Design technology guide

First assessment 2016

Diploma Programme

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International Baccalaureate®
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Diploma Programme
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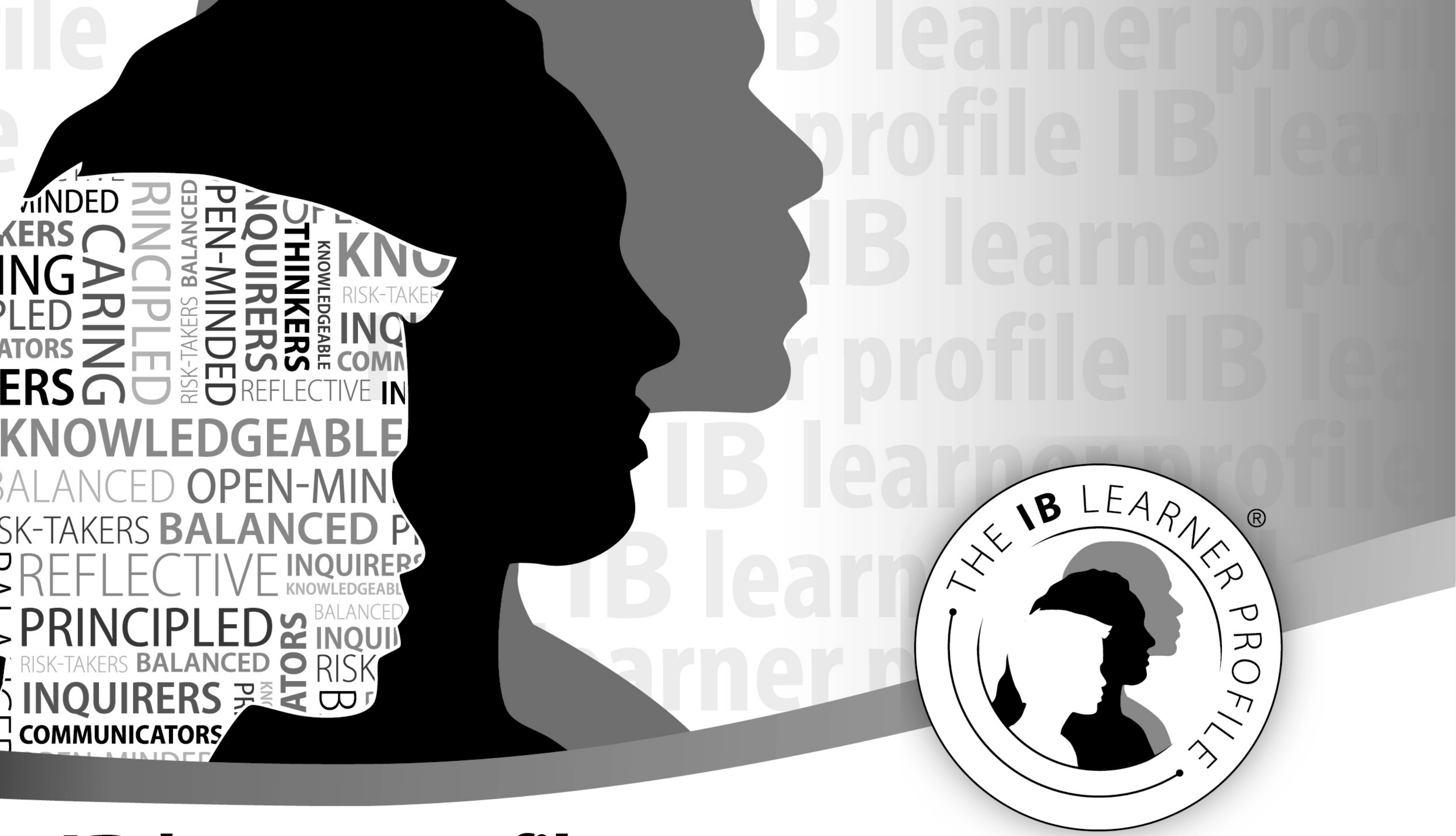
IB mission statement

The International Baccalaureate aims to develop inquiring, knowledgeable and caring young people who help to create a better and more peaceful world through intercultural understanding and respect.

To this end the organization works with schools, governments and international organizations to develop challenging programmes of international education and rigorous assessment.

These programmes encourage students across the world to become active, compassionate and lifelong learners who understand that other people, with their differences, can also be right.



IB learner profile

The aim of all IB programmes is to develop internationally minded people who, recognizing their common humanity and shared guardianship of the planet, help to create a better and more peaceful world.

As IB learners we strive to be:

INQUIRERS
We nurture our curiosity, developing skills for inquiry and research. We know how to learn independently and with others. We learn with enthusiasm and sustain our love of learning throughout life.

KNOWLEDGEABLE
We develop and use conceptual understanding, exploring knowledge across a range of disciplines. We engage with issues and ideas that have local and global significance.

THINKERS
We use critical and creative thinking skills to analyse and take responsible action on complex problems. We exercise initiative in making reasoned, ethical decisions.

COMMUNICATORS
We express ourselves confidently and creatively in more than one language and in many ways. We collaborate effectively, listening carefully to the perspectives of other individuals and groups.

PRINCIPLED
We act with integrity and honesty, with a strong sense of fairness and justice, and with respect for the dignity and rights of people everywhere. We take responsibility for our actions and their consequences.

OPEN-MINDED
We critically appreciate our own cultures and personal histories, as well as the values and traditions of others. We seek and evaluate a range of points of view, and we are willing to grow from the experience.

CARING
We show empathy, compassion and respect. We have a commitment to service, and we act to make a positive difference in the lives of others and in the world around us.

RISK-TAKERS
We approach uncertainty with forethought and determination; we work independently and cooperatively to explore new ideas and innovative strategies. We are resourceful and resilient in the face of challenges and change.

BALANCED
We understand the importance of balancing different aspects of our lives—intellectual, physical, and emotional—to achieve well-being for ourselves and others. We recognize our interdependence with other people and with the world in which we live.

REFLECTIVE
We thoughtfully consider the world and our own ideas and experience. We work to understand our strengths and weaknesses in order to support our learning and personal development.

The IB learner profile represents 10 attributes valued by IB World Schools. We believe these attributes, and others like them, can help individuals and groups become responsible members of local, national and global communities.

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Contents

Purpose of this document

This publication is intended to guide the planning, teaching and assessment of the subject in schools. Subject teachers are the primary audience, although it is expected that teachers will use the guide to inform students and parents about the subject.

This guide can be found on the subject page of the online curriculum centre (OCC) at http://occ.ibo.org, a password-protected IB website designed to support IB teachers. It can also be purchased from the IB store at http://store.ibo.org.

Additional resources

Additional publications such as specimen papers and markschemes, teacher support materials, subject reports and grade descriptors can also be found on the OCC. Past examination papers as well as markschemes can be purchased from the IB store.

Teachers are encouraged to check the OCC for additional resources created or used by other teachers. Teachers can provide details of useful resources, for example: websites, books, videos, journals or teaching ideas.

Acknowledgment

The IB wishes to thank the educators and associated schools for generously contributing time and resources to the production of this guide.

First assessment 2016

The Diploma Programme

The Diploma Programme is a rigorous pre-university course of study designed for students in the 16 to 19 age range. It is a broad-based two-year course that aims to encourage students to be knowledgeable and inquiring, but also caring and compassionate. There is a strong emphasis on encouraging students to develop intercultural understanding, open-mindedness, and the attitudes necessary for them to respect and evaluate a range of points of view.

The Diploma Programme model

The course is presented as six academic areas enclosing a central core (see figure 1). It encourages the concurrent study of a broad range of academic areas. Students study two modern languages (or a modern language and a classical language); a humanities or social science subject; a science; mathematics; and one of the creative arts. It is this comprehensive range of subjects that makes the Diploma Programme a demanding course of study designed to prepare students effectively for university entrance. In each of the academic areas students have flexibility in making their choices, which means they can choose subjects that particularly interest them and that they may wish to study further at university.

Figure 1

Diploma Programme model

Choosing the right combination

Students are required to choose one subject from each of the six academic areas, although they can, instead of an arts subject, choose two subjects from another area. Normally, three subjects (and not more than four) are taken at higher level (HL), and the others are taken at standard level (SL). The IB recommends 240 teaching hours for HL subjects and 150 hours for SL. Subjects at HL are studied in greater depth and breadth than at SL.

At both levels, many skills are developed, especially those of critical thinking and analysis. At the end of the course, students' abilities are measured by means of external assessment. Many subjects contain some element of coursework assessed by teachers.

The core of the Diploma Programme model

All Diploma Programme students participate in the three course elements that make up the core of the model.

Theory of knowledge (TOK) is a course that is fundamentally about critical thinking and inquiry into the process of knowing rather than about learning a specific body of knowledge. The TOK course examines the nature of knowledge and how we know what we claim to know. It does this by encouraging students to analyse knowledge claims and explore questions about the construction of knowledge. The task of TOK is to emphasize connections between areas of shared knowledge and link them to personal knowledge in such a way that an individual becomes more aware of his or her own perspectives and how they might differ from others.

Creativity, action, service (CAS) is at the heart of the Diploma Programme. The emphasis in CAS is on helping students to develop their own identities, in accordance with the ethical principles embodied in the IB mission statement and the IB learner profile. It involves students in a range of activities alongside their academic studies throughout the Diploma Programme. The three strands of CAS are Creativity (arts and other experiences that involve creative thinking), Action (physical exertion contributing to a healthy lifestyle) and Service (an unpaid and voluntary exchange that has a learning benefit for the student). Possibly, more than any other component in the Diploma Programme, CAS contributes to the IB's mission to create a better and more peaceful world through intercultural understanding and respect.

The extended essay, including the world studies extended essay, offers the opportunity for IB students to investigate a topic of special interest, in the form of a 4,000-word piece of independent research. The area of research undertaken is chosen from one of the students' Diploma Programme subjects, or in the case of the interdisciplinary world studies essay, two subjects, and acquaints them with the independent research and writing skills expected at university. This leads to a major piece of formally presented, structured writing, in which ideas and findings are communicated in a reasoned and coherent manner, appropriate to the subject or subjects chosen. It is intended to promote high-level research and writing skills, intellectual discovery and creativity. As an authentic learning experience it provides students with an opportunity to engage in personal research on a topic of choice, under the guidance of a supervisor.

Approaches to teaching and approaches to learning

Approaches to teaching and learning across the Diploma Programme refer to deliberate strategies, skills and attitudes which permeate the teaching and learning environment. These approaches and tools, intrinsically linked with the learner profile attributes, enhance student learning and assist student preparation for the Diploma Programme assessment and beyond. The aims of approaches to teaching and learning in the Diploma Programme are to:

- empower teachers as teachers of learners as well as teachers of content
- empower teachers to create clearer strategies for facilitating learning experiences in which students are more meaningfully engaged in structured inquiry and greater critical and creative thinking
- promote both the aims of individual subjects (making them more than course aspirations) and linking previously isolated knowledge (concurrency of learning)
- encourage students to develop an explicit variety of skills that will equip them to continue to be actively engaged in learning after they leave school, and to help them not only obtain university admission through better grades but also prepare for success during tertiary education and beyond
- enhance further the coherence and relevance of the students' Diploma Programme experience
- allow schools to identify the distinctive nature of an IB Diploma Programme education, with its blend of idealism and practicality.

The five approaches to learning (developing thinking skills, social skills, communication skills, self-management skills and research skills) along with the six approaches to teaching (teaching that is inquiry-based, conceptually focused, contextualized, collaborative, differentiated and informed by assessment) encompass the key values and principles that underpin IB pedagogy.

The IB mission statement and the IB learner profile

The Diploma Programme aims to develop in students the knowledge, skills and attitudes they will need to fulfill the aims of the IB, as expressed in the organization's mission statement and the learner profile. Teaching and learning in the Diploma Programme represent the reality in daily practice of the organization's educational philosophy.

Academic honesty

Academic honesty in the Diploma Programme is a set of values and behaviours informed by the attributes of the learner profile. In teaching, learning and assessment, academic honesty serves to promote personal integrity, engender respect for the integrity of others and their work, and ensure that all students have an equal opportunity to demonstrate the knowledge and skills they acquire during their studies.

All coursework—including work submitted for assessment—is to be authentic, based on the student's individual and original ideas with the ideas and work of others fully acknowledged. Assessment tasks that require teachers to provide guidance to students or that require students to work collaboratively must be completed in full compliance with the detailed guidelines provided by the IB for the relevant subjects.

For further information on academic honesty in the IB and the Diploma Programme, please consult the IB publications *Academic honesty* (2011), *The Diploma Programme: From principles into practice* (2009) and *General regulations: Diploma Programme* (2011). Specific information regarding academic honesty as it pertains to external and internal assessment components of this Diploma Programme subject can be found in this guide.

Acknowledging the ideas or work of another person

Coordinators and teachers are reminded that candidates must acknowledge all sources used in work submitted for assessment. The following is intended as a clarification of this requirement.

Diploma Programme candidates submit work for assessment in a variety of media that may include audio-visual material, text, graphs, images and/or data published in print or electronic sources. If a candidate uses the work or ideas of another person, the candidate must acknowledge the source using a standard style of referencing in a consistent manner. A candidate's failure to acknowledge a source will be investigated by the IB as a potential breach of regulations that may result in a penalty imposed by the IB final award committee.

The IB does not prescribe which style(s) of referencing or in-text citation should be used by candidates; this is left to the discretion of appropriate faculty/staff in the candidate's school. The wide range of subjects, three response languages and the diversity of referencing styles make it impractical and restrictive to insist on particular styles. In practice, certain styles may prove most commonly used, but schools are free to choose a style that is appropriate for the subject concerned and the language in which candidates' work is written. Regardless of the reference style adopted by the school for a given subject, it is expected that the minimum information given includes: name of author, date of publication, title of source, and page numbers as applicable.

Candidates are expected to use a standard style and use it consistently so that credit is given to all sources used, including sources that have been paraphrased or summarized. When writing text, candidates must clearly distinguish between their words and those of others by the use of quotation marks (or other method, such as indentation) followed by an appropriate citation that denotes an entry in the bibliography. If an electronic source is cited, the date of access must be indicated. Candidates are not expected to show faultless expertise in referencing, but are expected to demonstrate that all sources have been acknowledged. Candidates must be advised that audio-visual material, text, graphs, images and/or data published in print or in electronic sources that is not their own must also attribute the source. Again, an appropriate style of referencing/citation must be used.

Learning diversity and learning support requirements

Schools must ensure that equal access arrangements and reasonable adjustments are provided to candidates with learning support requirements that are in line with the IB documents *Candidates with assessment access requirements* and *Learning diversity in the International Baccalaureate programmes: Special educational needs within the International Baccalaureate programmes*.

Nature of design

1. What is design?

1.1 Design is a process that links innovation and creativity.

1.2 Design provides a structured process based on well-established design principles to resolve authentic problems.

1.3 Design involves generating ideas, exploring the possibilities and constraints to find solutions.

1.4 Design is a cyclical and iterative process.

1.5 Design is human-centred and focuses on the needs, wants and limitations of the end user.

1.6 Competent design can be achieved by all and is not restricted to uniquely skilled individuals. The use of well-established design principles and processes increases the probability that a design will be successful.

1.7 Designers use a wide variety of concepts, principles and strategies, which, taken together, make up what is known as design methodology. Designers adapt their approach to different design contexts, but they have a common understanding of the process necessary to form valid and suitable solutions.

1.8 Competent design requires imagination and creativity together with substantial factual, procedural and conceptual knowledge.

1.9 In-depth investigation of the nature of a problem is required to establish clear parameters for a design specification. This determines the scope of a solution and is necessary for good decision-making.

1.10 Designers must adopt an approach that allows them to think creatively within the constraints of a design specification. The ability to create unique and original solutions to a proposed problem is advantageous.

1.11 Designers need to critically explore the latest advances in technology to determine whether they can be used to develop the best solution to a problem. Traditional methods can be more appropriate and user-friendly.

1.12 Design is a collaborative endeavour requiring diverse teams of experts to realize a tangible solution.

1.13 Modelling is central to design. This involves cognitive, graphical, physical, aesthetic, mechanical, and digital modelling.

1.14 The growth in computing power has made modelling much more powerful. The generation of digital prototypes allows dynamic modelling of complex situations. Simulations involving large amounts of data, large numbers of variables and complex calculations speed up the design process and extend possible solutions.

1.15 A designer should maintain an unbiased view of a situation and evaluate a context objectively, highlighting the strengths, weaknesses and opportunities of a product, service or system.

1.16 Designers have a responsibility to the community and the environment. Their decisions often have major impact on both and they must always be aware of the ethical and moral dimensions of their work.

1.17 Design is carried out by a community of people from a wide variety of backgrounds and traditions, and this has clearly influenced the way design has progressed at different times. However, it is important to understand that design is universal and has common understandings, methodologies, and goals.

1.18 Designers must consider how users will interact with, use and misuse the products they design.

1.19 Designers should be aware that with the advancement of technology, there are now issues surrounding security and safety of personal data that need to be addressed in the majority of contexts.

1.20 Design permeates every aspect of human experience. Individuals make design decisions in all areas of their work, home and leisure.

2. The role of science and technology in design

2.1 Both science and technology have a fundamental relationship with design. Technology preceded science, but now most technological developments are based on scientific understanding.

2.2 Traditional technology comprised useful artifacts often with little understanding of the science underpinning their production and use. In contrast, modern technology involves the application of scientific discoveries to produce useful artifacts.

2.3 The application of scientific discovery to solve a problem enables designers to create new technologies.

2.4 These new technologies can be utilized by scientists to make new scientific discoveries.

2.5 Designers use new and existing technologies to create new products, services and systems.

2.6 The rapid pace of scientific discovery has impacted the rate that designers can develop new technologies. New technologies allow new products to be developed, which solve long-standing problems, improve on existing solutions and fill gaps in markets.

2.7 Often, by solving one problem and designing new technologies, there are unforeseen consequences, which bring new problems.

2.8 Technology is designed in response to changes in human needs. Many societies have benefited from the design of technologies to provide resources, such as electricity and fresh water supplies, clothing, food and transport.

2.9 The technologies that sustain the digital revolution are only one facet of technology. Design remains involved in developing technology to satisfy basic human needs and make people’s lives easier.

2.10 The concept of sustainability is becoming a greater priority for designers. The development of sustainable technologies is a response to environmental and social pressures relating to climate change, energy and resource depletion.

3. Characteristics of a good designer

The following characteristics frame a profile of both professional and aspiring designers. They reflect the desirable abilities, skill sets and mindset of all designers.

Designers can/are able to:

3.1 problem solve/troubleshoot in any context or situation, across a variety of design disciplines

3.2 realize innovative products, services, systems and technologies by learning through failure, extensive trialling, constant evaluation and redevelopment, perseverance and determination

3.3 seek, establish and verify broad concepts and general principles that underlie design methodology

3.4 conduct thorough research, synthesize evidence and apply the findings to the development of innovative products, services, systems and technologies

3.5 carefully observe human interactions and situations, identify and monitor short- and long-term trends and ask pertinent questions to explore design opportunities

3.6 assess the risks associated with the design and use of technology as well as any associated moral, social, ethical or environmental issues

3.7 think creatively and develop ideas beyond the confines of existing concepts, principles and modes of thinking

3.8 empathize with individuals or groups to ascertain and identify needs or design opportunities

3.9 collaborate, inspire and enthuse through effective communication using a variety of appropriate modes and media

3.10 appreciate the influence of others within the field of design including historical and current leaders, movements and organizations.

Nature of design technology

Design, and the resultant development of new technologies, has given rise to profound changes in society: transforming how we access and process information; how we adapt our environment; how we communicate with others; how we are able to solve problems; how we work and live.

Technology emerged before science, and materials were used to produce useful and decorative artifacts long before there was an understanding of why materials had different properties that could be used for different purposes. In the modern world the reverse is the case, and designers need to have an understanding of the possibilities offered by science to realize the full potential of what they can design in terms of new technologies, products and systems.

Design is the link between innovation and creativity, taking thoughts and exploring the possibilities and constraints associated with products or systems, allowing them to redefine and manage the generation of further thought through prototyping, experimentation and adaptation. It is human-centred and focuses on the needs, wants and limitations of the end user.

Competent design is within the reach of all. Through the practice and application of well-established design principles and methodologies, individuals can increase the likelihood that a design will be successful. These principles taken together make up what is known as the design cycle.

Designing requires an individual to be imaginative and creative, while having a substantial knowledge base of important factors that will aid or constrain the process. Decision-making needs to be supported by adequate and appropriate research and investigation. Designers must think "out of the box" to develop innovative solutions, while thinking "in the box" to conform to requirements set by clients or research.

Both the ideas of design and the process of design can only occur in a human context. Design involves multidisciplinary teams and stakeholders with different backgrounds and traditions. It is important to understand, however, that to design is to be involved in a community of inquiry with certain common beliefs, methodologies, understandings and processes. Design is multidisciplinary and draws from many areas including the natural and social sciences, mathematics and arts.

Diploma Programme design technology aims to develop internationally minded people whose enhanced understanding of design and the technological world can facilitate our shared guardianship of the planet and create a better world.

It focuses on analysis, design development, synthesis and evaluation. The creative tension between theory and practice is what characterizes design technology within the Diploma Programme sciences group.

Inquiry and problem-solving are at the heart of the subject. Diploma Programme design technology requires the use of the design cycle as a tool, which provides the methodology used to structure the inquiry and analysis of problems, the development of feasible solutions, and the testing and evaluation of the solution. In Diploma Programme design technology, a solution can be defined as a model, prototype, product or system that students have developed independently.

