

DESIGN & TECHNOLOGY

SYLLABUS

Upper Secondary

Express Course

Implementation starting with
2019 Secondary 3



Ministry of Education
SINGAPORE

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1. INTRODUCTION

1.1 Background

This Design & Technology (D&T) Syllabus is for the Express course at the upper secondary level.

In D&T, pupils learn mainly through design-and-make projects guided by a design process. The design process entails identifying design needs from real-world experiences, generating and developing ideas, and realising the design solution; with research carried out when necessary. Research includes testing ideas through quick mock-ups and evaluating the final design solution with the intended user. In doing so, pupils acquire related knowledge and develop skills to turn ideas into reality and values like mindfulness, empathy and sensitivity in the areas of social, culture and environment.

Since it was first implemented in 1986, the D&T syllabus has been reviewed twice for its relevance and inherent educational richness vis-à-vis the design process as a way of thinking and doing. The review included scanning relevant overseas D&T syllabi; uncovering a common key feature of the design-and-make learning platform to solve real-world ill-defined problems. Feedback was also obtained from pupils, teachers, academics and key stakeholders through communication platforms such as the syllabus review committee, focus group discussions, school visits and D&T Awards pitching sessions.

The 2019 D&T Syllabus emphasises the following:

- thinking through sketching to generate and to develop design solutions
- exploration and experimentation of ideas through mock-ups so as to allow pupils to fail early in seeking a practical and appropriate design solution for the identified user
- making of the prototype as a cognitive and hands-on endeavour

1.2 Philosophy of D&T Education

Learning in D&T emphasises contribution towards educating pupils as persons (Annex) through the development of cognitive skills and abilities unique in the field of design. It goes beyond pupils merely learning content knowledge and developing problem-solving skills.

Rather, learning in D&T is about pupils developing a way of thinking and doing to visualise and concretise design solutions for real-world contexts. It involves the manipulation of non-verbal codes (e.g. sketches, diagrams, objects) in the material culture to translate between abstract requirements (e.g. pleasurable use, appeals to children) and concrete objects; facilitating the constructive, solution-focused mindset in designing and making. Non-verbal codes are aids to imagining, creating, internal thinking and communicating ideas. The use of such codes is essential and effective for tackling the characteristically ill-defined or ill-structured problems that people face in everyday life.

1.3 D&T Education Teaching and Learning Framework

D&T education aims to nurture in our pupils a way of thinking and doing – designerly dispositions which are inherent in design practices – through designing and making. The designerly dispositions are as follows:

- embracing uncertainties and complexities
- be cognizant of and resolve real-world, ill-defined problems
- relentless drive to seek out how things work
- use of doodling and sketching, and 3D manipulation of resistant materials as a language for visualisation, communication and presentation

Central to this learning is the design process which requires pupils to apply basic design and technology knowledge and design thinking skills. They also acquire skills in doodling and sketching, and 3D manipulation as means of thinking and tinkering to develop design solutions. This learning approach is illustrated as a framework in Figure 1.

