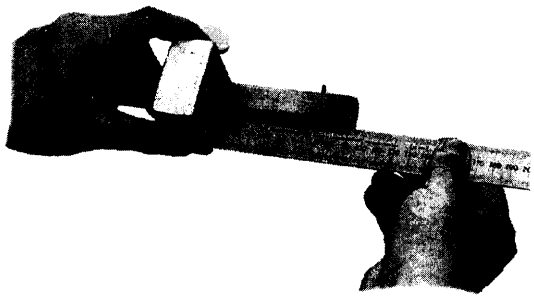
Several skills students acquire during the process of making their pencil holder:

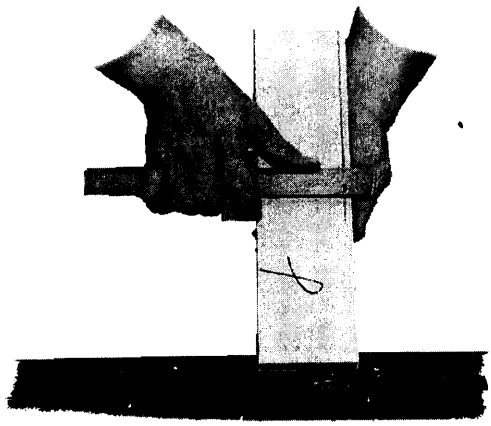


Checking for squareness on the face edges

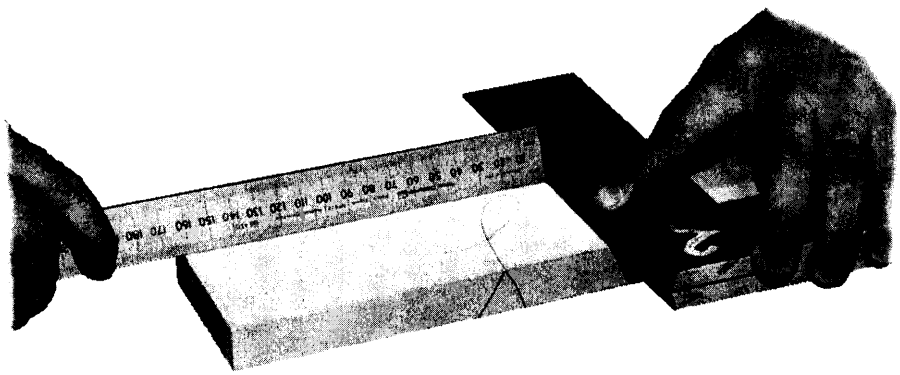


Marking a cutting line across the wood grain





Marking a parallel line to an edge of a wooden workpiece

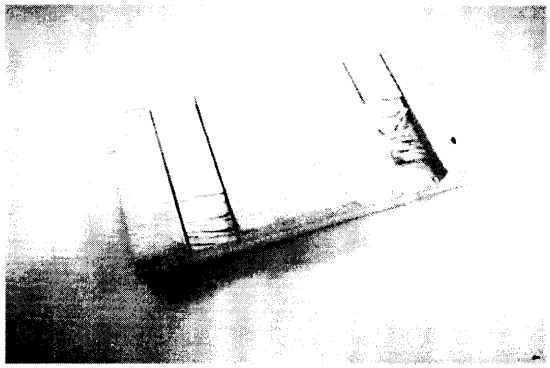


Measuring the dimension with a steel rule

Planing techniques using a smoothing plane

Using a firmer chisel to pare a housing joint

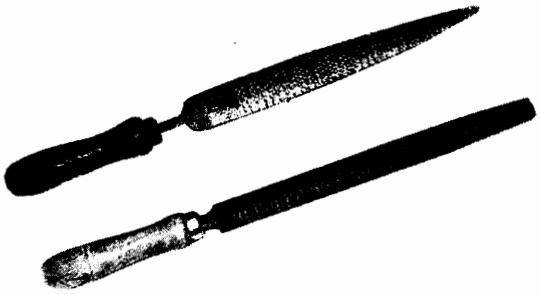
Using a tenon saw to cut a housing



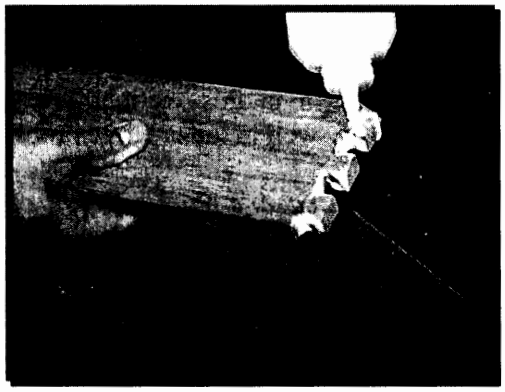
Incomplete housing joint produced

Using a bradawl to mark out locations of holes to be drilled

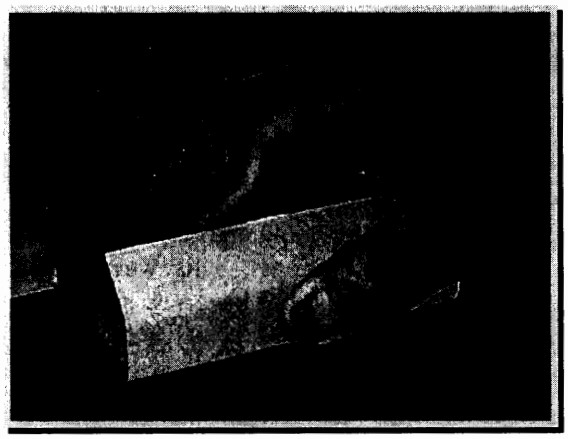
Drilling holes into the pine wood



Using Rasp to shape the wood



Using PVA glue



Sanding the wood with sanding paper

Applying lacquer as finishing

Results

We had a variety of creative abilities were displayed by the 25 students doing this project. During the process of coming up with the folio, we noticed that students had very few questions. However they started asking more questions about the project once they have to hand in their working drawings before embarking on the fabrication process. This shows us that, given time, students need a lot of motivation in the problem solving process. They are most motivated when they are about to do something to their liking. We would like to show samples from the design folios as well as artifacts, produced by the students, before and after testing with several pens and pencils. We feel it would be easier to categorize the projects into sections that achieved distinctions, satisfactory and poor performance (where there is room for improvement).

Creative Problem Solving Achievements (Excellent – A1/A2)

