International Technology Teacher Education in the Asia-Pacific Region

Central Taiwan University
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and
K-12 Education Administration,
Ministry of Education, Taiwan

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PREFACE

Taiwan values technology education and is committed to technology teacher preparation. The “Curriculum Guidelines of 12-Year Basic Education” implemented in 2019 also includes Technology as a newly-added learning area, and simultaneously strengthens the capability of technology teacher preparation to demonstrate the determination to enhance technology education.

Technology changes rapidly. Learning from international trends and generating innovative insights are critical approaches to enhancing the quality of technology teacher education. Accordingly, understanding the technology teacher education in the Asia-Pacific region should be our critical task.

In 1997, the Industrial Technology Education Association of Taiwan (ITEA-Taiwan) hosted the 1997 International Conference on Technology Education in the Asia-Pacific Region (ICTE) in Taipei. The ICTE Association to Association mode was formed at that conference. This mode has provided the technology educators in the Asia-Pacific region with a good platform for idea sharing and collaboration.

I am very pleased to learn that the ITEA-Taiwan will host ICTE in Taipei for the third time in 2021. In order to enable technology educators and the ICTE participants in ICTE 2021 to better understand technology teacher education in the Asia-Pacific region, the K-12 Education Administration, Ministry of Education, Taiwan and Central Taiwan University of Science and Technology jointly published this book. I appreciate the participation of every contributor and look forward to not only the advancement of technology education and its teacher preparation but also more students’ fruitful learning outcomes resulting from this book.

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TECHNOLOGY TEACHER EDUCATION IN AUSTRALIA

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ABSTRACT

Australia has a long history of formal technical studies, being first introduced in the early colonial days to deal with social issues and skills shortages. Until relatively recently, it was an elective component of the curriculum, then it became one of the core learning areas, but it was implemented differently in each state of Australia. It is now represented by a national Technologies curriculum, encompassing two subjects - Design and Technologies and Digital Technologies. There is still some state variation in the implementation of the curriculum, but the trend is toward national consistency, with a focus on design and computational thinking, in an active learning environment.

There remain many issues to the successful implementation of the Technologies curriculum. A focus on manipulative skill development remains in some schools, rather than a complementary focus on cognitive skill development. Training both primary and secondary teachers for such a broad curriculum is difficult and may result in a narrow or biased implementation. There is a significant shortage of Technologies teachers, and this is resulting in teachers teaching out of area in the short term, and the demise of technology programs in the medium term. Integrated STEM approaches are becoming more common in schools, which can present both an opportunity and threat to technologies education. However, there is general agreement that the structure of the Technologies curriculum is sound and is based on contemporary principles of pedagogy and learning, which provides an appropriate foundation for the continued development and delivery of relevant and meaningful experiences for students.

Keywords: Australia, Technologies, Design, Digital, Curriculum, Design and Technologies

INTRODUCTION

The schooling system in Australia is governed by the Australian Constitution (Commonwealth of Australia, 2010) which allows the states and territories to independently make decisions about the structure and operation of their education system. This independence allowed the jurisdictions to create different curricula, syllabi and assessments with no real commonality between them. This caused issues for families changing systems across the country with their children receiving inconsistent education, as well as universities having different entrance requirements. Over the last three decades however, there has been more direction from the Federal government to provide a national focus in education, resulting in a national curriculum. Compulsory education begins with primary, which includes students from Kindergarten to Year 6, while secondary education starts in Year 7 and concludes at the end of Year 12. Students do have the opportunity to leave school at the age of 15 if they continue to study at a technical college or have a job. Each state and territory has a regulatory authority that is charged with accrediting Initial Teacher Education programs at universities in their jurisdiction, which must be aligned to the Federal standards as prescribed by the Australian Institute for Teaching and School Leadership (AITSL). All teaching graduates as well as in-service teachers must ensure that they are meeting the standards based on their level of teaching experience in order to be registered to teach in their state or territory (AITSL, n.d.).

Schooling Structure

There are three types of schools in Australia. The Government public school system is the largest, and is managed by the various state and territory education authorities. The Catholic school system consists of schools established by the Catholic church, where students pay fees to attend and which are partly financially supported by the Federal government. Third are independent schools, which may be run by a range of religious or education organizations, where students also pay to attend and receive financial support from the government. As of 2016, the states and territories had to plan to use the Australian Curriculum as the basis for all schooling from K-10 with the allowance of small changes to accommodate their students. All schools regardless of type must follow their jurisdiction's curriculum, even those schools that offer an alternative curriculum such as the International Baccalaureate, Steiner or Montessori, need to be certified to do so (SCSA, 2016).

The Australian curriculum has a three-pronged approach to education which includes learning areas combined with cross-curricular priorities and general capabilities (ACARA, 2010). There are eight learning areas - English, Mathematics, Science, Humanities and Social Sciences, Health and Physical Education, Arts, Languages and Technologies. The cross-curricular priorities comprise Aboriginal and Torres Strait Islander Histories and Cultures, Asia and Australia's Engagement with Asia, and Sustainability (Australian Curriculum, n.d.a). These and the general capabilities must be integrated into the subjects as much as possible. The general capabilities include literacy, numeracy, information communication technology (ICT), critical and creative thinking, personal and social, ethical and intercultural understanding (Australian Curriculum, n.d.b.).

Consequently, all schools must teach Technologies education from early childhood to Year 8 with an option in Years 9 and 10 (ACARA, 2012). Some schools, particularly government schools, specialize in specific areas of the curriculum and become known for their expertise in these areas; for example, some will focus on the performing arts, sports or Science, Technology, Engineering and Mathematics (STEM). Many of these schools receive extra funding to support their specialization, and in turn may be required to provide support and professional development to surrounding schools, which is particularly the case with STEM schools (Australian Curriculum, n.d.c).

In Years 11 and 12, students can choose from a range of the learning area subjects that meet their interests. Schools may provide Vocational Education and Training (VET) courses for their students in addition to the regular curriculum. This type of education is not compulsory for all students, and tends to be relevant for those who choose not to continue studies at tertiary level. Vocational certificates can be offered by schools which are either registered training organizations (RTO) or which work in partnership with RTOs in areas such as hospitality, engineering and building. It is important to note that vocational education has a different purpose to general education, and teachers need to have further additional qualifications, apart from a teaching degree (Australian Government, 2019b). Another key difference is that vocational education is competency based which addresses the skills required for a vocafion, whereas non-VET technology education is based on a combination of skills, creativity and critical thinking to design solutions to societal problems.

Every teacher needs to be qualified by either achieving a 4-year undergraduate education degree or a 2 year postgraduate teaching degree. All institutions offering teaching degrees must be registered with their state or territory authority. These courses then need to be aligned with the requirements stipulated by AITSL. Recently, the Federal government has introduced new regulations to ensure that there is comparability between the institutions by ensuring that all teaching graduates have the necessary levels of literacy and numeracy, regardless of their learning area (Australian Government, 2020a). Most institutions in Australia offering initial teacher education are accredited universities, but there are some tertiary colleges specializing in Education.

THE PROFILE OF TECHNOLOGY EDUCATION

History

Prior to the Federation of Australia in 1901, the country was made up of six colonies that were independent of one another (Wise, 1905). Each colony looked after its own infrastructure which included the education and health systems. Before 1901, there were considerable social issues within the colonies and as a result, deprived and neglected children roamed the streets in large numbers. Combined with a desperate need for a skilled workforce, the government began to establish technical training schools for young people. In the 1970s some technical subjects became compulsory in schools. Before then they were optional and only available to specific gender groups - Manual Arts for males and Home Economics for females (SCSA, 2007). It was not until the 1990s that the Technologies learning area combined these subjects to become one of the eight core curriculum areas in all Australian schools (Education Council, 1994).

The rationale for the inclusion of Technologies as a core curriculum area during the '90s was related to the increasingly technological nature of society of the time, and as a consequence, a need for all students to have opportunities to develop, experience and critique a range of technologies as part of their education. The justification regarding the inclusion of Technologies as part of the core curriculum has had profound implications on the learning area and its purpose. Before this time, technology subjects were electives, with the implication that they were only relevant to certain students – typically those who were planning a career in a vocational area. In primary schools, technology education had largely been absent from the curriculum, and teachers had little experience to draw on to deliver content in the area.

The contemporary classroom activities in Technologies have developed from the technical traditions of both Manual Arts and Home Economics. In respect to activities in primary schools, most have developed from the combination of arts and craft with some science principles. Increasingly STEM (Science, Technology, Engineering, Mathematics) activities which tend to integrate the subjects together are being developed in primary education. In secondary education, many of the subjects were founded in vocational areas and still tend to be influenced by this philosophy. Past electives such as agriculture, business education, industrial arts and home economics were combined with other studies such as computing, systems and engineering under the Technologies banner.

