Relevant Knowledge

I Design Process

In secondary one curriculum, we have introduced basic knowledge of design process and carried out a few design activities and exercises. In this teaching material, we will introduce various design methods for solving problems. These methods include analysis of design factors, lateral thinking, mind maps and brainstorming.

a. Analysis of Design Factors

(i) Design Matrix

To analyse design factors, we can use the 'design matrix' approach to list the various design elements in the form of a matrix so as to give them a more detailed consideration. Then we can integrate them and work out different feasible designs, from which an innovative one may be sought.

Steps to apply the design matrix approach:

1. When applying a design matrix, put down the design features, which can be the internal parts, properties, quality and design elements. For example, the features of a pencil include its shaft and core materials, the hardness and diameter of its graphite core, as well as its quality (level), colour and weight.
2. Construct a table with the various features as the column headers and put down all possibilities underneath each feature, the more, the better. When completed, this table shows all possible designs.
3. Now, pick an appropriate and interesting combination by choosing an option from each column after considerations. Then a new design is given birth.
4. Focus the discussion on this new design and evaluate whether it fulfils the design requirements. Improve it until everyone feels satisfactory.

Drawbacks:

Since the contents of the table are a result of logical thinking, the overall creativity as a whole is limited.

Relevant Knowledge

Example:

Design matrix of a lighting design

Energy source	Light bulb	Brightness	Size	Style	Surface finishing	Material
Battery	Spotlight	Weak	Big	Popular	Black	Metal
Mains supply	Common light bulb	Medium	Medium	Classical	White	Ceramic
Solar energy	Natural light	Strong	Small	Roman	Metallic	Concrete
Generator	Coloured	Variable	Portable	Industrial	Ivory	Bone
Manual				Ethnic	Fibre	Glass
Fuel gas						Wood
Liquid fuel						Stone
						Plastic

The new designs drawn from the above design matrix can be a classical torch with spotlights or an ethnic oil lamp made of bone.

(ii) Checklist Technique – SCAMPER

SCAMPER stands for seven techniques, namely, Substitute, Combine, Adapt, Modify, Purposes, Eliminate and Reverse. When we want creativity, we can think of these seven aspects to find out new ways to solve problems.

Drawbacks:

Apart from substitute and combine, the other five techniques are comparatively more difficult to apply. Students who lack experience in technological design and relevant knowledge may find them hard, or even an obstruction when use.

Relevant Knowledge

Details of SCAMPER Checklists

S	Substitute	Try to think of any parts that can be substituted, e.g. alternative materials or processes. Through the process of looking for alternatives, you will come up with new ideas. **Typical questions:** What can be improved if a substitution is made? What else will happen if I carry out the substitution? What can be used to substitute the place, time, materials or people?
C	Combine	Try to combine two or more materials to attain a complementary effect. **Typical questions:** What materials, features, processes or people can be combined? How to achieve a synergistic effect?
A	Adapt	Try to adapt a component/process appropriately, or to improve the quality of a product/process. **Typical questions:** Which part of the product should be improved? What can be used to make the exchange? How will the exchange affect the features of this combination?
M	Modification	Try to locate the incoherent part and make modification, so as to alter its meaning or form and thus make the product unique. **Typical questions:** Which part can be modified? How to modify it?
P	Purposes	Consider how to repurpose current solutions/products/processes. For example, think of another way to solve the same problem or find another market for your products. **Typical questions:** How can the product fit in other uses? Is there a new role the product can play?
E	Eliminate	Try to find which part of a product can be eliminated. **Typical questions:** Which part can be eliminated? What will happen after the elimination? This allows you to imagine different situations using different methods.
R	Reverse	Consider what will happen if the product/process is produced/carried out in reverse order. This allows you to view things from a different perspective and thus generate new ideas. **Typical questions:** What will happen if I do it in an opposite way?

Application examples (http://tds.ic.polyu.edu.hk/ds/db/01_ino/index.htm)

S Substitute – Mop with electrostatic dust removal paper

Relevant Knowledge

C Combination – Camera phone

A Adapt – All-purpose bag

M Modification -- Ergonomic chair

Relevant Knowledge

P Purposes – Sushi calculators

E Elimination – Wireless mouse

R Reverse – Modular toy

b. Vertical Thinking and Lateral Thinking

i. Vertical Thinking

Vertical thinking is the traditional thinking model we use. Based on known theories, knowledge and experience, in-depth analysis and investigation are conducted according to a specific sequence of thinking. Vertical thinking is suitable for studying well-defined problems with greater depth and scrutiny.

ii. Lateral Thinking

With lateral thinking, we try to break away from the traditional thinking pattern and attempt to perceive the same matter from new perspectives. While vertical thinking puts emphasis on one single dimension of thinking, lateral thinking stresses the multi-dimensions of thinking. It tries to consider a problem from many different directions and angles. It promotes the derivation of possibilities rather than logic or sequence. Steps can be skipped in lateral thinking as it is of the least importance. It brings in from one dimension of vertical thinking to multi-dimensions and thus leads to possibilities of innovation.