We found that there are 5 students who obtained a distinction for both their design folios and artifacts in this pencil holder project. A few samples from the various sections of their folios are shown in this section. We start by showing an example of a student who performed very well in the creative problem solving process.

Example of A Student's Work In The Problem Solving Process

May Lee is a Secondary 3 Express student who has not performed well in her overall academic performance in 2003. As a result, she had to repeat the level again in 2004. Her positive change in attitude towards her studies, Design & Technology, in particular made an impact in her life. By the end of the first semester, May became the top student in Design & Technology and one of the highest in standards for every other subject. She achieved an overall grade of 89% for this project (93% for her Design Folio and 83% for her artifact). Strictly speaking, May never actually kept to the design constraints given to her. While going through her ideation stages, she found it necessary to ask for a small piece of clear acrylic that could be used in her design. She justifies to us why she needed such a piece of plastic. After discussion, we felt it would be alright for her to be given the acrylic. To be fair to the others, we also told them that should they require additional materials, they would have to justify their reasons for such needs.

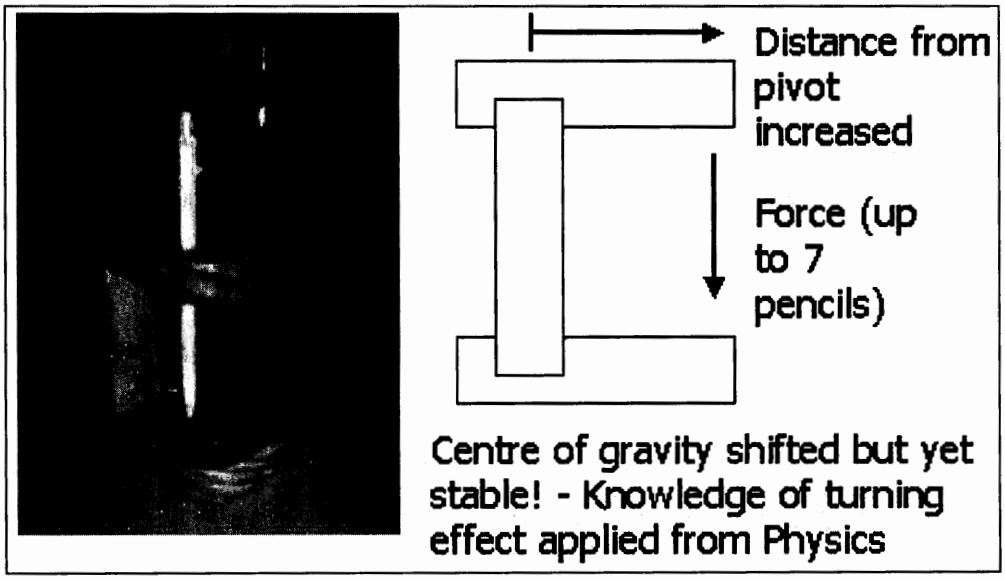
Harris (1998) explains to us clearly that creativity is an ability, attitude and process. This is evident in May's work. Her ability was enhanced due to the interesting and unconventional teaching and learning approaches both teacher and students adopts. This was clearly explained by Lee (2001). Her process of critical and creative thinking becomes evident in this problem solving process.