Diploma Programme design technology achieves a high level of design literacy by enabling students to develop critical-thinking and design skills, which they can apply in a practical context. While designing may take various forms, it will involve the selective application of knowledge within an ethical framework.

A well-planned design programme enables students to develop not only practical skills but also strategies for creative and critical thinking.

The design cycle

Each and every designer approaches a problem in a different way. Depending on the designers' specialism, they tend to have their own methodology, but there are some general activities common to all designers. The design cycle model is a fundamental concept underpinning the design process and central to a student's understanding of design activities.

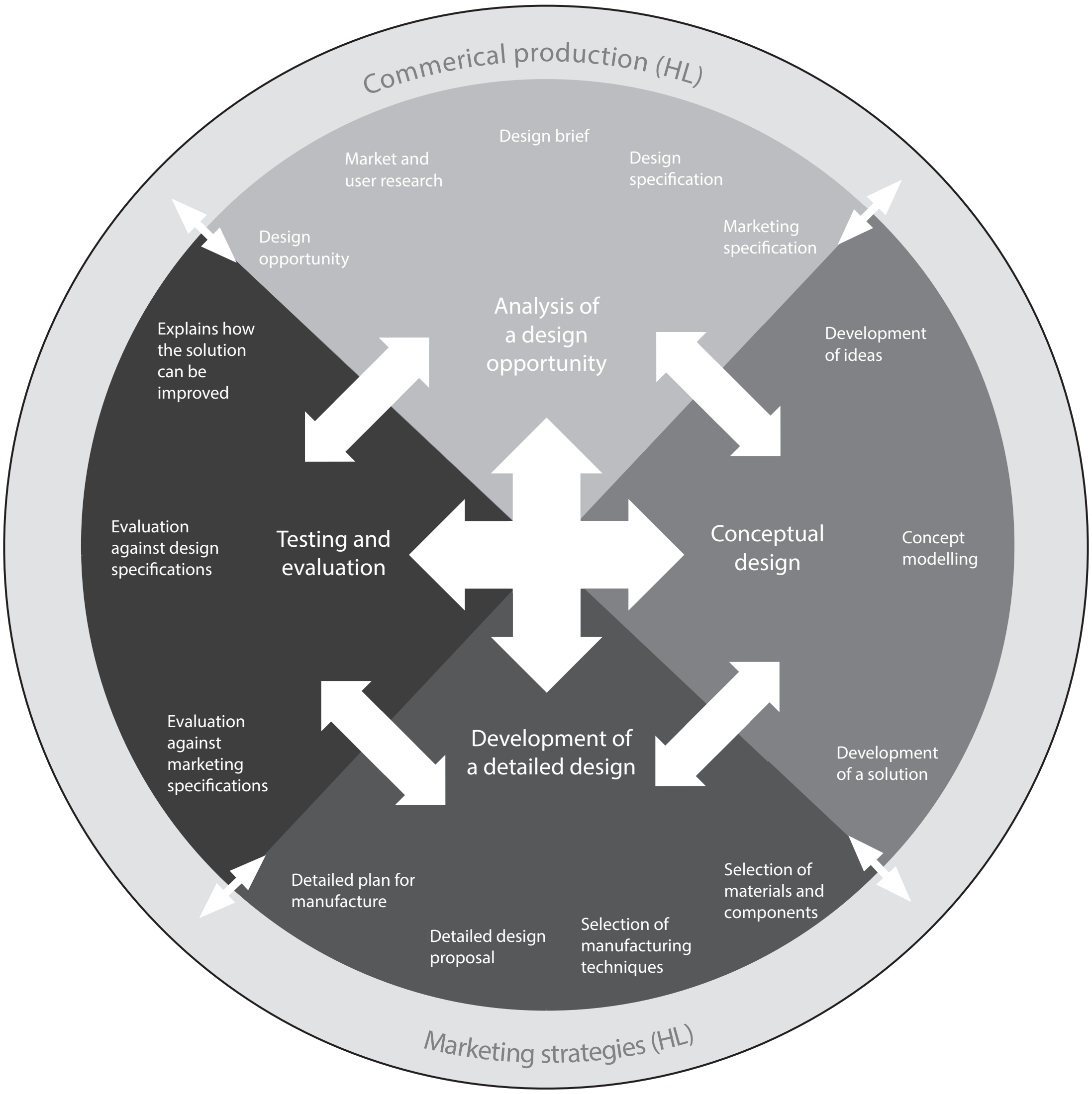


Figure 2

The Diploma Programme design cycle

The design cycle diagram (figure 2) represents the Diploma Programme design technology methodology of how designers develop products. The process is divided into the following four stages.

- Analysis of a design opportunity
- Conceptual design
- Development of a detailed design
- Testing and evaluation

This incremental process allows the designer to go from identifying a design opportunity to the testing and evaluation of a solution. This process leads to invention.

At higher level (HL), the following two additional stages are added.

- Commercial production
- Marketing strategies

The student must take his or her invention and plan to develop it into an innovation, that is get the product to diffuse into the marketplace. The two new stages are designed to extend the students' skills and ability to create innovations.

Design technology and the international dimension

Technology itself is an international endeavour; the exchange of information and ideas around the world has been both a cause and an effect of the development of technology. This exchange is not a new phenomenon but it has accelerated in recent times with the development of information and communication technologies. Indeed, the idea that technology is a modern invention is a myth—people began developing technologies when they first started fashioning tools from stones, making fire to process their food, and shaping material to keep themselves warm. Teachers are encouraged to emphasize this contribution in their teaching of various topics, perhaps through an analysis of the principles of early technologies and the use of timeline websites. The design technology method in its widest sense, with its emphasis on creativity, innovation, open-mindedness and freedom of thought, transcends politics, religion and nationality. Where appropriate within certain topics, the syllabus details sections in the group 4 guides contain links illustrating the international aspects of technology.

On an organizational level, many international bodies now exist to analyse and promote technology. International bodies such as the International Labour Organization, the United Nations Industrial Development Organization, the United Nations Framework Convention on Climate Change, the United Nations Conference on Trade and Development and many others monitor, plan and provide information about global technology issues. The rapid profusion of these international organizations attests to the global nature of technology: both the internationalization of the design and development of technology, and the global effects of technologies, for example, climate change. Students are encouraged to access the extensive websites of these international organizations to enhance their appreciation of the international dimensions of technology.

Some topics in the guide are specifically written to bring out this global dimension. On a practical level, the group 4 project mirrors real design methodology by encouraging collaboration between schools across the regions.

The power of technology to transform societies is unparalleled. It has the potential to produce great universal benefits or to reinforce inequalities and cause harm to people and the environment. In line with the IB mission statement, students need to be aware of the moral responsibility of designers to ensure that appropriate technologies are available to all communities on an equitable basis and that they have the technological capacity to use this for developing sustainable societies.

Students' attention should be drawn to sections of the syllabus with links to international-mindedness. Examples of issues relating to international-mindedness are given within sub-topics in the syllabus content.

Distinction between SL and HL

Design technology students at standard level (SL) and higher level (HL) undertake a common core and have four common assessment criteria used for their internal assessment (IA). They are presented with a syllabus that encourages the development of certain skills, attributes and attitudes, as described in the "Assessment objectives" section of this guide.

While the skills and activities of design technology are common to students at both SL and HL, students at HL are required to study additional topics and are required to meet two additional assessment criteria for internal assessment. The distinction between SL and HL is one of breadth and depth.

Prior learning

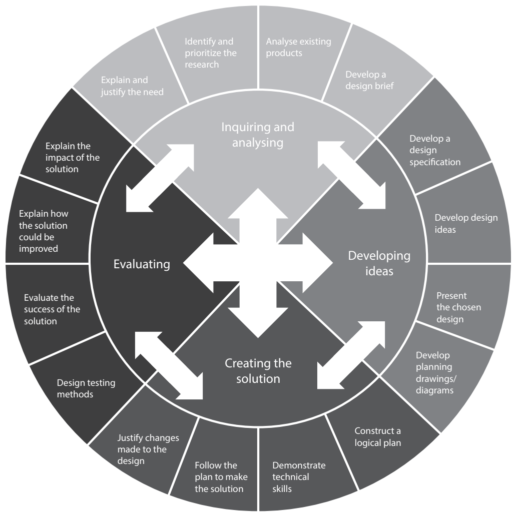
Past experience shows that students will be able to study design technology at SL successfully with no background in, or previous knowledge of, the subject. Their approach to study, characterized by the specific IB learner profile attributes—inquirers, thinkers and communicators—will be significant here.

However, for most students considering the study of design technology at HL some previous exposure to design would be beneficial. Specific topic details are not specified but students who have undertaken the IB Middle Years Programme (MYP) would be well prepared. Other national design technology education qualifications or a school-based design technology course would also be suitable preparation for study of design technology at HL.

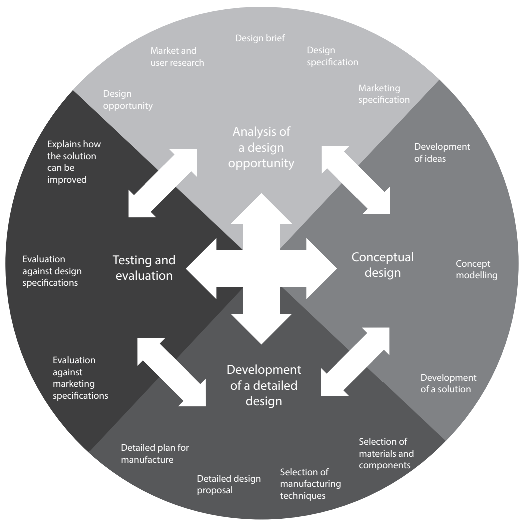
Links to the Middle Years Programme

Diploma Programme design technology builds on experiences of inquiry that students have gained in their time in the IB Primary Years Programme (PYP) and MYP. PYP teaching and learning experiences challenge students to be curious, ask questions, explore and interact with the environment physically, socially and intellectually to construct meaning and refine their understanding. Even when there is no design component in the PYP, the use of structured inquiry is a precursor to the problem-solving and inquiry-based approach of MYP design.

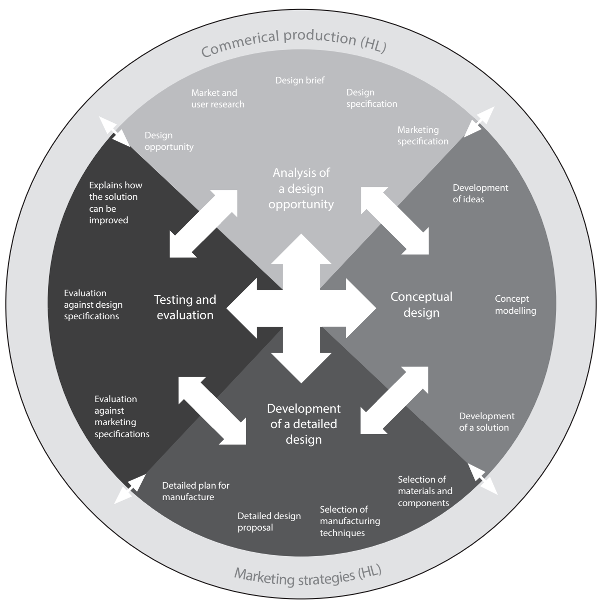
The inquiry-based approach of MYP design courses thoroughly prepare students for Diploma Programme design technology. The MYP design objectives and assessment criteria provide a clear and smooth transition from the MYP to Diploma Programme. The alignment between the design methodology expressed through the MYP design cycle is further developed in Diploma Programme design technology with problem-solving through invention at the heart of SL; and this is further extended towards innovation at HL. As such, students continuing on to Diploma Programme design technology from MYP have gained a wealth of experience using the MYP design cycle and will have developed critical-thinking and design skills, which they will be able to apply to solve more complex problems.



MYP design cycle



DP design cycle (SL)



DP design cycle (HL)

Design technology and theory of knowledge

The theory of knowledge (TOK) course (first assessment 2015) engages students in reflection on the nature of knowledge and on how we know what we claim to know. The course identifies eight ways of knowing: reason, emotion, language, sense perception, intuition, imagination, faith and memory. Students explore these means of producing knowledge within the context of various areas of knowledge: the natural sciences, the social sciences, the arts, ethics, history, mathematics, religious knowledge systems and indigenous knowledge systems. The course also requires students to make comparisons between the different areas of knowledge; reflecting on how knowledge is arrived at in the various disciplines, what the disciplines have in common, and the differences between them.

TOK lessons can support students in their study of design technology, just as the study of design technology can support students in their TOK course. TOK provides a space for students to engage in stimulating wider discussions about questions such as the extent to which technology is both an enabler and limiter of knowledge. It also provides an opportunity for students to reflect on the methodologies of design technology, and how these compare to the methodologies of other areas of knowledge.

In this way there are rich opportunities for students to make links between their design technology and TOK courses. One way in which design technology teachers can help students to make these links to TOK is by drawing students' attention to knowledge questions which arise from their subject content. Knowledge questions are open-ended questions about knowledge, and include questions such as:

- How does knowledge in design technology progress? How does that compare to how knowledge progresses in other areas of knowledge?
- Are intuitively appealing explanations more likely to be true than explanations supported by other means?
- What is the role of imagination in design technology?
- Are the methods used in design technology closer to the methods used in the arts or the methods used in the natural sciences?
- What is the relationship between facts/data and theories, and how does this differ in different areas of knowledge?
- What is the impact of culture in the production and distribution of knowledge in various areas of knowledge?
- To what extent does the methodology of an investigation limit or determine the possible outcomes?

Suggestions for TOK discussions and examples of relevant knowledge questions are provided throughout this guide, within the sub-topics in the syllabus content. Teachers can also find suggestions of interesting knowledge questions for discussion in the "Areas of knowledge" and "Knowledge frameworks" sections of the *Theory of knowledge guide*. Students should be encouraged to raise and discuss such knowledge questions in both their design technology and TOK classes.

Aims

Design technology aims

Through studying design technology, students should become aware of how designers work and communicate with each other. While the design methodology may take on a wide variety of forms, it is the emphasis on a practical approach through design work that characterizes this subject.

The aims of the subject state in a general way what the teacher may expect to teach or do, and what a student may expect to experience or learn.

The aims enable students, through the overarching theme of the nature of design, to develop:

1. a sense of curiosity as they acquire the skills necessary for independent and lifelong learning and action through inquiry into the technological world around them
2. an ability to explore concepts, ideas and issues with personal, local and global significance to acquire in-depth knowledge and understanding of design and technology
3. initiative in applying thinking skills critically and creatively to identify and resolve complex social and technological problems through reasoned ethical decision-making
4. an ability to understand and express ideas confidently and creatively using a variety of communication techniques through collaboration with others
5. a propensity to act with integrity and honesty, and take responsibility for their own actions in designing technological solutions to problems
6. an understanding and appreciation of cultures in terms of global technological development, seeking and evaluating a range of perspectives
7. a willingness to approach unfamiliar situations in an informed manner and explore new roles, ideas and strategies so they can articulate and defend their proposals with confidence
8. an understanding of the contribution of design and technology to the promotion of intellectual, physical and emotional balance and the achievement of personal and social well-being
9. empathy, compassion and respect for the needs and feelings of others in order to make a positive difference to the lives of others and to the environment
10. skills that enable them to reflect on the impacts of design and technology on society and the environment in order to develop their own learning and enhance solutions to technological problems.

Assessment objectives

The assessment objectives for design technology reflect those parts of the aims that will be formally assessed either internally or externally. Wherever appropriate, the assessment will draw upon environmental and technological contexts and identify the social, moral and economic effects of technology.

It is the intention of the design technology course that students are able to fulfill the following assessment objectives.

1. Demonstrate knowledge and understanding of:
    a. facts, concepts, principles and terminology
    b. design methodology and technology
    c. methods of communicating and presenting technological information.
2. Apply and use:
    a. facts, concepts, principles and terminology
    b. design methodology and technology
    c. methods of communicating and presenting technological information.
3. Construct, analyse and evaluate:
    a. design briefs, problems, specifications and plans
    b. methods, techniques and products
    c. data, information and technological explanations.
4. Demonstrate the appropriate research, experimentation, modelling and personal skills necessary to carry out innovative, insightful, ethical and effective designing.

Syllabus outline

Syllabus component	Teaching hours	
	SL	HL
Core	**90**	
1. Human factors and ergonomics	12	
2. Resource management and sustainable production	22	
3. Modelling	12	
4. Raw material to final product	23	
5. Innovation and design	13	
6. Classic design	8	
Additional higher level (AHL)		**54**
7. User-centred design (UCD)		12
8. Sustainability		14
9. Innovation and markets		13
10. Commercial production		15
Practical work	**60**	**96**
Design project	40	60
Group 4 project	10	10
Teacher-directed activities	10	26
Total teaching hours	**150**	**240**

The recommended teaching time is 240 hours to complete HL courses and 150 hours to complete SL courses as stated in the document *General regulations: Diploma Programme* (2011) (page 4 article 8.2).

Approaches to the teaching of design technology

Format of the syllabus

The format of the syllabus section of the group 4 guides gives prominence and focus to the teaching and learning aspects.

Topics

Topics are numbered for ease of reference (for example, "Topic 2: Resource management and sustainable production").

Sub-topics

Sub-topics are numbered as follows, "2.1 Resources and reserves". Further information and guidance about possible teaching times are contained in the teacher support material.

Each sub-topic begins with an essential idea. The essential idea is an enduring interpretation that is considered part of the general understanding of design.

Below the essential idea the sub-topic is presented in three columns.

The first column is the "Nature of design". This gives specific examples in context illustrating some aspects of the nature of design. These are linked directly to specific references in the "Nature of design" section of the guide to support teachers in their understanding of the general theme to be addressed.

The second column lists concepts and principles, which are the main general ideas to be taught, and "Guidance" gives information about the limits and constraints and the depth of treatment required.

The third column gives suggestions to teachers about relevant references to international-mindedness. It also gives examples of TOK knowledge questions (see *Theory of knowledge guide* published 2013) that can be used to focus students' thoughts on the preparation of the TOK prescribed essay. The "Utilization" section may link the sub-topic to other parts of the subject syllabus and other Diploma Programme subject guides. Finally, the "Aims" section refers to how design technology aims are being addressed in the sub-topic.

Format of the guide

Topic 1: <Title>

Essential idea: This lists the essential idea for each sub-topic.

1.1 Sub-topic		
Nature of design: This section relates the sub-topic to the overarching theme of nature of design.	**Concepts and principles:** • This section will provide specifics of the content requirements for each sub-topic. **Guidance:** • This section will provide constraints to the requirements for the concepts and principles.	**International-mindedness:** • Ideas that teachers can easily integrate into the delivery of their lessons. **Theory of knowledge:** • Examples of TOK knowledge questions. **Utilization:** (including syllabus and cross-curricular links) • Links to other topics within the *Design technology guide* and to other Diploma Programme courses. **Aims:** • Links to the design technology aims.

Design technology practical skills

> I hear and I forget. I see and I remember. I do and I understand.
>
> Confucius

Integral to the experience of students in any of the group 4 courses is their experience in the classroom, workshop, laboratory or in the field. Practical activities allow students to interact directly with natural materials, and primary and secondary data sources. These experiences provide the students with the opportunity to design investigations, collect data, develop manipulative skills, analyse results, collaborate with peers and evaluate and communicate their findings. Practical activities can be used to introduce a topic, investigate a phenomenon or allow students to consider and examine questions and curiosities.

By providing students with the opportunity for hands-on experimentation, they are carrying out some of the same processes that designers undertake.

It is important that students are involved in an inquiry-based practical programme that allows for the development of design thinking. It is not enough for students just to be able follow directions and to simply replicate a given procedure, they must be provided with the opportunities for genuine inquiry. Developing inquiry skills will give students the ability to construct an explanation based on reliable evidence and logical reasoning. Once developed, these higher-order thinking skills will enable students to be lifelong learners and design literate.

A school's practical scheme of work should allow students to experience the full breadth and depth of the course. This practical scheme of work must also prepare students to undertake the design project that is required for the internal assessment. The development of students' manipulative skills should involve them being able to follow instructions accurately and demonstrate the safe, competent and methodical use of a range of techniques and equipment, which can then be applied to a range of design contexts.

Mathematical requirements

All Diploma Programme design technology students should be able to:

- perform the basic arithmetic functions: addition, subtraction, multiplication and division
- carry out calculations involving means, decimals, fractions, percentages, ratios, approximations and reciprocals
- use standard notation (for example, 3.6×10^6)
- use direct and inverse proportion
- solve simple algebraic equations
- plot and interpret graphs (with suitable scales and axes) including two variables that show linear and non-linear relationships
- interpret graphs, including the significance of gradients, changes in gradients, intercepts and areas
- interpret data presented in various forms (for example, bar charts, histograms and pie charts).

Use of information and communication technology

Information and communication technology (ICT) involves the use of computers, its applications and communication facilities in teaching and learning activities. Therefore, the use of ICT goes beyond Diploma Programme design technology and extends to all the teaching and learning in all subjects across the curriculum. The effective use of ICT is included in approaches to learning (ATL) and, as such, schools must ensure that a whole-school approach is in place to allow students to develop information and technological literacy and become competent users of information and communication technologies such as computers and computer numerical control (CNC) machinery.

Depending upon the school resources, ICT should be used whenever appropriate:

- as a means of expanding students' knowledge of the world in which they live
- as a channel for developing concepts and skills
- as a powerful communication tool.

Planning your course

The syllabus as provided in the subject guide is not intended to be a teaching order. Instead it provides detail of what must be covered by the end of the course. A school should develop a scheme of work that best works for their students. For example, the scheme of work could be developed to match available resources, to take into account student prior learning and experience, or in conjunction with other local requirements.