The National Curriculum

Education in Australia has undergone considerable change in the last three decades. The education system is managed by the governments of the five states and two territories as defined by the constitution. Funding is provided by the Federal government to all schools, regardless of whether they are private or public, to support specific priorities and strategies. Most funding to the public schools comes from the individual authorities, while private schools rely heavily on Federal funding. This level of localized organization and management had led to variations in school starting age, curriculum, and division of primary and secondary stages across Australia.

In 1989, the Hobart Declaration saw all states and territories agree on the National Goals for Schooling in Australia (1989). This led to an historic agreement between the parties to improve Australian schooling through national collaboration. In 1994, "A Statement on Technology for Australian Schools" was published which called for the Technologies learning area to be established (Williams, 2006) . The name did vary in the different jurisdictions, for example: Western Australia called the area Technology and Enterprise, while New South Wales called it Technological and Applied Studies (Williams, 2006). The Adelaide Declaration replaced the Hobart Declaration in April 1999. In this declaration, there was an agreement amongst the Ministers of Education to create eight learning areas, including Technologies which all students would study until the end of Year 10 (Education Council, 1999). However, it was not until 2008 when the Ministers met again and created the Melbourne Declaration on Educational Goals for Young Australians that a commitment to a national curriculum was made (Education Council, 2008). Importantly, in this declaration, Technology skills were an important element as indicated in the rationale below which stressed its importance after school.

It stated

> "the curriculum will include practical knowledge and skills development in areas such as ICT and design and technology, which are central to Australia's skilled economy and provide crucial pathways to post-school success." (Education Council, 2008, p. 13)

In December 2010, the Australian Curriculum had its initial phase 1 release with four main subjects including *English, Mathematics, Science and History* (ACARA, 2010). It took another 3 years before Technologies was included in the Australian Curriculum as part of phase 3 in February 2014 (ACARA, 2015b). States and territories were able to decide when and how they would implement the curriculum for Technologies, which varied across the country. Western Australia (WA) made it compulsory for K-8 from 2018, whereas in New South Wales (NSW) it was not made compulsory until 2019 for Year 7 students and 2020 for Year 8 students (NESA, 2017).

The rationale for the inclusion of Technologies curriculum changed from 2008 to 2014 with the focus now on authentic problem-solving solution-based activities rather than on vocational skills, expressing that technologies education

> "provides students with opportunities to consider how solutions that are created now will be used in the future. Students will identify the possible benefits and risks of creating solutions. They will use critical and creative thinking to weigh up possible short- and long-term impacts." (ACARA, n.d.)

Each of the states and territories have taken the Australian Curriculum and made changes to suit their jurisdiction, with a few variations (NESA, 2017). Nevertheless, national consistency with the curriculum was introduced. The Technologies curriculum (ACARA, 2015b) consists of two subjects – Design and Technologies and Digital Technologies, which specifies the knowledge and processes to be taught from Foundation to Year 10 (F-10).

It is expected that students will learn to competently design and engage in an increasingly rigorous process to develop solutions to satisfy human needs in both subjects. Figure 1 (Australian Curriculum, n.d.a) specifies the key ideas within the learning area with a clear focus on design, systems and computational thinking and how these are related to create solutions through the process of project management.

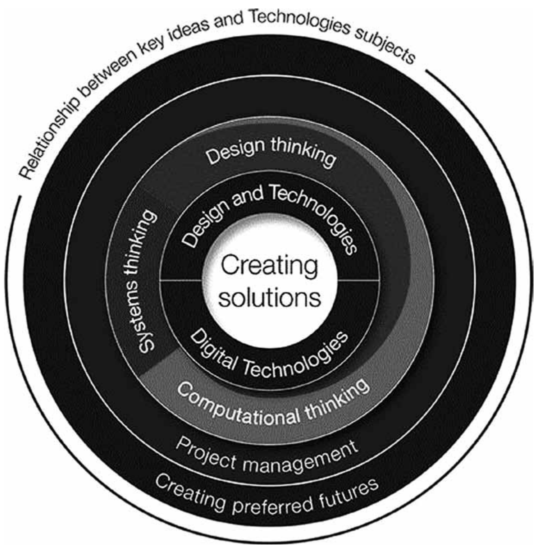

Figure 1. Relationship between key ideas and Technologies subjects (Australian Curriculum, 2015)

TECHNOLOGIES EDUCATION OVERVIEW

The Technologies learning area as stated is one of eight in Australian education which has been made a requirement from Kindergarten to Year 8 with an option in Years 9-10. From K-8, the form of technologies education is truly general – it is broad, relevant for all students in the development of their technological literacy, and is focused on design and problem solving. In Years 9-12, because technologies studies are not compulsory, there is a tendency to have more of a vocational focus and less of a general focus, be it preparation for entry into the workforce or for university. Many teachers create courses of work for their students that embrace the curriculum and ensure that students can develop their skills in both design and the production of artefacts.

The Technologies learning area, as illustrated in Figure 1, comprises two independent subjects – Digital Technologies and Design and Technologies. Even though the two subjects have different curricula, they are connected in their rationale, giving students the opportunity to develop their problem-solving and creative skills to address issues in society, as stated below

> "Design and Technologies, in which students use design thinking and technologies to generate and produce designed solutions for authentic needs and opportunities.
>
> Digital Technologies, in which students use computational thinking and information systems to define, design and implement digital solutions" (Australian Curriculum, 2015).

The Design and Technologies subject is further broken down into four available contexts – Engineering principles and systems, Food and fibre production, Food specialisations and Materials and technologies specialisation (Australian Curriculum, 2015). It is envisioned that students will have the opportunity to learn in more than one context; however in some jurisdictions this is not enforced. Therefore, some students may only get to experience one or two of the contexts throughout their schooling.

Digital technologies, the other subject within the learning area, does not have any contexts. The inclusion of this subject in the National Curriculum has caused a great deal of angst amongst primary teachers. It is important not to confuse this subject with the ICT general capability, where the latter is focused on the use of ICT in general teaching and learning across all eight learning areas. Before the introduction of the Digital Technologies curriculum, teachers would use ICT in their classroom, but not to teach aspects such as algorithms and data manipulation. Primary teachers are grappling with the new requirements that this course demands, including the theoretical aspects of Computer Science principles (Australian Curriculum, 2015).

The curriculum in both subjects has been further divided into two strands which are *Knowledge and understanding* and *Process and production skills* which are in both subjects. These are further broken down into different elements based on the subject. In Design and Technologies, under Knowledge and understanding, the *Technologies and society* element is common across all four contexts, as are the elements in the Process and production skills strand.

In Year 7, Design and Technology students "Investigate the ways in which products, services and environments evolve locally, regionally and globally and how competing factors including social, ethical and sustainability considerations are prioritised in the development of technologies and designed solutions for preferred futures" (ACARA, 2015a, p. 1). This syllabus statement is under the Technology and Society element, which is quite broad, with many in-service teachers finding it hard to capture the requirements in a program of work, especially as the content and approach will differ based on the context chosen. In Digital Technologies, there seems to be more direction in the statements; for example, students in Year 7 under the section Digital systems "Investigate how data is transmitted and secured in wired, wireless and mobile networks, and how the specifications affect performance" (ACARA, 2015a, p. 1). In reality, because of the level of vagueness in the Design and Technologies curriculum, there is still a tendency by some teachers to not change too much from their existing practice. Of course, other teachers embrace the vagueness and have created exciting and motivating courses for their students to undertake such as the inclusion of e-textiles which uses conductive thread to create circuits in clothing.

Digital Technologies and Design and Technologies are both seen as a requirement for students to learn with an equal number of instructional hours being recommended. Table 1 below highlights the notional hours that the Australian Curriculum, Assessment and Reporting Authority (ACARA) recommends compared to several key states. The states, in most cases, have followed the recommendations with some suggesting more hours than others in the different year bands.

Table 1. Notional hours of three states compared to the recommendation by ACARA

Notional Hours	K-2	3-4	5-6	7-8	9-10 Optional	11-12 Optional per subject
ACARA	60	80	120	160	0-160	200-240
NSW*	60-100	60-100	60-100	100-200	100-200	280
QLD	36-40	74-80	110-120	160	150	220
WA	160	160	160	160	0-160	220

Note: These notional hours are for the learning area, and are halved for both Design and Technologies and Digital Technologies for the two years (ACARA, 2012).

*NSW combines Science and Technology in the Primary years (NSW Government, n.d.) and in the secondary years students need to do a Technologies Mandatory course and then can choose further electives if desired, totalling 200 hours (NSW Government, 2019).

Pedagogical Approach

As with any learning area, it is important to vary the teaching and learning strategies employed to motivate and stimulate student learning in an engaging way. Therefore, a broad range of pedagogies are used in teaching Technology subjects. Traditionally, the prevailing strategy used was the process of demonstration. Typically, a teacher would demonstrate a skill and students would replicate this in a similar if not the same project. The contemporary basis for pedagogy in technologies is aligned with notions of constructivism and constructionism. Moreover, these philosophies of learning are particularly appropriate where students develop an understanding of knowledge through the process of applying skills and activities towards a practical task. The immediate relevance of information is affirmed by the student, to address the problem and plan for solutions. The process within which the pedagogies are applied, as stated, has traditionally been a project-based approach. To accommodate the more recent and sophisticated philosophical underpinnings, problem- and design-based approaches are now commonly observed in Australian classrooms.