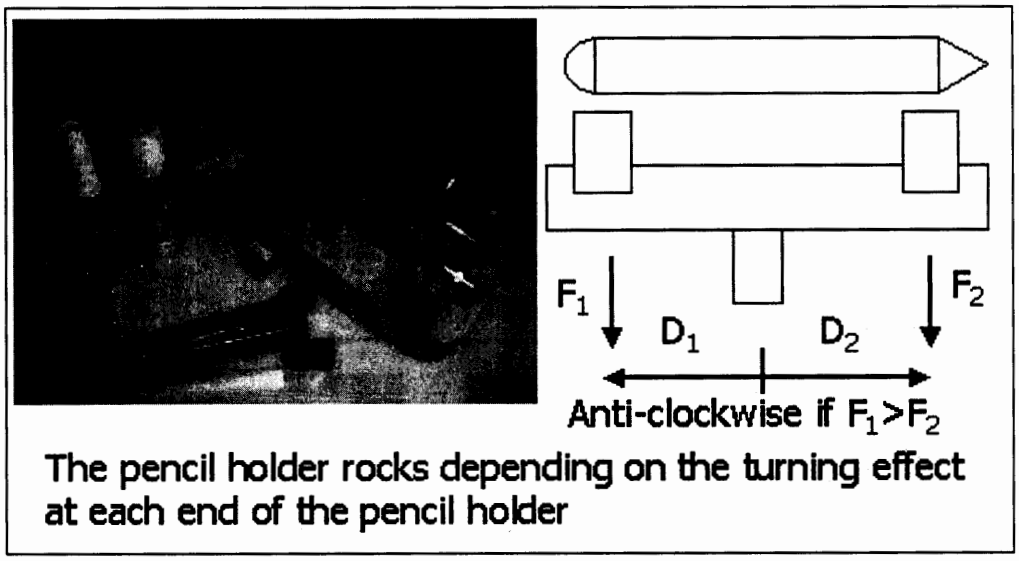
May's Results

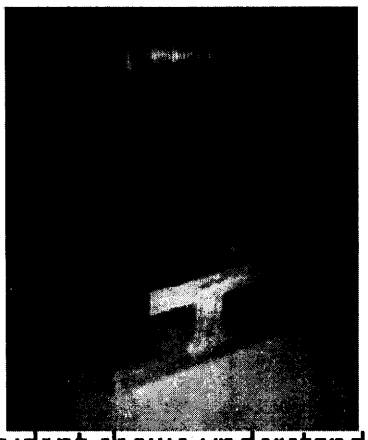
Design Folio (60%)	**Marks**	**Artifact (40%)**	**Marks**
Analysis of Theme	10/10	Creativeness & Inventiveness of Proposed Solution	12.5/15
Exploration of Ideas	10/10		
Detailed Development	22/25		
Production Planning	9/10	Workmanship	11.5/15
Graphic Communications	4.5/5	Evaluation	8.5/15
Total for Folio	55.5/60	Total for Artifact	33/40
Percentage for Folio	*93%*	*Percentage for Artifact*	*83%*
Overall Percentage for Project = 55.5 + 33 = 88.5%			

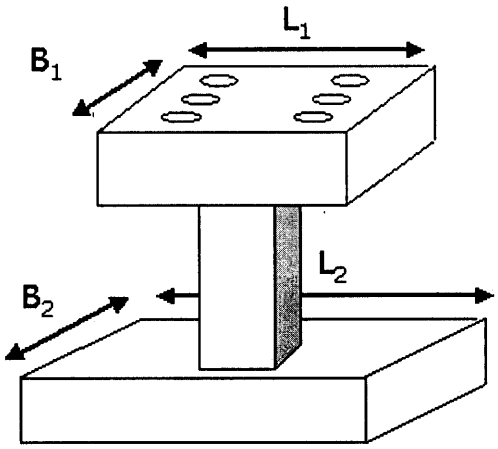
Student's Application of Scientific Concepts Into Their Projects

In this section, we show that students were able to apply scientific knowledge acquired from Physics into their artifacts.