HL teachers may choose to teach the core and AHL topics at the same time or teach them in a spiral fashion, by teaching the core topics in year one of the course and revisiting the core topics through the delivery of the AHL topics in year two of the course.

However the course is planned, adequate time must be provided for examination revision. Time must also be given for students to reflect on their learning experience and their growth as learners.

The IB learner profile

The design technology course is closely linked to the IB learner profile. By following the course, students will have engaged with the attributes of the IB learner profile. For example, the requirements of the internal assessment provide opportunities for students to develop every aspect of the profile. For each attribute of the learner profile, a number of references are given below.

Learner profile attribute	
Inquirers	Aims 1, 2 and 8 Practical work and internal assessment
Knowledgeable	Aims 1, 2, 4 and 10 Practical work and internal assessment
Thinkers	Aims 2, 3, 4, 7 and 10 Practical work and internal assessment
Communicators	Aims 2, 4 and 7; external assessment Practical work and internal assessment; group 4 project
Principled	Aims 5, 6 and 9 Practical work and internal assessment: ethical behaviour/practice (*Ethical practice poster*, *Animal experimentation policy*); academic honesty
Open-minded	Aims 2, 3, 6, 7, 8 and 9 Practical work and internal assessment; group 4 project
Caring	Aims 6, 8 and 9 Practical work and internal assessment; group 4 project; ethical behaviour/practice (*Ethical practice poster*, *Animal experimentation policy*)
Risk-takers	Aims 1, 3 and 7 Practical work and internal assessment; group 4 project
Balanced	Aims 5, 6, 8, 9 and 10 Practical work and internal assessment
Reflective	Aims 1, 5, 6, 8, 9 and 10 Practical work and internal assessment; group 4 project

Syllabus content

Syllabus component			Recommended teaching hours SL	HL
Core			**90**	
1	Human factors and ergonomics	• Anthropometrics • Psychological factors • Physiological factors	12	
2	Resource management and sustainable production	• Resources and reserves • Waste mitigation strategies • Energy utilization, storage and distribution • Clean technology • Green design • Eco-design	22	
3	Modelling	• Conceptual modelling • Graphical modelling • Physical modelling • Computer-aided design (CAD) • Rapid prototyping	12	
4	Raw material to final production	• Properties of materials • Metals and metallic alloys • Timber • Glass • Plastics • Textiles • Composites • Scales of production • Manufacturing processes • Production systems • Robots in automated production	23	

Syllabus component			Recommended teaching hours	
			SL	HL
5	Innovation and design	• Invention • Innovation • Strategies for innovation • Stakeholders in invention and innovation • Product life cycle • Rogers' characteristics of innovation and consumers • Innovation, design and marketing specifications	13	
6	Classic design	• Characteristics of classic design • Classic design, function and form	8	
Additional higher level (AHL)			**54**	
7	User-centred design	• User-centred design (UCD) • Usability • Strategies for user research • Strategies for UCD • Beyond usability—designing for pleasure and emotion		12
8	Sustainability	• Sustainable development • Sustainable consumption • Sustainable design • Sustainable innovation		14
9	Innovation and markets	• Corporate strategies • Market sectors and segments • Marketing mix • Market research • Branding		13
10	Commercial production	• Just in time (JIT) and just in case (JIC) • Lean production • Computer-integrated manufacturing (CIM) • Quality management • Economic viability		15

Topic 1: Human factors and ergonomics

12 hours

Essential idea: Designers consider three human factors to ensure products meet ergonomic needs.

1.1a Anthropometrics		
Nature of design: Design is human centred and, therefore, designers need to ensure that the products they design are the right size for the user and therefore comfortable to use. Designers have access to data and drawings, which state measurements of human beings of all ages and sizes. Designers need to consider how users will interact with the product or service. Use and misuse is an important consideration. (1.5, 1.18, 1.20)	**Concept and principles:** • Anthropometric data: static and dynamic data, structural and functional data • Primary data versus secondary data • Percentiles and percentile ranges • Range of sizes versus adjustability • Clearance, reach and adjustability **Guidance:** • Collecting anthropometric data considering reliability and limitations • Interpreting percentile tables for user populations • Design contexts where different percentile ranges are used	**International-mindedness:** • A wide selection of anthropometric data is published and regionalized, for example, Asian data versus western European data. The designer must work with data appropriate to the target market. **Theory of knowledge:** • Do the methods of data collection used in design technology have more in common with disciplines in the human sciences or the natural sciences? **Utilization:** • Design technology topic 7 **Aims:** • **Aim 6:** Anthropometric data sets can vary significantly between populations. Particularly in the fashion industry, the variance in these data sets impacts the size range of clothes for particular markets.

1.1b Psychological factors

Nature of design:

Human beings vary psychologically in complex ways. Any attempt by designers to classify people into groups merely results in a statement of broad principles that may or may not be relevant to the individual. Design permeates every aspect of human experience and data pertaining to what cannot be seen such as touch, taste, and smell are often expressions of opinion rather than checkable fact. (1.5, 1.18, 1.20, 2.9)

Concepts and principles:

- Psychological factor data
- Human information processing systems
- Effect of environmental factors
- Alertness
- Perception

Guidance:

- Data in relation to light, smell, sound, taste, temperature and texture as qualitative or quantitative (ordinal/interval)
- Methods of collecting psychological factor data
- Representing the human information processing system using flow diagrams
- Applying the human information processing system to a common task
- Evaluating effects and reasons for a breakdown in the human information processing system
- User responses to environmental factors
- How environmental factors induce different levels of alertness
- The importance of optimizing environmental factors to maximize workplace performance
- Assessing the impact of perception in relation to the accuracy and reliability of psychological factor data

International-mindedness:

- The origin of psychology (as a mainly western academic subject) along with recent neurological insights on a global scale need to be taken into account in applying any psychological factors to global design problems.

Theory of knowledge:

- How might the collection and interpretation of data be affected by the limitations of our sense perception?

Utilization:

- Design technology topic 7
- Biology option A
- Psychology part 1: core

Aims:

- **Aim 3:** The analysis of the human information processing system requires a designer to critically analyse a range of causes and effects to identify where a potential breakdown could occur and the effect it may have.

1.1c Physiological factors

Nature of design:	Concepts and principles:	International-mindedness:
Designers study physical characteristics to optimize the user's safety, health, comfort and performance. (1.5, 1.18, 1.20, 2.9)	• Physiological factor data • Comfort and fatigue • Biomechanics **Guidance:** • Types of physiological factor data available to designers and how they are collected • How data related to comfort and fatigue informs design decisions • The importance of biomechanics to the design of different products considering muscle strength, age, user interface and torque	• It is important that the physiological factor data are either regional/national data or great care is taken when applying data from one source to a potentially inappropriate target market. **Theory of knowledge:** • This topic is about human factors. How do ethical limitations affect the sort of investigations that can take place where human subjects are involved? **Utilization:** • Design technology topic 7 • Biology topics 6 and 11 • Physics topic 2 • Sports exercise and health topics 1, 2 and 4 **Aims:** • **Aim 8:** Understanding complex biomechanics and designing products to enable full functionality of body parts can return independence and personal and social well-being to an individual.

Topic 2: Resource management and sustainable production 22 hours

Essential idea: Resource management and sustainable production carefully consider three key issues—consumption of raw materials, consumption of energy, and production of waste—in relation to managing resources and reserves effectively and making production more sustainable.

2.1 Resources and reserves		
Nature of design: As non-renewable resources run out, designers need to develop innovative solutions to meet basic human needs for energy, food and raw materials. The development of renewable and sustainable resources is one of the major challenges of the 21st century for designers. (2.9)	**Concepts and principles:** • Renewable and non-renewable resources • Reserves • Renewability **Guidance:** • The economic and political importance of material and land resources and reserves considering set-up cost, efficiency of conversion, sustainable and constant supply, social impact, environmental impact and decommissioning • Comparison of renewable and non-renewable resources • Positive or negative impact that a development may have on the environment	**International-mindedness:** • The impact of multinational companies when obtaining resources in different countries/regions can be a significant issue for the local population and have major social, ethical and environmental implications. **Theory of knowledge:** • To what extent should potential damage to the environment limit our pursuit of knowledge? **Utilization:** • Design technology topics 4, 8 and 10 • Biology topic 4 • Business management topic 5 • Economics topic 1 • Environmental systems and societies topics 1 and 8 • Physics topic 8

2.1 Resources and reserves		
		Aims: • **Aim 3:** Much of the development of new resources is the product of creating sustainable solutions to existing problems. • **Aim 10:** The legacy of the industrial revolution is now being felt as we face resource depletion. The challenge for designers is to continue to develop products that meet the needs of humans, while conserving the environment for future generations.

Essential idea: Waste mitigation strategies can reduce or eliminate the volume of material disposed to landfill.

2.2 Waste mitigation strategies		
Nature of design: The abundance of resources and raw materials in the industrial age led to the development of a throwaway society, and as resources run out, the many facets of sustainability become a more important focus for designers. The result of the throwaway society is large amounts of materials found in landfill, which can be considered as a new source to mine resources from. (2.7)	**Concepts and principles:** • Re-use • Recycle • Repair • Recondition • Re-engineer • Pollution/waste • Methodologies for waste reduction and designing out waste • Dematerialization • Product recovery strategies at end of life/ disposal • Circular economy—the use of waste as a resource within a closed loop system **Guidance:** • Use and recovery of standard parts at the end of product life • Recovery of raw materials • Reduction of total material and energy throughput of a product or service, and the limitation of its environmental impact through: reduction of raw materials at the production stage; energy and material inputs at the user stage; waste at the disposal stage	**International-mindedness:** • The export of highly toxic waste from one country to another is an issue for all stakeholders. **Theory of knowledge:** • The circular economy can be seen as an example of a paradigm shift in design. Does knowledge develop through paradigm shifts in all areas of knowledge? **Utilization:** • Design technology topics 4, 8 and 10 • Environmental systems and societies topic 8 **Aims:** • **Aim 2:** The exploration of possible solutions to eliminate waste in our society has given rise to ideas developed as part of the circular economy. By redesigning products and processes, the waste from one product can become the raw material of another.

2.2 Waste mitigation strategies		
	• How dematerialization can improve product efficiency by saving, reusing or recycling materials and components • The impacts of dematerialization on each stage of the product life cycle including: material extraction; eco-design; cleaner production; environmentally conscious consumption patterns; recycling of waste • Potential results of successful dematerialization	

Essential idea: There are several factors to be considered with respect to energy and design.

2.3 Energy utilization, storage and distribution

Nature of design:

Efficient energy use is an important consideration for designers in today’s society. Energy conservation and efficient energy use are pivotal in our impact on the environment. A designer’s goal is to reduce the amount of energy required to provide products or services using newer technologies or creative implementation of systems to reduce usage. For example, driving less is an example of energy conservation, while driving the same amount but with a higher mileage car is energy efficient. (1.11, 1.16, 2.10)

Concepts and principles:

- Embodied energy
- Distributing energy: national and international grid systems
- Local combined heat and power (CHP)
- Systems for individual energy generation
- Quantification and mitigation of carbon emissions
- Batteries, capacitors and capacities considering relative cost, efficiency, environmental impact and reliability

Guidance:

- Total energy consumed in production (cradle to [factory] gate) and throughout the lifecycle of a product (cradle to grave)
- Batteries are limited to hydrogen fuel cells, lithium, NiCad, lead acid, and LiPo batteries

International-mindedness:

- There are instances of energy sources (for example, oil and electricity) crossing national boundaries through cross-border networks leading to issues of energy security.

Theory of knowledge:

- The Sun is the source of all energy and essential for human existence. Is there some knowledge common to all areas of knowledge and ways of knowing?

Utilization:

- Design technology topics 8 and 10
- Biology topic 4
- Chemistry option C
- Environmental systems and societies topic 2
- Physics topics 5, 8 and 11

Aims:

- **Aim 1:** As we develop new electronic products, electrical energy power sources remain an ever-important issue. The ability to concentrate electrical energy into ever-decreasing volume and weight is the challenge for designers of electronic products.

Essential idea: Clean technology seeks to reduce waste/pollution from production processes through radical or incremental development of a production system.

2.4 Clean technology		
Nature of design: Clean technology is found in a broad range of industries, including water, energy, manufacturing, advanced materials and transportation. As our Earth's resources are slowly depleted, demand for energy worldwide should be on every designer's mind when generating products, systems and services. The convergence of environmental, technological, economic and social factors will produce more energy-efficient technologies that will be less reliant on obsolete, polluting technologies. (1.11, 1.16, 2.10)	**Concepts and principles:** • Drivers for cleaning up manufacturing: promoting positive impacts; ensuring neutral impact or minimizing negative impacts through conserving natural resources; reducing pollution and use of energy; reducing wastage of energy and resources • International legislation and targets for reducing pollution and waste • End-of-pipe technologies • Incremental and radical solutions • System level solutions **Guidance:** • The role of legislation to provide impetus for manufacturers to clean up manufacturing processes • Advantages and disadvantages of incremental and radical solutions • How manufacturers react to legislation • How legislation can be monitoring and policing	**International-mindedness:** • The development of clean technology strategies for reducing pollution and waste can positively impact local, national and global environments. **Theory of knowledge:** • International targets may be seen to impose the view of a certain culture onto another. Can one group of people know what is best for others? **Utilization:** • Design technology topics 4, 8 and 10 • Chemistry option C • Environmental systems and societies topics 1 and 4 **Aims:** • **Aim 5:** The legislation for reducing pollution often focuses on the output and, therefore, end-of-pipe technologies. By implementing ideas from the circular economy, pollution is negated and waste eliminated.

Essential idea: Green design integrates environmental considerations into the design of a product without compromising its integrity.

2.5 Green design		
Nature of design: The starting point for many green products is to improve an existing product by redesigning aspects of it to address environmental objectives. The iterative development of these products can be incremental or radical depending on how effectively new technologies can address the environmental objectives. When newer technologies are developed, the product can re-enter the development phase for further improvement. (1.4)	**Concepts and principles:** • Strategies for green design (incremental and radical) • Green legislation • Timescale to implement green design • Drivers for green design (consumer pressure and legislation) • Design objectives for green products • Strategies for designing green products • The prevention principle • The precautionary principle **Guidance:** • How strategies for green design often involve a focus on one or two environmental objectives when designing or re-designing products • How green legislation encourages incremental rather than radical changes • How environmental legislation has encouraged the design of products that tackle specific environmental issues • How design objectives for green products address three broad environmental categories—materials, energy and pollution/waste • Evaluating products in terms of: consumption of raw materials; packaging; incorporation of toxic chemicals; energy in production and use; end-of-life disposal; production methods; and atmospheric pollutants	**International-mindedness:** • The ability and will of different countries to enact environmental legislation varies greatly. **Theory of knowledge:** • Green issues are an area where experts sometimes disagree. On what basis might we decide between the judgments of experts if they disagree? **Utilization:** • Design technology topics 4, 5 and 8 • Environmental systems and societies topic 1 • Visual arts **Aims:** • **Aim 9:** The purpose of green design is to ensure a sustainable future for all.

Essential idea: Eco-design considers the design of a product throughout its life cycle (from cradle to grave) using lifecycle analysis.

2.6 Eco-design		
Nature of design: Consideration of the environmental impact of any product, service or system during its life cycle should be instigated at the earliest stage of design and continue through to disposal. Designers should have a firm understanding of their responsibility to reduce the ecological impact on the planet. Eco-design concepts currently have a great influence on many aspects of design. (1.16)	**Concepts and principles:** • Timescale for implementing eco-design • The “cradle to grave” and “cradle to cradle” philosophy • Life cycle analysis (LCA) • LCA stages: pre-production; production; distribution including packaging; utilization and disposal • Environmental considerations • Environmental impact assessment matrix • Product life cycle stages: the role of the designer, manufacturer and user • The major considerations of the United Nations Environmental Programme Manual on Eco-design • “Design for the environment” software • Converging technologies **Guidance:** • How designers use LCA to assess and balance environmental impact over a product’s life cycle • Benefits of organizing the life cycle stages and the environmental considerations into an environmental impact assessment matrix in which elements differ in importance according to the particular design context	**International-mindedness:** • The differing stages of economic development of different countries/regions and their past and future contributions to global emissions is an issue. **Theory of knowledge:** • There is no waste in nature. Should areas of knowledge look at natural processes beyond human endeavour? **Utilization:** • Design technology topics 4, 5 and 8 • Environmental systems and societies topic 1 • Visual arts **Aims:** • **Aim 3:** The smart phone is an innovative example of converging technologies that combines multiple technologies into one space-saving device. The resultant reduction of materials, and energy used in production and distribution has environmental benefits.

2.6 Eco-design		
	• How LCA enables data to be compared and acts as a useful tool for communicating with clients/outside agencies • How LCA can be used to identify potential conflicts between clients/outside agencies, which need to be resolved through prioritization • Consider complexity, time and expense of LCA • The use of checklists to guide the design team during a product's design development stages • How "design for the environment" software is used to assist designers in the assessment of environmental implications and particular facets of a design • Advantages and disadvantages of converging technology	

Topic 3: Modelling

12 hours

Essential idea: A conceptual model originates in the mind and its primary purpose is to outline the principles, processes and basic functions of a design or system.

3.1 Conceptual modelling		
Nature of design: Designers use conceptual modelling to assist their understanding by simulating the subject matter they represent. Designers should consider systems, services and products in relation to what they should do, how they should behave, what they look like and whether they will be understood by the users in the manner intended. (1.2, 1.3, 1.8)	**Concepts and principles:** • The role of conceptual modelling in design • Conceptual modelling tools and skills **Guidance:** • How conceptual models are used to communicate with oneself and others • How conceptual models vary in relation to the context • How the designer visualizes concepts, design thinking and learning • Advantages and disadvantages of using conceptual modelling	**Theory of knowledge:** • In the construction of a model, how can we know which aspects of the world to include and which to ignore? **Utilization:** • Design technology internal assessment • Chemistry topic 6 • Environmental systems and societies topic 1 • Visual arts **Aims:** • **Aim 7:** The starting point for solving a problem springs from an idea developed in the mind. A detailed exploration of the idea is vital to take it from the intangible to the tangible, along with the ability to articulate the idea to others.

Essential idea: Graphical models are used to communicate design ideas.

3.2 Graphical modelling		
Nature of design: Graphical models can take many forms, but their prime function is always the same—to simplify the data and present it in such a way that understanding of what is being presented aids further development or discussion. Designers utilize graphical modelling as a tool to explore creative solutions and refine ideas from the technically impossible to the technically possible, widening the constraints of what is feasible. (1.13, 3.7)	**Concepts and principles:** • 2D and 3D graphical models • Perspective, projection and scale drawings • Sketching versus formal drawing techniques • Part and assembly drawings **Guidance:** • How graphical models are used to communicate with oneself and others • How the choice of graphical models varies in relation to the context • Advantages and disadvantages of using different graphical models	**Theory of knowledge:** • Are there aspects of the world that are not amenable to modelling? • To what extent does graphical communication shape and limit our knowledge? **Utilization:** • Design technology internal assessment • Visual arts **Aims:** • **Aim 2:** The development of ideas through graphical models allows designers to explore and deepen their understanding of a problem and context of use.

Essential idea: A physical model is a three-dimensional, tangible representation of a design or system.

3.3 Physical modelling		
Nature of design: Designers use physical models to visualize information about the context that the model represents. It is very common for physical models of large objects to be scaled down and smaller objects scaled up for ease of visualization. The primary goal of physical modelling is to test aspects of a product against user requirements. Thorough testing at the design development stage ensures that an appropriate product is developed. (1.2, 1.13, 3.2)	**Concepts and principles:** • Scale models • Aesthetic models • Mock-ups • Prototypes • Instrumented models **Guidance:** • Applications of physical models • Use of instrumented models to measure the level of a product’s performance and facilitate ongoing formative evaluation and testing • Advantages and disadvantages of using physical models	**Theory of knowledge:** • Models that only show aspects of reality are widely used in design. How can they lead to new knowledge? **Utilization:** • Design technology topics 1, 5 and 7 • Design technology internal assessment • Visual arts **Aims:** • **Aim 4:** Physical modelling not only allows designers to explore and test their ideas, but to also present them to others. Engaging clients, focus groups and experts to interact with physical models of products allows designers to gain valuable feedback that enable them to improve the design and product-user interface.

Essential idea: A computer-aided design is the generation, creation, development and analysis of a design or system using computer software.

3.4 Computer-aided design (CAD)

Nature of design:

As technologies improve and the software becomes more powerful, so do the opportunities for designers to create new and exciting products, services and systems. Greater freedom in customization and personalization of products has a significant impact on the end user. The ability to virtually prototype, visualize and share designs enhances the whole design cycle from data analysis through to final designs. (1.14)

Concepts and principles:

- Types of CAD software
- Surface and solid models
- Data modelling including statistical modelling
- Virtual prototyping
- Bottom-up and top-down modelling
- Digital humans: motion capture, haptic technology, virtual reality (VR), and animation
- Finite element analysis (FEA)

Guidance:

- Advantages and disadvantages of using computer-aided modelling
- How data models structure data through database models
- Design of information systems to enable the exchange data
- How haptic technology, motion capture, VR and animation can be used to simulate design scenarios and contexts
- Comparison of FEA with testing physical models
- Use of FEA systems when designing and developing products

International-mindedness:

- Improved communication technologies allow designs to be developed collaboratively by different global teams on a 24/7 basis.

Theory of knowledge:

- How is new knowledge acquired through the use of digital models?
- Does technology allow us to gain knowledge that our human senses are unable to gain?