In some schools, the pedagogical approaches are constrained by the physical facilities. Traditional school room layout in Design and Technologies often consisted of materials-based workshops (timber and metal workshops), which were appropriate when the focus was entirely on skill development derived through the construction of projects. Recently constructed or remodeled schools retain workshops, but recognize that students also need design spaces and computer access as they progress through their design projects, and so incorporate appropriate spaces for a range of activities.

There are several schools that require students to have a computing device that they use throughout the day. However, these devices typically do not have enough RAM or graphics capability to run Computer Aided Design (CAD) applications like Fusion 360 or Solidworks which are needed to create 3D models of student designs using laser cutters or 3D printers. Therefore, many schools tend to still have a small number of computer laboratories to run these sophisticated applications. These spaces may or may not be used to teach Digital Technologies, as most of the algorithmic software required is free to use or is cloud based.

Since the number of hours is quite limited for both Technology subjects coupled with the breadth of the curriculum, many teachers create student workbooks to guide students in their learning. These workbooks tend to be heavily scaffolded in the younger years and less so in Year 10 and above. They are useful to support study with small amounts of content included based on the area of interest, as well as leading students through the stages of the design process. The small number of Australian textbooks that are available are a good resource for teachers to use, but are not useful in a classroom environment where teachers have the autonomy to decide what area within the context they are teaching, coupled with the amount of time available.

Types of Assessments

Regardless of the learning area, it is essential that assessments are fair, reliable and valid and that they enable students to demonstrate their learning in the most effective way (Wooff et al. 2013). Just as important is the requirement for teachers to plan for different types of assessment including assessment as learning (*diagnostic*), assessment for learning (*formative*) and assessment of learning (*summative*) (Churchill et al., 2019) . It is also essential to use a variety of assessments in order to cater for differentiation and student learning styles (Churchill, et al., 2019).

Traditionally in Technology education, students were awarded marks based on their completed project or artefact. This is still a required element of technology education; however, it is only one element of the process in which the student engages while completing the task. As stated, the Australian Technologies Curriculum is divided into two strands - *Knowledge and understanding and Process and production skills.* When teachers design a unit of work, they must ensure that they include these strands in their teaching program and assessments. The process and production skills outlined in the curriculum emphasize the essential criteria within the strand. These include investigating a need or opportunity; generating ideas and plans; selecting and justifying decisions in the choice of materials, tools and equipment; producing the solution; and evaluating ideas and solutions combined with project management skills to work both independently and collaboratively (ACARA, 2012). Some of the states and territories, especially in the senior curriculum, outline the types of assessments that could be used to collect evidence of learning. Some types that have been suggested which could be either individual or group projects include portfolios, tests, examinations, research tasks, posters, videos and website creations (SCSA, 2020).

Portfolios

A portfolio can be a collection of work addressing different projects or a single project. In Technology education, a portfolio also contains the different components of a design process that students undertook to work through a task. A typical portfolio in K-8 tends to use a linear scaffolded approach which includes analyzing a design brief, investigation, research, initial designs, final design, production and evaluation. As students become familiar with the process, it is envisioned that their critical thinking and application will become more sophisticated as they continue into the senior years. Portfolio submission has become a key component in most Year 12 technology courses (SCSA, 2020).

Digital portfolio submission is also possible in most university settings, and assessment strategies which capitalize on digital capabilities can provide a very authentic form of assessment (Williams, 2012). With options to include video and voice files within a portfolio, the depth of understanding of a student's level of design thinking can be enhanced.

Tests and Examinations

In the senior years, many Technology subjects require students to complete a final examination or extended test as part of their graduation score. With this requirement, it is imperative that students become familiar with this type of assessment and therefore some teachers do include a sampling in their programs. It is questionable, of course, whether this type of assessment is appropriate for practical problem-solving subjects.

Independent and Group Work

The Australian Technologies curriculum encourages students to develop both independent and collaboration skills. With this in mind, many teachers create projects that incorporate group work, where students team up to address certain criteria. These activities may be part of either formative or summative assessment. Group activities could include research, website development, informative posters, presentations, group debates or problem-based learning projects. Appropriate summative assessment in a context where several students contribute to a single outcome needs to be thought out thoroughly in order to accurately assess students' learning (Williams, 2012).

Use of Contracts

Another pedagogical and assessment option available is the use of contracts (Williams & Williams, 2004), where students negotiate a contract with their teacher. Here a plan is developed to fulfil the contract which includes specific criteria for the assessment. In a broader sense, it is particularly appropriate for technology education because it provides a mechanism for the individualization of learning, it accommodates a concern for the development of cognitive and affective skills, and it facilitates the development of independence and self-direction through the ownership of the learning process (Williams & Williams, 2004).

Technology Education K-6

Primary education overall tends to be taught in a holistic manner where cross-curriculum links between the different learning areas are emphasized. Technologies curriculum integration is no different from other areas in the primary education sector. Key aspects within the curriculum emphasize both the knowledge required and the process that students should adopt in their exploration to find solutions to design-orientated problems. In general, the curriculum is broad to ensure that teachers can have control of the types of areas and projects that they believe will be of interest to their students.

Many primary teachers have concerns about the new curriculum, and many have had to upskill in the area. There have been several resources created by organizations including HourofCode.org and CoderDojo.com for Digital Technologies to support teachers in developing their understanding of algorithms, computational thinking as well as theoretical aspects of hardware components. The Digital Technologies Hub has also created student learning packages as well as developing scope and sequence exercises and topics (Education Services Australia, n.d.).

Unlike the Digital Technologies support for primary teachers, there is limited availability for Design and Technology activities. There are a couple of books written by educators in the area which have gone some way to supporting teachers, but the resources that have been created are limited and address only some aspects of the curriculum. This is an area that needs further attention to help teachers gain an understanding of the types of activities and projects that can be generated to engage and motivate students in this space.

Technology Education 7-10

Traditionally, Technologies studies have tended to be delivered more discretely in the junior to middle secondary years. Even though Design and Technologies is the title of the formal curriculum, schools can provide a broad range of subjects that fit into the different contexts to deliver the curriculum, such as Design, Manufacturing, Engineering, Textile technology, and Food technology. Some schools also continue to label their offerings using traditional terms such as Woodwork, Metalwork or Cooking. This type of labelling nonetheless continues to have implications, as many people are consequently not aware that the purpose of the Technologies curriculum has changed over time.

There is still a strong focus on practical work in the way schools deliver Design and Technologies. This is partly due to the history where making projects was the key focus, and the continued expectation by students and parents that these subjects involve an extensive emphasis on practical activities. It is important to note that this focus and expectation is not necessarily inconsistent with the contemporary approach to Design and Technologies. However, this is only part of the overall curriculum, and the emphasis is now on achieving other goals such as creativity, problem solving and other cognitive skills, rather than only practical skills.

Digital Technologies has replaced subjects such as Computer Studies, Interactive Media, and Photography, to name a few. Prior to the new curriculum, these courses would include various aspects such as coding, databases, interactive banners, websites and photo manipulation. The content required in this new subject does not necessarily align with many of the preceding courses. There is an emphasis on the theoretical aspects that were not there before, for example in Years 7 and 8, students need to begin to understand aspects of networking including devices, protocols, etc. One of the other key issues that teachers are facing is the inclusion of algorithms. Many teachers have had to upskill themselves in this area as previously it was not mandated unless teaching software development, which tended to be an optional subject.

Technology Education in the Senior Years

Years 11 and 12 are covered in the Australia Curriculum, however only for English, Mathematics, Science, History and Geography. Even though there are plans to look at other subjects and learning areas, they are still currently managed by the authority within their state or territory. Due to this autonomy, many have developed quite different offerings, as illustrated in Table 2. In each of these, the subjects offered can be placed in either Digital Technologies or in Design and Technologies; however, these labels are not generally used within the Senior Curriculum, except in New South Wales.