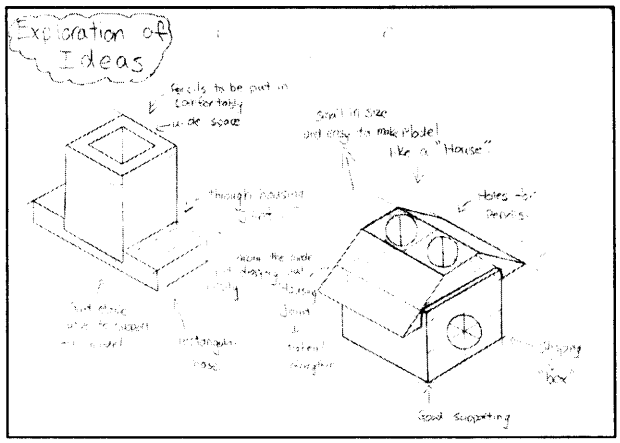


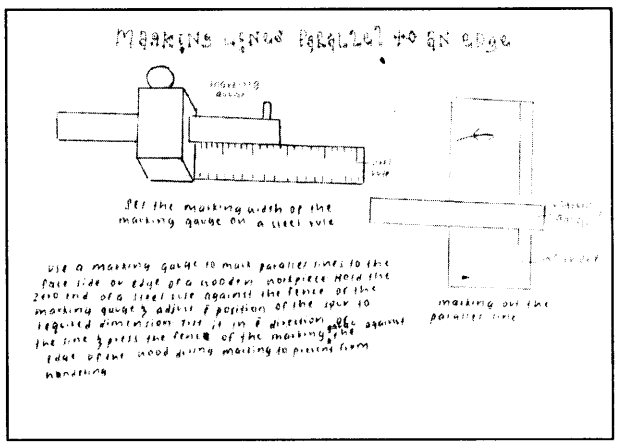


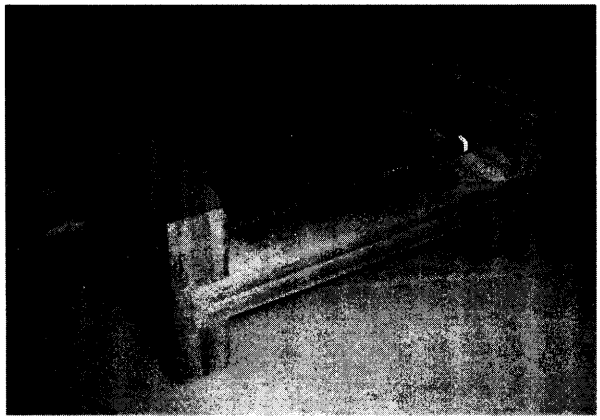


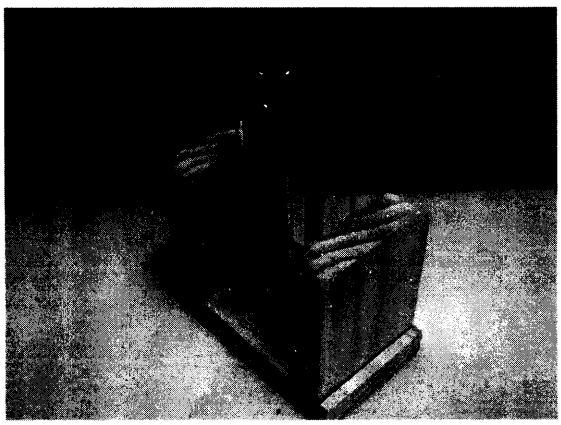
Student shows understanding of stability – to keep the pencil holder stable, the base area has to have a larger surface area than the top $(L_2 \times B_2) > (L_1 \times B_1)$

Samples of Pencil Holder Folios & Artifacts









Observations During The Problem Solving Process

While marking the folios, it is evident that students go through divergent and convergent thinking. However, we were hoping that students would actually synthesize various ideas before coming up with the chosen idea during the process of convergent thinking. This was missing on many of the student's part. Even if they did go through synthesis of several ideas, this was not reflected it in their folios. They seemed to choose an idea which they liked rather than picking out the best features of each of the ideas to come up with the chosen idea.

Another common misconception we notice is that students think that evaluation takes place only at the end of the project. Students constantly try to show that they think design is a very structured linear process. They fail to link up the components of this process to make up a story flow. Renwick (2003) explains that even teachers have difficulty allowing students to see the flow in a big picture. A teacher commented:

"Currently, we find that students have difficulty in linking the different portions of the design process in the folio properly"

Renwick encourages teachers to recognize how thinking, designing, making, graphics, the folio and the process are linked in an explicit manner.

Most teachers who teach Design & Technology now are engineering graduates. We recommend these teachers explain that engineering is the process of applying scientific and mathematical principles, experience, judgment, and common sense to design products or processes that benefit society.

Misconceptions In Design Folios That Lead To Poor Performance

Several students developed misconceptions that being able to be creative is to draw something nice or 'to even edge out their friends' by trying to be different. This is shown on a few folios where students cut papers and stick them into their folios thinking that they can score better by impressing the teacher. Shown here are few examples:

Students' misconception in trying to impress that they are creative

It is important to note that students have a good grasp of the 'big picture' of the design process. Being able to be creative is not about decorating their folios or impressing the

teachers. It is to go through the design process and be weary of the steps taken to engineer a solution.

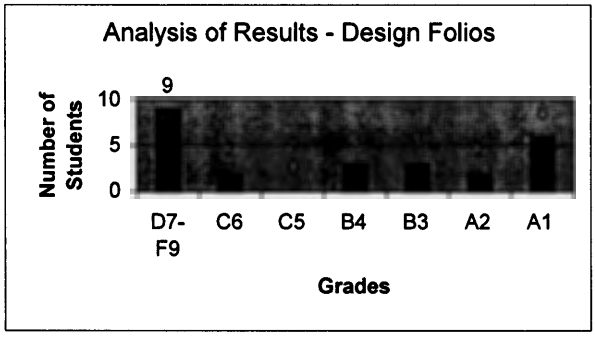
Analysis of Results & Discussions

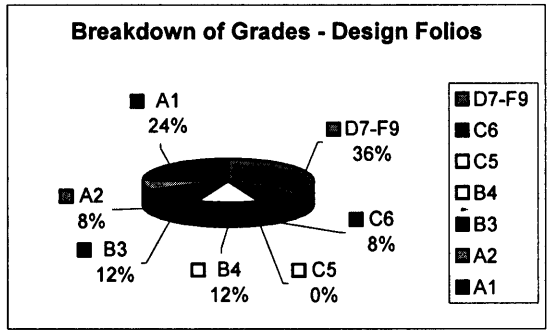
Analysis of Results

This section aims to show how we measure the creative levels of the students through our rubrics. We first analyzed the results of the 25 students in terms of grades they obtained for their Design Folios, Artifacts and their combined grades. The results for this project are shown as follows.