For instance, when we want to send a text message to someone far away, the predictable ways via which to do so is either mailing or emailing.

Actually, there exist other possibilities:

(1) Morse code (if the recipient owns a suitable receiving device)
(2) A written document put inside a floating glass bottle (although it may never reach the recipient)
(3) A small note tied to a pigeon (the pigeon must know the location of the recipient)
(4) Purchasing a space on the newspaper the recipient reads for placing a message

With lateral thinking, we start with one idea and it will lead to matters with similar or related features.

Vertical thinking and lateral thinking
Daily life example – Dinner for a family

A housewife is preparing a dinner for her family. The first logical step is to decide the ingredients. Next, she goes to the market and buys the necessary food. Then, she goes home to do the cooking. The final step is to serve the food.

What happens if these steps are skipped, reshuffled or reversed? Can her family members still enjoy a dinner? The answer is probably yes. Can she order take-away or delivery?

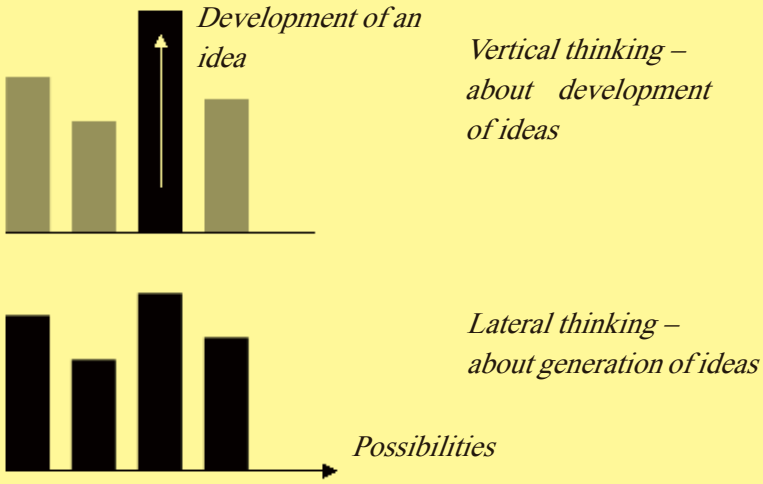
Can she bring her family members to visit a friend and stay there for dinner? Can she instruct her son the way to cook so that he does the cooking instead? Can she hire a temporary cook? Can she make a microwave dinner? These possibilities of serving a dinner, fundamentally, cannot be eliminated.

Relevant Knowledge

Vertical thinking and lateral thinking

Making use of their strengths at various stages

Vertical thinking and lateral thinking are entirely different in nature. These two thinking approaches complement each other during different periods of idea generation and different stages of a development process. At the beginning of a design process when a lot of ideas are required, a designer should employ lateral thinking. Nevertheless, at later stages, especially the production stage, vertical thinking is more often employed. Flexible switching between the two thinking approaches is very important.



Differences between vertical and lateral thinking methods

Characteristics of lateral thinking

It breaks away from traditional constraints, targets any possible directions and finds new features of a problem which traditional thinking approaches cannot spot. When an idea flashes across the mind, grasp it and dig deeper to explore new ideas in depth.

Drawbacks of lateral thinking

Unrestrained lateral thinking may result in products completely detached from the design requirements.

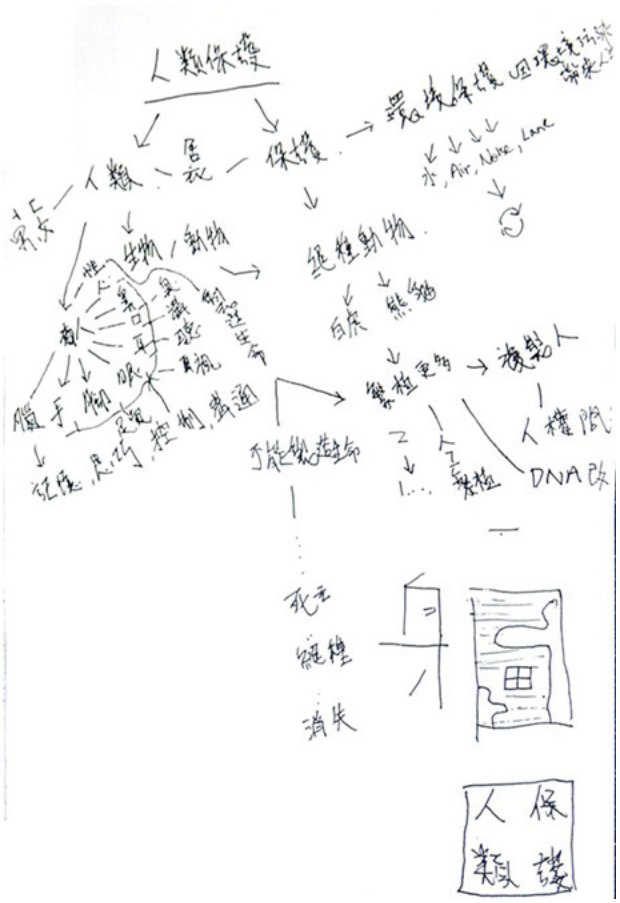
There is no conflict between vertical thinking and lateral thinking. People tend to use both approaches in normal circumstances and there is not a clear-cut differentiation between them during the thinking process.