Table 2. Senior Secondary courses available across the states

NEW SOUTH WALES	QUEENSLAND	SOUTH AUSTRALIA	TASMANIA	VICTORIA	WESTERN AUSTRALIA
*Agriculture	*Aerospace System s	*Agriculture Production or Systems	*Agricultural Systems	*Agricultural & Horticultural Studies	*Applied Information Technology
*Design & Technology	Building & Construction Skills	*Business Innovation	*Computer Graphics and Design	*Food Studies	Automotive Engineering and Technology
*Engineering Studies	*Design	*Child studies	*Computer Science	*Product Design & Technology	*Aviation
*Food Technology	*Digital Solutions	*Community studies	*Electronics	*Systems Technology	Building & Construction
*Industrial Technology	*Engineering Skills	*Design, Technology and Engineering	*Food and Nutrition	*Algorithmics (HESS)	*Children, family and the community
*Information Processes and Technology	Fashion	*Digital Technologies	*Housing and Design	*Applied Computing	*Computer Science

(continued)

NEW SOUTH WALES	QUEENSLAND	SOUTH AUSTRALIA	TASMANIA	VICTORIA	WESTERN AUSTRALIA
*Software Design & Development	*Food & Nutrition	*Food and Hospitality	*Information Systems and Digital Technologies	Plus 17 VET qualifications	*Design
*Textiles and Design	Furnishing Skills	*Information Processing and Publishing	*Technical Graphics		*Engineering Studies
Computing Applications	Hospitality Practices	*Nutrition	Plus various VET qualifications		*Food Science and Technology
Marine Studies	Industrial Graphics Skills	*Tourism			Materials Design and Technology
7 x Technology Life Skills courses	Industrial Technology Skills				Plus 8 VET industry specific certificates
	Information & Communication Skills				

*ATAR Subjects that can count towards university entrance. These subjects are also offered in most states at different levels for non-university and vocational pathways.

In most cases, the subjects illustrated in Table 2 fall into three categories – subjects known as ATAR (Australian Tertiary Admission Rank) used for university entrance, non-ATAR and Vocational certificates. Subject selections in these years ensure that students have an opportunity to orientate their studies towards their post-school goals. These include going to university, vocational colleges, apprenticeships or employment. However, the number of schools offering and students choosing ATAR subjects in Technologies are quite low compared to other learning areas. There is a perception on the part of the various stakeholders that the subjects are not necessarily as "academic" and as a result schools tend to offer the non-ATAR subjects which tend to attract non-university bound students. A minority of schools, which tend to be private, will offer ATAR subjects in the Technologies area with the majority in the Digital Technologies space concentrating mainly on design and software development.

The Australian government has created a few initiatives including the introduction of Trade Training Centres in Schools and the recent Pathways in Technology (P-TECH) which has a STEM basis. In 2008, schools were invited to apply for funding to set up vocational trade centers in their schools. Schools were also encouraged to combine with others to offer these opportunities to many students (Australian Government, 2008). According to the latest statistics there are now 375 Trade Training Centres and 136 Trade Skills Centres in schools funded by the Federal government (Australian Government, 2020d). These centers offer students the opportunity to complete Vocational certificates at different levels, mainly in Certificate 1 or 2, depending on the availability of experienced industry-trained teachers who have trade certificates plus a teaching degree. The types of offerings vary, and schools can choose which ones they wish to offer. These certificates are highly valued by students because a Certificate 2 in Building & Construction, for example, will shave off time from an apprenticeship, and due to the basic knowledge already accredited, can be seen to be highly desirable by employers.

Pathways in Technology (P-TECH) is a relatively new initiative from the Federal government whereby STEM-related industries partner with schools and tertiary institutes, including TAFE and Universities, to offer high school students opportunities to develop an understanding of and interest in STEM-related careers. A pilot began in 2016 with two schools, and now currently in 2020 there are 14 schools in six states enrolled in the program (Australian Government, 2020b). An evaluation of the program in 2019 identified key positive outcomes from all stakeholders which saw an increase in student confidence and interest in STEM-related careers and study (Australian Government, 2019a). Currently the government is trying to work out an effective way to roll out the program to more schools across the nation and entice other industry and tertiary organizations to get on board.

THE STATE-OF-THE-ART OF TECHNOLOGY TEACHER EDUCATION

In order to be a school teacher in Australia, candidates need to undertake specific study at a tertiary institution that specializes in education. There are a few types of teaching degrees on offer ranging from undergraduate to post-graduate qualifications. As can be seen especially in the Senior Secondary offerings, the breadth of Technologies education is immense. It is virtually impossible for an institution to offer training across all contexts. Therefore, only a small number of universities still offer a major in Design and Technologies in Australia. There are more universities offering Digital Technologies but only as a minor in their undergraduate program with a few as a major, mainly in their post-graduate offerings.

The entrance requirements for teacher education differ across universities and states. There are a few ways of entering university. The main option for most candidates is through gaining an ATAR score of at least 70. This supposedly equates to being academically in the top 30% of students; however there are a number of universities that accept a score of less than this to enter a teaching degree (Singhal, 2018). It is also possible to enter a degree through alternative pathways including gaining a Certificate IV plus passing the Special Tertiary Admissions Test (STAT) or by completing a university preparation course (ACER, 2020b). These alternative entry options have an equivalence of a 70 ATAR. Within the Technologies learning area, 40% of candidates on average come from a Trade or Hospitality background and use the alternative pathways instead of coming directly from school.

Regarding Primary education, most universities have developed a unit or two addressing the ICT General Capability whereby teachers need to develop their digital pedagogy in order to address the needs of their students. This capability requires all teachers to seek opportunities within their teaching programs to have students use ICT as they research, create documents and use applications in various settings. It is important to be clear that it does not address the subject of Digital Technologies. Digital Technologies stands alone in its requirements as it promotes the creation of applications and usable ICT solutions for given problems. In some cases, universities have created a STEM unit; however, this tends to be more Science orientated.

The main focus of the Technologies curriculum in universities is in secondary education where teachers are trained as specialists to teach the breadth of the learning area. Historically, schools tended to break the learning area into Agriculture, Design and Technologies, Home Economics and Computing. Many universities also had this breakdown and, in many cases, still tend to package their teaching degrees in the same way. It is not unusual to have pre-service teachers completing a major in Design and Technology and a minor in another subject like Home Economics or even outside of the learning area. This compartmentalization of the learning area sadly continues to reinforce many of the issues that the new curriculum is trying to address. There are a couple of universities trying to rectify this deficiency by ensuring that teachers have further breadth in the area; however, this could potentially influence the depth of knowledge taught in certain areas as there are only so many units allocated to a degree.

AITSL works with the different authorities to ensure that Initial Teacher Education (ITE) across the country fulfills certain obligations including the curriculum, pedagogy and content units required for the learning areas. The number of professional experience days in schools is also determined, and all graduates are assessed against the AITSL standards. Over the last decade there has been quite a bit of rhetoric regarding graduate teachers and their lack of skills, especially in literacy and numeracy. In 2015, the Federal government released a requirement that all graduate teachers, regardless of whether the degree is an undergraduate or postgraduate degree, must sit the Literacy and Numeracy Test for Initial Teacher Education (LANTITE) which became effective as of July 1, 2016 (Australian Government, 2020a). This test is administered by an external organization known as the Australian Council for Educational Research (ACER) (ACER, 2020a). Pre-service teachers can take the test three times to pass. After this, only in exceptional circumstances can a candidate have a fourth attempt. By passing the tests the candidate is deemed to be in the top 30% of the adult population in Australia in terms of personal literacy and numeracy.

In 2020, an additional assessment has been introduced to ensure that all tertiary institutes conducting teacher education are addressing the needs and requirements stated by AITSL. It is known as the Teaching Performance Assessment (TPA) (AITSL, 2019b) - a tool that will assess pre-service teachers. It requires the collection of evidence during the final professional experience against the AITSL standards. A written report, annotated work samples and a presentation before a panel of experts is required as part of graduation with a pass grade. This is a form of moderation between universities to confirm that the education being received from one institute to another is comparable. Universities can join with others to address this requirement. Currently there are a few consortiums that an institute can join, or they can go through the process to have their own tool accredited by AITSL.

Types of Teaching Degrees

The types of teaching degrees available vary across states but can be broken into several categories that must be accredited and aligned with the AITSL standards. Unlike some other degrees, teaching requires a minimum 4-year undergraduate degree or 2-year postgraduate degree. These degrees can take place online or on campus, however with the practical nature of the Technologies curriculum it is more common to conduct learning on campus. The training typically takes place within the university environment. In accordance with AITSL and the states, each teaching course is a combination of curriculum, pedagogy and content units, with a professional experience requirement consisting of blocks of time spent applying teaching and learning principles in schools. In many universities, the specific subject content is delivered in areas other than the school or faculty of Education. Science for example, would normally have the content units taught within the Faculty of Science. In regard to the Technologies learning area, this can be problematic as there is no obvious faculty that deals with the discipline, except in the area of Digital Technologies which tends to be taught by Computer Science areas; however, its principles are generally pitched at a level inaccessible to most secondary students. Concerning Design and Technologies, this type of degree requires extensive workshops for timber and metal classes as well as kitchens for food. Couple this with expert staffing resources dedicated to teaching the content and you have an expensive teaching area which has resulted in a number of universities shifting their focus.

Several universities offer the 4-year Bachelor of Education only to people that have a trades certificate and several years' experience. These candidates receive a credit towards their degree, normally of about 2 years. The university then focuses on the pedagogy and curriculum required to teach in the Technologies learning area. The concern with this type of degree is the assumption that the learning area is still focused in the skills area with materials such as timber and metal, even though it is so much more than that. It also excludes a good percentage of people who may be capable of teaching in the area but who do not have a trade background.