Utilization:

- Design technology topics 4, 7 and 10
- Design technology internal assessment
- Visual arts

Aims:

- **Aim 10:** The use of CAD to simulate the conditions in which a product will be used allows the designer to gain valuable data at low cost. For example, simulating the flow of air across a car exterior negates the need for a car and wind tunnel.

Essential idea: Rapid prototyping is the production of a physical model of a design using three-dimensional CAD data.

3.5 Rapid prototyping		
Nature of design: The growth in computing power has had a major impact on modelling with computer-aided manufacture. Rapid software and hardware developments allow new opportunities and exciting new technologies to create dynamic modelling of ever-greater complexity. Models can be simulated by designers using software, tested and trialled virtually before sending to a variety of peripheral machines for prototype manufacture in an ever-increasing range of materials. The ease of sending this digital data across continents for manufacture of prototypes has major implications for data and design protection. (1.19)	**Concepts and principles:** • Stereolithography • Laminated object manufacturing (LOM) • Fused deposition modelling (FDM) • Selective laser sintering (SLS) **Guidance:** • Different types of 3D printing techniques • Advantages and disadvantages of rapid prototyping techniques	**International-mindedness:** • The high cost of some new processes does not allow for their rapid dissemination globally. **Theory of knowledge:** • Which ways of knowing do we use to interpret indirect evidence gathered through the use of technology? **Utilization:** • Design technology topics 4, 7 and 10 • Design technology internal assessment **Aims:** • **Aim 10:** The increasing effectiveness of rapid prototyping techniques in terms of both cost and speed enables designers to create complex physical models for testing.

Topic 4: Raw material to final product

23 hours

Essential idea: Materials are selected for manufacturing products based primarily on their properties.

4.1 Properties of materials		
Nature of design: The rapid pace of scientific discovery and new technologies has had a major impact on material science, giving designers many more materials from which to choose for their products. These new materials have given scope for "smart" new products or enhanced classic designs. Choosing the right material is a complex and difficult task with physical, aesthetic, mechanical and appropriate properties to consider. Environmental, moral and ethical issues surrounding choice of materials for use in any product, service or system also need to be considered. (2.1)	**Concepts and principles:** • Physical properties: mass, weight, volume, density, electrical resistivity, thermal conductivity, thermal expansion and hardness • Mechanical properties: tensile and compressive strength, stiffness, toughness, ductility, elasticity, plasticity, Young's modulus, stress and strain • Aesthetic characteristics: taste, smell, appearance and texture • Properties of smart materials: piezoelectricity, shape memory, photochromicity, magneto-rheostatic, electro-rheostatic and thermoelectricity **Guidance:** • Design contexts where physical properties, mechanical properties and/or aesthetic characteristics are important • Design contexts where properties of smart materials are exploited • Using stress/strain graphs and material selection charts to identify appropriate materials	**International-mindedness:** • Smart materials are likely to be developed in specific regions/countries and their benefits can be limited globally in the short term. **Theory of knowledge:** • Through specialized vocabularies, is it the case that shaping of knowledge is more dramatic in some areas of knowledge than others? **Utilization:** • Design technology topics 2, 3, 8 and 10 • Design technology internal assessment • Biology topic 2 • Chemistry option A • Physics topic 7 • Visual arts

4.1 Properties of materials		
		Aims: • **Aim 2:** Materials are often developed by materials engineers to have specific properties. The development of new materials allows designers to create new products, which solve old problems in new ways. For example, the explosion of plastic materials following the second world war enabled products to be made without using valuable metals.

Essential idea: Materials are classified into six basic groups based on their different properties.

4.2a Metals and metallic alloys		
Nature of design: Typically hard and shiny with good electrical and thermal conductivity, metals are a very useful resource for the manufacturing industry. Most pure metals are either too soft, brittle or chemically reactive for practical use and so understanding how to manipulate these materials is vital to the success of any application. (2.2)	**Concepts and principles:** • Extracting metal from ore • Grain size • Modifying physical properties by alloying, work hardening and tempering • Design criteria for super alloys • Recovery and disposal of metals and metallic alloys **Guidance:** • An overview of the metal extraction process is sufficient • Super alloy design criteria include creep and oxidation resistance • Contexts where different metals and metallic alloys are used	**International-mindedness:** • Extraction takes place locally with added value often occurring in another country. **Theory of knowledge:** • How does classification and categorization help and hinder the pursuit of knowledge? **Utilization:** • Design technology topics 2 and 10 • Chemistry topic 4 and option A **Aims:** • **Aim 5:** Design for disassembly is an important aspect of sustainable design. Valuable metals, such as gold and copper, are being recovered from millions of mobile phones that have gone out of use following the end of product life. Some laptops and mobile phones can be disassembled very quickly without tools to allow materials to be recovered easily.

4.2b Timber		
Nature of design: Timber is a major building material that is renewable and uses the Sun's energy to renew itself in a continuous cycle. While timber manufacture uses less energy and results in less air and water pollution than steel or concrete, consideration needs to be given to deforestation and the potential negative environmental impact the use of timber can have on communities and wildlife. (3.6)	**Concepts and principles:** • Characteristics of natural timber: hardwood and softwood • Characteristics of man-made timbers • Treating and finishing timbers • Recovery and disposal of timbers **Guidance:** • Characteristics include tensile strength, resistance to damp environments, longevity, aesthetic properties • Design contexts in which different timbers would be used	**International-mindedness:** • The demand for high-quality hardwoods results in the depletion of ancient forests in some regions/countries impacting on the environment in multiple ways. **Theory of knowledge:** • Designers are moving from exploitation of resources towards conservation and sustainability. Is the environment at the service of man? **Utilization:** • Design technology topics 2 and 10 **Aims:** • **Aim 9:** Designers have great influence over the materials that they specify for products. The move towards using timber from sustainably managed forestry gives consumers confidence that rare species found in rainforests have an opportunity to recover.

4.2c Glass		
Nature of design: The rapid pace of technological discoveries is very evident in the manufacture and use of glass in electronic devices. Different properties have been presented in glass for aesthetic or safety considerations for many years but the future of glass seems to be interactivity alongside electronic systems. The structure of glass is not well understood, but as more is learned, its use is becoming increasingly prominent in building materials and structural applications. (2.2)	**Concepts and principles:** • Characteristics of glass • Applications of glass • Recovery and disposal of glass **Guidance:** • Characteristics include transparency, colour and strength • Design contexts in which different types of glass are used	**Utilization:** • Design technology topics 2 and 10 • Chemistry option A **Aims:** • **Aim 6:** The earliest found examples of glass objects come from the third millennium BCE, and up until the 1850s glass was considered a luxury item. Since then, glass has permeated and revolutionized many aspects of human life and culture in diverse fields such as the arts, architecture, electronics and communication technologies.

4.2d Plastics		
Nature of design: Most plastics are produced from petrochemicals. Motivated by the finiteness of oil reserves and threat of global warming, bio-plastics are being developed. These plastics degrade upon exposure to sunlight, water or dampness, bacteria, enzymes, wind erosion and in some cases pest or insect attack, but in most cases this does not lead to full breakdown of the plastic. When selecting materials, designers must consider the moral, ethical and environmental implications of their decisions. (3.6)	**Concepts and principles:** • Raw materials for plastics • Structure of thermoplastics • Structure of thermosetting plastics • Temperature and recycling thermoplastics • Recovery and disposal of plastics **Guidance:** • Properties of PP, PE, HIPS, ABS, PET and PVC • Properties of polyurethane, urea-formaldehyde, melamine resin and epoxy resin • Design contexts in which different types of plastics are used	**International-mindedness:** • The raw material for plastics (mainly oil) is extracted in a country, exported to other countries where conversion to plastics takes place and these are re-exported at considerable added value. **Utilization:** • Design technology topics 2 and 10 • Chemistry option A **Aims:** • **Aim 3:** Early plastics used from 1600 BCE through to 1900 CE were rubber based. Prompted by the need for new materials following the first world war, the invention of Bakelite and polyethylene in the first half of the 20th century sparked a massive growth of plastic materials and as we identify the need for new materials with particular properties, the development of new plastics continues.

4.2e Textiles		
Nature of design: The continuing evolution of the textiles industry provides a wide spread of applications from high-performance technical textiles to the more traditional clothing market. More recent developments in this industry require designers to combine traditional textile science and new technologies leading to exciting applications in smart textiles, sportswear, aerospace and other potential areas. (2.2)	**Concepts and principles:** • Raw materials for textiles • Properties of natural fibres • Properties of synthetic fibres • Conversion of fibres to yarns • Conversion of yarns into fabrics: weaving, knitting, lacemaking, and felting • Recovery and disposal of textiles **Guidance:** • Properties of wool, cotton and silk • Properties of nylon, polyester and Lycra® • Consider absorbency, strength, elasticity and the effect of temperature • Design contexts in which different types of textiles are used	**International-mindedness:** • The economics and politics of the production and sale of clothing by multinationals can be a major ethical issue for consumers and the workforce. **Theory of knowledge:** • Designers use natural and man-made products. Do some areas of knowledge see an intrinsic difference between these? **Utilization:** • Design technology topics 2 and 10 **Aims:** • **Aim 5:** There are many ethical considerations attached to the production of natural fibres. The strongest natural silk known to man is harvested from silk spiders and notoriously difficult to obtain, and labour intensive. In an effort to produce higher yields, scientists have altered the genome of goats so that they produce the same silk proteins in their milk.

4.2f Composites		
Nature of design: Composites are an important material in an intensely competitive global market. New materials and technologies are being produced frequently for the design and rapid manufacture of high-quality composite products. Composites are replacing more traditional materials as they can be created with properties specifically designed for the intended application. Carbon fibre has played an important part in weight reduction for vehicles and aircraft. (2.2)	**Concepts and principles:** • Form: fibres/sheet/particles and matrix • Process: weaving, moulding, pultrusion and lamination • Composition and structure of composites: concrete, engineered wood, plywood, particleboard, fibreglass, Kevlar®, carbon-reinforced plastic, laminated veneer lumber (LVL) **Guidance:** • Fibres/sheets/particles: textiles, glass, plastics and carbon • Matrix: thermoplastics, thermosetting plastics, ceramics, metals • Advantages and disadvantages of composite materials • Design contexts in which different types of composite materials are used	**International-mindedness:** • Many composite materials are expensive to produce and their dissemination globally is limited. **Utilization:** • Design technology topics 2, 5 and 10 • Chemistry option A **Aims:** • **Aim 1:** As designers develop new products, they should always be aware of the materials available. In an effort to increase productivity and lose weight, carbon fibre parts are often glued together. The use of an epoxy adhesive rather than traditional fastening methods allows manufacturers to create complex shapes quickly and easily. These materials and methods are being transferred to consumer products.

Essential idea: The scale of production depends on the number of products required.

4.3 Scales of production		
Nature of design: Decisions on scale of production are influenced by the volume or quantities required, types of materials used to make the products and the type of product being manufactured. There are also considerations of staffing, resources and finance. (1.15)	**Concepts and principles:** • One-off, batch production and continuous flow • Mass customization **Guidance:** • Selecting an appropriate scale of production • Advantages and disadvantages of different scales of production	**International-mindedness:** • Mass customization enables global products to become individual items. **Utilization:** • Design technology topics 3 and 10 • Design technology internal assessment • Business management topic 5 **Aims:** • **Aim 9:** The growing phenomenon of mass customization brings consumers into the design process, allowing them to make choices that make a product unique, to make it their own. Companies have developed “design stations” in their retail stores where consumers can create virtual 3D models, “try them out” using digital technology and place their order.

Essential idea: Different manufacturing processes have been developed to innovate existing products and create new products.

4.4 Manufacturing processes		
Nature of design: Designers sometimes engineer products in such a way that they are easy to manufacture. Design for manufacture (DfM) exists in almost all engineering disciplines, but differs greatly depending on the manufacturing technologies used. This practice not only focuses on the design of a product’s components, but also on quality control and assurance. (1.11)	**Concepts and principles:** • Additive techniques: paper-based rapid prototyping, laminated object manufacture (LOM), stereolithography • Wasting/subtractive techniques: cutting, machining, turning and abrading • Shaping techniques: moulding, thermoforming, laminating, casting, knitting, weaving • Joining techniques: permanent and temporary, fastening, adhering, fusing **Guidance:** • Selecting appropriate manufacturing techniques based on material characteristics (form, melting/softening point), cost, capability, scale of production, desired properties • Advantages and disadvantages of different techniques • Design contexts where different manufacturing processes are used	**International-mindedness:** • More expensive modern processes tend to take place in technologically advanced regions/countries. **Utilization:** • Design technology topics 2, 3 and 10 • Design technology internal assessment **Aims:** • **Aim 8:** Advancements in 3D printing have resulted in the ability to have a 3D printer at home. Consumers can download plans for products from the internet and print these products themselves.

Essential idea: The development of increasingly sophisticated production systems is transforming the way products are made.

4.5 Production systems		
Nature of design: As a business grows in size and produces more units of output, then it will aim to experience falling average costs of production—economies of scale. The business is becoming more efficient in its use of inputs to produce a given level of output. Designers should incorporate internal and external economies of scale when considering different production methods and systems for manufacture. (1.11)	**Concepts and principles:** • Craft production • Mechanized production • Automated production • Assembly line production • Mass production • Mass customization • Computer numerical control (CNC) • Production system selection criteria • Design for manufacture (DfM): design for materials, design for process, design for assembly, design for disassembly • Adapting designs for DfM **Guidance:** • Advantages and disadvantages of different production systems • Impact of different production systems on the workforce and environment • Production system selection criteria include time, labour, skills and training, health and safety, cost, type of product, maintenance, impact on the environment and quality management • Design contexts where different production systems are used	**International-mindedness:** • The geographical distribution of different modes of production is an economic and political issue. **Theory of knowledge:** • The increased dependency on automation and robots has affected craftsmanship. How has technology affected traditional ways of knowing? **Utilization:** • Design technology topics 2, 3, 6 and 10 • Design technology internal assessment • Economics **Aims:** • **Aim 7:** The design of a production system requires a complete understanding of a product, its function and the quality of finish. Each system can be unique and specific to the product it is creating, often requiring the designers to adapt their design to be manufactured using certain methods.

Essential idea: The development of increasingly sophisticated robotic manufacturing systems is transforming the way products are made.

4.6 Robots in automated production		
Nature of design: Designers should consider the benefits of increased efficiency and consistency when using robots in production and be able to explore the latest advances in technology to ensure the optimum manufacturing process is used. However, a good designer will also understand their responsibility to consider the moral and ethical issues surrounding increased use of automation, and the historical impact of lost jobs. (2.5)	**Concepts and principles:** • Primary characteristics of robots: work envelope and load capacity • Single-task robots • Multi-task robots • Teams of robots • Machine to machine (M2M) **Guidance:** • Advantages and disadvantages of using robotic systems in production • Consider first, second, and third generation robots	**International-mindedness:** • The use of robots in automated production can depend on the local cost of manual labour. **Theory of knowledge:** • Technology in the form of robots currently serves man. Is man's place secure? Will the nature of man change due to technological enhancement? Will he be superseded altogether by technological developments? **Utilization:** • Design technology topics 1, 8 and 10 **Aims:** • **Aim 8:** The introduction of robots to an assembly line has had a major impact on the labour force, often making skilled workers redundant in favour of a technician who can maintain and equip a large number of robots.

Topic 5: Innovation and design

13 hours

Essential idea: The protection of a novel idea of how to solve a problem is a major factor in commercial design.

5.1 Invention

Nature of design:	Concepts and principles:	International-mindedness:
Invention by lone inventors or in collaborative, creative teams is at the forefront of design. Designers must not only be creative and innovative, but also understand the concepts that will make a new product viable. A designer must use imagination and be firmly grounded in factual and procedural knowledge while remembering the needs and limitations of the end user. (2.3, 2.4)	• Drivers for invention • The lone inventor • Intellectual property (IP) • Strategies for protecting IP: patents, trademarks, design protection, copyright. • First to market • Shelved technologies **Guidance:** • Drivers for invention include personal motivation to express creativity/for personal interest, scientific or technical curiosity, constructive discontent, desire to make money, desire to help others • The advantages and disadvantages of being a lone inventor	• The role of intellectual property and patents in stifling or promoting inventions globally needs to be considered, especially with regard to the inequalities between countries. **Theory of knowledge:** • What is the role of imagination in invention? Are there limits to what can be imagined? • Sometimes there are unforeseen consequences of inventions. To what extent might lack of knowledge be an excuse for unethical conduct? **Utilization:** • Design technology topics 2, 3, 4, 6, 7, 9 • Design technology internal assessment

5.1 Invention		
	• Benefits of IP include differentiating a business from competitors, selling or licensing to provide revenue streams, offering customers something new and different, marketing/branding, its value as an asset • IP symbols and their application to products and services: patent pending, ™, ®, ©, ^{SM} • The effectiveness of strategies for protecting IP • Reasons why some innovators decide not to protect their IP and alternative strategies to ensure success • Reasons why some patented inventions are shelved	**Aims:** • **Aim 1:** Inventions are often the result of an individual or group's curiosity about whether something can be done or a problem can be solved. On occasion, inventions are the result of an individual's curiosity about something other than the product that they finally develop. These inventions include microwave ovens, ink-jet printers and Post-it® notes.

Essential idea: There are many different types of innovation.

5.2 Innovation		
Nature of design: Designers will be successful in the marketplace when they solve long-standing problems, improve on existing solutions or find a "product gap". The constant evaluation and redevelopment of products is key, with unbiased analysis of consumers and commercial opportunities. (1.1)	**Concepts and principles:** • Invention and innovation • Categories of innovation: sustaining innovation, disruptive innovation, process innovation • Innovation strategies for design: architectural innovation, modular innovation, configurational innovation • Innovation strategies for markets: diffusion and suppression **Guidance:** • Reasons why few inventions become innovations • Examples of products within the categories of innovation • Examples where innovation strategies have been used for products	**International-mindedness:** • Innovations may have positive consequences in some countries/regions and negative ones in others. **Theory of knowledge:** • Design is always looking to the future and new development. Do other areas of knowledge have universal, timeless truths or are they continually in flux? **Utilization:** • Design technology topics 3, 8, 9, 10 • Design technology internal assessment • Business management topic 5 **Aims:** • **Aim 4:** In order for an invention to become an innovation, the idea of the product needs to be effectively communicated. The communication can take many forms and be between many stakeholders.

Essential idea: Designers have a range of strategies for innovation.

5.3 Strategies for innovation		
Nature of design: Companies encourage advancements in technology and services, usually by investing in research and development (R&D) activities. Even though the R&D may be carried out by a range of different experts from varied fields of research, the development process is often based on common principles and strategies to identify the direction of development. This methodology structures the R&D of new technologies and services. (1.7)	**Concepts and principles:** • Act of insight • Adaptation • Technology transfer • Analogy • Chance • Technology push • Market pull **Guidance:** • Design contexts where each strategy has been applied	**Theory of knowledge:** • Design is continually changing due to its openness to new ideas. Do other areas of knowledge recognize new influences to the same extent? **Utilization:** • Design technology topics 3, 7, 8 and 9 • Design technology internal assessment **Aims:** • **Aim 6:** Innovation should always occur in context and a deep understanding of the culture as well as the behaviours, needs and wants of the consumer is required.

Essential idea: There are three key roles in invention and innovation, which can be shared by one or more people.

5.4 Stakeholders in invention and innovation		
Nature of design: Collaborative generation of knowledge and high efficiency information flow allow for diversity, increased resilience, reliability and stability within an organization. Through participatory research, stakeholders can make full use of the resulting innovation and invention, by transferring findings relevant to the sector in which they are positioned. A designer's increased awareness through shared industry knowledge enhances profitability and policy. (1.17)	**Concepts and principles:** • The inventor, the product champion, the entrepreneur • The inventor as a product champion and/or entrepreneur • A multidisciplinary approach to innovation **Guidance:** • Roles of the product champion and entrepreneur in the innovation of products and systems • Reasons why inventors often take the role of product champion and/or entrepreneur • The advantages and disadvantages of multidisciplinary teams	**Theory of knowledge:** • Design favours collective wisdom. Do other areas of knowledge value collaborative thinking? **Utilization:** • Design technology topics 6, 7 and 9 **Aims:** • **Aim 7:** On occasion, the inventor needs to act as both entrepreneur and product champion. The adoption of these additional roles requires a significant amount of learning to take an idea from the mind, realize it and then diffuse it successfully into the marketplace.

Essential idea: There are several key stages in the product life cycle.

5.5 Product life cycle		
Nature of design:	**Concepts and principles:**	**International-mindedness:**
Designers need to consider the whole product cycle of potential products, services and systems throughout the design cycle and beyond. Products may have an impact not only on the direct consumer but also on society at large and the environment. (1.16)	• Key stages of the product life cycle: launch, growth, maturity, decline • Obsolescence: planned, style (fashion), functional, technological • Predictability of the product life cycle • Product versioning/generations **Guidance:** • Examples of products at different stages of the product life cycle including those new to the market and classic designs • Length of the product life cycle considering the effect of technical development and consumer trends • Advantages and disadvantages for a company of introducing new versions and generations of a product	• The transition from a linear to a circular economy in the move towards sustainable societies has major implications for the ideas associated with product life cycle. **Theory of knowledge:** • Design considers areas other than man in its thinking. Are other areas of knowledge confined to human influence and values? **Utilization:** • Design technology topics 1, 3, 6, 8 and 9 • Design technology internal assessment • Environmental systems and societies topic 8 • Business management topic 4 **Aims:** • **Aim 2:** An understanding of the product life cycle allows the designer to design a product with obsolescence in mind. Doing this at the design stage can potentially eliminate the effect of a product on the environment when it is no longer in use.