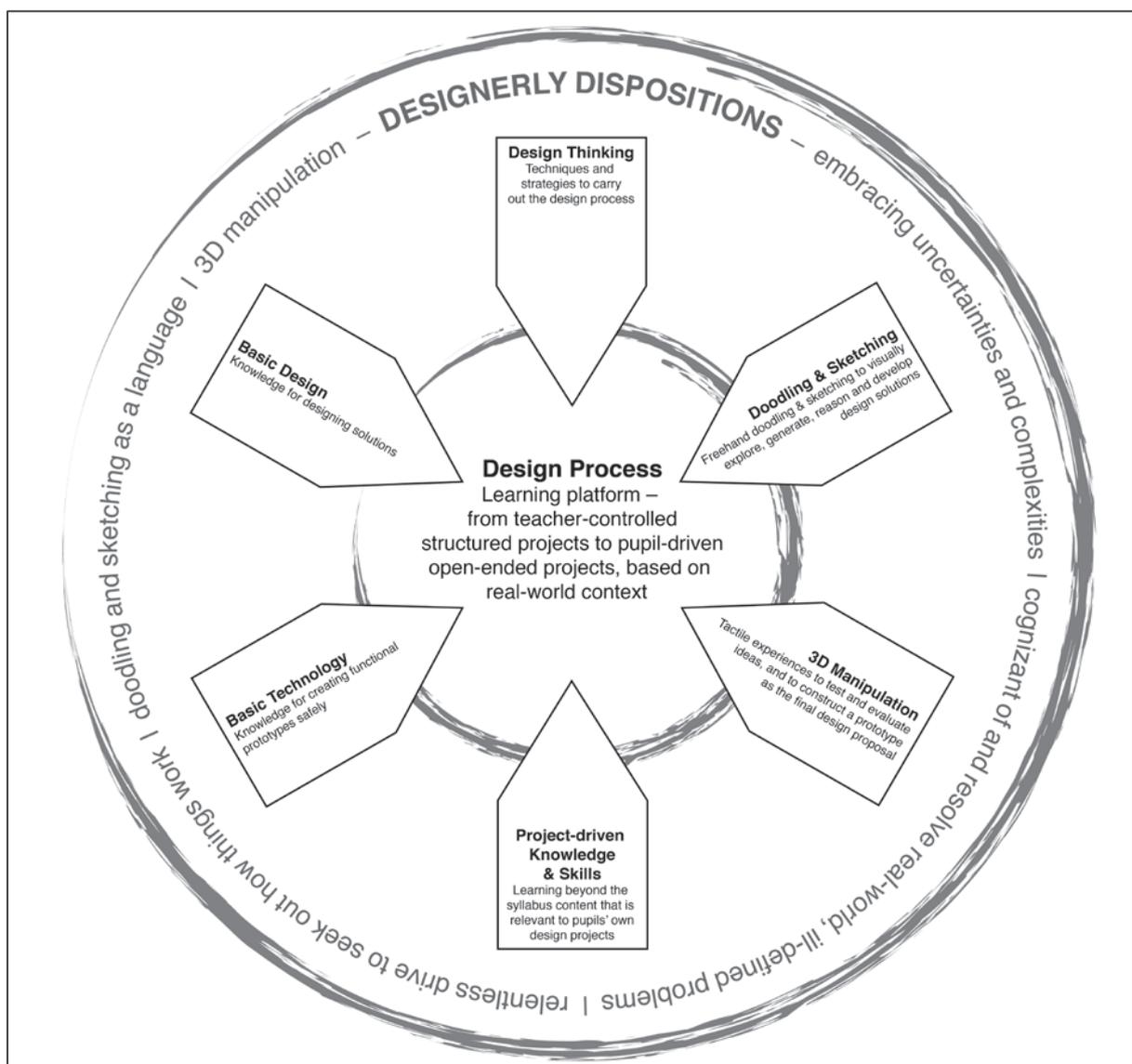


Figure 1: D&T education teaching and learning framework

1.3.1 Design Process as a Learning Platform

The design process is central to the learning experiences in D&T. It guides the act of conceptualising and creating design solutions that are practical and appropriate in everyday life. It is a set of stages that takes pupils from a design opportunity to a product solution to address user needs based on real-world contexts.

Through this learning platform, pupils undertake a series of projects progressively to consolidate their learning and to acquire new knowledge and skills. These projects range from teacher-controlled structured projects, at the start, to pupil-driven open-ended projects that are based on real-world contexts.

Teacher-controlled structured projects are project tasks that are focused and pupils are given substantial scaffolds and guidance in the enactment of the design process. In such projects, teachers may give directly a design brief to pupils or guide pupils closely to seek a design opportunity and work on a common design brief.

Pupil-driven open-ended projects are project tasks typically introduced at the upper secondary level. They are based on themes or design tasks that have no predefined design opportunities. Pupils seek their own design opportunities that are authentic and meaningful from the given themes or design tasks. Pupils' enactment of the design process tends to be more iterative and dynamic. Details of the enactment of the design process are explained in Section 1.4.

1.3.2 Six Essential Dimensions in D&T Learning

For the enactment of the design process, there are six essential dimensions that are characteristic of learning in D&T. They are:

(I) Basic Design

The thinking-and-doing process in D&T centres on basic design knowledge that allows pupils to be thoughtful, and to experience the visual language in the design of solutions. The knowledge includes ergonomics and anthropometry; design elements and design principles; influence of social, cultural, economic and sustainable factors, and designers' responsibilities.

(II) Basic Technology

As pupils create functional prototypes, they leverage on appropriate technology to fulfil the purpose. The basic technology in D&T includes structures, mechanisms, electronics and simple control systems. It also involves a safe working knowledge of resistant materials and its properties, and the relevant practical processes to manipulate these materials in a safe manner.

(III) Project-driven Knowledge and Skills

As pupils embark on their own design projects, they take on areas of learning that are based on real-world design context. This encourages learning relevant to pupils' own projects that may be beyond the syllabus content. For example, pupils may seek to understand the

behaviour of users at a public space for a design opportunity, find out the use of a musical instrument to value-add its function, or learn about sound reverberation to design a device for beat boxing.

(IV) Design Thinking

Design thinking is a way of thinking in designing which pupils will acquire over time as they immerse in the design process. It is an amalgamation of thought processes that engage pupils as they seek solutions based on thoughtful consideration of user, functionality and environment. Pupils will learn techniques and strategies such as the opportunities-interpret-imagine protocol, shape borrowing and SCAMPER to develop good design thinking.

(V) Doodling & Sketching

Freehand doodling & sketching are skills in designing that are used to visually explore, generate, reason and develop design solutions. As pupils gain confidence in doodling and sketching, these skills would serve as another language for communication, conceptualisation and creation of ideas and solutions. Doodling and sketching plays a significant role in the creation of ideas as it is the prevalent design thinking tool.

(VI) 3D Manipulation

Manipulating 3D objects in the form of quick mock-ups and working with resistant materials serves as tactile experiences to tinker, test and evaluate ideas, and to construct a prototype as the final design proposal. These tactile experiences bring about the uniqueness of D&T, in which pupils take an idea from conception on paper to fruition via a prototype. 3D manipulation serves as an extension of the cognitive development of the pupils through practical processes.

1.4 The Design Process in D&T

The design process in D&T is the key platform for pupils to make meaning of their learning, facilitated by their teachers. Pupils learn the design process through experience via design-and-make projects.