Other universities have developed a hybrid 4-year degree in Technologies education where practical skills and specific content units are taught at a Technical and Further Education (TAFE) institute specializing in different vocational courses geared towards developing apprentices. The university still teaches the pedagogical, assessment and curriculum units. In this course, the student has the potential advantage of receiving the current TAFE qualification, enabling them to provide vocational training in schools. The potential disadvantage for pre-service teachers is the exposure of conflicting pedagogies – whereas the TAFE focus is on the mastery and competency achievement of skills, the university focus is on constructivism and professional development within the teaching profession. An issue with this type of approach in Technologies education is that only one area tends to be addressed, such as timber aspects but not necessarily metal or other contexts.

The postgraduate 2-year Master of Teaching course has replaced the Graduate Diploma of Education and builds on an existing degree. The university focuses on teaching the pedagogy, assessment and curriculum units, while the practical skills and subject specific content are assumed knowledge from the prior degree. As for Digital Technologies, many of these candidates come with a degree in ICT and therefore do have a good grasp of the required content, especially in the senior years. With Design and Technologies though, it is a different situation as there really is no degree that fulfils the breadth of the different aspects that make up the different contexts within the subject. Candidates that have Engineering, Design or Architect degrees tend to be attracted to Design and Technologies teaching; however, the content in many of the contexts is missing.

The Graduate Certificate of Education or Teaching is a type of conversion course for already qualified teachers wanting to develop their content and skills knowledge into a different learning area. This type of course can also help to rectify an unequal balance within a State's education system where there are too many qualified in-service teachers in one learning area and a shortage in another. These courses assume that the candidate has already mastered the pedagogical and assessment knowledge. The conversion course has a focus on the specific learning area curriculum as well as the skills and other content required. An issue with this course however is that the number of units to complete is small and they are targeted specifically at teaching up to Year 10. There is currently only one university offering this course for timber and metal content development. There are a couple of universities offering the course in Digital technologies as well as Design fundamentals.

Practicalities of Technology Teacher Education

All Initial Teacher Education programs need to be accredited by the jurisdiction that they exist based on the requirements of AITSL (2019a). Each needs to have units that address various aspects of teaching education including curriculum, content and pedagogical units. The curriculum and pedagogical units address both the Australian and the state or territory curriculum. Students are taught how to create teaching and learning programs as well as assessments and resources. In Secondary education, these units are geared towards the specialization. There is a requirement that students studying secondary education have both a major and a minor teaching area. In Technology specializations the requirements can be problematic, depending on the teaching area. In the practical content units, students must learn not only the curriculum but also the necessary skills required in the safe use of the equipment and tools, in order to become proficient in the teaching areas, such as materials.

UNIVERSITY OFFERINGS IN AUSTRALIA

In December 2019, ACARA and 35 invited universities took part in a 1-day symposium, in Sydney NSW, to discuss Technologies education in Australia, and specifically with universities that focus on Initial Teacher Education. This group became known as the Australian Technologies Teacher Educators Network (ATTEN, 2019b). As part of the meeting, each university had to map how their degrees were addressing the needs of the Australian Technologies Learning area (ATTEN, 2019a). Universities specializing in Design and Technologies comprised a small number and, surprisingly, so did Digital Technologies. There is confusion regarding the purpose and delivery of the ICT General Capability and the subject Digital Technologies. When the scope and sequence of both are compared, the difference in the content is obvious. Most universities ensure that they have at least one unit covering the ICT General Capability in their offerings.

In 2016, just after the Australian Curriculum depicting the compulsory aspects of Technologies Education, MacGregor and Middleton (2016) reviewed Design and Technology teacher education in Australia. They found that the number of universities offering specifically Design and Technologies education had declined due to reduced university funding, staffing and limited student demand. That number as of 2020 has reduced even further to only a handful of universities offering a good range of contexts within the Technologies learning area. The state synopsis below highlights universities that have a specialization in either Design and Technologies and/or Digital Technologies in a Bachelor teaching degree.

New South Wales (NSW)

New South Wales currently has the highest number of universities offering Technologies education. Currently there are five - these are Australian Catholic University, Avondale University College, Charles Sturt University, Southern Cross University and the University of Newcastle.

The Australian Catholic University in response to the new curriculum has launched a new course in their Bachelor of Teaching/Bachelor of Arts (Technology) (ACU, 2020). This course covers several key areas as core elements within Technology education including Digital Technologies and textiles, food, metal, timber and STEM. Students then specialize further in one of the Design and Technologies areas. This is an excellent coverage of the curriculum and one that especially gives their graduates a grounding across the key areas with the ability to teach competently in all contexts to Year 10.

Avondale University College received university status in 2019 (AVC, 2020). They offer a Technology and Applied Studies (TAS) specialization where candidates complete all their content units in the Technologies learning area. TAS is the term that NSW uses to name their Technology offerings, and it has not changed since the introduction of the new curriculum. AVC do give their students a choice as to what major and minor they take within the area, including a double major in Home Economics and Design and Technologies.

Charles Sturt University (CSU) (2020) offers a Bachelor of Education (Technology and Applied Studies) which covers a range of majors in the following areas - agriculture, information technology, food, industrial design, graphics, and VET certificates, and they have a reciprocal arrangement with Southern Cross University (SCU) in the area of textiles. CSU also offers the degree to candidates that have industry experience, and gives them advanced credits.

Southern Cross University (SCU) (2020) offers a good range of subject specializations in Design and Technologies in their Bachelor of Technology/Bachelor of Education (Secondary). Their students must study two main areas within Technologies education chosen from Computing Technology, Food, Graphics/Multimedia, Industrial Technology (timber and metal) and Textiles.

The University of Newcastle (TUN) (2020) offers a Bachelor degree specializing in Design and Technology which includes the contexts of Engineering, Design, ICT, Textiles and Food Technology.

Queensland (QLD)

At their Gold Coast campus, Griffith University (GU) (2020) offers both Design and Technology and Food and Nutrition as teaching areas within the Technologies learning area. Their content units are covered by other schools in the university including Engineering and IT. A scan of their offerings indicates that the area of textiles, timber and metal materials are not covered; instead there is a key focus on Design including 3D printing and modeling.

Queensland University of Technology (QUT) (2020) no longer offers Home Economics in their degrees; however, they do offer a double degree in Education and Information Technology, thus enabling candidates to become Digital Technology subject specialists.

Central Queensland University (CQU) (2020) offers major and minor teaching areas in most Design and Technologies contexts except for Food and fibre production. They do not offer a course in Digital Technologies. In some of their units, especially timber and metal, they tend to have residential experiences whereby their students' complete units by attending class for a block of time.

South Australia (SA)

University of South Australia (USA) (2020), is the only South Australian university to offer a major and sub-majors in all contexts except Fibre and food production. They also offer a sub-major in Digital Technologies covering the key areas within this subject. Several schools including the School of Art, Architecture and Design as well as the School of Mechanical Engineering teach a number of their content units.

Tasmania (TAS)

In 2013, the University of Tasmania (UTAS) discontinued their Design and Technology specialization, replacing it with a Bachelor of Education in Applied Learning (UTAS, 2020). The course is not available to recent high school graduates. A candidate must have a trade certificate or equivalent in the teaching area and at least 4 years of industry experience to qualify. UTAS does not offer any content units within the degree, only pedagogy and curriculum units.

Victoria (VIC)

In Victoria there is only one university that offers an undergraduate degree in any form of Technologies education. La Trobe University (LTU) (2020) offers a Bachelor of Technology Education which is only available to candidates that already have a Vocational certificate and relevant industry experience in either a trade or as a chef. The university allocates credit for the first 2 years of the degree. The remaining 2 years focus on the curriculum and pedagogy requirements of becoming a teacher.

Western Australia (WA)

Out of the four universities in WA there is only one that offers a good range of specialization in Technologies. Edith Cowan University (ECU) (2020) offers majors in Home Economics, Design and Technology, and minors in both as well as Computing. Even though the labels of the areas are not consistent with the new curriculum, they still cover all the contexts except for Food and fiber production. The content units for Home Economics (Food and Textiles) and Computing are taught by other schools; however, in the area of Design and Technology (timber, metal, systems) all nine content units are taught within the School of Education which includes two units that address the Engineering principles and systems components of the Australian Curriculum. In 2019, the School of Education updated most of the machinery in both the timber and metal workshops at a cost of around $250k, an expense that many universities would find challenging considering the small number of students (<100) undertaking the current undergraduate course.

CHALLENGES AND INNOVATION OF TECHNOLOGY TEACHER EDUCATION

The new national curriculum in Australia has brought both challenges and opportunities to schools and universities, especially in the Technologies learning area. Schools continue to grapple with timetabling, the allocation of teaching resources and finding teacher expertise. To be a Technologies teacher, especially through years K-8, has brought pressure on current teachers as many are required to teach across the contexts and in some cases both subjects. As can be seen, there are only a couple of universities that have repackaged their offerings to equip teachers to be able to teach across the whole breadth of the Technologies curriculum, while others target one or two areas.