The key factor of lateral thinking is to use opportunity to inspire other ideas. There are two commonly used methods:

A. Brainstorming

Brainstorming is a means to generate innovative ideas without the constraints of logic. It can be conducted individually or in a group. The designer notes down, through writing or drawing, the concepts in his mind with no particular format. It is an effective way to solve problems especially during the initial idea development stage of a design process. Brainstorming can be extremely efficient in generating a broad range of ideas and developing them further. During a brainstorming session, the following points should be noted.

a. No ideas should be criticised. Criticism causes intimidation to the participants of the brainstorming session.
b. Exchange of ideas is important. When a brainstorming session comes to a standstill, it signals the time to adjourn the meeting, which is to be resumed at a later time.
c. The atmosphere of the discussion should be free, encouraging and comfortable. If a participant is being imperious, he will discourage other participants from expressing their views.



A record made by a student using brainstorming approach

Brainstorming is often carried out by a group and ideas are given rise to by the experience of members. It is very effective in the way that when a member has exhausted his ideas, other members can pick up and extend the ideas readily. As a result, more in-depth ideas can be generated through group brainstorming than individual brainstorming.

A good idea of somebody can be seen as stupid by the others. To prevent a member being insulted and to facilitate the effective running of a brainstorming session, the group leader should control the discussion process and pay attention to the following points.

a. The problem to be solved should be clearly defined.
b. Ensure that members focus on the problem at all times during the discussion.
c. No criticism or evaluation of ideas should occur.
d. Encourage active participation of all members.
e. Encourage creativity.
f. Terminate the discussion of an idea which appears to have lasted longer than enough.
g. Encourage members to follow up on others' ideas.
h. All ideas should be noted down to avoid omitting any discussion results. .

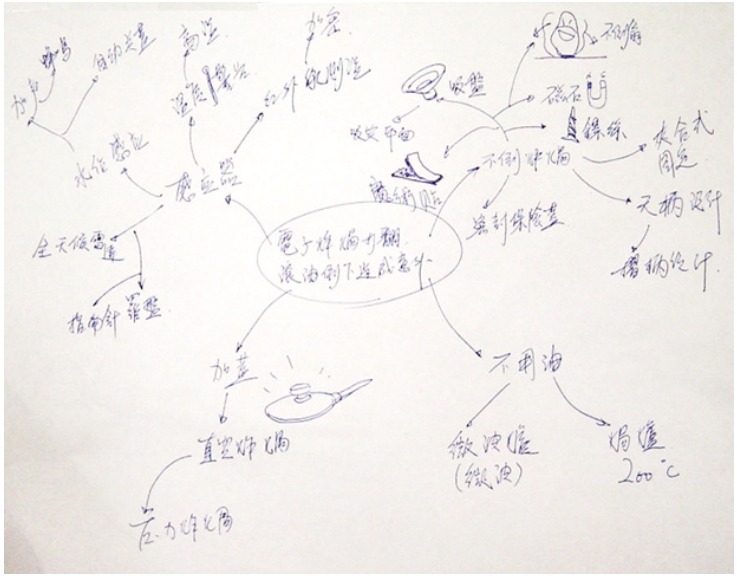
In conclusion, brainstorming can induce the generation of aggressive ideas rapidly. Individually brainstorming can bring about more ideas but it is not as effective as group brainstorming.

Relevant Knowledge

Example: deep fryer

Brainstorming is a good means to stimulate the brain to solve problems and expand new horizons. Its way of thinking relies on 'instant inspirations' and 'collective creation'. The four basic principles of brainstorming are as follows.

a. Assume that all questions have more than one answer.
b. Many of the most successful solutions begin with a seemingly infeasible idea, illogical at first glance and more like a joke.
c. Idea creation and evaluation belong to different thinking processes.
d. Less than objective criticisms, personal habits and social convention are always possible to put the dampers on students' creativity.



Procedures of brainstorming:

1. First decide the topic of discussion.
2. Take turns to express everyone's views. Every idea that comes to mind should be expressed.
3. Jot down the ideas mentioned by every member on a whiteboard or poster paper so that everyone can see them.
4. Finally, select one or combine several suggestions out of those being raised to be the feasible solution, which will be regarded as the ultimate answer.