Essential idea: Innovations take time to diffuse into a target audience.

5.6 Rogers' characteristics of innovation and consumers

Nature of design:

Rogers' four main elements that influence the spread of new ideas (innovation, communication channels, time and a social system) rely heavily on human capital. The ideas must be widely accepted in order to be self-sustainable. Designers must consider various cultures and communities to predict how, why and at what rate new ideas and technology will be adopted. (1.7)

Concepts and principles:

- Diffusion and innovation
- The impact of Rogers' characteristics on consumer adoption of an innovation
- Social roots of consumerism
- The influence of social media on the diffusion of innovation
- The influence of trends and the media on consumer choice
- Categories of consumers in relation to technology adoption

Guidance:

- Examples of product innovations for each of Rogers' characteristics
- The impact of Rogers' characteristics on consumer adoption of an innovation can be considered in terms of relative advantage, compatibility, complexity, observability, trialability
- The social roots of consumerism include lifestyle, values and identity
- Issues for companies in the global marketplace when attempting to satisfy consumer needs in relation to lifestyle, values and identity
- Categories of consumers include innovators, early adopters, early majority, late majority, laggards

International-mindedness:

- The origin of Rogers' theory in one or two areas may lead to inappropriate application on a global basis. Positive and negative aspects may be opposite in different regions/countries.

Theory of knowledge:

- Design takes into account cultural differences. Are other areas of knowledge universal or culture specific?

Utilization:

- Design technology topics 6, 8 and 9
- Business management topic 4

Aims:

- **Aim 10:** By categorizing consumers, the designer can identify particular segments with a market sector to gain feedback. By engaging with these stereotypes, the designer can utilize their experiences with a prototype in order to guide further development.

Essential idea: Successful innovations typically start with detailed design and marketing specifications.

5.7 Innovation, design and marketing specifications		
Nature of design: Designers must establish clear parameters for a marketing specification in order to create unique and creative solutions to a problem. Designers need to collect valid and useful data from the target market and audience throughout the design cycle to ensure the specification includes certain essential components. (1.9, 1.10)	**Concepts and principles:** • Target markets • Target audiences • Market analysis • User need • Competition • Research methods • Design specifications **Guidance:** • How market sectors and segments can be used to establish target markets • How a target audience is used to establish the characteristics of users • Design contexts for different target markets and audiences	**International-mindedness:** • The characteristics of users in different countries/regions need to be taken into account. Cultural differences may play a major role. **Theory of knowledge:** • Design is evidence-based. How do other areas of knowledge value the importance of evidence? **Utilization:** • Design technology topics 1, 2, 3, 4, 7 and 9 • Design technology internal assessment • Business management topic 4 **Aims:** • **Aim 4:** The ability to transform their research findings into a series of specifications is a skill that designers must develop to become successful. Being able to express parameters and requirements succinctly allows the designer to develop focused solutions to the design problem and meet a client or the target market's wants and needs.

Topic 6: Classic design

8 hours

Essential idea: A classic design has a timeless quality, which is recognized and remains fashionable.

6.1 Characteristics of classic design		
Nature of design: A classic design is not simply defined by how well it functions or its impact. Classic designs can be recognized as from their design movement/era. Yet, originality—whether it is evolutionary or revolutionary—seems to be the trait that makes a product "timeless". (3.10)	**Concepts and principles:** • Image • Status and culture • Obsolescence • Mass production • Ubiquitous/omnipresence • Dominant design **Guidance:** • How image makes a classic design instantly recognizable and provokes emotional reactions • How a classic design defies obsolescence and transcends its original function • How the role of mass production contributes to a product reaching classic design status • How the constant presence of a product in a changing context leads to classic design status • How classic designs are dominant in the marketplace and difficult to change	**International-mindedness:** • Classic designs are often recognized across culture and hold iconic status. **Theory of knowledge:** • Classic design often appeals to our emotions. Are emotions universal? **Utilization:** • Design technology topics 1, 4, 5, 9 and 10 • Visual arts **Aims:** • **Aim 8:** The iconic status of classic designs is often attributed to them being "breakthrough products".

Essential idea: For a design to become a classic design, the form can transcend the function.

6.2 Classic design, function and form		
Nature of design: Classic design holds "form follows function" as a fundamental principle, but this is not always evident in practice. Some products are so well designed with function as their primary goal, that their use is intuitive. As designers develop new technologies, the lines between the form and function of a product continue to blur. (3.3)	**Concepts and principles:** • Form versus function • Retro-styling • Conflict and compromise • Practical function versus psychological function **Guidance:** • How retro-styling a new product needs to respect and understand the original form and underlying structure before making changes • The tension between form and function when developing new products based on a classic design • Comparison of retro-styled products with the original production models in relation to form and function • Identify products where either practical function or psychological function has been the determining factor in the design	**International-mindedness:** • The emergence of retro-styling products as new technologies are developed relate to the emotional response that comes with nostalgia. This is often not only different between countries and between generations, but at the same time can transcend both. **Theory of knowledge:** • Is aesthetic value purely a subjective matter? **Utilization:** • Design technology topics 1, 3, 5, 7 and 9 • Visual arts **Aims:** • **Aim 6:** The balance between function and form is often an area of difficulty for the designer. If a product is purely functional, it may be lacking in appeal to consumers, no matter how good it may be at completing its job. Often we are drawn to products that have been developed with form as a primary consideration. The human psyche appreciates beauty.

Topic 7: User-centred design (UCD) 12 hours

Essential idea: The fundamental principle of UCD is that understanding the needs of the users is the key to designing the best products and services.

7.1 User-centred design (UCD)		
Nature of design: A designer must consider the needs, wants and limitations of the end user within every element of the design cycle. The ability to identify how users will interact with a product, service or system is vital for its success. To achieve this, designers must be able to acquire and analyse valid data without making assumptions about how the product may be used. (3.1)	**Concepts and principles:** • The designer needs to have a deep understanding of the user, task and the environment. • The process is iterative, led by the user and developed through user-centred evaluation. • The product must address the whole user experience. • UCD design teams are multidisciplinary. • The five stages of UCD: research, concept, design, implementation, launch • Inclusive design **Guidance:** • UCD design teams may include anthropologists, ethnographers and psychologists. • Inclusive design requires designing universally accessible products for all users including those with physical, sensory, perceptual and other challenges and impairments.	**International-mindedness:** • Even though the task addressed through UCD may not change from region to region, there can be an impact on the success of a global product due to variations in users and environments. **Utilization:** • Design technology topics 1, 5, and 9 • Design technology internal assessment • Business management units 4 and 5 **Aims:** • **Aim 5:** The ability to put aside one's own ideas and bias is essential for UCD. Designers must act with integrity and not project their own ideas of what the user requirements are when trying to create technological solutions to their problems.

Essential idea: Usability is about how easy it is to use a product or system.

7.2 Usability		
Nature of design: A design team should be "user" driven and frequent contact with potential users is essential. To understand how a product, service or system may be used, the designer must consider the prior knowledge and experience of the users, as well as their typical psychological responses. Evaluation methods that utilize appropriate testing and trialling strategies must be used to determine these aspects. (1.5, 1.16, 1.18)	**Concepts and principles:** • Usability objectives • Enhanced usability • Characteristics of good user-product interfaces • Population stereotypes **Guidance:** • Usability objectives include usefulness, effectiveness, learnability, attitude (likeability) • Benefits of enhanced usability include product acceptance, user experience, productivity, user error, training and support • Characteristics of good user-product interfaces include simplicity, ease of use, intuitive logic and organization, low memory burden, visibility, feedback, affordance, mapping and constraints. • Advantages and disadvantages of using population stereotypes for designers and users	**International-mindedness:** • Population stereotypes based on cultural expectations contribute to human error and designers must consider this when designing good user-product interfaces. **Utilization:** • Design technology topics 1 and 3 • Design technology internal assessment **Aims:** • **Aim 3:** Designers must consider the limits of population stereotypes. Through recognizing these limits, the designers can critically assess the appropriateness of their product in relation to those who will use it.

Essential idea: The designer needs to understand the reasons behind the behaviours, wants, and needs of the user.

7.3 Strategies for user research		
Nature of design: Designers should select research strategies based on the desired user experiences in the context of the product, service or system. The purpose of user research is to identify needs that reveal the complexities of personae. Real-life scenarios that simulate "actual" user experiences can generate new findings. (3.4, 3.5, 3.6)	**Concepts and principles:** • User population • Classification of users • The use of personae, secondary personae and anti-personae in user research • Scenarios provide physical and social context for different personae • Use case **Guidance:** • Users can be classified by age, gender and physical condition. • Scenarios are based on best, worst and average case.	**International-mindedness:** • User population behaviours, wants and needs may vary from one community of potential users to another, which may result in the development of a product family. **Theory of knowledge:** • Design considers the needs of individuals as paramount. Is this the case in other areas of knowledge? **Utilization:** • Design technology topics 1 and 9 • Design technology internal assessment **Aims:** • **Aim 2:** The various strategies for user research can be used by the designer to explore the true nature of a problem. Through the use of personae and use cases, the designer can build a range of possible scenarios with which to explore the problem in detail.

Essential idea: Users have a central role in evaluating whether the product meets their wants and needs.

7.4 Strategies for user-centred design (UCD)		
Nature of design: For designers to successfully integrate usability into the design process, they require a holistic understanding of how a product, service or system is used. Designers must identify user requirements through the use of careful observation and interviews. A clear strategy for UCD will improve acceptability and usability, reducing costs and effort, while fulfilling user requirements. (1.6, 3.5)	**Concepts and principles:** • Field research • Method of extremes • Observation, interviews and focus groups • Questionnaires • Affinity diagramming • Participatory design, prototype and usability testing sessions • Natural environments and usability laboratories • Testing houses versus usability laboratories **Guidance:** • Advantages and disadvantages of different UCD strategies	**International-mindedness:** • Testing in the environment where a product will be used is often extremely important for the design of products, especially where the problem to solve occurs in a country foreign to the design team. **Theory of knowledge:** • Is it ever possible to eliminate the effect of the observer? • To what extent does the language used on questionnaires shape the results? **Utilization:** • Design technology topics 1, 4, 5, and 9 • Design technology internal assessment **Aims:** • **Aim 9:** By including potential consumers in the testing of designs and prototypes, designers gain valuable data relating to how they will interact with a product.

Essential idea: Usability is not the only factor for a designer to consider; products can be designed to evoke pleasure and emotion.

7.5 Beyond usability—designing for pleasure and emotion		
Nature of design: A designer's ability to provide satisfaction through aesthetic appeal and pleasure can greatly influence the success of a product, service or system. Understanding attitudes, expectations and motivations of consumers plays a significant role in predicting product interaction. Designers need to be empathetic and sympathetic to user emotion, which acts as a critical component to determine how he or she interprets and interacts with a product, service or system. (3.8)	**Concepts and principles:** • The four-pleasure framework: socio-pleasure, physio-pleasure, psycho-pleasure and ideo-pleasure • Design for emotion • The attract/converse/transact (ACT) model **Guidance:** • How designing for emotion can increase user engagement, loyalty and satisfaction with a product by incorporating emotion and personality • How the ACT model can be used as a framework for creating designs that intentionally trigger positive emotional responses	**Theory of knowledge:** • Are emotions purely physiological or are they culturally bound? **Utilization:** • Design technology topics 1 and 6 • Visual arts **Aims:** • **Aim 4:** The ability to express emotion through a product can not only build appeal for the consumer, but also build affinity between a product and consumer. It can enable a product to communicate how one should interact with it.

Topic 8: Sustainability

14 hours

Essential idea: Sustainable development is concerned with satisfying human needs for resources now and in the future without compromising the carrying capacity of the planet.

8.1 Sustainable development		
Nature of design: Designers utilize design approaches that support sustainable development across a variety of contexts. A holistic and systematic approach is needed at all stages of design development to satisfy all stakeholders. In order to develop sustainable products, designers must balance aesthetic, cost, social, cultural, energy, material, health and usability considerations. (2.10)	**Concepts and principles:** • Triple bottom line sustainability: environmental, economic and social • Decoupling: disconnecting economic growth and environmental impact so that one no longer depends on the other • The use of international and national laws to promote sustainable development • Sustainability reporting • Product stewardship **Guidance:** • How using resources more productively and redesigning production, it is technically possible to deliver the same or equivalent goods and services with lower environmental impact while maintaining social and equity benefits. • Consider the benefits and limitations of decoupling as an appropriate strategy for sustainability	**International-mindedness:** • Changes in governments sometimes result in the reversal of sustainable development policies leading to different approaches to international agreements. **Theory of knowledge:** • Design involves making value judgments in deciding between different ways of interacting with the environment. Is this the case in other areas of knowledge? **Utilization:** • Design technology topics 2, 4, 5, 9 and 10 • Environmental systems and societies topics 1 and 8

8.1 Sustainable development		
	• How international and national laws encourage companies to focus on something other than shareholder value and financial performance • Benefits of sustainability reporting for governments, manufacturers and consumers • Product stewardship examples include organic foods, genetically modified food, green cotton, forest stewardship and bio-plastics	**Aims:** • **Aim 9:** Triple bottom line sustainability does not only focus on the profitability of an organization or product, but also the environmental and social benefit it can bring. Organizations that embrace triple bottom line sustainability can make significant positive effects to the lives of others and the environment by changing the impact of their business activities.

Essential idea: Sustainable consumption focuses on reducing the use of resources of a product to minimize its environmental impact.

8.2 Sustainable consumption		
Nature of design: Designers develop products, services and systems that satisfy basic needs and improve quality of life. To meet sustainable consumption requirements, they must also minimize the use of natural resources, toxic materials and waste, and reduce emissions of pollutants at all stages of the life cycle. (2.10, 3.7)	**Concepts and principles:** • Consumer attitudes and behaviours towards sustainability: eco-warriors, eco-champions, eco-fans, eco-phobes • Eco-labelling and energy labelling schemes • Creating a market for sustainable products: pricing considerations, stimulating demand for green products, production of green products • Pressure groups • Lifestyle and ethical consumerism • Implications of take-back legislation for designers, manufacturers and consumers **Guidance:** • Consider eco-labelling and energy labelling schemes from different country contexts • Advantages and disadvantages of consumer and environmental pressure groups for the user, manufacturer and designer • How pressure groups exert influence for changes on these issues and support or undermine development of specific technologies	**International-mindedness:** • There are many different eco-labelling and energy-labelling schemes across the world that could be standardized. **Theory of knowledge:** • Eco-warriors sometimes break laws to express their views. Does the rightness or wrongness of an action depend on the situation? **Utilization:** • Design technology topics 2, 4, 5 and 10 • Economics topic 1 • Environmental systems and societies topic 1 **Aims:** • **Aim 5:** It is not only the role of designers to create markets for sustainable products. Consumers need to change their habits and express a want and need for these products.

8.2 Sustainable consumption		
	• How consumer and environmental pressure groups can attract widespread support using the media (including social media) • How consumers have become increasingly aware of information provided by pressure groups and as markets have globalized, so has consumer power • Consider strategies for managing western consumption while raising the standard of living of the developing world without increasing resource use and environmental impact	

Essential idea: Sustainable design is a philosophy of developing products in line with social, economic, and ecological sustainability principles.

8.3 Sustainable design		
Nature of design: The first step to sustainable design is to consider a product, service or system in relation to eco-design and analyse its impact using life cycle analysis. The designer then develops these to minimize environmental impacts identified from this analysis. Considering sustainability from the beginning of the process is essential. (2.8)	**Concepts and principles:** • Green design versus sustainable design • Datschefski's five principles of sustainable design: cyclic, solar, safe, efficient, social **Guidance:** • The differences between green design and sustainable design • Comparison of timescale between green design and sustainable design	**International-mindedness:** • The application of Datschefski's social principle of sustainable design can have different effects across different countries. **Theory of knowledge:** • Datschefski developed his five principles of sustainable design to help designers structure their approach and thoughts. In what ways and areas would the absence of experts most severely limit our knowledge? **Utilization:** • Design technology topics 1, 2, 4, 5 and 10 **Aims:** • **Aim 10:** Datschefski's five principles of sustainable design equip the designer with a tool not only to design new products, but also to evaluate an existing product. This can lead to new design opportunities and increase the level at which a product aligns with these principles.

Essential idea: Sustainable innovation facilitates the diffusion of sustainable products and solutions into the marketplace.

8.4 Sustainable innovation		
Nature of design: Sustainable innovation yields both bottom line and top line returns as developing products, services and systems that are environmentally friendly lowers costs through reducing the resources required. Designers should view compliance with government legislation as an opportunity for sustainable innovation. (2.9)	**Concepts and principles:** • Complexity and timescale of sustainable innovation • Top-down strategies • Bottom-up strategies • Government intervention in innovation • Macro energy sustainability • Micro energy sustainability • Energy security **Guidance:** • Examples of top-down and bottom-up strategies and the advantages and disadvantages for consumers/users • Government intervention includes regulation, education, taxes and subsidies • How macro energy sustainability can be influenced through international treaties and energy policies, instruments for change and disincentives, and national systems changing policy when government leadership changes • How micro energy sustainability can be influenced by the role of the government in raising awareness and changing attitudes, and promotion of individual and business action towards energy sustainability • How energy security can be influenced by energy demand/supply trends and forecasting, demand response versus energy efficiency, and smart grids	**International-mindedness:** • The internal policies of particular governments have international implications. **Theory of knowledge:** • To what extent should environmental concerns limit our pursuit of knowledge? **Utilization:** • Design technology topics 2, 4, 5 and 10 • Environmental systems and societies topic 1 **Aims:** • **Aim 1:** As energy security becomes an ever more important issue for all countries, designers, engineers and inventors need to develop new ways of efficiently generating energy. As new energy production technologies become available, designers need to harness them to be used in new products to improve their energy efficiency.

Topic 9: Innovation and markets — 13 hours

Essential idea: Companies and businesses can utilize a range of different strategies to develop products, services and systems.

9.1 Corporate strategies		
Nature of design: The success of a company relies heavily on the strategies it adopts. The evaluation of products, services and systems can inform the selection of the most appropriate strategies to follow that will enable a company to achieve its objectives. (1.12)	**Concepts and principles:** • Pioneering strategy • Imitative strategy • Market development • Product development • Market penetration • Product diversification • Hybrid approaches • The relative success of pioneering and innovative strategies • Corporate social responsibility **Guidance:** • Comparison of success between pioneering and imitative strategies • Examples of companies and products that have used the above strategies • Examples of a company and its products that are a result of a hybrid approach	**International-mindedness:** • Adoption of corporate social responsibility by multinational companies can be used as a distraction from their core business practices. **Theory of knowledge:** • Is strategic planning more influenced by reason, intuition or imagination? Or by a combination of all of the ways of knowing? **Utilization:** • Design technology topics 3, 5, 7, 8 and 10 • Business management topic 1 • Economics topic 1 **Aims:** • **Aim 5:** The designer must consider the ethical implications of imitating the products of others and their implications on a cultural, economic, and intellectual property level.

9.1 Corporate strategies		
	• How corporate social responsibility may be a particular goal of a company whereby the aim is to manage the economic, social and environmental impacts of their operation to maximize the benefits and minimize the disadvantages • Examples of evidence of effective corporate social responsibility for a major multinational company	

Essential idea: Designers must research and consider the target market sectors and segments in the design of their products.

9.2 Market sectors and segments		
Nature of design: Designers must consider the market when targeting their product, service or system. The smaller the sector, the more the target audience will have in common. Companies may decide to compete in the whole market or only in segments that are attractive and/or familiar. A designer's understanding of the identified market is essential. (2.6)	**Concepts and principles:** • Categories of market sectors • The influence of market sectors • Classifications of consumer market segments: income, profession, age, family, values, behaviour • The development of a product family **Guidance:** • Broad categories of market sectors include geographical sectors focusing on values, culture and characteristics of purchasers in a particular region and purchasing power; client-based sectors focusing on consumers, industrial, public sector and commercial • How companies take into account market sectors in the design and manufacture of products • Examples of products designed for only one sector and products designed to be sold to more than one sector • How the needs of the markets segments listed impact on the design of products and scale of production • Examples of product families	**International-mindedness:** • Two broad categories of market sectors are geographical- and client-based, with specific segments varying greatly. **Theory of knowledge:** • Gaining information on market sectors often employs many of the methods of gaining knowledge most closely associated with the human sciences. What are these methods of gaining knowledge, and how do they compare to the methods used in the natural sciences? **Utilization:** • Design technology topics 5 and 7 • Design technology internal assessment • Business management topic 4 **Aims:** • **Aim 6:** By identifying the market sectors and segments a product will be designed for, a designer can gain data directly from the perspective of the potential consumer.

Essential idea: The marketing mix is often crucial when determining a product or brand's offering.

9.3 Marketing mix		
Nature of design: Empathy for, and understanding of the target audience is developed through thorough analysis of the market chosen. This informs several factors: the standards that end users demand; how and where to distribute and sell the product; how much they are willing to pay for a certain product and its quality; and how to communicate the launch of a product. Correct analysis of these factors could determine the success or failure of a product, despite its quality. (3.8)	**Concepts and principles:** • Marketing mix—the 4Ps: product, place, price, promotion • Product: standardization of products • Place: implications of internet selling for a company in relation to its supply chain and distribution network • Strategies of setting price: cost-plus, demand pricing, competitor-based pricing, product line pricing, psychological pricing • Promotion: advertising, publicity, personal selling **Guidance:** • Consider government standards for a particular market segment, component standardization and industry-wide standards • Examples of trigger products and incremental products • Analysis of product pricing that matches each of the price setting strategies • Examples of promotion campaigns for different products	**International-mindedness:** • When developing marketing campaigns, companies take account of different cultures and sectors in the target market. **Theory of knowledge:** • Some advertisers emphasize the "science" behind their products. Does this suggest that some people may see scientific knowledge as being more reliable than knowledge in other areas of knowledge? **Utilization:** • Design technology topics 2, 8 and 10 • Business management topic 4 **Aims:** • **Aim 7:** Marketing is often a new area for designers to consider. Exploring unfamiliar aspects of innovation improves their understanding of the market needs of the products they are designing.