Analysis of Results – Design Folios (60% of overall grade)

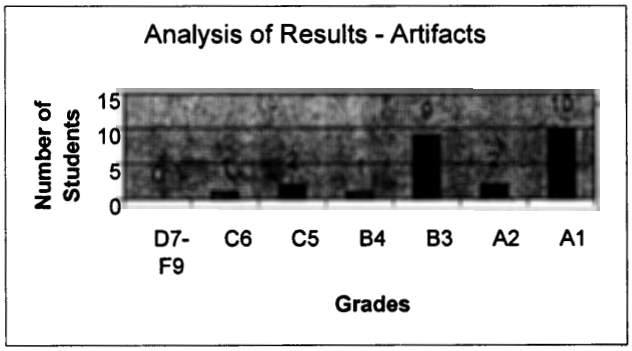
Marks Range	Grades	Class		Total No. of Students
		3E2 (16 Students)	3E3 (9 Students)	
0 - 49	**D7 – F9**	6	3	**9**
50 – 54	**C6**	1	1	**2**
55 – 59	**C5**	0	0	**0**
60 - 64	**B4**	2	1	**3**
65 – 69	**B3**	3	0	**3**
70 - 74	**A2**	1	1	**2**
>75	**A1**	3	3	**6**

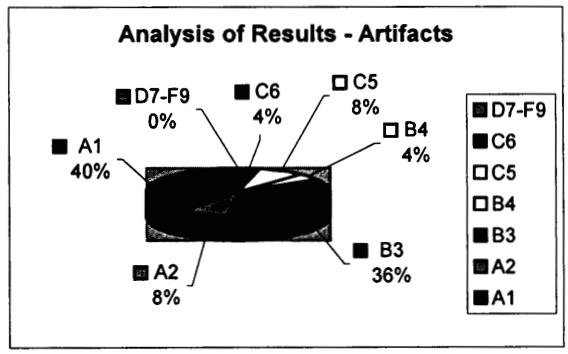




Analysis of Results – Artifacts (40% of overall grade)

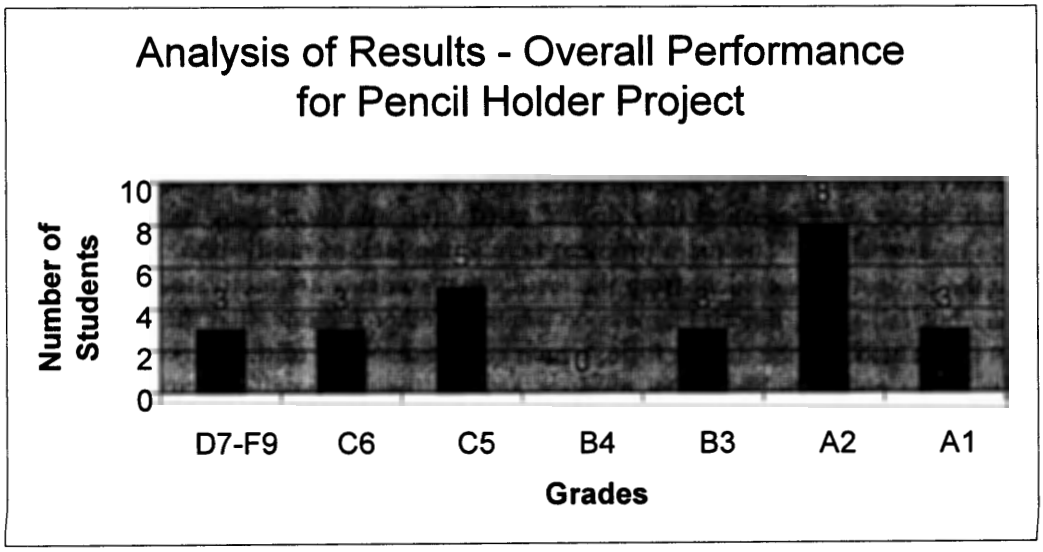
Marks Range	Grades	Class		Total No. of Students
		3E2 (16 Students)	3E3 (9 Students)	
0 - 49	**D7 – F9**	0	0	**0**
50 – 54	**C6**	0	1	**1**
55 – 59	**C5**	1	1	**2**
60 - 64	**B4**	1	0	**1**
65 – 69	**B3**	5	4	**9**
70 - 74	**A2**	2	0	**2**
>75	**A1**	7	3	**10**



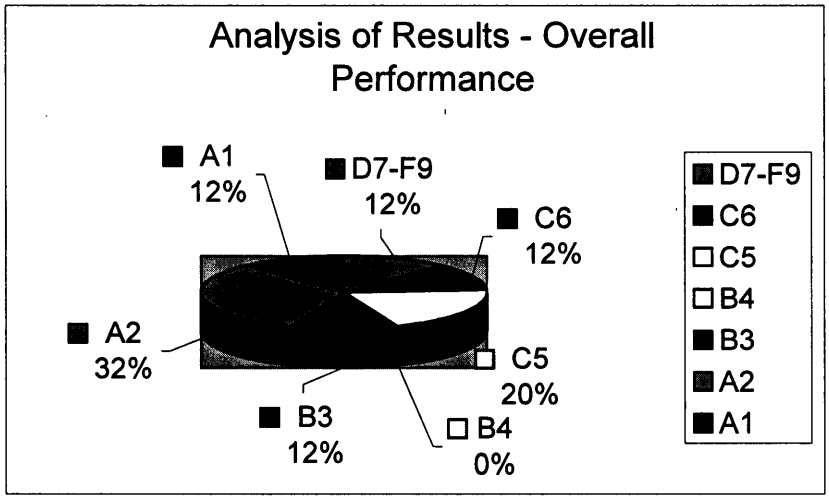


Analysis of Results – Combined Grades For Pencil Holder Project (100%)