Principles that must be held when use:

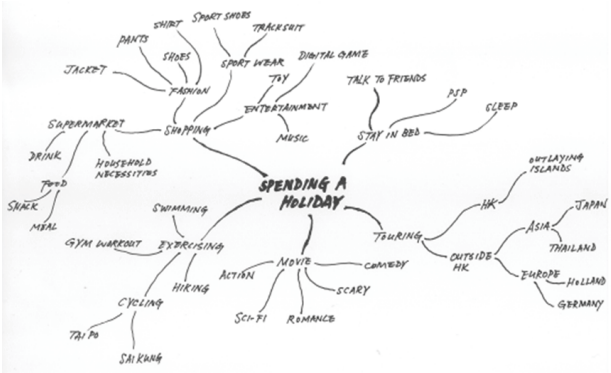
- Never criticise others' opinions. (No criticism)
- The more opinions, the better. (Large quantity)
- Allow members to make association freely. (Unrestrained thinking)
- Opinions can be built on those of the others. (Exchange of ideas)
- Each session should not exceed one hour; otherwise adverse effects might be resulted. In fact, experience suggests that attention spans of most people last for only about 20 minutes.
- A group should consist of a maximum of seven or eight people. In fact, experience shows that seven or eight is the optimal number of people for conducting brainstorming.

Constraints:

- The time brainstorming takes to find an answer is longer and it is limited to handling simpler problems.
- When a group leader is not controlling well, the discussion topic can easily become shifted.

B.Mind map

Drawing mind maps is an important technique to improve the way of recording and to support and enhance creativity for solving problems. Through the use of a mind map, the structure of the subject matter can be quickly identified and understood. All related information is connected and presented clearly, working as a record of the raw facts being written down on standard notes.



Creativity radiates outwards from a single point

A mind map provides a structure which encourages the construction of creative solutions. The format of a mind map allows students to record and review information more easily and quickly.

Abandoning the conventional way of recording information on tables, mind maps facilitate the laying out of information on a two-dimensional structure. A complete mind map illustrates the ‘shape’ of the subject matter, the relative importance of each key point and the inter-relationship among these facts. Mind maps are more concise than conventional notes and are usually drawn on a single page. Mind maps enable associations readily. If more information is found after a mind map is drawn, it can easily be added without much interruption。

A mind map is also useful for

a. summarising information;
b. consolidating information obtained from different research sources;
c. studying a complex problem thoroughly; and
d. presenting information of a subject matter in all perspectives.

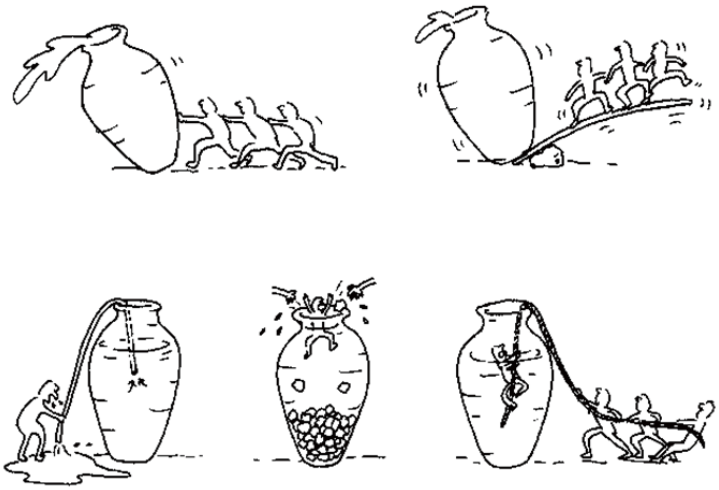
A simple mind map is easily accessible. With a quick glance, students can memorise and absorb the information, refreshing their memory frequently. The following suggestions can improve the effectiveness of a mind map.

a. Use single words or short phrases to record information. The more words are used, the more disorganised the mind map will become.
b. Write or draw neatly. Scribbly writings or drawings will cause the mind map difficult to read
c. Use colours to distinguish different ideas. Colours are helpful to show the structure of the subject matter.
d. Use symbols and figures. Compared to text, images are more effective in helping one to remember information.
e. Use cross-linkages. Students can draw lines to indicate the relationships among different pieces of information. These linkages can help students understand the influence of one part to another part.

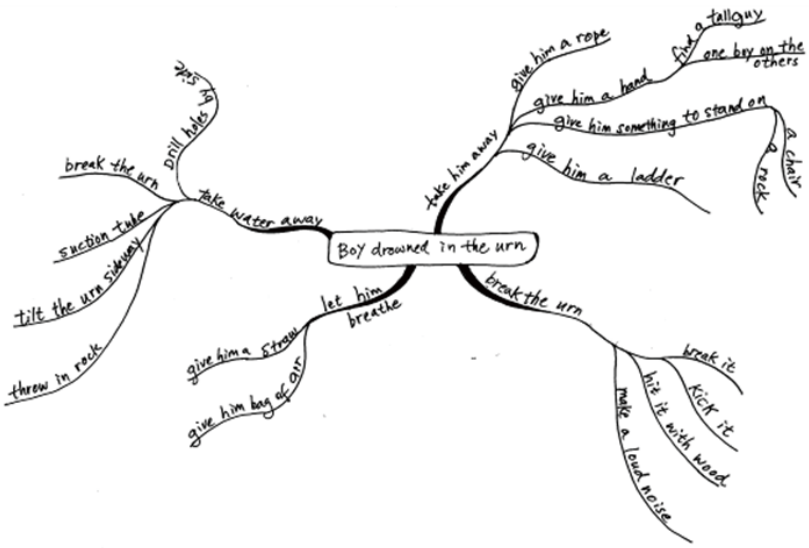
Example: Saving the boy in the urn

The famous story of Sima Guang (司馬光) about saving a friend who fell into an urn showed his wit in lateral thinking.