It is the vehicle for designing to create change so as to affect empathy, practicality and appropriateness in everyday life. As a way of thinking and doing, it focuses on creating solutions using appropriate technology for purposeful intent. This broadly involves rational thought processes and intuitive responses that are nested within a holistic fabric of analytical, creative and critical thinking. The design process involves five phases; namely Needs Analysis, Idea Conceptualisation, Development and Prototyping, all supported by Research as shown in Figure 2.

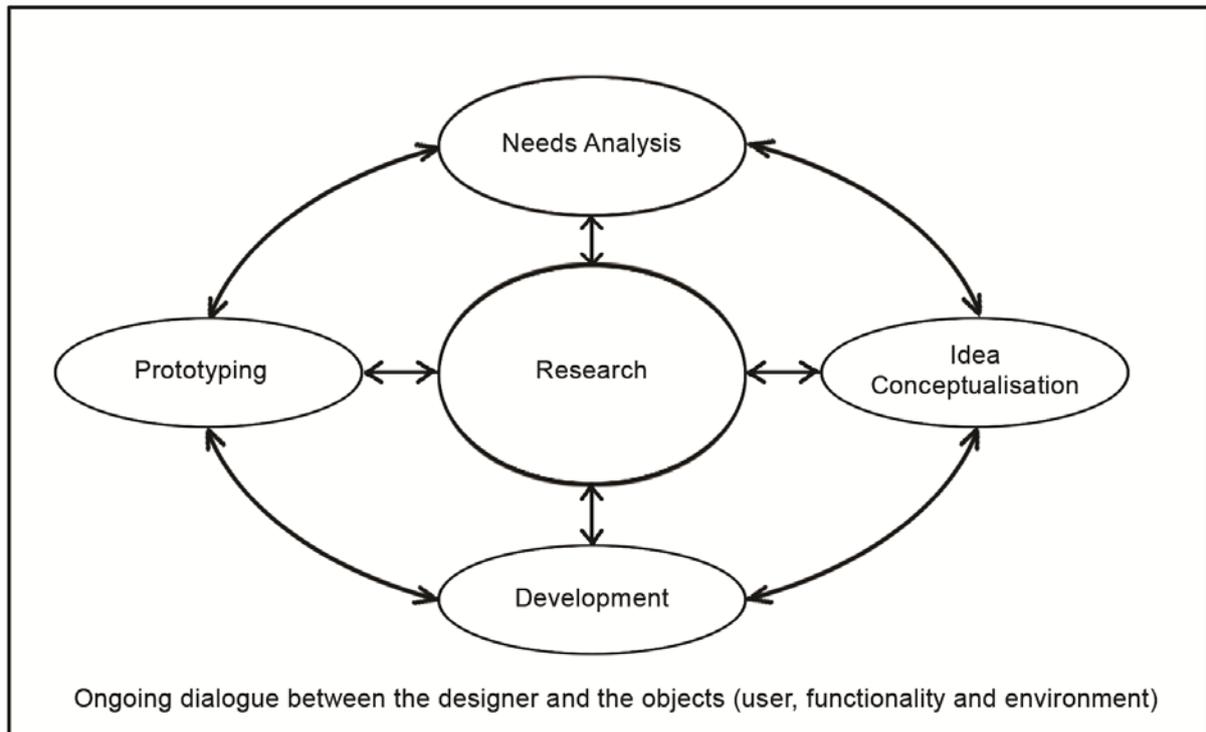


Figure 2: The design process model

(I) Research

Research is a necessary endeavour to support all phases of the design process. Information from various credible sources is used for decision making to propel the design process. In this phase, pupil design activities may include:

- observing and recording a user in-action in real-world context to identify design opportunities
- gathering visuals to create an image board to trigger idea generation and development
- analysing design features of relevant products for idea conceptualisation and development
- testing and evaluating configurations of a mechanism/electronic circuit/structure via a mock-up for functionality and practicality
- obtaining feedback on ideas from identified user for further exploration or refinements
- seeking alternative construction methods during prototyping when the planned method failed

(II) Needs Analysis

Needs Analysis is the phase where user needs are established and defined through the writing of the design need, design brief and design specifications. This writing sets the direction and focus for design-and-make projects. It may undergo iterations as design opportunities become clearer and compelling. Pupil design activities may include:

- writing guiding questions for investigation and exploration
- studying stimulus (e.g. visuals or videos), observing or interacting with people to identify design opportunities
- doodling quick tentative ideas in response to potential design opportunities
- rationalising the design need for clarity and worthiness for undertaking

(III) Idea Conceptualisation

Idea conceptualisation is the phase of generating ideas using doodles/sketches/drawings and/or mock-ups, with reference to the user, functionality and the environment. The extent of how these references are considered may vary from idea to idea. The process calls for imaginative and creative thinking. Pupil design activities may include:

- sketching basic elements like lines and circles or applying other ideation techniques (e.g. SCAMPER, shape borrowing)
- considering relevant factors like the user, functionality and the environment
- creating mock-ups of the conceptual idea/s to seek user feedback
- reviewing the design need, design brief and design specifications as the pupil gain clarity in the design opportunities
- deciding on a viable conceptual idea for development