Marks Range	Grades	Class		Total No. of Students
		3E2 (16 Students)	3E3 (9 Students)	
0 - 49	**D7 – F9**	2	1	**3**
50 – 54	**C6**	2	1	**3**
55 – 59	**C5**	3	2	**5**
60 - 64	**B4**	0	0	**0**
65 – 69	**B3**	3	0	**3**
70 - 74	**A2**	3	5	**8**
>75	**A1**	3	0	**3**



Grades the 25 students achieved for this project



Percentage breakdown of the grades

Discussion

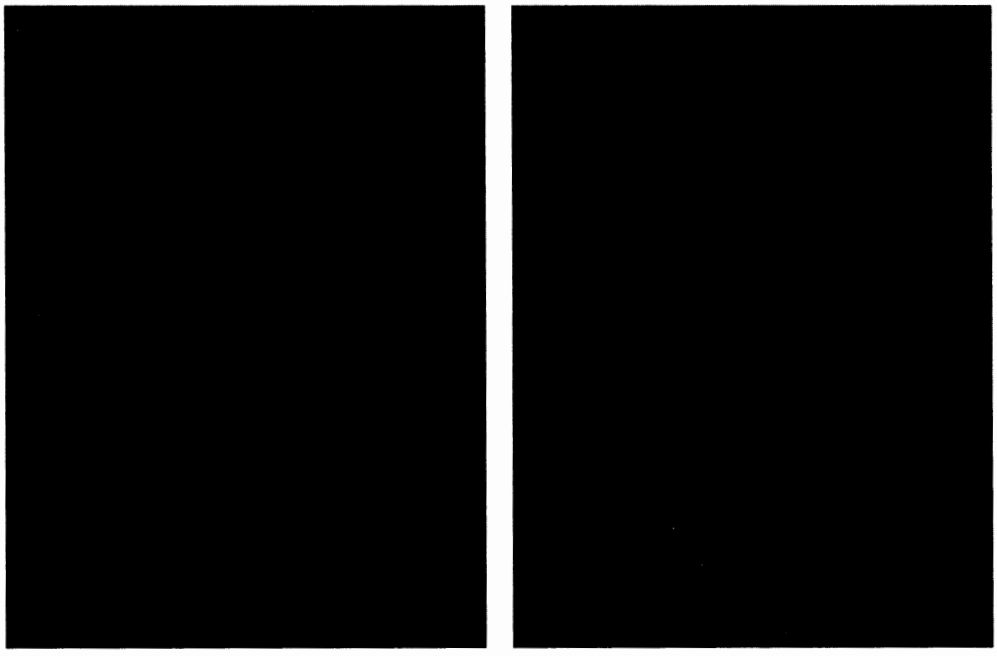
Statistical analysis shows that only 8 students (32%) scored a distinction for their design folios. A major concern would be to look into areas of why the 9 students (36%) did not obtain a pass grade for their folios. However, most of them passed this project due to their performance in the fabrication of their artifacts. We found that 12 students (48%) managed to obtain a distinction grade for the fabrication of their artifacts. None of them failed this component – remarkable! This reflects that a majority of these students would rather spend time doing hands-on activities and producing a good job on their artifacts. On the whole, 11 students (44%) obtained a distinction for this Pencil Holder Project while 3 students (12%) failed the projects due to their performance on the design folios.

It is likely that students who fail in their design folios do not put in enough effort to come up with proper drawings and thus do not satisfy the minimum pass requirements of the rubrics of assessment. The main problem here is the lack of motivation of the students in doing the project. It is evident from the results that students are motivated to do the pencil holders but fall short, due to laziness or whatever other reasons, that they do not wish to put in much effort in the design folio, which constitutes 60% of the marks for this project. As such, the pencil holders they produce are not their optimal designs. In short, these students who failed did not stretch their creative potentials.

Those who fail usually want to come up with a product as quickly as possible. They generate ideas as soon as the challenge is given to them but do not want to reproduce these ideas and thoughts on paper. They tend to like the 'hands-on-experience' in doing the projects but do not wish to spend much time thinking about various ways to solve the challenge. Many of these students may get stuck in the process of fabrication or ideas may just pop up while they are fabricating their products – this might prove a little too late to incorporate the new ideas into their products. We affirm that students who go through the *process* of problem solving display a more 'creative' product.

Further Work – Impact On Learning
A lot of skills that a student picks up in the workshop will be extremely relevant in the GCE O Level theory questions. As such, it is important that a student is profound in acquiring skills in the workshop. This provides a strong foundation to be able to analyze and sketch a solution to a given situation in theory. Much of the experiential learning a student goes through in the workshop will directly or indirectly affect how well he is able to perform in the theory paper.