Essential idea: Market research is any organized effort to gather information about markets or customers.

9.4 Market research		
Nature of design: Market research often identifies how to improve the product, service or system and increase its chance of success within a particular sector or segment. The price a user is prepared to pay is usually determined through market research. This in turn sets an upper limit of cost to the design and production of a potential product, service or system. Market research has a crucial role in determining the constraints a designer has to work within. (1.5)	**Concepts and principles:** • Purpose of market research • Consumers' reaction to technology and green design, and subsequent impact on design development and market segmentation • Market research strategies **Guidance:** • The purpose of market research includes idea generation and development; evaluating market potential and economic trends; collecting data relating to demographics, family roles, consumers; identifying suitable promotional strategies; considering technological trends and scientific advances • Market research strategies include literature search, expert appraisal, user trial, user research, perceptual mapping and environmental scanning • Advantages and disadvantages of each market research strategy considering the nature, reliability and cost of the research and importance to the design development process	**International-mindedness:** • Determining the purpose of market research allows designers to clearly identify who needs to be included and their differing requirements. **Theory of knowledge:** • What are the assumptions that underlie methods used to gain knowledge in this area? **Utilization:** • Design technology topics 5 and 7 • Design technology internal assessment • Business management topic 4 **Aims:** • **Aim 1:** Often designers will work on projects that have new and radically unfamiliar contexts. This will deepen their understanding of market research, equipping them with a range of tools and skills that they can employ in many areas of life and empowering them as lifelong learners.

Essential idea: Branding creates an identity for a product or company, which makes it distinct from another and can provide added value.

9.5 Branding		
Nature of design: In order to diffuse products into the marketplace, the identity of a company is typically embodied in a brand. The brand is communicated to the consumer through a value proposition. Designers help to communicate this by: building a strong user experience around the brand identity; determining content design; establishing the tone of message through advertisements; promotion. (3.9)	**Concepts and principles:** • Brand loyalty • How brands appeal to different market segments • The difference between a trademark and registered design • The implications for a company of positive and negative publicity on brand image • Contribution of packaging to brand identity • Effects of product branding • Evaluating the global impact of branding **Guidance:** • Examples of positive and negative effects of product branding on different market segments • Examples of products affected by branding on a global scale	**International-mindedness:** • A globally recognized and appealing brand allows organizations and companies to engage with global markets. This raises ethical issues with some products. **Utilization:** • Design technology topics 3, 5 and 6 • Business management topic 4 **Aims:** • **Aim 4:** A brand encapsulates the identity of a company and its products. The brand designer needs to ensure that the message of a company is communicated clearly and creatively to allow them to stand out from the competition.

Topic 10: Commercial production

15 hours

Essential idea: Just in time and just in case are opposing production strategies utilized by the manufacturer.

10.1 Just in time (JIT) and just in case (JIC)		
Nature of design: While inventory creates a safety net for companies, maintenance and potential waste of resources can have significant implications for companies and the environment. Manufacturers must evaluate and analyse each market and determine whether a JIT or JIC strategy is the best to follow. (2.7)	**Concepts and principles:** • Just in case (JIC) • Just in time (JIT) **Guidance:** • Advantages and disadvantages of JIC and JIT	**International-mindedness:** • Effective business processes and practices developed in some countries have been exported successfully. **Theory of knowledge:** • Manufacturers decide whether to pursue JIT or JIC as a production strategy depending on their perception of where the market is going. To what extent do different areas of knowledge incorporate doubt as a part of their methods? **Utilization:** • Design technology topic 4 • Business management topic 5 **Aims:** • **Aim 2:** An in-depth knowledge and understanding of the potential success of a product can lead manufacturers to decide in favour of JIC or JIT. This can vary from one product to the next and requires experience and intuition.

Essential idea: Lean production aims to eliminate waste and maximize the value of a product based on the perspective of the consumer.

<table>
<tr><th colspan="3">10.2 Lean production</th></tr>
<tr>
<td>Nature of design:
Lean production considers product and process design as an ongoing activity and not a one-off task, and should be viewed as a long-term strategy. (3.5)</td>
<td>Concepts and principles:
• Characteristics of lean production
• Principles of lean production
• Value stream mapping
• Workflow analysis
• Product family
• Role of the workforce
• Kaizen
• Lead time
• The 5 Ss: sorting, stabilizing, shining, standardizing, sustaining the practice
• The 7 wastes: overproduction, waiting, transporting, inappropriate processing, unnecessary inventory, unnecessary/excess motion, defects
Guidance:
• Characteristics of lean production include JIT supplies; highly trained multi-skilled workforce; quality control and continuous improvement; zero defects, zero inventory
• Principles of lean production include: eliminating waste; minimizing inventory; maximizing flow; pulling production from customer demand; meeting customer requirements; doing it right first time; empowering workers; designing for rapid changeover; partnering with suppliers; creating a culture of continuous improvement (kaizen)</td>
<td>International-mindedness:
• The implementation of lean production has benefits for the global environment.
Theory of knowledge:
• The importance of the individual is recognized in design processes. Is this the case in other areas of knowledge?
Utilization:
• Design technology topics 2, 4, 5 and 8
• Environmental systems and societies topic 1
Aims:
• Aim 9: The role of the workforce in lean production is paramount, relying on their wisdom and experience to improve the process, reducing waste, cost and production time. Recognizing this results in motivated workforces whose interests are in the success of the product.</td>
</tr>
</table>

10.2 Lean production		
	• The role of the workforce includes training, devolution in power relating to process improvement and kaizen • Consider the contribution of value stream mapping and workflow analysis to the design of an effective lean production method • Advantages and disadvantages of lean production	

Essential idea: Computer-integrated manufacturing uses computers to automatically monitor and control the entire production of a product.

10.3 Computer integrated manufacturing (CIM)		
Nature of design: When considering design for manufacture (DfM), designers should be able to integrate computers from the earliest stage of design. This requires knowledge and experience of the manufacturing processes available to ensure integration is efficient and effective. Through the integration of computers, the rate of production can be increased and errors in manufacturing can be reduced or eliminated, although the main advantage is the ability to create automated manufacturing processes. (1.16)	**Concepts and principles:** • Elements of CIM: design, planning, purchasing, cost accounting, inventory control, distribution • CIM and scales of production **Guidance:** • Advantages and disadvantages of CIM in relation to initial investment and maintenance • Advantages and disadvantages of CIM in relation to different production systems	**International-mindedness:** • A CIM system allows for efficient global workflow and distribution. **Theory of knowledge:** • Technology has a profound influence in design. How have other areas of knowledge been influenced by technology? **Utilization:** • Design technology 4 and 8 **Aims:** • **Aim 8:** The integration of computer control into manufacturing can streamline systems, negating the need for time-consuming activities, such as stocktaking, but also reducing the size of the workforce.

Essential idea: Quality management focuses on producing products of consistent required quality.

10.4 Quality management		
Nature of design: Designers should ensure that the quality of products is consistent through development of detailed manufacturing requirements. They also need to focus on the means to achieve it. The importance of quality management through quality control (QC), statistical process control (SPC) and quality assurance (QA) reduces the potential waste of resources. (1.5)	**Concepts and principles:** • Quality control (QC) • Statistical process control (SPC) • Quality assurance (QA) **Guidance:** • How QC at source eliminates waste from defects • How continuous monitoring ensures that machines perform to the pre-determined standard/quality • How QC, SPC and QA contribute to quality management • The differences between QC, SPC and QA	**International-mindedness:** • Effective quality management can have major benefits for the environment. **Theory of knowledge:** • There are commonly accepted ways of assuring quality in design. How do other areas of knowledge ensure the quality of their outputs? **Utilization:** • Design technology topics 2, 3, 4, 5 and 8 • Design technology internal assessment • Business management topic 5 **Aims:** • **Aim 3:** The implementation of quality management strategies requires a critical and complete understanding of the needs of a product. To ensure efficiency and efficacy, these measures need to be designed into the product and its production system.

Essential idea: Designers must consider the economic viability of their designs for them to gain a place in the market.

10.5 Economic viability		
Nature of design: Designers need to consider how the costs of materials, manufacturing processes, scale of production and labour contribute to the retail cost of a product. Strategies for minimizing these costs at the design stage are most effective to ensure that a product is affordable and can gain a financial return. (1.15)	**Concepts and principles:** • Cost-effectiveness • Value for money • Costing versus pricing: fixed costs, variable costs, cost analysis, break-even • Pricing strategies: price-minus strategy, retail price, wholesale price, typical manufacturing price, target costs, return on investment, unit cost, sales volume, financial return **Guidance:** • The relationship between what a product is worth and how much it costs • Calculation of prices based on the listed pricing strategies	**International-mindedness:** • The cost effectiveness of a product can determine whether it can enter economically diverse national and international markets. **Theory of knowledge:** • The retail price of a product is partly based on evidence of its potential position in the market. What counts as evidence in various areas of knowledge? **Utilization:** • Design technology topics 2, 4, 5 and 9 • Design technology internal assessment • Economics topic 1 **Aims:** • **Aim 7:** The economic viability of a product is paramount for designers if they are to get their product into production. Understanding how to design a product to specification, at lowest cost and to the appropriate quality while giving added value, can determine the relationship between what a product is worth and how much it costs.

Assessment in the Diploma Programme

General

Assessment is an integral part of teaching and learning. The most important aims of assessment in the Diploma Programme are that it should support curricular goals and encourage appropriate student learning. Both external and internal assessments are used in the Diploma Programme. IB examiners mark work produced for external assessment, while work produced for internal assessment is marked by teachers and externally moderated by the IB.

There are two types of assessment identified by the IB.

- Formative assessment informs both teaching and learning. It is concerned with providing accurate and helpful feedback to students and teachers on the kind of learning taking place and the nature of students' strengths and weaknesses in order to help develop students' understanding and capabilities. Formative assessment can also help to improve teaching quality, as it can provide information to monitor progress towards meeting the course aims and objectives.
- Summative assessment gives an overview of previous learning and is concerned with measuring student achievement.

The Diploma Programme primarily focuses on summative assessment designed to record student achievement at, or towards the end of, the course of study. However, many of the assessment instruments can also be used formatively during the course of teaching and learning, and teachers are encouraged to do this. A comprehensive assessment plan is viewed as being integral with teaching, learning and course organization. For further information, see the IB *Programme standards and practices* (2010) document.

The approach to assessment used by the IB is criterion-related, not norm-referenced. This approach to assessment judges students' work by their performance in relation to identified levels of attainment, and not in relation to the work of other students. For further information on assessment within the Diploma Programme please refer to the publication *Diploma Programme assessment: Principles and practice* (2009).

To support teachers in the planning, delivery and assessment of the Diploma Programme courses, a variety of resources can be found on the OCC or purchased from the IB store (http://store.ibo.org). Additional publications such as specimen papers and markschemes, teacher support materials, subject reports and grade descriptors can also be found on the OCC. Past examination papers as well as markschemes can be purchased from the IB store.

Methods of assessment

The IB uses several methods to assess work produced by students.

Assessment criteria

Assessment criteria are used when the assessment task is open-ended. Each criterion concentrates on a particular skill that students are expected to demonstrate. An assessment objective describes what students should be able to do, and assessment criteria describe how well they should be able to do it. Using assessment criteria allows discrimination between different answers and encourages a variety of responses.

Each criterion comprises a set of hierarchically ordered level descriptors. Each level descriptor is worth one or more marks. Each criterion is applied independently using a best-fit model. The maximum marks for each criterion may differ according to the criterion's importance. The marks awarded for each criterion are added together to give the total mark for the piece of work.

Markbands

Markbands are a comprehensive statement of expected performance against which responses are judged. They represent a single holistic criterion divided into level descriptors. Each level descriptor corresponds to a range of marks to differentiate student performance. A best-fit approach is used to ascertain which particular mark to use from the possible range for each level descriptor.

Analytic markschemes

Analytic markschemes are prepared for those examination questions that expect a particular kind of response and/or a given final answer from students. They give detailed instructions to examiners on how to break down the total mark for each question for different parts of the response.

Marking notes

For some assessment components marked using assessment criteria, marking notes are provided. Marking notes give guidance on how to apply assessment criteria to the particular requirements of a question.

Inclusive assessment arrangements

Inclusive assessment arrangements are available for candidates with assessment access requirements. These arrangements enable candidates with diverse needs to access the examinations and demonstrate their knowledge and understanding of the constructs being assessed.

The IB document *Candidates with assessment access requirements* provides details on all the inclusive assessment arrangements available to candidates with learning support requirements. The IB document *Learning diversity in the International Baccalaureate programmes: Special educational needs within the International Baccalaureate programmes* outlines the position of the IB with regard to candidates with diverse learning needs in the IB programmes. For candidates affected by adverse circumstances, the IB documents *General regulations: Diploma Programme* (2011) and the *Handbook of procedures for the Diploma Programme* provide details on access consideration.

Responsibilities of the school

The school is required to ensure that equal access arrangements and reasonable adjustments are provided to candidates with learning support requirements that are in line with the IB documents *Candidates with assessment access requirements* and *Learning diversity in the International Baccalaureate programmes: Special educational needs within the International Baccalaureate programmes*.

Assessment outline—SL

First assessment 2016

Component	Overall weighting (%)	Approximate weighting of objectives (%)		Duration (hours)
		1+2	3	
Paper 1	30	30		¾
Paper 2	30	12	18	1½
Internal assessment Design project	40	All assessment objectives are tested equally		40

Assessment outline—HL

First assessment 2016

Component	Overall weighting (%)	Approximate weighting of objectives (%)		Duration (hours)
		1+2	3	
Paper 1	20	20		1
Paper 2	20	8	12	1½
Paper 3	20	10	10	1½
Internal assessment Design project	40	All assessment objectives are tested equally		60

External assessment

The method used to assess students is through detailed markschemes specific to each examination paper (except paper 1, multiple-choice).

External assessment details—SL

Paper 1

Duration: ¾ hour
Weighting: 30%
Marks: 30

- 30 multiple-choice questions on the core material.
- The questions on paper 1 test assessment objectives 1 and 2.
- The use of calculators is not permitted.
- No marks are deducted for incorrect answers.

Paper 2

Duration: 1½ hours
Weighting: 30%
Marks: 50

- Section A: one data-based question and several short-answer questions on the core material (all compulsory). Maximum of 30 marks.
- Section B: one extended-response question on the core material (from a choice of three). Maximum of 20 marks.
- The questions on paper 2 test assessment objectives 1, 2 and 3.
- The use of calculators is permitted. (See calculator section on the OCC.)
- This paper is common with HL paper 2.

External assessment details—HL

Paper 1

Duration: 1 hour
Weighting: 20%
Marks: 40

- 40 multiple-choice questions on the core and HL extension material.
- The questions on paper 1 test assessment objectives 1 and 2.
- The use of calculators is not permitted.
- No marks are deducted for incorrect answers.

Paper 2

Duration: 1½ hours
Weighting: 20%
Marks: 50

- Section A: one data-based question and several short-answer questions on the core material (all compulsory). Maximum of 30 marks.
- Section B: one extended-response question on the core material (from a choice of three). Maximum of 20 marks.
- The questions on paper 2 test assessment objectives 1, 2 and 3.
- The use of calculators is permitted. (See calculator section on the OCC.)
- This paper is common with SL paper 2.

Paper 3

Duration: 1½ hours
Weighting: 20%
Marks: 40

- Section A: two structured questions on the HL extension material, both compulsory and each worth a maximum of 10 marks.
- Section B: one structured question on the HL extension material based on a case study. Maximum of 20 marks.
- The use of calculators is permitted. (See calculator section on the OCC.)

Internal assessment

Purpose of internal assessment

Internal assessment is an integral part of the course and is compulsory for both SL and HL students. It enables students to demonstrate the application of their skills and knowledge, and to pursue their personal interests, without the time limitations and other constraints that are associated with written examinations. The internal assessment should, as far as possible, be woven into normal classroom teaching and not be a separate activity conducted after a course has been taught.

The internal assessment requirements at SL and at HL are different. The first four assessment criteria (A–D) are common between SL and HL; however, HL design projects have additional requirements, which are assessed using two additional criteria (E and F). This internal assessment section of the guide should be read in conjunction with the internal assessment section of the teacher support material.

Guidance and authenticity

The work submitted for internal assessment must be the student's own work. However, it is not the intention that students should decide upon a title or topic and be left to work on the internal assessment component without any further support from the teacher. The teacher should play an important role during both the planning stage and the period when the student is working on the internally assessed work. It is the responsibility of the teacher to ensure that students are familiar with:

- the requirements of the type of work to be internally assessed
- the IB animal experimentation policy
- the assessment criteria; students must understand that the work submitted for assessment must address these criteria effectively.

Teachers and students must discuss the internally assessed work. Students should be encouraged to initiate discussions with the teacher to obtain advice and information, and students must not be penalized for seeking guidance. As part of the learning process, teachers should read and give advice to students on one draft of the work. The teacher should provide oral or written advice on how the work could be improved, but not edit the draft. The next version handed to the teacher must be the final version for submission.

It is the responsibility of teachers to ensure that all students understand the basic meaning and significance of concepts that relate to academic honesty, especially authenticity and intellectual property. Teachers must ensure that all student work for assessment is prepared according to the requirements and must explain clearly to students that the internally assessed work must be entirely their own. Where collaboration between students is permitted, it must be clear to all students what the difference is between collaboration and collusion.

All work submitted to the IB for moderation or assessment must be authenticated by a teacher, and must not include any known instances of suspected or confirmed academic misconduct. Each student must confirm that the work is his or her authentic work and constitutes the final version of that work. Once a student has officially submitted the final version of the work it cannot be retracted. The requirement to confirm the authenticity of work applies to the work of all students, not just the sample work that will be submitted to the IB for the purpose of moderation. For further details refer to the IB publication *Academic honesty* (2011), *The Diploma Programme: From principles into practice* (2009) and the relevant articles in *General regulations: Diploma Programme* (2011).

Authenticity may be checked by discussion with the student on the content of the work, and scrutiny of one or more of the following:

- the student's initial proposal
- the first draft of the written work
- the references cited
- the style of writing compared with work known to be that of the student
- the analysis of the work by a web-based plagiarism detection service such as http://www.turnitin.com.

The same piece of work cannot be submitted to meet the requirements of both the internal assessment and the extended essay.

Group work

Each design project is an individual piece of work based on different research collected.

It should be made clear to students that all work connected with the writing of the design project, should be their own. It is therefore helpful if teachers try to encourage in students a sense of responsibility for their own learning so that they accept a degree of ownership and take pride in their own work.

Time allocation

Internal assessment is an integral part of the design technology course, contributing 40% to the final assessment in the SL and the HL courses. This weighting should be reflected in the time that is allocated to teaching the knowledge, skills and understanding required to undertake the work, as well as the total time allocated to carry out the work.

It is recommended that a total of approximately 40 hours (SL) and 60 hours (HL) should be allocated to the work. This should include:

- time for the teacher to explain to students the requirements of the internal assessment
- class time for students to work on the internal assessment component and ask questions
- time for consultation between the teacher and each student
- time to review and monitor progress, and to check authenticity.

Safety requirements and recommendations

While teachers are responsible for following national or local guidelines, which may differ from country to country, attention should be given to the guidelines below, which were developed for the International Council of Associations for Science Education (ICASE) Safety Committee by The Laboratory Safety Institute (LSI).

It is a basic responsibility of everyone involved to make safety and health an ongoing commitment. Any advice given will acknowledge the need to respect the local context, the varying educational and cultural traditions, the financial constraints and the legal systems of differing countries.

The Laboratory Safety Institute's Laboratory Safety Guidelines ...

40 suggestions for a safer lab

Steps Requiring Minimal Expense

1. Have a written health, safety and environmental affairs (HS&E) policy statement.
2. Organize a departmental HS&E committee of employees, management, faculty, staff and students that will meet regularly to discuss HS&E issues.
3. Develop an HS&E orientation for all new employees and students.
4. Encourage employees and students to care about their health and safety and that of others.
5. Involve every employee and student in some aspect of the safety program and give each specific responsibilities.
6. Provide incentives to employees and students for safety performance.
7. Require all employees to read the appropriate safety manual. Require students to read the institution's laboratory safety rules. Have both groups sign a statement that they have done so, understand the contents, and agree to follow the procedures and practices. Keep these statements on file in the department office
8. Conduct periodic, unannounced laboratory inspections to identify and correct hazardous conditions and unsafe practices. Involve students and employees in simulated OSHA inspections.
9. Make learning how to be safe an integral and important part of science education, your work, and your life.
10. Schedule regular departmental safety meetings for all students and employees to discuss the results of inspections and aspects of laboratory safety.
11. When conducting experiments with hazards or potential hazards, ask yourself these questions:
    - What are the hazards?
    - What are the worst possible things that could go wrong?
    - How will I deal with them?
    - What are the prudent practices, protective facilities and equipment necessary to minimize the risk of exposure to the hazards?
12. Require that all accidents (incidents) be reported, evaluated by the departmental safety committee, and discussed at departmental safety meetings.
13. Require every pre-lab/pre-experiment discussion to include consideration of the health and safety aspects.
14. Don't allow experiments to run unattended unless they are failsafe.
15. Forbid working alone in any laboratory and working without prior knowledge of a staff member.
16. Extend the safety program beyond the laboratory to the automobile and the home.
17. Allow only minimum amounts of flammable liquids in each laboratory.
18. Forbid smoking, eating and drinking in the laboratory.
19. Do not allow food to be stored in chemical refrigerators.