(IV) Development

The Development phase involves exploring and developing details for the chosen conceptual idea using sketches/drawings and/or mock-ups, with in-depth consideration of the user, functionality and the environment, where applicable. The outcome is a proposed design solution that is practical and appropriate in addressing the design need. Pupil design activities may include:

- exploring the configuration for shape, forms, design compactness and/or functionality with respect to the user and the environment
- exploring the use of mechanisms/electronic kits for functionality
- gathering relevant anthropometric data and measurements for sizing the design
- building mock-ups to test whole or part of the design
- gathering user feedback
- deciding on the materials choice and construction details for realising the prototype
- preparing a working drawing for use during prototype realisation and the accompanying materials list for materials request

(V) Prototyping

This phase is about realising the prototype using suitable resistant materials. Substitute materials may be used if it is not feasible to work with the suitable materials in the D&T Studios, e.g. replacing stainless steel with aluminium. Safety must be observed at all times during this phase. Pupil design activities may include:

- learning and applying knowledge beyond the syllabus and/or how to use tool/equipment/machines that are not learnt previously
- exploring alternative ways to realise the prototype when the planned methods failed
- tinkering and experimenting to ensure that the mechanisms/electronics work
- evaluating their design proposal by having the users test the prototype

1.4.1 Design Process at the Upper Secondary Level

Learning at upper secondary level should be strategically planned for pupils to experience all five design phases of the design process through pupil-driven open-ended projects. It should also allow for pupils to experience a repertoire of practical processes, including handling general equipment and machine capabilities offered by the brazing hearth, milling machine and centre lathe, for appropriate realisation of their proposed design solution. These

learning experiences are necessary to prepare pupils for the undertaking of a coursework task in the GCE examination.

1.5 Goals and Aims of D&T Education

All pupils can sketch and make. This is based on the primordial dispositions of mankind evidenced by cave drawings and stone-age artefacts like the prehistoric wheel and tools. It is the goal of D&T education to build on this innate human ability for pupils to grow their confidence in sketching and making to create and innovate.

At the upper secondary level D&T, designing and making are dealt with at greater depth and scope. Pupils do research to understand and define user needs, explore and develop design solutions, and prototype their ideas using basic hand tools/equipment/machines. Such learning activities leverage and build on pupils' experiences in design and technology, with a focus on understanding of everyday activities to create possibilities to make life better. In the process, pupils cultivate creative, critical and reflective thinking and develop design related dispositions and skills. It aims to enable pupils to:

- i) develop confidence, pride and tenacity through exploring real-world design opportunities for which ideas are developed within a given timeframe;
- ii) develop the quality of mindfulness, empathy and sensitivity through improving some aspects of their environment in everyday life;
- iii) embrace uncertainties, complexities and the inherent social dimension of the design process when exploring design opportunities vis-à-vis design ideas;
- iv) cultivate thinking through doodling and sketching/drawing,
- v) experiment and prototype ideas using appropriate materials and tools;
- vi) build on their innate curiosity and ability to create; and
- vii) exercise judgements and make evidence-based decisions of technological, aesthetic and economic nature.

In achieving the above aims, pupils also develop safe working habits.

2. CONTENT

2.1 Preamble

The contents are organised in two sections; namely (i) Design and (ii) Technology. They define the foundational knowledge and skills for pupils to work on design-and-make projects. Learning of the contents is integrative in nature via the design process. The broad attainment levels for learning are as follows:

- develop design-related dispositions
- acquire design techniques and strategies
- consolidate a sound working knowledge of technology (materials, workshop processes, structures, mechanisms and electronics)

Health and safety is one important aspect of the D&T classrooms. They must be taught together with the respective contents. For example,

- safety precautions for specific tools/equipment/machines
- steps in finishing an acrylic edge using the disc-belt sander should follow only after removing the waste close to the finishing line

Practices that promote the health and safety of all users in the D&T classrooms should be highlighted, reinforced and enforced.

Any ICT tools/platforms used in the D&T classrooms should enhance pupils' learning experiences. Learning to use the tools/platforms should not require an inordinate amount of pupils' time.

2.2 Content

Section 1 Design

No	Pupils should be able to:	Content
1	<u>plan</u> for a project taking into consideration the stages of work and resources required	Gantt chart, flow chart
2	monitor and, where necessary, make adjustments to the <u>plan</u> to ensure the completion of the project within a given timeframe	
3	produce <u>sub-plans</u> of specific activities for each stage of work	
4	use various <u>sources</u> for gathering relevant data	print materials, Internet, interviews, surveys, observations
5	apply <u>analysis techniques</u> using appropriate means like products or visuals/images	PIES analysis, product analysis, user analysis, PMI, SWOT analysis
6	construct guiding <u>questions</u> for investigation and exploration	5W1H
7	present <u>data</u> from investigative research	diagrams, flowcharts, graphs, test results
8	interpret <u>data</u> for decision making	
9	consider the <u>range of human needs</u> for decision making	social, culture, economics, sustainability
10	formulate a <u>design brief</u> based on a design opportunity	design brief
11	formulate <u>design specifications</u> based on the considerations and constraints of the design brief	design specifications
12	apply <u>ideation techniques</u> to generate ideas	brainstorming, SCAMPER, shape borrowing, attribute listing
13	apply the principles of <u>ergonomics and anthropometric</u> data	ergonomics, anthropometric data
14	apply appropriate <u>means</u> to ideate and develop ideas	2D and 3D freehand sketches, mock-ups, prototypes
15	refine design ideas through <u>testing and evaluation</u>	
16	test and evaluate <u>feasibility of ideas</u>	
17	apply the concept of <u>basic drawing techniques</u> to communicate details for prototyping and the proposed design solution	isometric drawing, perspective drawing, orthographic projection drawing, exploded and sectional views, presentation drawing, working drawing, materials list
18	apply the concept of <u>design elements and design principles</u>	line, shape, form, colour, texture, balance, proportion, contrast and emphasis
19	explain the <u>relationship between design and technology</u>	the evolution of mobile phone, personal computers, lighting
20	explain the <u>responsibilities of designers in relation to society and the environment</u>	social design, sustainable design