Impact On Theory Paper
We created an environment where students could see an impact in learning. We set the revision for the mid-year exams from one of the pencil holders done by one of the students. Kris, another cheerful student, had her design of the pencil holder that would suit her room. There are many teddy bears in her room and as such, she wanted to design one that could allow the teddy bear to be 'seated' on her pencil holder. This thought alone motivated her to do the project. Since she is in the same age group as the 'client', she came up with a very interesting design of a pencil holder in the form of a chair that incorporates 2 housing joints. The 'play factor' coming from the colour and visual form attracts other students to the pencil holder Kris made as shown here:



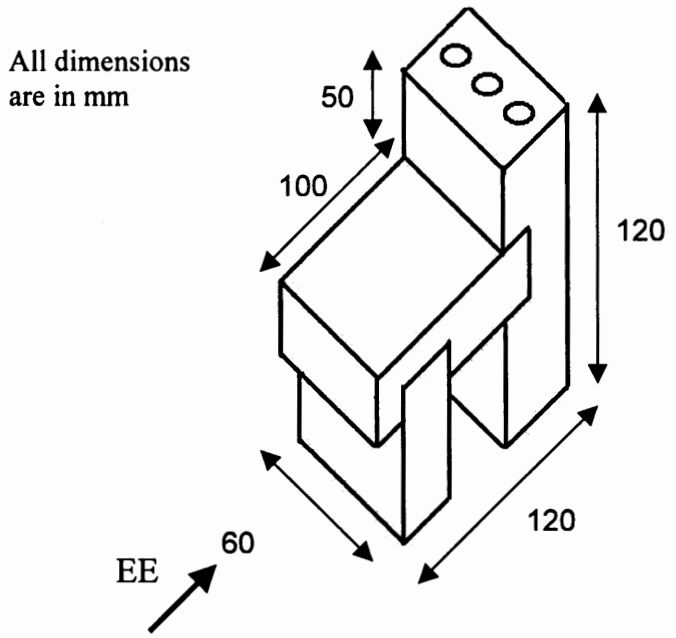
Kris's pencil holder with and without her teddy bear. The teddy bare adds the 'play factor' to the product. We tap on this play factor to set examination revision theory questions.

Knowing that many students are attracted to Kris's simple but attractive pencil holder, we tap on this 'play factor' to set meaningful theory questions that would create an impact in learning.

We wanted to test if the students could still remember the steps taken in drawing a first angle orthographic projection in their folios. This is important since it may be asked in the 'O' level theory question. As such we set the question using Kris's pencil holder design as shown:

Example – Exam Revision Question Using Student's Work

The following picture shows a simple pencil holder made from Pine Wood **20mm thick**. The designer has incorporated two housing joints in the design of her pencil holder. Each hole is to be drilled has a **diameter of 10mm** and a **depth of 40mm**.



(a) Draw, to a scale of 1:2, the first angle orthographic projection of the pencil holder. Show clearly in your diagram the Front Elevation, End Elevation and Plan views of the pencil holder. Hidden details and six main dimensions should be included.

(b) Draw the symbol for the first angle orthographic projection in your diagram.

On the same approach, a question was set in the Design & Technology mid-year exam paper to test students' knowledge on understanding skills learnt in their design folios and workshop skills. In this case, we used the design from Mr. Nazir's pencil holder.

Example – Exam Question Using Teacher's Work

Section 2 – Processes

The drawing in Figure 5 below shows a diagram of a simple pencil holder that is made out of Pine wood.

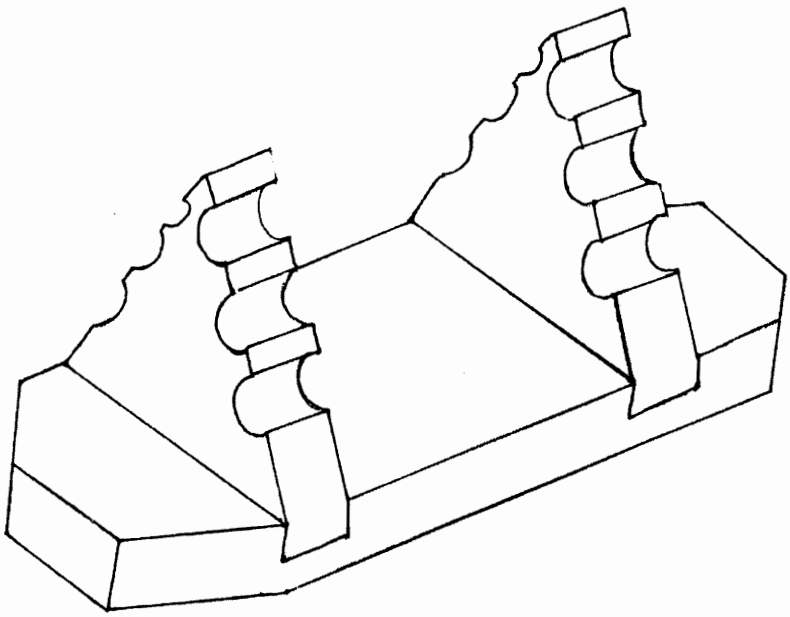


Figure 5

(a) Study the drawing and state 3 design specifications a designer would have thought of before sketching the above design. [3]

(b) Explain with the aid of notes and sketches, how the pencil holder could be made, in the workshop, from a piece of Pine wood of dimensions 300 x 70 x 20 mm. Show your sequential steps in detail. [12]

(c) Give one reason why a housing joint is chosen for the construction of a pencil holder. [2]

We found that students were motivated in answering the above two questions, possibly because they have gone through a similar design of the pencil holder and as well as the 'play factor' involved in the designs.