In the story, he cracked the urn with a rock to drain the water, saving the boy inside the urn. What happened if the urn could not be broken? What other ways could he use?



These solutions can be full of imaginations. They are the results of lateral thinking induced by brainstorming or mind maps.



A mind map drawn for saving the boy in the urn. Note that the mind map describes the possible abstract actions Sima Guang could do, such as ‘taking him away’ and ‘making him breathe’. Further possibilities can be extended at the end of each branch.

Relevant Knowledge

II Design Consideration

Ethical Issues Related to the Design, Production and Sales of Products

The design, production and sales of knives are a sound idea when the knives are used properly. They are useful products and a kind of must-have tool in every home. However, if they are used in an evil way, they can become tools for conducting criminal activities or murders. Should the improper use of knives prohibit the design, production and sales of them?

In Hong Kong, there is an acute housing demand, which leads to the development of housing units such as caged homes and sub-divided units. The design, production and sales of them, nevertheless, have raised many social and ethical issues.

There are products having few problems with their design. Nonetheless, to save costs, these products are manufactured in underdeveloped countries, where there are sweatshops that exploit the workers. There is thus an issue regarding the production aspect.

Another example is about the drugs for treating AIDS and cancers. The design and production of these drugs have merit but selling them at high prices is under query.

Lesson Activity

Regarding the following two controversial objects, students will discuss in groups whether the objects should be designed, produced and sold.

1. Military weapons

The formation of United Nations once brought mankind the hope of world peace. Unfortunately, wars of different scales are still happening at different parts of the world nowadays. The design, production and sales of military weapons are going on every day. Some say this is for the sake of stopping fanatics or terrorists from sabotaging the peace of the world. "World's police" must have tools they can use also. What do you think?

a. What is the original purpose of designing and producing weapons?

_____

_____

b. What possible ethical issues might the designing of weapons lead to? Suggest a way to solve this problem.

_____

_____

c. What possible ethical issues might the production of weapons lead to? Suggest a way to solve this problem.

_____

_____

d. What possible ethical issues might the sales of weapons lead to? Suggest a way to solve this problem.

_____

Relevant Knowledge

2. Genetically modified food

◆The world's first genetically modified (GM) food was introduced to the market in 1996. Since then, GM foods have become a hot issue.

◆People against them consider that GM foods are only consumed by 'Frankenstein' and are threatening our well-being, as well as environmental and ecological balance.

◆People in favour of them consider that GM foods not only are safe and environmentally friendly, they also solve problems including shortage of food supply and famine.

◆Whether you are for or against GM foods, it is impossible for you to avoid eating them because these foods and their raw materials have already hidden in the foods we are consuming every day…

http://cquestgarden.com/view.php?sec=2&id=3409&pt=SP&mode=public

a. What is the original purpose of designing and producing GM foods?

_____

_____

b. What possible ethical issues might the designing of GM foods lead to? Suggest a way to solve this problem.

_____

_____

c. What possible ethical issues might the production of GM foods lead to? Suggest a way to solve this problem.

_____

_____

d. What possible ethical issues might the sales of GM foods lead to? Suggest a way to solve this problem.

_____

_____

Relevant Knowledge

III Considerations in Choosing Appropriate Production Processes

1. Selection of appropriate hand tools, machines and equipment for use with a variety of materials and a range of technological components in a safe and correct manner

The figure on the right is a Japanese brand of a simulated workplace. Craftsmen will choose the appropriate processes and prepare the proper tools and equipment prior to making handmade leather cases for cameras.

The figure on the right is a chair commonly seen in Hong Kong restaurants. Take making the framework of a chair as an example, if we use the wrong tools, unsatisfactory effect will result and we may not achieve our purpose or even damage the tools. If machinery or equipment is used, accidents may happen and the consequences may be even more severe.

The production **processes** may include

- choosing materials;
- cutting a long material into segments of suitable lengths;
- modifying shapes;
- joining segments of the bar-shaped materials to form the frame of the chair; and
- performing surface finishing, such as addition of cushions.

Taking the **cutting** process as an example, relevant considerations include

- materials used,
- shapes of materials,
- constraints,
- tools, equipment and other factors.

Relevant Knowledge

(a) Processes

To cut common materials, the first tools that come to mind are hand tools such as files, chisels, saws and melting tools. If machine tools are to be used, there are sawing machines, lathes, laser cutters, etc.

(b) Materials

Consider the properties of the materials, such as hardness, brittleness and melting points.

- For objects such as paper and thin plastic sheets, consider using snips and cutters.
- For harder materials, consider using saws.
- For more brittle materials such as acrylic sheets and Formica, consider using plastic cutters.
- For materials with lower melting points such as foam, consider using melting tools.