Section 2 Technology

No	Pupils should be able to:	Content
21	use appropriate <u>materials</u> to build mock-ups	objects, paper, cardboard, foam board
22	show working knowledge of <u>plastics</u> and its uses	thermoplastics: nylon, polythene, polyvinyl chloride, polypropylene, acrylic, polystyrene; thermosets: polyester resin including G.R.P., melamine, urea and phenol formaldehyde
23	show working knowledge of <u>wood</u> and its uses	natural timber: jelutong, meranti, pine; processed wood: plywood, MDF boards, veneer
24	show working knowledge of <u>metal</u> and its uses	ferrous metal: mild steel and high carbon steels; non-ferrous metal: aluminium and the alloy duralumin, copper and its alloys (brass, bronze and pewter), zinc, lead and tin
25	explore materials for their <u>properties</u> and implications of their use in terms of cost, aesthetics, emotive response and sustainability	toughness, durability, stiffness, strength, hardness, elasticity
26	analyse everyday products in relation to <u>forces</u>	tension, compression, bending, torsion, shear
27	explore <u>structural strengthening</u> for stability and rigidity	folds, gussets, ribs, braces, laminating
28	explain the application of <u>control systems</u> in everyday products	open-loop system: thermometer, table lamp, stapler, can opener; closed-loop system: hot water dispenser, water cistern, air conditioner
29	consider the components of a <u>control system</u> in relation to user interface and functionality	input, process, output, feedback
30	adapt available <u>electronic kits</u> for practical application with working knowledge of the electronic components involved	counting, sensing of light, moisture and temperature
31	adapt simple <u>mechanisms</u> involving motion transmission, conversion and control for practical application	levers, linkages, screw, rack and pinion, pulley, cams, gears, springs
32	carry out <u>measuring and marking out</u> processes appropriate to the selected resistant material in a safe manner	datum referencing, measuring, scribing, gauging, marking centres for drilling
33	carry out <u>shaping</u> processes appropriate to the selected resistant material in a safe manner	sawing, filing, planing, snipping, chiselling, drilling, boring, thread cutting, countersinking, bending metals, thermoforming, lathe turning, milling
34	carry out <u>joining and assembling</u> processes appropriate to the selected resistant material in a safe manner	use of jigs and formers, adhesives, nailing, screwing, joining wood (butt, dowelled, mitre, housing), joining metal (bolts and nuts, machine screws, rivets, solder, weld), joining plastics (solvent, cement), hinges, knock-down fittings
35	carry out <u>finishing</u> processes appropriate to the selected resistant material in a safe manner	cleaning up, polishing, staining, painting, plastics coating

3. Assessment

3.1 Formative Assessment

Formative assessment is a learning partnership between teachers and pupils. It provides information for teachers to understand the pupils' learning and, where necessary, regulate and modify their teaching to impact learning. It is an integral part of the teaching-learning process where both teachers and pupils are intentional learners.

The opportunities for formative assessment are ample in the design process in-action. When designing, three central questions that both teachers and pupils can ask themselves are:

- What is the status of the current achievement?
- Where should my learning be progressing?
- What are the necessary actions to progress learning?

The process of formative assessment involves deliberate teacher actions so as to elicit feedback on pupils' learning through what they do, say, sketch, write or make. The feedback via doodling & sketching, 3D manipulation and verbal/written form help teachers to assess learning, and adjust ongoing intervention (e.g. instructions, demonstrations and visual stimuli) for pupils' further learning. Examples of specific scenarios for formative assessment are as follows:

- a think-aloud teacher demonstration on generating ideas via whole class discussion to elicit pupils' contribution to shape the ideas
- group critique sessions of pupils' ideas in the form of sketches or mock-ups
- pupils capturing thought process in their design journal
- pupils presenting their design project in-progress
- testing functionality using mock-ups
- reflecting and evaluating on pupils' outcomes arising from observations, questioning, discussion, presentations, games, short quizzes, short tests and/or others

Worksheets to formatively assess pupils' learning in applying knowledge should be considered.

3.2 Examination

There are two assessment modes to measure pupils' achievements at upper secondary level. They are the Written Paper (Paper 1) and the Design Project (Paper 2). The weighting of the two papers is provided in [Table 1](#).