Small number of Universities offering Technology courses

As already highlighted, a concerning issue is the reduced number of universities offering courses in the Technologies learning area, and especially in the coverage of required contexts. With Technologies education as a key compulsory learning area from K-8 with options past this, it is concerning that none of the territories nor Tasmania have an undergraduate course offering in the area. New South Wales and Queensland have more than one, while the remaining states have one university that adequately prepares their pre-service teachers to teach in the area. Collaboration between universities in supporting the Technologies curriculum would be useful, especially with the opportunity to share units amongst different providers within a teaching degree. This would allow the sharing of resources without the necessity of duplication.

Technologies teacher shortages

The demand for specialized technology teachers is greater than the supply, and as such, there is a risk of many non-technology teachers teaching in the area without adequate training. This shortage of qualified technology teachers has been existent for a while in Australia and as such a few government education departments have sponsored existing teachers to requalify in areas of need, and especially in working with timber and metal materials. Pre-service teacher numbers in the area are relatively low across the board, and even with the small number of universities offering courses, there is a relatively low perception of the area by universities, schools and existing teachers.

In August 2019, the Design and Technology Teachers' Association (DATTA Australia) conducted a nationwide survey to gain an understanding of the shortage and concerns of Technologies teachers across the nation (DATTA, 2019). The survey results represented almost 3,000 teachers and 404 schools, and highlighted key issues. Teachers from all contexts of Design and Technologies as well as Digital Technologies teachers took part in the survey.

Table 3. Survey results from DATTA 2019 report (DATTA, 2019, pp. 4-5)

Question	2019
Schools having difficulty finding qualified Technologies teachers	96%
Schools using unqualified teachers from other learning areas due to shortage of qualified Technologies teachers	84%
Schools that have reduced their Technologies Education programs due to shortage of qualified teachers	39%
Schools that believe the quality of their Technologies Education programs have been compromised by the shortage of qualified teachers	68%
Percentage of Technologies Teachers predicted to leave the teaching profession over the next 5 years.	26%
Schools that believe Work Health and Safety for students and teachers is being compromised in the Technologies learning area due to widespread use of unqualified teachers from other learning areas	70%
Number of qualified Technologies teachers in surveyed schools that come from an industry or professional background	42%
Number of schools that have indicated they have received no direct STEM funding, resources or support	71%

As shown in Table 3, the results are quite alarming, especially in the top two results where there are unqualified teachers in the area due to a real shortage, which has the potential to compromise student and teacher safety in the workshops. In most states and territories not all contexts in Design and Technologies need to be offered, and as a result of the lack of qualified teachers, some contexts are diminishing or not being offered at all. It has been suggested that more scholarships be offered by universities and potentially funded by government departments to encourage both school leavers and tradespeople to consider teaching as a career.

Issues with University entry requirements

Most students enter university through achieving an ATAR score by sitting external Year 12 examinations. The issue of course is that there are small numbers of students attempting Technologies courses at ATAR level due mainly to schools not offering them owing to the perception that students undertaking these types of courses do so for vocational reasons. As shown in Table 3, 42% of qualified Technologies teachers have an industry or professional background which is reasonably high. Alternative pathways are now available to students entering teaching including the recognition of vocational certificates, portfolios, experience and university preparation courses for students that have not gained an ATAR score. This development has over a period of time enabled many people with diverse backgrounds to enter Technologies education. However, with the current LANTITE requirements and the new TPA assessment, this may reduce over time.

Primary teachers unsure of how to teach technology

Due to the recent introduction of the Australian curriculum, many primary teaching courses are only just introducing units that cater for the Technologies learning area. Existing primary teachers have not necessarily been supported with professional development to improve their understanding of the key concepts. The 2019, the Programme for International Student Assessment (PISA) results for Australia were concerning, especially in reading, mathematics and science (SMH, 2019). Due to the falling results in the PISA testing over the last few years, coupled with the National Assessment Program – Literacy and Numeracy (NAPLAN) focus, many primary schools have made these areas a priority (ACARA, 2016b). These aspects have resulted in less time spent on understanding and implementing the new Technologies curriculum which has resulted in teachers having low confidence to experiment and develop their teaching ideas. Professional learning opportunities from specific associations and universities directed to both preservice and in-service teachers would go a long way towards supporting content and pedagogical knowledge.

Concern regarding One- and Two-year teacher education programs

The Graduate Diploma of Education has now ceased to exist in Australian universities, and has been succeeded by the 2-year Master of Teaching course. This requires a candidate to already have completed a degree in a discipline. This can be an issue for Technologies as there is no one degree that covers the breadth of content required in the contexts and especially to the depth required in the Senior years. There are more universities offering this type of degree, with some of them requiring candidates to undertake extra study to develop their practical skills at TAFE. Many degrees that fall into the area include engineering, architects and designers. Some jurisdictions offer existing teachers the opportunity to retrain in areas of need, with Design and Technologies being high on the list. In this situation, even though these candidates do complete several content units, they still do not cover the depth or breadth required; however, they do have training to safely instruct a class in certain teaching environments. In a school environment, there is a tendency to teach across the contexts to Year 10 with specialists in Years 11 and 12. Materials Technology either in timber or metal is very common in the senior years as well as Food and Textiles. These candidates do not tend to have experience in these areas and therefore are not as easily placed in a school timetable. This of course results in disappointment by schools, with many preferring to employ a 4-year undergraduate teacher. It also causes frustration for teachers as they feel that they do not possess all the necessary skills. As a result, many leave the profession. Teachers would benefit from further professional development including short courses and mentoring, creating an opportunity for both universities and teacher associations.

Focus on Vocational and General Technology education

Historically many technology programs in schools have involved the provision of vocational education. Due to the nature of Design and Technologies, many teachers currently hold certificates in trades and as such continue to deliver vocational certificates alongside general education. This creates a confused approach to program delivery in some schools, because the focus in the vocational programs is on skill and competency development, whereas in Technologies the focus is broader and oriented toward the individual developing critical thinking and problem-solving skills. A number of schools have addressed this issue by establishing trade centers which only cater for Vocational training in Years 11 and 12. Teachers in this environment do not tend to teach K-10.

The confusion of STEM

Alongside the National curriculum, ACARA has created a project called STEM Connections which aims to focus teachers on developing cross-disciplinary projects that support student learning in Science, Technology, Engineering and Mathematics (ACARA, 2016a). The Federal government has spent an enormous amount of money developing STEM skills in young people through various initiatives (Australian Government, 2020c). The projects that have been supported financially tend to be related to mathematics, science and digital technologies, and even though there is a desire to be interconnected, many still tend to stand alone.

In secondary schools, it seems that Science and Digital Technologies teachers are mainly becoming involved in STEM, which may represent a missed opportunity for Design and Technologies teachers. In primary teacher education in Australia, it was recently mandated that graduates have some form of specialization, whereas in the past this was not deemed necessary and primary teachers were almost all generalists. The opportunity to offer a specialization has resulted in some university programs offering STEM units. It is increasingly common for a STEM elective to be offered rather than one in Design and Technologies. The extent to which these types of specializations include representation of all STEM areas is doubtful, but it is an opportunity for Design and Technologies to play a core role in the conceptualization and enactment of STEM, especially in primary teaching. Schools have begun to create STEM clubs that tend to occur out of school hours, especially in secondary schools where it is still difficult to bring teachers together from different disciplines. An evaluation of the ACARA pilot (2016a, p. 10) though found the Technologies learning area a key driver in STEM especially if the solution required the development of a product. Hence Technologies represents the ‘T’ and ‘E’ in STEM, and developments in the area have a potentially significant influence on the direction of Technologies education.

CONCLUSION

Technology education in Australia has undergone much change over the last three decades, and with the recent introduction of the National Curriculum it continues to develop. Even though jurisdictions still have the power to manipulate the curriculum to a limited degree to cater for their own students, there is now more commonality than before. Although Technologies as a learning area is now essential, there are many obstacles and concerns still to be addressed. Some schools, parents, teachers and students continue not to see the value of Technologies subjects in the senior years for ATAR achievement. The low academic status perception of the area due to its roots in vocational skills training still needs to be addressed, and unlike any other learning area, it is the space where students have opportunities to be innovative and to create and produce solutions.

Universities that offer Design and Technologies need to evaluate the Australian curriculum against their courses to provide the breadth that is now required, especially from Kindergarten to Year 10. There are considerable concerns in this area as generally only a small number of universities cover a reasonable breadth. Active recruitment needs to be undertaken by the government and universities as the shortage of Technologies teachers is a serious issue within Australia.