Conclusion

Learning Points & Conclusion

It is clear that a student who performs well in fabrication of their projects may not necessarily perform well in the overall results in the exams. Teachers ought to adopt a variety of methods to enhance students' motivation levels in various areas of creative problem solving. This would mean constructing playful yet meaningful activities that could engage students to be self-driven in coming up with optimal solutions. This could include using toys and games as part of creative teaching strategies. Students have to be made aware that the design process is important. Students must plan and reflect their thoughts and feelings on their portfolios. Many teachers adopt a reverse engineering approach to ensure students complete their work on time. Students who go through such a method may eventually obtain pass grades (or even good grades) for their artifacts but they move into a superficial world in trying to complete their design folios. They create stories and possible scenarios for the sake of completing a design folio. The student's creative talents can be suppressed in such a process. Their abilities will not be enhanced and the only motivation they will get out of it would be to complete their artifacts – be it a good product or not. Students who do not go through the divergent process and synthesizing of ideas fall short of being able to produce creative results in their problem-solving process. They may lack ideas, or even if they do generate ideas, it would display a variation of the same idea. Such mindsets tend to be biased on 'already knowing what they want to do'. They create a mental block, which does not allow them to see the views of others. These students want to complete their design folios quickly without paying much attention of what the design process really means – not that they are bothered on how powerful this process can offer them when they go out and work in the world outside. Teachers to minimize the use of reverse engineering methods of 'aiding' students when they go through the problem-solving process. We encourage looking at existing products and manipulate with them – allow students to give their comments and change designs of existing products to serve a different purpose. Only then are we able to take up the first steps into instilling a creative mindset in our students.

Throughout the course, as the students go along the planning stages, we encouraged them to imagine and be wild with their ideas. Students reflect their learning points and explain ways of improving their portfolios and artifacts. We asked student's opinions on the projects they work on and the design process they study in Design & Technology. Listed here are a few interesting quotes from several teachers and students on the design process and projects in Design & Technology:

"……the design process would help students when they go out in the working world"
- Mr. Ridzuan, HOD Science

".....I read up in a book that Asian students are not creative. We need to show how creative we can be by getting a lot of ideas from our teachers and friends."
- Muhammad Fauzee (Secondary 3E3)

".....Cher (teacher), last time I did not like D&T, but now I am beginning to like it!"
- Fatin Atikah (Secondary 3E2)

"...a ..such project allows students to have fun and display their creative talents which can be seen!"
- Mdm. Aini, Science staff of Greenview Secondary School

"....I went to MOE Auditorium and found several D&T artifacts on display. Such artifacts are so simple and yet show creative talents of students. We should encourage students to make simple but meaningful artifacts..."
- Mr. Taufik, Design & Technology Teacher

".....It's great that students are actually learning Physics from their D&T projects! Students are having fun and that makes a difference in their motivation"
- Mr. Jake Tan, Physics Teacher

References

Bernard Zubrowski (2002), *Integrating Science into Design Technology Projects: Using a Standard Model in the Design Process:* Journal of Technology Education. Vol. No. 2 Spring 2002.

Daniel Raviv (2002), *Do We Teach Them How to Think*: Department of Electrical Engineering, Florida Atlantic University

Donna Walker Tileston. (2000). *10 Best Teaching Practices*, Corwin Press, Inc. Thousand Oaks, CA ISBN: 07619-7585-3

Ho Boon Tiong and Toh Kok Aun (2001), *Challenges Facing the Singapore Education System Today. Chapter 5 - Secondary School Teachers' Reflections On The Use Of Problem-Based Learning (PBL) In Classroom Teaching*: Prentice Hall, pp 71-82.

Koberg, D and Bagnall, J (1981) *The All New Universal Traveler: A Soft-Systems Guide To Creativity, Problem-Solving, And The Process Of Reaching Goals.* Los Altos, CA: William Kaufmann, Inc.

Liu, Y. T. (1996). *"What" and "Where" is design creativity: a cognitive model for the emergence of creative design.* IDATER Loughborough University

Lucille Lee K W (2001). *Fostering Creativity In Science Education.* Review of Educational Research and Advances for Classroom Teachers (REACT), NIE/NTU, Vol 20, No 2, Dec 2001 (27-31)

Michael D. Williams (2000). *Integrating Technology into Teaching and Learning. Chapter 11 – Thinking Skills and Creativity: Student Projects Using IT*: Prentice Hall, pp 202-229

Peter Renwick, Wong Hang Fah, Jason Tan, Kwek Ah Kow, Chan Weng Cheong (2003) *Teaching Design and Technology.* Prentice Hall pp. 4-5, 12-21,33, 41-42, 116

Raffles Junior College. (2004). *RJC Inventors Challenge 2004. Invention Design Form*

Robert Harris (July 1998). *Creative Problem Solving: A Step-by-step Approach - Introduction to Creative Thinking.*

Sean Covey (1998). *The 7 Habits of Highly Effective Teens.* Fireside Book, pp 74-84, 194-195.