Table 1: Weighting for upper secondary D&T assessment modes

Paper	Assessment Mode	Weighting
1	Written Paper	40%
2	Design Project	60%

Paper 1 Written Paper

The format for the written paper is described in [Table 2](#).

Table 2: Format of D&T written paper

Duration	2 hour
Total mark	80
Number of questions to be answered	4
Question Type	One case-based design question set based mainly on the Design content section (26 marks)
	Three design application questions relating to structures, mechanisms and electronics from the Technology content section; one question on each area (54 marks)

Paper 2 Design Project

The Design Project is an individual coursework-based examination. Pupils will be required to work on a design and prototyping project based on the examination question. For Design Project that requires further research and specialisation beyond the syllabus content, schools should encourage the inclusion of other technology where appropriate. Meaningful use of ICT tools to support designing activities should also be encouraged. Teachers, however, need to be mindful that such endeavours should not require inordinate amount of pupils' time as D&T is just one subject that they study in their school curriculum.

The duration for Design Project is 22 weeks.

The Design Project has two components: Design Journal (DJ) and Presentation Board (PB).

DJ is a real-time document that reflects the pupil's attempt at managing his/her personal design process. It comprises:

- A3-size sheets that are securely fastened or A3-size sketch pads
- mock-up(s)
- prototype and mould/jig/former if any

PB is to communicate succinctly the proposed design solution in relation to the design brief and design specifications. It should show the functional and aesthetic details using appropriate graphic skills to highlight the practicality and appropriateness of the proposed design solution. It comprises A2-size boards, single-side, two pieces maximum.

The Assessment Rubrics for marking the Design Project is described in [Table 3](#) on Page 13.

Table 3: Assessment rubrics for O-level D&T design project [total marks: 60]

Criteria (max. mark)	Level 0	Level 1	Level 2	Level 3	Level 4
Planning for and monitoring of the design project	No evidence of planning for and monitoring of design project.	Plan shows main design stages with cursory monitoring of progress by indicating the time taken for each design stage.	Plan shows main design stages with monitoring in the form of sub-plans that are unclear or superficial to guide progress.	Plan shows main design stages with monitoring in the form of sub-plans that are appropriate to guide progress.	Plan shows main design stages with monitoring in the form of sub-plans based on meaningful evaluation of work done to guide progress.
(4)	0	1	2	3	4
Formulating design brief and design specifications	No investigation carried out, no design brief and design specifications stated.	Investigation carried out on the design opportunity provides little or no evidence, leading to the weak set of design brief and design specifications formulated.	Investigation carried out on the design opportunity provides obvious evidence leading to the superficial set of design brief and design specifications formulated.	Relevant investigative work carried out on the design opportunity. It provides credible evidence leading to the clear set of design brief and design specifications formulated.	Incisive investigative work carried out on the design opportunity. It provides compelling evidence leading to the meaningful set of design brief and design specifications formulated.
(10)	0	1 - 2	3 - 5	6 - 8	9 - 10
Generating and developing ideas	No evidence of generating and developing ideas.	Little or no consideration of the user, functionality and environment when generating and developing ideas for the design opportunity. The process is cursory.	General consideration of the user, functionality and the environment when generating and developing ideas for the design opportunity. The process is basic.	Appropriate consideration of the user, functionality and the environment in relation to the design opportunity. The idea generation and development process is reasonable and adequate.	User, functionality and the environment in relation to the design opportunity are well considered and precise. The idea generation and development process is thorough and thoughtful.
(14)	0	1 - 3	4 - 7	8 - 11	12 - 14
Sketching and drawing to design	No sketch and drawing.	Sketches and drawings are rarely used to trigger, visualise and develop ideas, and work out details for prototyping.	Sketches and drawings are occasionally used to trigger, visualise and develop ideas, and work out details for prototyping.	Sketches and drawings are frequently used to trigger, visualise and develop ideas, and work out details for prototyping.	Sketches and drawings are consistently used to trigger, visualise and develop ideas, and work out details for prototyping.
(6)	0	1	2 - 3	4 - 5	6
Using mock-up(s) to design	No evidence of using mock-up(s).	Mock-up(s) has limited purpose.	Mock-up(s) is superficial with tenuous links to development.	Mock-up(s) is meaningful, assisting in the development of design ideas.	Mock-up(s) is purposeful, leading to insightful decision-making in the development of design ideas.
(6)	0	1	2 - 3	4 - 5	6
Communicating the proposed design solution	No Presentation Board submitted.	Communication of the proposed design solution is inconclusive. Illustrations are vague in showing how the solution would function as intended.	Communication of the proposed design solution is plausible. Illustrations more or less show how the solution would function as intended.	Communication of the proposed design solution is clear. Illustrations are adequate in showing how the solution would function as intended.	Communication of the proposed design solution is convincing. Illustrations are detailed to show clearly how the solution would function as intended.
(8)	0	1 - 2	3 - 4	5 - 6	7 - 8
Realising the prototype	No prototype submitted.	Prototype is incomplete or reflects poor making skills. Limited quality control has resulted in minimal level of accuracy and an outcome that barely functions.	Prototype reflects fair making skills. Average quality control has resulted in few inaccuracies and functions more or less as intended.	Prototype reflects competent making skills. Adequate quality control has resulted in an outcome that functions as intended.	Prototype reflects proficient making skills. Attention to details has resulted in an outcome that meets fully the intended requirements.
(12)	0	1 - 3	4 - 6	7 - 9	10 - 12