While the position of Technologies in the school curriculum seems stable and secure now in Australia, there are developing threats which may impact on its future. Like many other countries, teacher education programs in Technologies have diminished over recent years, despite there being a shortage of teachers. There is potential that this will result in a crisis in the near future whereby schools may choose to diminish their Design and Technologies contexts and instead offer those that are easier to implement, such as Digital Technologies. As initial technology teacher education programs react to curriculum pressures, as well as general university pressures, the significant contribution that technologies education makes to children's learning needs to remain the focus.

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TECHNOLOGY TEACHER EDUCATION IN CHINA

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ABSTRACT

This paper depicts technology education and technology teacher education in Mainland China (other areas of China such as Hong Kong are not included). Technology education is implemented in both separate and integrative ways to boost all students' technological literacy. Technology education programs cover Technology & Engineering (T&E) integrated with Science, Information Technology (IT), Labor & Technology (LT) and General Technology (GT). Students take compulsory courses to guarantee a unified level of technological literacy, and take elective programs out of their interest. Comparatively speaking, technology education in Grades 1-9 emphasizes design and making, while in Grades 10-12 it emphasizes the integration of theory and practice. Frequently applied instructional approaches include integrative-activity-based approaches such as the investigation & exploration approach and the design & making approach, multi-discipline-based approaches that consist of the project-based approach and the problem-based approach, the STEM approach and the whole-task-based teaching and learning approach.

Technology teacher education started in the early 2000s when teacher educators managed to advocate technology as an independent learning field. China practices a teacher qualification system. A Chinese citizen needs to pass the national teacher qualification test to become a teacher. Technology teacher education programs serve the diverse purposes of cultivating pre-service teachers or facilitating in-service teachers' continuing education. With increasing international exchange, Mainland China actively takes the perspective of globalization to boost the professionalism of technology teacher education, and has gradually formed the theory and practice of Chinese Characteristics. Major problems that technology teacher education face are the lower discipline status of technology compared to other school subjects, insufficient provision of pre-service and in-service technology teacher education, and lack of candidates for technology teachers to receive teacher education. In this case, the provision of technology teacher education needs to be increased, technology teacher education curricula to be refined, a network of teaching and researcher leadership with disciplinary perspectives to be built, and the technology culture to be enhanced.

Keywords: Technology education, Technology teacher education, Mainland China

INTRODUCTION

China has the largest schooling system in the world. Children usually go to kindergarten at the age of 3 to receive 3 years pre-school education. Compulsory education starts from elementary school when children are 6 or 7 years old and lasts for 9 years: 5 or 6 years at elementary school, and 3 or 4 years at junior high school where they receive the first stage of secondary education. After completing their compulsory education, school leavers can go to either technical and vocational schools or academic senior high schools for the second stage of secondary education for another 3 years. At the end of their secondary education, students take the highly competitive college entrance examination (*gao kao*) for the qualification to receive higher education. Higher education institutions consist mainly of colleges and universities. Typically, it takes 4 years to get a Bachelor's degree, 3 years to get a Master's and another 3 years to get a Ph.D. degree (OECD, 2016).

Today, technology education has become "an integral part of general education" in China as Wu (1991) anticipated almost 30 years ago. Ever since the late 1970s, the slogan that "technology is the superior productive force" initiated by an influential political leader Mr. Deng Xiaoping has increasingly become a common belief in China. The Central Committee of the Communist Party of China (1985) decided to reform the education structure and to establish "a system of vocational and technical education with a rational structure, ranging from elementary to advanced levels, embracing all trades and other areas in Chinese societal structure." Technology education has been gaining attention and has become an important field of general education for all the elementary and secondary school students. All students take technology courses regularly.

All elementary and secondary schools are supposed to offer technology education programs to students who receive basic education. In order to guarantee the implementation of technology education programs, the State Council and the Ministry of Education have formulated various policies and required all schools to carry out the policies.

THE PROFILE OF TECHNOLOGY EDUCATION

Program Status of Tchnology Education

Technology is a required course with both compulsory and elective programs for students to select from: compulsory technology education programs for all students in order to foster all citizens' necessary technological literacy to live in such a technological world, and elective programs for those who are especially interested in specific areas of technology or who show talent in technological studies.

Technology education programs are implemented in both integrated and separate ways in China. They are embodied as a part of Integrated Practice Activities (IPA, *zong he shi jian huo dong*) for students from Grades 1 to 12. In addition, Technology and Engineering (T&E) is offered to elementary school students as one of the four content fields in the subject of Science, whereby technology education is integrated with science; separate subjects of General Technology (GT, *tong yong ji shu*) and Information Technology (IT, *xin xi ji shu*) are provided to senior high school students as technology education is recognized as one of eight independent learning domains of the senior secondary school curriculum. What is more, IT and GT in senior secondary schools organically incorporate part of the IPA program.

Technology education mainly serves as a literacy booster in the basic education period, but it also facilitates students' career experience. All the abovementioned programs are literary-oriented to enhance students' technological literacy, except for some elective modules for senior secondary students in GT titled as vocational experience (*zhi ye ti yan)*, which aims to increase students' connection to the real working world so as to help them find the fields that they are probably interested in, and to prepare them for their future careers.

Program Titles of Technology Education and Time Allocation

Technology education is conducted through more than one course, and consists of various programs in China. Technology and Engineering (T&E) is identified as one of the four learning fields of science education in elementary school. As is stated in the *Curriculum Standards of Science in Elementary Schools* (Ministry of Education, 2017a), T&E takes up 1/4 of 36 school hours each semester, that is, 18 school hours per year.

In Grades 1-9, Information Technology (IT) education and Labor & Technology (*LT, lao dong ji shu*) education are integrated into the compulsory course of Integrative Practice Activities (IPA). IPA is implemented through comprehensive educational activities that fall into four categories: inquiry activities, community service activities, vocational experience activities and Design & Making activities. Design & Making Activities consist of IT and LT activities. The Ministry of Education (2017b) requires that IPA take no less than 2 school hours (1 school hour is 45 minutes) per week. Usually students take 35 weeks of classes per year during the compulsory education period. Thus, students spend at least 70 school hours per year on IPA activities. It is noteworthy that the Ministry of Education just set the minimum requirement of school hours for IPA. Actually, the Ministry of Education strongly encourages schools to provide more school time for IT and LT. As a matter of fact, many schools offer the separate subject of IT to students once a week because of the foundational and decisive role information technology plays in people's daily life and careers.

Technology education, identified as one of the eight fields of senior secondary schooling, is guaranteed by two national documents issued by the Ministry of Education: one is the Information Technology Curriculum Standards of Academic Senior Secondary Schools (The Ministry of Education, 2017c), and the other is the General Technology Curriculum Standards of Academic Senior High Schools (The Ministry of Education, 2017d). Information Technology (IT) and General Technology (GT) are two separate subjects. IT is a globally popular technology course, while GT probably very much features Chinese characteristics. General technology, differing from professional technologies, refers to the technology that is more foundational and basic in the contemporary technology system, and more extensive in its daily life application. It possesses a special educational value in basic education, helping students adapt to social life and laying a solid foundation for students to enter the work world or to receive higher education (Gu, 2010).

Both IT and GT are made up of compulsory and elective modules. IT comprises two required modules, two elective modules and two groups of optionally compulsory modules. Students are required to spend at least 72 school hours to earn 4 credits for compulsory modules and at least 54 school hours to earn 3 more credits by taking one of the two groups of optionally compulsory modules. As for GT, each student should spend 72 school hours learning two compulsory modules to achieve 4 credits, and 72 more hours learning elective modules to achieve 4 more credits, which is the minimum. Additionally, those students who are interested or who show talent in one specific field of technologies can take more modules and get more credits.

Table 1. Program titles of technology education and pertinent information

Program titles	Program Status	Credits	School hours
Technology & Engineering in Science	Integrated for Grade 1-6	/	18 per year
Labor & Technology (LT) in IPA	Integrated for Grade 1-12	/	17.5+ per year
Information Technology (IT)	Integrated for Grade 1-9 Separate for Grade 10-12	/ 7+	17.5+ per year 126+ in 3 years
General Technology (GT) incorporating IPA	Separate for Grade 10-12	8+	144+ in 3 years

Major Objectives of Technology Education

In China, all technological programs work together to achieve the general goal of boosting students' technological literacy, although different technological programs are implemented at different grades with their specific objectives. Technology education, like any other form of education in a certain learning field, serves the fundamental task of education – establishing morality and cultivating personality (*li de shu ren*), as was officially initiated at the 18th National Congress of the Communist Party of China in 2012. *The 13th five-year plan of the development of national education* (State Council, 2017) put forward two approaches to the fulfillment of the fundamental task: one is to foster students' innovative spirit and ability, and the other is to strengthen their practical ability. As for the first approach, elementary and secondary school students should develop their interest in learning, enhance their scientific interest and innovation consciousness, and acquire scientific methods, logical thinking and dialectical thinking; as for the second approach, teaching and learning are supposed to help students improve their ability to apply theories they have learned to practice; in addition, schools should attach more significance to labor education and maximize its comprehensive educational function to cultivate well-rounded students.