20. Develop plans and conduct drills for dealing with emergencies such as fire, explosion, poisoning, chemical spill or vapour release, electric shock, bleeding and personal contamination.
21. Require good housekeeping practices in all work areas.
22. Display the phone numbers of the fire department, police department, and local ambulance either on or immediately next to every phone.
23. Store acids and bases separately. Store fuels and oxidizers separately.
24. Maintain a chemical inventory to avoid purchasing unnecessary quantities of chemicals.
25. Use warning signs to designate particular hazards.
26. Develop specific work practices for individual experiments, such as those that should be conducted only in a ventilated hood or involve particularly hazardous materials. When possible most hazardous experiments should be done in a hood.

Steps Requiring Moderate Expense

27. Allocate a portion of the departmental budget to safety.
28. Require the use of appropriate eye protection at all times in laboratories and areas where chemicals are transported.
29. Provide adequate supplies of personal protective equipment—safety glasses, goggles, face shields, gloves, lab coats and bench top shields.
30. Provide fire extinguishers, safety showers, eye wash fountains, first aid kits, fire blankets and fume hoods in each laboratory and test or check monthly.
31. Provide guards on all vacuum pumps and secure all compressed gas cylinders.
32. Provide an appropriate supply of first aid equipment and instruction on its proper use.
33. Provide fireproof cabinets for storage of flammable chemicals.
34. Maintain a centrally located departmental safety library:
    - “Safety in School Science Labs”, Clair Wood, 1994, Kaufman & Associates, 101 Oak Street, Wellesley, MA 02482
    - “The Laboratory Safety Pocket Guide”, 1996, Genium Publisher, One Genium Plaza, Schnectady, NY
    - “Safety in Academic Chemistry Laboratories”, ACS, 1155 Sixteenth Street NW, Washington, DC 20036
    - “Manual of Safety and Health Hazards in The School Science Laboratory”, “Safety in the School Science Laboratory”, “School Science Laboratories: A Guide to Some Hazardous Substances”, Council of State Science Supervisors (now available only from LSI)
    - “Handbook of Laboratory Safety”, 4th Edition, CRC Press, 2000 Corporate Boulevard NW, Boca Raton, FL 33431
    - “Fire Protection Guide on Hazardous Materials”, National Fire Protection Association, Batterymarch Park, Quincy, MA 02269
    - “Prudent Practices in the Laboratory: Handling and Disposal of Hazardous Chemicals”, 2nd Edition, 1995
    - “Biosafety in the Laboratory”, National Academy Press, 2101 Constitution Avenue, NW, Washington, DC 20418
    - “Learning By Accident”, Volumes 1–3, 1997–2000, The Laboratory Safety Institute, Natick, MA 01760

    (All are available from **LSI**.)

35. Remove all electrical connections from inside chemical refrigerators and require magnetic closures.
36. Require grounded plugs on all electrical equipment and install ground fault interrupters (GFIs) where appropriate.
37. Label all chemicals to show the name of the material, the nature and degree of hazard, the appropriate precautions, and the name of the person responsible for the container.
38. Develop a program for dating stored chemicals and for recertifying or discarding them after predetermined maximum periods of storage.
39. Develop a system for the legal, safe and ecologically acceptable disposal of chemical wastes.
40. Provide secure, adequately spaced, well ventilated storage of chemicals.

LSI The Laboratory Safety Institute

Using assessment criteria for internal assessment

For internal assessment, a number of assessment criteria have been identified. Each assessment criterion has level descriptors describing specific achievement levels, together with an appropriate range of marks. The level descriptors concentrate on positive achievement, although for the lower levels failure to achieve may be included in the description.

Teachers must judge the internally assessed work at SL and at HL against the criteria using the level descriptors.

- There are four common criteria used to assess both SL and HL; however, HL is assessed using two additional criteria.
- The aim is to find, for each criterion, the descriptor that conveys most accurately the level attained by the student, using the best-fit model. A best-fit approach means that compensation should be made when a piece of work matches different aspects of a criterion at different levels. The mark awarded should be one that most fairly reflects the balance of achievement against the criterion. It is not necessary for every single aspect of a level descriptor to be met for that mark to be awarded.
- When assessing a student's work, teachers should read the level descriptors for each criterion until they reach a descriptor that most appropriately describes the level of the work being assessed. If a piece of work seems to fall between two descriptors, both descriptors should be read again and the one that more appropriately describes the student's work should be chosen.
- Where there are two or more marks available within a level, teachers should award the upper marks if the student's work demonstrates the qualities described to a great extent; the work may be close to achieving marks in the level above. Teachers should award the lower marks if the student's work demonstrates the qualities described to a lesser extent; the work may be close to achieving marks in the level below.
- Only whole numbers should be recorded; partial marks (fractions and decimals) are not acceptable.
- Teachers should not think in terms of a pass or fail boundary, but should concentrate on identifying the appropriate descriptor for each assessment criterion.

- The highest level descriptors do not imply faultless performance but should be achievable by a student. Teachers should not hesitate to use the extremes if they are appropriate descriptions of the work being assessed.
- A student who attains a high achievement level in relation to one criterion will not necessarily attain high achievement levels in relation to the other criteria. Similarly, a student who attains a low achievement level for one criterion will not necessarily attain low achievement levels for the other criteria. Teachers should not assume that the overall assessment of the students will produce any particular distribution of marks.
- It is recommended that the assessment criteria be made available to students.

Practical work and internal assessment

General introduction

The internal assessment (IA) requirement is worth 40% of the final assessment and consists of one design project.

Student work is internally assessed by the teacher and externally moderated by the IB. The performance in IA at both SL and HL is marked against 4 common assessment criteria, with an additional 2 assessment criteria for HL.

The expectations at SL and HL for the 4 common assessment criteria are the same.

The IA task consists of one design project. At SL, this project will be completed in about 40 hours. At HL, this project will be completed in about 60 hours. Each criterion should be addressed in about 10 hours.

Clarifications follow each assessment criterion with further detail of what is expected for each strand of the criterion. Indications of the scope and size of the sections of each project can be found in the clarifications. These amount to approximately 34 A4 pages (or equivalent) at SL and 44 A4 pages (or equivalent) at HL. The maximum page limit at SL is 38 A4 pages (or equivalent). The maximum page limit at HL is 50 A4 pages (or equivalent). These limits should be made clear to the students. The teacher should not award any marks for work on pages over this limit. If selected in the sample for moderation, the examiner will stop reading the project at this limit.

The 4 common assessment criteria are mirrored by the stages of the design cycle, which focuses on invention. The additional two criteria used for HL only extend the scope of the design cycle to include aspects of innovation.

The design project allows a wide range of contexts to be explored through the varying material disciplines of design technology, including product design, food product design, fashion design/textiles, electronic product design, robotics, and so on. The design project addresses many of the learner profile attributes as well.

The task produced should be complex and commensurate with the level of the course. It should require a purposeful research question and the rationale for it. The marked exemplar material produced in the teacher support material demonstrates that the assessment will be rigorous and of the same standard as the assessment in the previous courses.

Exemplars of a range of design contexts appear in the teacher support material.

The assessment criteria are detailed in the following section and are all assessed using a 9 point scale.

Internal assessment details

SL IA component

Duration: 40 hours
Weighting: 40%

- Individual design project
- This design project covers assessment objectives 1, 2, 3 and 4.
- At SL, the design project is assessed against the 4 common criteria:
  - Criterion A: Analysis of a design opportunity
  - Criterion B: Conceptual design
  - Criterion C: Development of a detailed design
  - Criterion D: Testing and evaluation

HL IA component

Duration: 60 hours
Weighting: 40%

- Individual design project
- This design project covers assessment objectives 1, 2, 3 and 4.
- At HL, the design project is assessed against the 4 common criteria and 2 HL only criteria:
  - Criterion A: Analysis of a design opportunity
  - Criterion B: Conceptual design
  - Criterion C: Development of a detailed design
  - Criterion D: Testing and evaluation
  - Criterion E: Commercial production
  - Criterion F: Marketing strategies

Internal assessment criteria—Common to SL and HL

Criterion A: Analysis of a design opportunity

Clients and designers establish a design opportunity before engaging with the design process. Establishing the design opportunity often stems from a real-life problem, which needs to be solved. By investigating this problem and design opportunity thoroughly, designers can gain clear direction in the requirements for a product. To meet the requirements of this criterion, students must:

- describe a problem which leads to a design opportunity
- investigate the problem to develop a design brief
- develop marketing and design specifications.

Marks	Level descriptor
0	The work does not reach a standard described by the descriptors below.
1–3	The student: • **identifies** a problem • **states** the key findings from relevant market and user research • develops a simple brief, which identifies **few** relevant parameters of the problem • develops a marketing specification, which **states** the requirements • develops a design specification, which **states** the requirements.
4–6	The student: • **identifies** an appropriate problem, which leads to a design opportunity • **describes** the key findings from relevant market and user research • develops a brief, which identifies **some** of the relevant parameters of the problem • develops a marketing specification, which **outlines** the requirements • develops a design specification, which **outlines** the requirements.
7–9	The student: • **describes** an appropriate problem, which leads to a design opportunity • **explains** the key findings from relevant market and user research • develops a **detailed** brief, which identifies the relevant parameters of the problem • develops a marketing specification, which **justifies** the requirements • develops a design specification, which **justifies** the requirements.

Clarifications

Describes an appropriate problem, which leads to a design opportunity
The design problem should be clearly stated using supporting materials, which may include: • photographs • extracts from letters, magazines and news articles • summarized results from questionnaires or interviews. The evidence for achievement against this strand should be presented in approximately two A4 pages or the equivalent.
Explains the key findings from relevant market and user research
The key findings should be provided in a summative form that shows evidence of: • quantitative and qualitative data collected using a range of techniques and appropriate primary and secondary sources • an analysis of competing or similar products. The evidence for achievement against this strand should be presented in approximately two A4 pages or the equivalent.

Develops a detailed brief which identifies the relevant parameters of the problem
A design brief comprises the expected outcome and broad requirements determined from the market and user research. The feasibility of the project should also be considered. The evidence for achievement against this strand should be presented in approximately one A4 page or the equivalent.
Develops a marketing specification, which justifies the requirements
Marketing specifications relate to market and user characteristics of the proposed design. • Target market—Consideration only needs to be given to market sectors and segments. • Target audience—Differentiate between the target market and the target audience. Characteristics of the users should be established. • Market analysis—A summary is required of the important information gathered about potential users and the market. An appraisal of economic viability of the proposed design from a market perspective is important taking into account fixed and variable costs and pricing. • User need—Specifications should identify the essential requirements that the product must satisfy in relation to market and user need. • Competition—A thorough analysis of competing designs is required to establish the market need. The marketing specification must be developed from the design brief and research. The evidence for achievement against this strand should be presented in approximately one A4 page or the equivalent.
Develops a design specification, which justifies the requirements
A design specification details: • aesthetic requirements • cost constraints • customer requirements • environmental requirements • size constraints • safety considerations • performance requirements and constraints • materials requirements • manufacturing requirements. All of the requirements, constraints and considerations must be specific, feasible and measureable. The design specification must be developed from the design brief and research. The evidence for achievement against this strand should be presented in approximately one A4 page or the equivalent.

Criterion B: Conceptual design

Once the design brief and specifications have been established, designers explore a range of possible concepts through modelling. As the concepts are developed and refined, their feasibility is determined against the specifications, which helps determine the most appropriate ideas to take forward into detailed design development. Students will use concept modelling to develop ideas to meet appropriate specifications, which explore solutions to the problem and justify the most appropriate idea for detailed development.

Marks	Level descriptor
0	The work does not reach a standard described by the descriptors below.
1–3	The student: • demonstrates **limited** development of **few** ideas, which explore solutions to the problem • selects the most appropriate idea for detailed development **with no justification**.
4–6	The student: • develops ideas with reference to the specifications, which explore solutions to the problem • uses concept modelling **with limited analysis** • selects the most appropriate idea for detailed development **with limited justification**.
7–9	The student: • develops **feasible** ideas to meet appropriate specifications, which explore solutions to the problem • uses concept modelling **to guide design development** • **justifies** the most appropriate idea for detailed development.

Clarifications

Develops ideas to meet appropriate specifications which explore solutions to the problem
Ideas must be **developed** and **refined** to enable a decision to be made about the preferred design to be developed in detail. This must include: • generating original ideas • selecting ideas to incrementally improve them to meet appropriate specifications • communicating ideas clearly using appropriate techniques • annotation to identify key features and explain how they meet the design specifications • undertaking additional research as required to inform development. The evidence for achievement against this strand should be presented in approximately six A4 pages or the equivalent.

Uses concept modelling to guide design development
Concept models in the form of sketches, CAD, 2D and 3D models should be used to establish the validity of ideas against specifications before refining ideas through detailed development. Concept modelling is used to: • test design ideas to find out if they will meet requirements • provide feedback, which is used to develop designs further. Students should consider the appropriate use of conceptual, graphical, physical and CAD models to develop, refine and test their ideas. The evidence for achievement against this strand should be presented in approximately four A4 pages or the equivalent.
Justifies the most appropriate idea for detailed development
The most appropriate idea should be validated against specifications before development is refined to enable manufacture. • Evaluate ideas and models against the design specification to identify the most feasible solution. • Present the most feasible idea. The evidence for achievement against this strand should be presented in approximately one A4 page or the equivalent.

Criterion C: Development of a detailed design

The designer needs to refine the concept design chosen further and detail all aspects of it in order to create a testable prototype. Through determining these details, they should develop a detailed design proposal, which includes all details necessary to make the prototype. Students will produce a detailed design proposal and then sequence the manufacturing process in enough detail for a third party to be able to follow to create a prototype.

Marks	Level descriptor
0	The work does not reach a standard described by the descriptors below.
1–3	The student: • **lists** some appropriate materials and components for a prototype • **lists** some appropriate manufacturing techniques for prototype production • develops a design proposal **that includes few details** • produces an **incomplete** plan **that contains some production details**.
4–6	The student: • **outlines** some appropriate materials and components for a prototype • **outlines** some appropriate manufacturing techniques for prototype production • develops a design proposal **that includes most details** • produces a plan for the manufacture of the prototype.
7–9	The student: • **justifies** the choice of appropriate materials and components for a prototype • **justifies** the choice of appropriate manufacturing techniques for prototype production • develops an **accurate and detailed** design proposal • produces a **detailed** plan for the manufacture of the prototype.

Clarifications

Justifies the choice of appropriate materials and components for a prototype
• Materials and components are identified and selected according to the requirements of the prototype. • Valid reasons for their choice need to be provided. • Selection can be justified through many aspects including cost, supply, physical and mechanical properties, and so on. The evidence for achievement against this strand should be presented in approximately two A4 pages or the equivalent.

Justifies the choice of appropriate manufacturing techniques for prototype production
• Manufacturing techniques are identified and selected according to the requirements of the prototype including joining, cutting, and so on. • Valid reasons for their choice need to be provided. • Selection can be justified through many aspects including cost, supply, material choice, working properties of the materials, and so on. The evidence for achievement against this strand should be presented in approximately two A4 pages or the equivalent.
Develops an accurate and detailed design proposal
• Develop the design to take into account the choice of materials, components and manufacturing techniques. • Use appropriate techniques and methods to finalize the details of the design (CAD, hand drawn, paper/card models) • Develop designs to sufficient detail for a third party to be able to interpret them correctly • Include details such as sizes, materials, components, assembly, production methods, and so on. The evidence for achievement against this strand should be presented in approximately three A4 pages or the equivalent.
Produces a detailed plan for the manufacture of the prototype
An appropriate plan should provide sufficient details including timings, techniques and risk assessment to allow the product to be made by a third party. Detailed plans could be presented using the following formats. • Gantt charts • Flow diagrams • Tables The evidence for achievement against this strand should be presented in approximately two A4 pages or the equivalent.

Criterion D: Testing and evaluation

Once the detailed design has been determined, a prototype can be created for testing against the marketing and design specifications. The testing should determine the success of the prototype as a solution to the initial problem and will indicate areas of weakness that the prototype has. This then allows for further iterative development. Students will evaluate the success of the solution against the specifications and then suggest how the solution can be improved.

Marks	Level descriptor
0	The work does not reach a standard described by the descriptors below.
1–3	The student: • evaluates the success of the solution against **few** aspects of the marketing specification **with no evidence of testing** • evaluates the success of the solution against **few** aspects of the design specification **with no evidence of testing** • **lists** how the solution could be improved.
4–6	The student: • evaluates the success of the solution against **some** aspects of the marketing specification • evaluates the success of the solution against **some** aspects of the design specification • **outlines** how the solution could be improved.
7–9	The student: • evaluates the success of the solution against the marketing specification • evaluates the success of the solution against the design specification • **explains** how the solution could be improved.

Clarifications

Evaluates the success of the solution against the marketing specification
Identify strengths and weaknesses by testing the prototype(s) against the marketing specification in criterion A. • Target market • Target audience • Market analysis • User need • Competition The evidence for achievement against this strand should be presented in approximately two A4 pages or the equivalent.

Evaluates the success of the solution against the design specification
Identify strengths and weaknesses by testing the prototype(s) against the design specification in criterion A. • Cost constraints • Environmental requirements • Size constraints • Safety considerations • Performance requirements and constraints • Materials requirements • Manufacturing requirements Where possible strengths and weaknesses should be measureable. The evidence for achievement against this strand should be presented in approximately two A4 pages or the equivalent.
Explains how the solution could be improved
Suggest improvements to address weaknesses identified through evaluation against marketing and design specifications. Improvements should be presented in the form of revised specifications, annotated photographs and drawings, or CAD. If the finished product does not meet either the market or the design specification, suggest modifications that are valid and feasible to bring the product up to specification. The evidence for achievement against this strand should be presented in approximately three A4 pages or the equivalent.

Internal assessment criteria—HL only

Criterion E: Commercial production

At this stage, prototypes have been developed to demonstrate proof of concept and tested successfully against the criteria detailed in the design brief and specifications. Students will modify their detailed design proposal appropriately for commercial manufacture.

Marks	Level descriptor
0	The work does not reach a standard described by the descriptors below.
1–3	The student: • **lists** appropriate materials and components for commercial production • **lists** appropriate manufacturing techniques for commercial production • **lists** design modifications to the solution required for commercial manufacture.
4–6	The student: • **outlines** appropriate materials and components for commercial production • **outlines** appropriate manufacturing techniques for commercial production • **outlines** design modifications to the solution required for commercial manufacture.
7–9	The student: • **justifies** the choice of materials and components appropriate for commercial production • **justifies** the choice of manufacturing techniques appropriate for commercial production • **explains** design modifications to the solution required for commercial manufacture.

Clarifications

Justifies the choice of materials and components appropriate for commercial production
Prototypes need to be modified in order to make them suitable for commercial production with materials and components chosen, which are compatible with the manufacturing process and design specification. • Materials and components are identified and selected according to the requirements of making the product commercially viable. • Valid reasons for their choice need to be provided. • Selection can be justified through many aspects including cost, supply, physical and mechanical properties, and so on. The evidence for achievement against this strand should be presented in approximately two A4 pages or the equivalent.

Justifies the choice of manufacturing techniques appropriate for commercial production
Manufacturing techniques should be appropriate to be effective at the chosen scale of production. • Manufacturing techniques are identified and selected according to the requirements of making the product commercially viable. • Valid reasons for their choice need to be provided. • Selection can be justified through many aspects including cost, supply, material choice, working properties of the materials, and so on. The evidence for achievement against this strand should be presented in approximately two A4 pages or the equivalent.
Explains design modifications to the solution required for commercial manufacture
The detailed design should be modified in order to be compatible with the manufacturing techniques for commercial production and the design specification. Improvements should be presented in the form of revised specifications, annotated drawings/ photographs, or CAD. The evidence for achievement against this strand should be presented in approximately two A4 pages or the equivalent.

Criterion F: Marketing strategies

An invention becomes an innovation by diffusing into the marketplace. In order to increase the potential for an invention to become an innovation, marketing strategies need to be explored and implemented. Students will consider the implications of diffusing a product into the marketplace by determining the cost-effectiveness of their solution, determining the appropriate target sales price and exploring appropriate promotional strategies.

Marks	Level descriptor
0	The work does not reach a standard described by the descriptors below.
1–3	The student: • **states** a target sales price • **lists** some promotional strategies for the solution.
4–6	The student: • **identifies** a target sales price • **identifies** appropriate promotional strategies for the solution.
7–9	The student: • **justifies** an appropriate target sales price • **discusses** appropriate promotional strategies for the solution.

Clarifications

Justifies an appropriate target sales price
Evidence is required to justify the target sales price based on competing or similar products market need and break-even point. Compare the cost of existing products against the cost of making a prototype and adjust costs to suit proposed scale of manufacture. The evidence for achievement against this strand should be presented in approximately two A4 pages or the equivalent.
Discusses appropriate promotional strategies for the solution
Appropriate promotional strategies should be discussed in relation to the suggested initial production run and the nature of the target market. These could include: • advertising • sales promotion • personal selling • internet marketing • sponsorship. The evidence for achievement against this strand should be presented in approximately two A4 pages or the equivalent.