First published in North Star: A publication for educational practitioners, 2(2), pp.99-107, Curriculum Planning & Development Division/Ministry of Education and ASCD/Singapore, 2010

Teaching Design & Technology to Develop Pupils as Persons: A Singapore Vision

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Abstract

Since its first implementation in the mid-eighties, teaching of Design & Technology (D&T) in Singapore secondary schools has progressed from a focus on what-to-teach to one that emphasises on how-to-teach for effective learning. Emerging from the latter is an ongoing pursuit for a philosophy of practice that is influenced by the works of eminent design educator-researchers; in particular Nigel Cross's three main areas of justification for design education within general education. The three areas are developing abilities in solving real-world, ill-defined problems; cognitive development in the concrete/iconic modes of cognition; and the development of a wide range of abilities in nonverbal thought and communication. In explicating these areas for the classroom, the D&T fraternity seeks a practice that contributes to the development of pupils as persons.

Introduction

Design & Technology (D&T) is a subject in the secondary school curriculum in Singapore. It was first implemented at Secondary One in 1986 to replace the two subjects Woodwork and Metalwork in response to Singapore's changing economic landscape. Currently, D&T is a compulsory subject at the lower secondary level for both boys and girls. At the upper secondary level, it is offered as an elective subject. Today, about 12% (12,000 pupils) of each cohort from more than 120 secondary schools study the subject.

As part of the holistic secondary school curriculum, D&T engages pupils in designing and prototyping ideas through the mind and hands. The design process offers opportunities to understand human needs and to create possibilities to make life better. Educationally, it offers an opportunity for pupils to develop skills that turn ideas into reality and values like mindfulness, empathy and sensitivity in the areas of social, culture and environment.

As a preparation to implement D&T, teachers teaching Woodwork and Metalwork then were re-trained, and engineers from various fields were recruited and trained to teach the subject. With the introduction of the product and industrial design degree programme at the National University of Singapore in 1999, there is a small but growing number of designers teaching the subject. Today, the D&T teaching force is formed mainly by engineers.

Phases of D&T Practice

What D&T was designed in the early eighties by looking closely at similar subjects offered by schools in the UK. The implementation had a strong flavour of craft and vocational emphasis akin to Woodwork and Metalwork. Generally the programme had three distinct areas, namely theory (content knowledge), design process, and practical skills training. The design process was then taught as content knowledge and deployed as a tool for project opportunities for problem-solving design activities. With a teaching force seeking to understand the new subject matter and to teach it at the same time, treatment of the design process in a linear fashion then was understandable.

Why Moving into the second decade of D&T, a two-year part-time Advanced Diploma in D&T was developed for in-service training by the Product and Industrial Design Department at the Temasek Polytechnic. The objective was for teachers to further develop design skills and to gain exposure to design work. As teachers sought to better understand design and gain design related knowledge and skills, they also turned to events like design graduate shows, design forums and conferences for additional exposure to industrial design practice. Some keen teachers also began to make reference from academic research on design and design-related education for their classroom practice.

Such exposures to industry practices and research led a group of teachers to think deeply into the value of design for general education, i.e. the education of children 16 years and below. The belief that D&T offers opportunities to shape the pupils' values and attitudes, and develop skills that are crucial to their development is shared by many teachers. This was expounded by Archer (1974) in his paper *Design in General Education* and encapsulated in a subsequent paper (Archer, 1975, p. 8) thus:

There exists an area of human experience, knowledge and action, centred on man's desire and ability to mould his physical environment to meet his material and spiritual needs, which is as important to his well-being as such well-recognised areas of learning as literacy and numeracy. We call this area of experience, knowledge and action, design.

This forms the foundational lead in the search for a philosophy of practice in D&T education that will contribute to the holistic development and education of the young.

How As teachers gain deeper understanding of design practices and sharpen design skills, they grapple with mediating the demands of the multi-faceted and complex nature of the design process for the D&T classroom. Design process knowledge and skills, materials,

technology, values and attitudes inherent in the fields of designing guide and drive the teaching and learning of D&T. Contents from these various domains are largely organised for projects in a just-in-time manner. The integrative approach, a shift from the early approach of distinct areas of learning, offers experiences for pupils to make better meaning of their learning.

In recent years, D&T practice grew more vibrant. Relating to real life becomes an impetus for more meaningful learning. For example, pupils experienced the ritual of tea drinking and discussed the design of related products to surface design needs. Folding bicycles featured in one programme in which pupils tried various models to understand the design features and to surface design opportunities. Establishments like furniture company, marine centre, child care centre, senior citizens corner and health care centre also provided real situations and real users for pupils to work on their projects. This is in contrast with the usually fictitious contexts and design needs that were formulated for projects in the initial years. The real life setting gives added meaning to classroom learning and heightens sensitivity in the areas of social, culture and environment.