(c) Shapes

There are many tools for cutting straight lines, which is very common. However, if we want to cut curved shapes, we need special tools.

(d) Constraints

Factors such as curve cutting, high precision and time constraints will limit our choices of tools and equipment.

(e) Tools, equipment and other factors

The amount of materials that need to be cut, the availability of sufficient tools or equipment, the cost of each operation and the need to acquire assistance from specialised personnel are the factors to consider.

Choices of hand tools for cutting a few pieces of materials commonly available in workshops:

	Tenon saw	Hacksaw	Hot wire cutter
Timber	Satisfactory	Possible but the blade will easily be clogged. Additional forces will cause the blade to break.	Does not work
Metals	Possible to cut a short length but due to the insufficient hardness of its blade, its saw teeth will break.	Satisfactory effect	Does not work
Foam	Possible but will leave a ragged edge. Not possible to cut curves.	Possible but will leave a ragged edge. Difficult to cut curves.	Satisfactory as the edges are melt apart.

Therefore, other considerations, such as cutting results and wearing of tools, have to be made when choosing the desired processes and tools.

2. Basic concepts of product design for manufactured products or systems

If products or systems need to be mass-produced, then the following considerations should be given to.

- Production processes
- Time required
- Equipment needed for production
- Cost。

A traditional potato peeler

Redesigned plastic peeler

The first costly item is the production of a mould for use in an injection moulding machine. When the production quantity reaches 1,000 or above, then the average cost will be lower than the traditional design. In mass production, the design on plastics will be a less expensive solution, which requires a smaller amount of investment on the materials, production time and component assembly. The metal peeler, in contrast, involves a more complex production procedure, for example, cutting, bending, welding and machining of metals, and assembly of parts.

	Design A		Design B	
	Unit cost (HK$)	Total (HK$)	Unit cost (HK$)	Total (HK$)
Production	0.5+0.9+1.2	3.6	0.2	0.3
Assembly	1.0		0.1	
Packaging	1.0	1.0	1.0	1.0
Storage	0.5 (Box)	0.5	0.2 (Blister pack)	0.2
Transportation	2.0	2.0	1.0 (smaller and lighter package)	1.0
	Total cost per unit	7.1	Total cost per unit	2.5

When mass-produced, the basic investment costs on items such as equipment and moulds can be shared, such that the average production cost and time can be lowered. To achieve the purpose, the materials used, production methods, designs, etc. have to be adjusted. Sometimes, a part of the original design needs to be compromised or sacrificed.

4 Interactive information

	Website	Content
1.	http://www.williamson-labs.com/design.htm Design Flow Chart	Using a design flow chart to introduce design processes step by step
2.	http://tds.ic.polyu.edu.hk/ds/db/08_pd1/index.htm	Introduce every step in a product design process

5 Glossary of terms

Design factor analysis	設計因素分析	Brainstorming	腦力激盪法
Design matrix	設計矩陣	Mind map	心智圖
Vertical thinking	垂直思考	SCAMPER	檢核表技術
Horizontal thinking	水平思考		

Case Study – Design Process (Innovative Hair Dryer)

Case Study Guidelines

1. Objectives

Identify a technological problem and attempt to find an innovative solution with both knowledge in science and technology and apply creative thinking skills.

2. On completion of the design project, students should be able to

- apply lateral thinking through mind maps and brainstorming; and
- apply knowledge in science and technology flexibly.

3. Activity Outline

- Understanding the working principles of traditional hair dryers
- The choice of materials and production methods for traditional hair dryers
- Coming up with other methods for drying hair through lateral thinking
- Redesigning hair dryers through the use of mind maps and brainstorming

4. Recommended Time

5 teaching periods × 40 minutes (total 200 minutes)

5. Required Materials

1. Worksheet
2. Teachers prepare a hair dryer. If students have other kinds of hair dryers at home, they can bring them back after acquiring the permission from teachers as references for other students.

6. Grouping

To facilitate discussion, students are divided into groups of four, with one of them as the group leader for hosting the discussion.

Name of group leader: _____ ( )