Rationale for practical work

Although the requirements for IA are centred on the design cycle and do not require students to create their proposed solution themselves, the different types of practical and modelling work (10 hours at SL and 26 hours at HL) that a student may engage in serve other purposes, including:

- illustrating, teaching and reinforcing theoretical concepts
- developing an appreciation of the essential hands-on nature of much design work
- developing an appreciation of designers' use of secondary data from databases
- developing an appreciation of designers' use of modelling
- developing an appreciation of the benefits and limitations of design methodology.

Therefore, there is good justification for teachers to conduct further practical activities/investigations beyond that required for the IA scheme.

Practical scheme of work

The practical scheme of work (DT/PSOW) is the practical course planned by the teacher and acts as a summary of all the investigative activities carried out by a student. Students at SL and HL in the same subject may carry out some of the same practical activities/investigations.

Syllabus coverage

The range of practical work carried out should reflect the breadth and depth of the subject syllabus at each level, but it is not necessary to carry out a practical activity/investigation for every syllabus topic. However, all students must participate in the group 4 project and meet the requirements of the IA.

Planning your practical scheme of work

Teachers are free to formulate their own practical schemes of work by choosing practical activities/investigations according to the requirements outlined. Their choices should be based on:

- subjects and levels taught
- the needs of their students
- available resources
- teaching styles

Each scheme must include some complex practical activities/investigations that make greater conceptual demands on students. A scheme made up entirely of simple practical activities/investigations, such as ticking boxes or exercises involving filling in tables, will not provide an adequate range of experience for students.

Teachers are encouraged to use the OCC to share ideas about possible practical activities by joining in the discussion forums and adding resources in the subject home pages.

Creating a prototype

Students are not required to manufacture their own prototype; however, they do require a prototype of their design in order to evaluate and test it when addressing criterion D.

Students are encouraged to manufacture their own prototype; however, this can be outsourced. The prototype must be of sufficient quality so that it can be tested against the design and marketing specifications. Students may require more than one prototype to test fully.

Teacher-directed activities (formative tasks)

Time has been allocated in the course for teacher-directed tasks: 10 hours at SL and 26 hours at HL. This time can be used by teachers to direct students:

- to practise and develop appropriate design and practical skills
- to complete a mini-project that can be formatively assessed against the assessment criteria
- to ensure that a prototype is manufactured (by themselves or outsourced) for evaluation as part of the IA.

Flexibility

The practical programme is flexible enough to allow a wide variety of practical activities/investigations to be carried out. These could include:

- data-gathering exercises such as questionnaires, user trials and surveys
- using databases for secondary data

- data-analysis exercises
- developing and using different types of modelling techniques and models
- computer simulations and CAD
- focused workshop/laboratory-based practical activities or projects extending over several weeks.

Practical work documentation

Details of the practical scheme of work are recorded on *Form DT4/PSOW* provided in the *Handbook of procedures for the Diploma Programme*.

Time allocation for practical work

The recommended teaching times for all Diploma Programme courses are 150 hours at SL and 240 hours at HL. Students at SL are required to spend 60 hours, and students at HL 96 hours, on practical activities (excluding time spent writing up work). These times include 10 hours for the group 4 project and 40 hours (SL) and 60 hours (HL) for the IA. The remaining time is allocated to teacher-directed activities.

The group 4 project

The group 4 project is an interdisciplinary activity in which all Diploma Programme science students must participate. The intention is that students from the different group 4 subjects analyse a common topic or problem. The exercise should be a collaborative experience where the emphasis is on the processes involved in, rather than the products of, such an activity.

In most cases students in a school would be involved in the investigation of the same topic. Where there are large numbers of students, it is possible to divide them into several smaller groups containing representatives from each of the science subjects. Each group may investigate the same topic or different topics—that is, there may be several group 4 projects in the same school.

Students studying environmental systems and societies are not required to undertake the group 4 project.

Summary of the group 4 project

The group 4 project is a collaborative activity where students from different group 4 subjects work together on a scientific or technological topic, allowing for concepts and perceptions from across the disciplines to be shared in line with aim 10—that is, to “develop an understanding of the relationships between scientific disciplines and their influence on other areas of knowledge”. The project can be practically or theoretically based. Collaboration between schools in different regions is encouraged.

The group 4 project allows students to appreciate the environmental, social and ethical implications of science and technology. It may also allow them to understand the limitations of scientific study, for example, the shortage of appropriate data and/or the lack of resources. The emphasis is on interdisciplinary cooperation and the processes involved in scientific investigation, rather than the products of such investigation.

The choice of scientific or technological topic is open but the project should clearly address group 4 aims 7, 8 and 10 of the biology, chemistry and physics subject guides.

Ideally, the project should involve students collaborating with those from other group 4 subjects at all stages. To this end, it is not necessary for the topic chosen to have clearly identifiable separate subject components. However, for logistical reasons, some schools may prefer a separate subject “action” phase (see the following “Project stages” section).

Project stages

The 10 hours allocated to the group 4 project, which are part of the teaching time set aside for developing the practical scheme of work, can be divided into three stages: planning, action and evaluation.

Planning

This stage is crucial to the whole exercise and should last about two hours.

- The planning stage could consist of a single session, or two or three shorter ones.
- This stage must involve all group 4 students meeting to “brainstorm” and discuss the central topic, sharing ideas and information.

- The topic can be chosen by the students themselves or selected by the teachers.
- Where large numbers of students are involved, it may be advisable to have more than one mixed subject group.

After selecting a topic or issue, the activities to be carried out must be clearly defined before moving from the planning stage to the action and evaluation stages.

A possible strategy is that students define specific tasks for themselves, either individually or as members of groups, and investigate various aspects of the chosen topic. At this stage, if the project is to be experimentally based, apparatus should be specified so that there is no delay in carrying out the action stage. Contact with other schools, if a joint venture has been agreed, is an important consideration at this time.

Action

This stage should last around six hours and may be carried out over one or two weeks in normal scheduled class time. Alternatively, a whole day could be set aside if, for example, the project involves fieldwork.

- Students should investigate the topic in mixed-subject groups or single-subject groups.
- There should be collaboration during the action stage; findings of investigations should be shared with other students within the mixed/single-subject group. During this stage, in any practically based activity, it is important to pay attention to safety, ethical and environmental considerations.

> **Note:** Students studying two group 4 subjects are not required to do two separate action phases.

Evaluation

The emphasis during this stage, for which two hours are probably necessary, is on students sharing their findings, both successes and failures, with other students. How this is achieved can be decided by the teachers, the students or jointly.

- One solution is to devote a morning, afternoon or evening to a symposium where all the students, as individuals or as groups, give brief presentations.
- Alternatively, the presentation could be more informal and take the form of a science fair where students circulate around displays summarizing the activities of each group.

The symposium or science fair could also be attended by parents, members of the school board and the press. This would be especially pertinent if some issue of local importance has been researched. Some of the findings might influence the way the school interacts with its environment or local community.

Addressing aims 7 and 8

Aim 7: "develop and apply 21st century communication skills in the study of science."

Aim 7 may be partly addressed at the planning stage by using electronic communication within and between schools. It may be that technology (for example, data logging, spreadsheets, databases and so on) will be used in the action phase and certainly in the presentation/evaluation stage (for example, use of digital images, presentation software, websites, digital video and so on).

Aim 8: "become critically aware, as global citizens, of the ethical implications of using science and technology."

Addressing the international dimension

There are also possibilities in the choice of topic to illustrate the international nature of the scientific endeavour and the increasing cooperation required to tackle global issues involving science and technology. An alternative way to bring an international dimension to the project is to collaborate with a school in another region.

Types of project

While addressing aims 7, 8 and 10 the project must be based on science or its applications. The project may have a hands-on practical action phase or one involving purely theoretical aspects. It could be undertaken in a wide range of ways:

- designing and carrying out a laboratory investigation or fieldwork
- carrying out a comparative study (experimental or otherwise) in collaboration with another school
- collating, manipulating and analysing data from other sources, such as scientific journals, environmental organizations, science and technology industries and government reports
- designing and using a model or simulation
- contributing to a long-term project organized by the school.

Logistical strategies

The logistical organization of the group 4 project is often a challenge to schools. The following models illustrate possible ways in which the project may be implemented.

Models A, B and C apply within a single school, and model D relates to a project involving collaboration between schools.

Model A: mixed-subject groups and one topic

Schools may adopt mixed-subject groups and choose one common topic. The number of groups will depend on the number of students.

Model B: mixed-subject groups adopting more than one topic

Schools with large numbers of students may choose to do more than one topic.

Model C: single-subject groups

For logistical reasons some schools may opt for single-subject groups, with one or more topics in the action phase. This model is less desirable as it does not show the mixed subject collaboration in which many scientists are involved.

Model D: collaboration with another school

The collaborative model is open to any school. To this end, the IB provides an electronic collaboration board on the OCC where schools can post their project ideas and invite collaboration from other schools. This could range from merely sharing evaluations for a common topic to a full-scale collaborative venture at all stages.

For schools with few Diploma Programme (course) students it is possible to work with non-Diploma Programme or non-group 4 students, or undertake the project once every two years. However, these schools are encouraged to collaborate with another school. This strategy is also recommended for individual students who may not have participated in the project, for example, through illness or because they have transferred to a new school where the project has already taken place.

Timing

The 10 hours that the IB recommends be allocated to the project may be spread over a number of weeks. The distribution of these hours needs to be taken into account when selecting the optimum time to carry out the project. However, it is possible for a group to dedicate a period of time exclusively to project work if all/most other schoolwork is suspended.

Year 1

In the first year, students' experience and skills may be limited and it would be inadvisable to start the project too soon in the course. However, doing the project in the final part of the first year may have the advantage of reducing pressure on students later on. This strategy provides time for solving unexpected problems.

Year 1–Year 2

The planning stage could start, the topic could be decided upon, and provisional discussion in individual subjects could take place at the end of the first year. Students could then use the vacation time to think about how they are going to tackle the project and would be ready to start work early in the second year.

Year 2

Delaying the start of the project until some point in the second year, particularly if left too late, increases pressure on students in many ways: the schedule for finishing the work is much tighter than for the other options; the illness of any student or unexpected problems will present extra difficulties. Nevertheless, this choice does mean students know one another and their teachers by this time, have probably become accustomed to working in a team and will be more experienced in the relevant fields than in the first year.

Combined SL and HL

Where circumstances dictate that the project is only carried out every two years, HL beginners and more experienced SL students can be combined.

Selecting a topic

Students may choose the topic or propose possible topics and the teacher then decides which one is the most viable based on resources, staff availability and so on. Alternatively, the teacher selects the topic or proposes several topics from which students make a choice.

Student selection

Students are likely to display more enthusiasm and feel a greater sense of ownership for a topic that they have chosen themselves. A possible strategy for student selection of a topic, which also includes part of the planning stage, is outlined here. At this point, subject teachers may provide advice on the viability of proposed topics.

- Identify possible topics by using a questionnaire or a survey of students.
- Conduct an initial "brainstorming" session of potential topics or issues.
- Discuss, briefly, two or three topics that seem interesting.
- Select one topic by consensus.
- Students make a list of potential investigations that could be carried out. All students then discuss issues such as possible overlap and collaborative investigations.

A reflective statement written by each student on their involvement in the group 4 project must be included on the coversheet for each internal assessment investigation. See the *Handbook of procedures for the Diploma Programme* for more details.

Glossary of command terms

Command terms with definitions

Students should be familiar with the following key terms and phrases used in examination questions, which are to be understood as described below. Although these terms will be used frequently in examination questions, other terms may be used to direct students to present an argument in a specific way.

These command terms indicate the depth of treatment required.

Assessment objective 1

Command term	Definition
Define	Give the precise meaning of a word, phrase, concept or physical quantity.
Draw	Represent by means of a labelled, accurate diagram or graph, using a pencil. A ruler (straight edge) should be used for straight lines. Diagrams should be drawn to scale. Graphs should have points correctly plotted (if appropriate) and joined in a straight line or smooth curve.
Find	Obtain an answer showing relevant stages in the working.
Label	Add labels to a diagram.
List	Give a sequence of brief answers with no explanation.
Measure	Obtain a value for a quantity.
Present	Offer for display, observation, examination or consideration.
State	Give a specific name, value or other brief answer without explanation or calculation.

Assessment objective 2

Command term	Definition
Annotate	Add brief notes to a diagram or graph.
Apply	Use an idea, equation, principle, theory or law in relation to a given problem or issue.
Calculate	Obtain a numerical answer showing the relevant stages in the working.

Command term	Definition
Describe	Give a detailed account.
Distinguish	Make clear the differences between two or more concepts or items.
Estimate	Obtain an approximate value.
Identify	Provide an answer from a number of possibilities.
Outline	Give a brief account or summary.

Assessment objective 3

Command term	Definition
Analyse	Break down in order to bring out the essential elements or structure.
Comment	Give a judgment based on a given statement or result of a calculation.
Compare	Give an account of the similarities between two (or more) items or situations, referring to both (all) of them throughout.
Compare and contrast	Give an account of similarities and differences between two (or more) items or situations, referring to both (all) of them throughout.
Construct	Display information in a diagrammatic or logical form.
Deduce	Reach a conclusion from the information given.
Demonstrate	Make clear by reasoning or evidence, illustrating with examples or practical application.
Derive	Manipulate a mathematical relationship to give a new equation or relationship.
Design	Produce a plan, simulation or model.
Determine	Obtain the only possible answer.
Discuss	Offer a considered and balanced review that includes a range of arguments, factors or hypotheses. Opinions or conclusions should be presented clearly and supported by appropriate evidence.
Distinguish	Make clear the differences between two (or more) concepts or objects
Evaluate	Make an appraisal by weighing up the strengths and limitations.
Explain	Give a detailed account including reasons or causes.
Justify	Give valid reasons or evidence to support an answer or conclusion.
Predict	Give an expected result.
Show	Give the steps in a calculation or derivation.

Command term	Definition
Sketch	Represent by means of a diagram or graph (labelled as appropriate). The sketch should give a general idea of the required shape or relationship, and should include relevant features.
Solve	Obtain the answer(s) using algebraic and/or numerical and/or graphical methods.
Suggest	Propose a solution, hypothesis or other possible answer.

Bibliography

This bibliography lists the principal works used to inform the curriculum review. It is not an exhaustive list and does not include all the literature available: judicious selection was made in order to better advise and guide teachers. This bibliography is not a list of recommended textbooks.

Aikenhead, G and Michell, H. 2011. *Bridging Cultures: Indigenous and Scientific Ways of Knowing Nature*. Toronto, Canada. Pearson Canada.

Andain, I and Murphy, G. 2008. *Creating Lifelong Learners: Challenges for Education in the 21st Century*. Cardiff, UK. International Baccalaureate Organization.

Anderson, LW et al. 2001. *A Taxonomy for Learning, Teaching, and Assessing: A Revision of Bloom's Taxonomy of Educational Objectives*. New York, New York, USA. Addison Wesley Longman, Inc.

Aspelund, K. 2010. *The Design Process*. (Second Edition). New York, New York, USA. Fairchild Books.

Baxter, M. 1995. *Product Design: Practical Methods for the Systematic Development of New Products*. London, UK. Chapman and Hall.

Bowles, C and Box, J. 2011. *Undercover: User Experience Design*. Berkeley, California, USA. New Riders.

Brian Arthur, W. 2009. *The Nature of Technology: What It Is and How It Evolves*. London, UK. Penguin Books.

Collins, S, Osborne, J, Ratcliffe, M, Millar, R and Duschl, R. 2012. "What *'ideas-about-science'* should be taught in school science? A Delphi study of the expert community". Paper presented at the Annual Conference of the American Educational Research Association, Seattle, Washington, USA.

Cooper, A, Reimann, R and Cronin, D. 2007. *About Face 3: The Essentials of Interaction Design*. Indianapolis, Indiana, USA. Wiley Publishing Inc.

Douglas, H. 2009. *Science, Policy, and the Value-Free Ideal*. Pittsburgh, Pennsylvania, USA. University of Pittsburgh Press.

Edgerton, D. 2008. *The Shock of the Old: Technology and Global History Since 1900*. (Paperback Edition). London, UK. Profile books Ltd.

Ehrlich, R. 2001. *Nine Crazy Ideas in Science: A Few Might Even Be True*. Princeton, New Jersey, USA. Princeton University Press.

Gerzon, M. 2010. *Global Citizens: How Our Vision of the World is Outdated, and What We Can Do About it*. London, UK. Rider Books.

Hattie, J. 2009. *Visible Learning: A Synthesis of Over 800 Meta-Analyses Relating to Achievement*. Oxon, UK/New York, New York, USA. Routledge.

Haydon, G. 2006. *Education, Philosophy and the Ethical Environment*. Oxon, UK/New York, New York, USA. Routledge.

Headrick, D. 2009, *Technology: A World History*. Oxford, UK. Oxford University Press.

Heskett, J. 1980. *Industrial Design*. London, UK. Thames and Hudson Ltd.

Jewkes, J, Sawers, D and Stillerman, R. 1969. *The Sources of Invention*. (Second Edition). New York, New York, USA. WW Norton & Co.

Khine, MS. 2012. *Advances in Nature of Science Research: Concepts and Methodologies*. Dordrecht, The Netherlands. Springer.

Kuhn, TS. 1996. *The Structure of Scientific Revolutions*. (Third Edition). Chicago, Illinois, USA/London, UK. The University of Chicago Press.

Lanier, J. 2011. *You Are Not A Gadget: A Manifesto*. London, UK. Penguin Books Ltd.

Lawson, B. 2005. *How Designers Think: The Design Process Demystified*. (Fourth Edition). Oxford, UK. Architectural Press.

Lloyd, C. 2012. *What on Earth Happened?: The Complete Story of the Planet, Life and People from the Big Bang to the Present Day*. London, UK. Bloomsbury Publishing.

Martin, J. 2006. *The Meaning of the 21st Century: A Vital Blueprint for Ensuring Our Future*. London, UK. Eden Project Books.

Papanek, V. 1997. *Design for the Real World: Human Ecology and Social Change*. (Second Edition). London, UK. Thames and Hudson Ltd.

Petty, G. 2009. *Evidence-Based Teaching: A Practical Approach*. (Second Edition). Cheltenham, UK. Nelson Thornes Ltd.

Popper, KR. 1980. *The Logic of Scientific Discovery*. (Fourth Edition). London, UK. Hutchinson.

Powell, D. 1999. *Presentation Techniques*. (Seventh Edition). London, UK. Little, Brown and Company (UK).

Roberts, B. 2009. *Educating for Global Citizenship: A Practical Guide for Schools*. Cardiff, UK. International Baccalaureate Organization.

Roberts, RM. 1989. *Serendipity: Accidental Discoveries in Science*. Chichester, UK. Wiley Science Editions.

Royal College of Art, Schools Technology Project. 2002. *Advanced Manufacturing Design And Technology*. London, UK. Hodder and Staughton.

Sanders, M and McCormick, E. *Human Factors in Engineering and Design*. (Seventh Edition). Singapore. McGraw Hill Book Inc.

Sparke, P. 1986. *An Introduction to Design and Culture in the Twentieth Century*. London, UK. Routledge.

Spier, F. 2010. *Big History and the Future of Humanity*. Chichester, UK. Wiley-Blackwell.

Stokes Brown, C. 2007. *Big History: From the Big Bang to the Present*. New York, New York, USA. The New Press.

Swain, H, (ed). 2003. *Big Questions in Science*. London, UK. Vintage.

The Design and Technology Association. 2010. *Minimum Competencies for Trainees to Teach Design and Technology in Secondary Schools*. (Updated Version). Wellesbourne, UK. The Design and Technology Association.

Trefil, J. 2008. *Why Science?* New York, New York, USA/Arlington, Virginia, USA. NSTA Press and Teachers College Press.

Trefil, J and Hazen, RM. 2010. *The Sciences: An Integrated Approach*. (Sixth Edition). Chichester, UK. Wiley-Blackwell.

Webster, K and Johnson, C. 2010. *Sense and Sustainability: Educating for a Circular Economy*. (Second Edition). TerraPreta in association with the Ellen MacArthur Foundation and InterfaceFLOR.

Williams, R. 2008. *The Non-Designer's Design Book: Design and Typographical Principles for the Visual Novice*. (Third Edition). Berkeley, California, USA. Peachpit Press.

Winston, M and Edelbach, R. 2012. *Society, Ethics, and Technology*. (Fourth Edition). Boston, Massachusetts, USA. Wadsworth CENGAGE Learning.

Additional resources

American Association for the Advancement of Science. 1990. *Science for All Americans Online*, http://www.project2061.org/publications/sfaa/online/sfaatoc.htm. Accessed 1 February 2013.

Big History Project. 2012. *Big History: An Introduction to Everything*. http://www.bighistoryproject.com. Accessed 1 February 2013.

ICASE. 2010. *Innovation in Science and Technology Education: Research, Policy, Practice*. Tartu, Estonia. ICASE/UNESCO/University of Tartu (Estonia).

Nuffield Foundation. 2012. *How Science Works*. http://www.nuffieldfoundation.org/print/994. Accessed 1 February 2013.

Programme for International Student Assessment (PISA). http://www.oecd.org/pisa. Accessed 1 February 2013.

The Geological Society of America. 2012. *Nature of Science and the Scientific Method*. http://www.geosociety.org/educate/naturescience.pdf. Accessed 1 February 2013.

The Relevance Of Science Education (ROSE). www.roseproject.no/. Accessed 1 February 2013.

The Trends in International Mathematics and Science Study (TIMSS). www.itmssandpirls.bc.edu. Accessed 1 February 2013.

University of California Museum of Paleontology. 2013. www.understandingscience.org. Accessed 1 February 2013.