In seeking to further understand what it takes to facilitate the design process in the classroom and to enable pupils to think design, pockets of research related to facilitating and scaffolding took place. Tan (1996) surfaced the theory of Double Looping Learning Model to help explain the dynamics of facilitating and scaffolding pupils in the design process. It aims to serve as a framework for the D&T classroom practice. In another research (Imram, 2010), pupils were observed to inevitably get stuck in the design process. The researcher coined this as the Stuck Syndrome and that it offers opportunity for knowledge construction and intervention to develop skills and to shape values and attitudes.

The pursuit of a D&T pedagogical content knowledge is on-going. There is firm belief that the teacher should model the design process through thinking aloud and through sketching for pupils to emulate and to better understand what it means to be engaged in design thought process. An example of the teacher modelling the design process is to show in action how he/she morph a design solution from scratch or visual reference, to an end product to serve a design need. This process is termed idea growing (Tan, 2010) and is currently beginning to propagate in the classrooms through in-service training.

Philosophy of D&T Practice

Many researchers, especially design educator-researchers, have long been looking closely at design as an epistemological domain of knowledge liken to literacy and numeracy, and design-and-make as another important platform that may contribute to the holistic human development (Archer, 1975; Cross, 2007).

In his justification for design education within the context of general education, Cross (2007, p. 29) identified five aspects of 'designerly' ways of knowing:

- *Designers tackle 'ill-defined' problems.*
- *Their mode of problem-solving is 'solution-focused'.*
- *Their mode of thinking is 'constructive'.*

- *They use 'codes' that translate abstract requirements into concrete objects.*
- *They use these codes to both 'read' and 'write' in 'object languages'.*

From these five aspects, three main areas of justification for design education within general education were defined (Cross, 2007, p. 30), namely:

- *Design develops innate abilities in solving real-world, ill-defined problems.*
- *Design sustains cognitive development in the concrete/iconic modes of cognition.*
- *Design offers opportunities for development of a wide range of abilities in nonverbal thought and communication.*

These three main areas of justification suggest a probable reference for the D&T fraternity to reflect on how D&T can contribute to general education. This seems logical as was pointed out by Cross (1980):

Since general education is in principle non-technical and non-vocational, design can only achieve parity with other disciplines in general education if it is organised as an area of study which contributes as much to the individual's self-realisation as to preparation for social roles (p. 202).

Now that D&T is in its third decade of implementation, the quest for an educational philosophy to inform and to guide classroom practice becomes necessary. The above arguments have influenced the thinking of D&T education in the local context, and to a certain extent provided a direction for the D&T fraternity to continue to grow a philosophy of practice. They are instrumental in shaping the 'visuacy' and 'graphicacy' orientation and the concept of manipulation of three-dimensional object that are central to the D&T subject matter.

The three areas of justification, namely, developing abilities in solving real-world, ill-defined problems; cognitive development in the concrete/iconic modes of cognition; and the development of a wide range of abilities in nonverbal thought and communication (Cross, 2007) serve as sound and reasonable tenets for a philosophy of D&T practice to evolve, and for D&T education to work towards playing an important role in the Singapore school curriculum to develop the pupils in an area of cognition offered by design education.

The articulation of a philosophy of D&T practice serves to anchor a practice and provides good reason for the demanding role of being a teacher of design education that is well described by Adams (1991, p. 170):

The teacher's task is a complex and demanding one. It requires them to create opportunities for learning, to manipulate situations to stretch able pupils and support weaker ones; to introduce unfamiliar concepts and new ways of working appropriate for their pupils. It involves them in a variety of roles: organiser, mentor, devil's advocate, information source, guide,

supervisor, instructor, commentator, demonstrator, facilitator, referee, critic, interpreter, counsellor and fellow traveller.

The meaning of *fellow traveller* may be interpreted as co-designers and co-learners alongside pupils as suggested by Tan (1996). This pedagogical stance is beginning to take root in the D&T classrooms as teachers begin to appreciate that design cannot be taught but to be coached and learned.

In conclusion, it is therefore reasonable to suggest at this infancy stage the philosophy of a practice in design education be centred on Nigel Cross's three main justification for design education within general education. Such understanding would bring about a more profound depth of practice that goes towards contributing to the human development - the development of pupils as persons.

Implications

It is understandable that a philosophy of practice did not exist when D&T was first implemented more than twenty years ago in Singapore schools. Today as D&T teachers grow in their pedagogical knowledge, there is an inclination to also question how the subject matter may educate pupils as suggested by the syllabus (SEAB, 2011).

With an emergent philosophy articulated, it offers the D&T fraternity a collective understanding of how D&T education can contribute to the development of pupils through design education. The understanding could help propagate an area of research-teaching practice among D&T teachers in seeking to build D&T pedagogical stances and related pedagogical knowledge.

The philosophy hence would provide assurance for a grounded focus in gearing and driving the diverse D&T curriculum practices in schools. It also paints a clear picture for D&T teachers to articulate the *why* and *how* to *what* they are teaching. This heightens their awareness in their pedagogical approaches, in particular their facilitation process in the teaching and learning of D&T. Last, the philosophy of D&T practice offers an initial framework for like-minded educators to rationalise the practice of D&T education; to have a common notion that D&T is not about training and developing future designers; and that it exists in the curriculum as a niche area that would contribute to the pupils' holistic education and development.

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