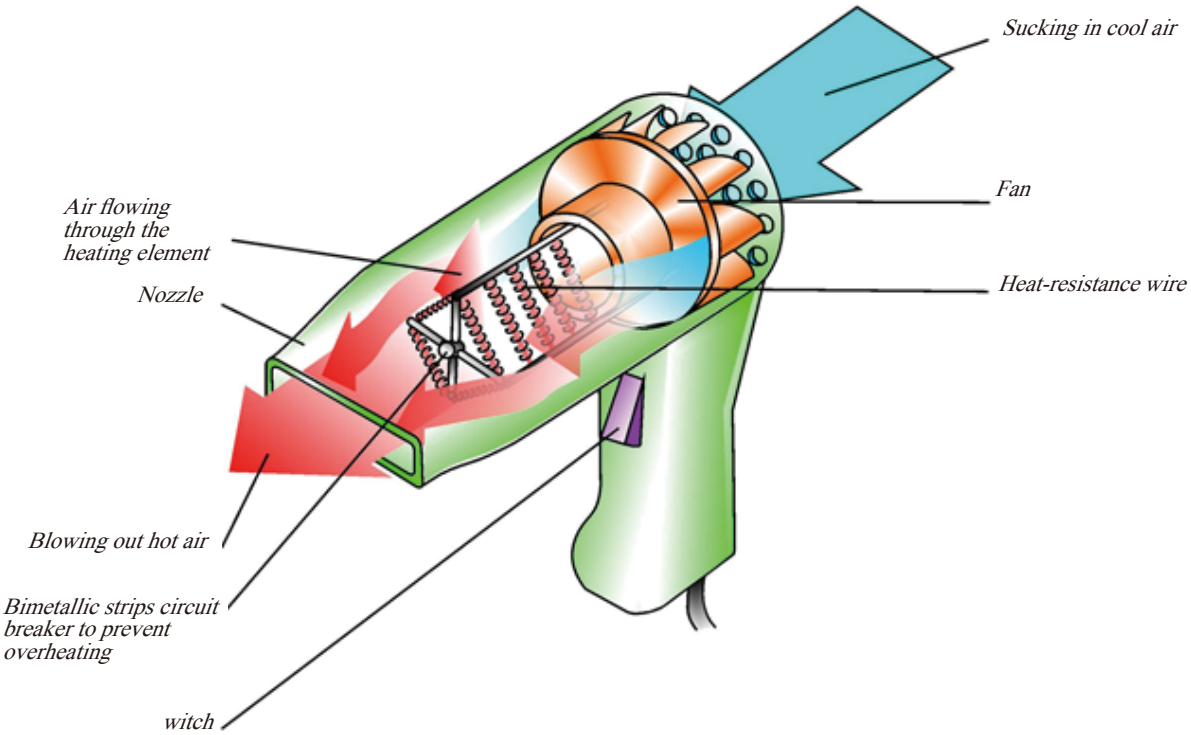
Names of group members:

(1) : _____ ( ) (2) : _____ ( )

(3) : _____ ( )

7. Activity Content

A. Traditional hair dryers



The above figure shows the working principle of a hair dryer. In the following, fill in suitable words to point out the scientific principles applied on the hair dryer.

i. Application of scientific principles

The scientific principles the hair dryer applies include: thermodynamics (_____ induction), electricity (_____ wire and _____ circuit), electromagnetics (motor), fluid mechanics (_____).

ii. Way of application

The hair dryer passes the _____ through the _____, and blow it on the hair. The _____ speeds up the evaporation of the water on the hair.

iii. Way of operation

When the_____is turned on, electric current causes the motor to rotate to _____. At the same time, electric current passes through metal resistance wires to produce_____. Air is sucked in by the fan at the back, passed through the hot heat-resistance wire and blown out at the front.

iv. Disposal of products

When a hair dryer reaches the end of its service life, which part of its materials can be recycled?

a._____

b._____

c._____

d._____

e._____

B. Hair-drying methods

Group leader and each member suggest two ways to dry hair respectively.

i._____

ii._____

iii._____

iv._____

v._____

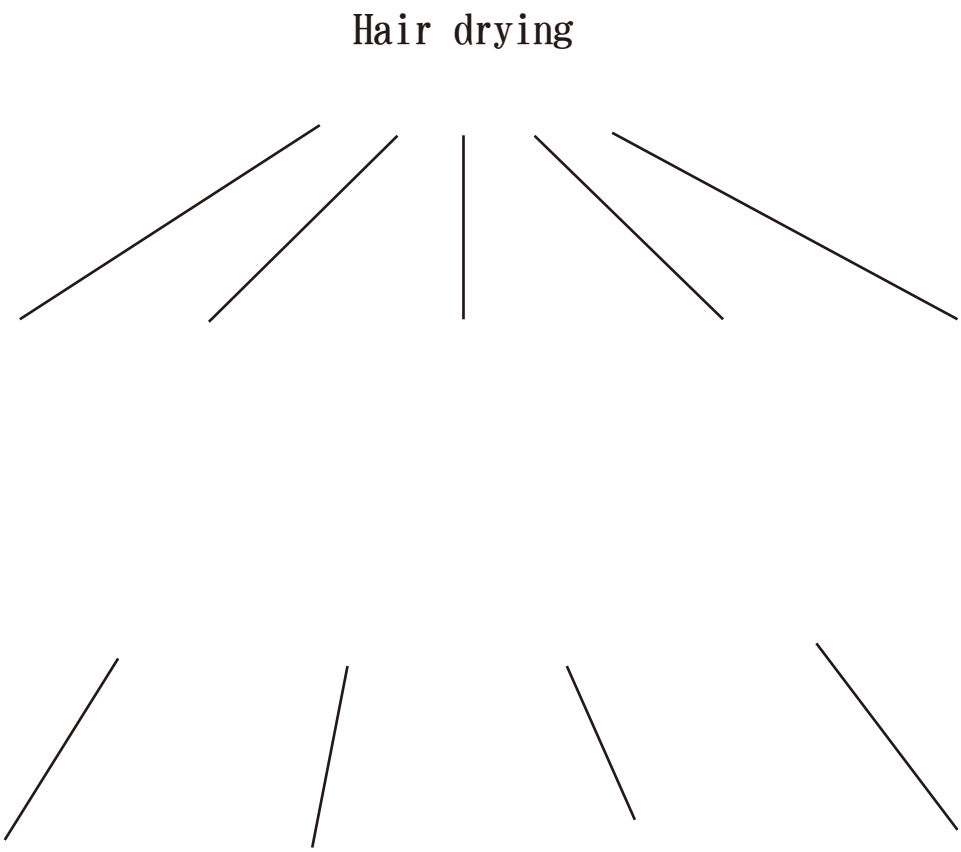
vi._____

vii._____

viii._____

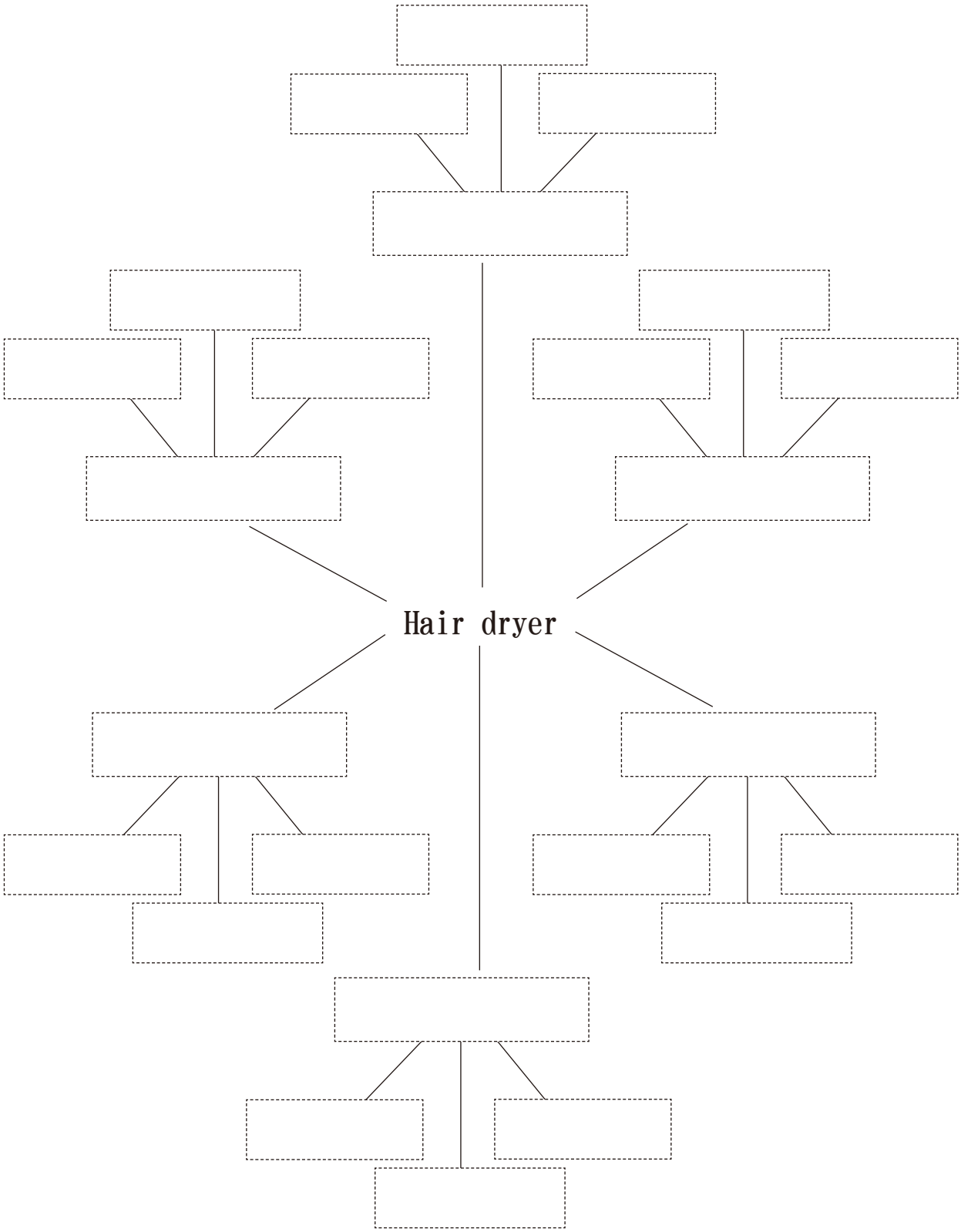
C. Considerations in hair drying

Write/Draw the considerations in hair drying. (The following figure is a basic brainstorming diagram. Students can extend it.)



D. Mind map

Use a mind map to illustrate the considerations in the design of a hair dryer and the possible solutions. (The following figure is a basic mind map. Students can extend it or draw it on another piece of paper and colour it.)



E. Innovative hair dryer

Redesign a hair dryer with innovative ideas and draw its design in the following space.