Objectives of T&E in Science in Elementary Schools

Science in elementary schools is a comprehensive and integrative course to improve students' ability to better understand nature and to solve problems by integrating knowledge and methodologies from four fields: the material world, life science, the Earth and the Cosmos, and Technology and Engineering (T&E) (Ministry of Education, 2017b).

The objectives of the T&E field in Science in elementary schools are to have students understand that: a) science is applied in people's daily life; b) humans' activities affect the environment, people's life and society; humans' needs and wants drive the development of science and technology; science and technology have been the most important force to boost the economy and society; and c) people should observe ethics when doing research and applying science and technology: they should learn to treasure life and care for the natural environment and the human society (Ministry of Education, 2017a).

Objectives of IT/LT Activities Integrated in IPA

The goal of Integrative Practice Activities (IPA) is to enable students to enrich themselves with practical experience through their individual life, social life and contact with nature so that they will be able to deepen their overall understanding of the internal relationship between nature, society and individuals, and enhance their awareness of and ability to recognize values and observe ethics, take responsibility, solve problems and innovate. Design & Making activities are mainly IT and LT activities, the objectives of which are problem-solving and innovative making. Table 2 below shows the objectives differentiated by grades (Ministry of Education, 2017b).

Table 2. Objectives of IT/LT activities integrated into IPA in Mainland China

	Problem solving	Innovative Making
Grades 1-6	With teachers' guidance, students can initiate real-world problems that interest them, turn the problems into research topics, experience the process of research with proper methods, share ideas, and finally provide preliminary explanations of the problem.	Students can master the basic skills of manual design and production through hands-on practice, and use information technology to design and produce creative digital works.
Grades 7-9	Students can observe phenomena in nature, society and life, think deeply and initiate valuable problems, turn problems into valuable research topics, and use scientific methods to implement research; students can apply the knowledge they have gained to understand and solve problems, and produce research findings based on evidence and norms.	Students can apply operation skills to solve real-life problems and put ideas into practice; students can optimize complex processes or products through design and making, and gradually develop awareness and ability of innovation and aesthetics.
Grades 10-12	Students can make extensive practical explorations in fields of interest, identify innovative and deep problems, and apply comprehensive knowledge to analyze problems, inquire with scientific methods and solve problems. Students can review, reflect and optimize the research process and results in time, and produce research findings based on evidence and norms.	Students can actively do hands-on operation practice, master various operation skills, and apply comprehensive skills to solve complex problems in life. Their abilities of creative design, hands-on operation, technology application and production will be enhanced. Students learn to learn and to solve problems in a comprehensive way during the process of practice.

Objectives of IT in Senior High Schools

Core literacy (*he xin su yang*) of a discipline represents the effect of teaching and learning of the discipline. Through teaching and learning of a discipline, core literacy is embodied in students with the right values, necessary personalities and critical competencies (The Ministry of Education, 2017d). It aims to outline the image of new talents in the new era, and regulate the direction, content and methods of school education activities (Zhong, 2016). Core literacy has been the backbone of education in Mainland China.

Objectives of IT in senior secondary schools are derived from the requirement of core literacy in senior schools. The Ministry of Education (2017c) clarifies that the core literacy of IT in senior secondary schools is information literacy, which covers four dimensions:

(a) Information awareness
(b) Computing thinking
(c) Digital learning and innovation, and
(d) Sense of responsibility for information society.

Ma (2019) argues that the goal of core literary of IT is to help students apply information technology to solve practical problems, realize the value of information technology, and foster students' computing thinking. At the same time, students can transfer computer thinking to other fields and solve problems in a creative way, and simultaneously form the habit of lifelong learning and observing information laws and regulations.

The Ministry of Education (2017c) regulates that the subject of IT in senior secondary school is supposed to boost students' competencies of digital learning, help students to understand what information system is in the digital learning environment, understand principles pertinent to information systems, and understand the role that information systems play in human production and life. It is believed that learning IT will improve students' multiple understanding abilities as well.

Objectives of GT in Senior Secondary Schools

GT in senor secondary school aims to boost students' technology literacy and empower their all-round development with their specific characteristics (Ministry of Education 2017d). Technology literacy consists of five dimensions as follows:

(a) Technology awareness (*ji shu yi shi*)
(b) Engineering mindset (*gong cheng si wei*)
(c) Creative design (*chuang xin she ji*)
(d) Engineering drawings (*tu yang biao da*)
(e) Competence of materialization (*wu hua neng li*)

Through learning GT in senior high school, students are expected to acquire the core literacy of the subject to lay a solid foundation for their future development and life: they learn to engage in lifelong learning, to live a better life, to undertake national rejuvenation, and to build the society with their creative ideas, design skills, practical skills and innovation. When taking GT, students are supposed to: 1) acquire basic knowledge, basic skills, basic ideas and attitudes that reflect the characteristics of the current era and the needs of social development, and also accumulate basic experience so as to form a sense of affinity and sensitivity to technology, to form a rational spirit, a sense of responsibility, and enhance their cultural perception of technology; 2) boost their competencies of design, engineering drawings, process selection and making and doing to a certain degree through experiencing the whole process of technological design; 3) understand the basic technical thought, develop preliminary system thinking, creative thinking and an engineering mindset, form the good habit of using technology to solve practical problems; 4) experience the difficulties and complexity during the process of technological problem solving, seek truth from facts, strive for perfection and pursue the excellence of work; and 5) cultivate a spirit of craftsmanship, realize the importance of diligent work, form preliminary career planning and entrepreneurship consciousness, and form the consciousness of safety, norms, ethics, environmental protection, quality economics and innovation (The Ministry of Education, 2017d).

Some technology educators and practitioners in Mainland China have been sparing no efforts to establish a consistent technology education system throughout the period of basic education to boost one's technological literacy. GU advocates (2005) that technology education in elementary school lies in the enlightenment of technological literacy, that in junior secondary school lies in the formation of technological literacy, and that in senior secondary school lies in the improvement of technological literacy. In this way, objectives of the technology education in elementary and secondary school are closely interlinked and form a system like an upward spiral. However, the goal has not yet been arrived at despite the efforts that have been made.

Characteristics of the Target Group

Every student in China is entitled to and is supposed to receive technology education as guaranteed by the Ministry of Education's policies and/or documents such as the Curriculum Standards of Science in elementary school, IPA Guidance, and the IT /GT curriculum standards in academic senior secondary school. Today students have access to formal technology education beginning in elementary school Grade 1. Table 3 shows the age groups and grade levels when students take technology education programs. As stated above, elementary students in Grades 1-6 take T&E programs integrated into Science and IT/LT programs integrated into IPA; junior secondary school students take IT/LT integrated into IPA; and senior secondary school students take IT and GT respectively as two separate programs with IPA incorporated.

Table 3. Age groups, grade levels and technology education programs

Age	Grade	Technology education programs
6-12	1-6	T&E integrated into Science IT/LT integrated into IPA
13-15	7-9	IT/LT integrated into IPA
16-18	10-12	IT/GT as separate programs that incorporate IPA

Content Organizers of Technology Education

Content organizers of T&E in elementary Science: three big ideas

Science in elementary schools, as is required by its curriculum standards, is organized according to 18 big ideas. T&E, as one of its four learning fields, focuses on three big ideas as follows (Ministry of Education, 2017a):

(a) A colorful man-made world is designed and produced to boost people's work and life.

(b) Technology, characterized by inventions, interferes with nature.

(c) Engineering, characterized by design, is the process and activity of solving real-life problems and producing items/ systems by employing science and technology.

The above three core ideas of T&E aim to make students recognize the significance of technology to people's living world and daily life, and to have a basic understanding of the definitions of technology and engineering.

Content organizers of IT and LT integrated into IPA: Design & Making

As its title shows, the course of Integrative Practice Activities (IPA, *zonghe shijian huodong*) is implemented in the form of integrated activities based on practice. Activities are the content organizers of IPA. The IT and LT activities recommended by the Ministry of Education (2017b) are shown in Table 4. Schools can refer to these activities to organize IPA programs.

Table 4. Content organizers of IT/LT integrated into IPA as Design & Making activities

Grade	IT activities	LT activities
1-2	Not identified	Handmade paper and pottery Handmade tumblers, parachutes, whipping tops, etc.
3-6	An "aboriginal" in the information society "Little typist" challenge I am a computer painter Distinguishing useful information online Effective management of computer documents Presentation exhibition	Learning to cook simple family meals Handicraft workshop Charming ceramic world Creative wood workshop Safe use and proper maintenance of household appliances Wonderful knots Tools in life
3-6	Information exchange and security My electronic newspaper Beautiful world under the camera Digital voice and life 3D interesting design Introduction to fun coding Colorful gardens in the coding world Design of simple interactive media works Manual production and digital processing	Design and make building models Creative design and making of toys, cars, schoolbags, dustbins, etc.

(continued)

Grade	IT activities	LT activities
7-9	Assembling my computer Setting up a home LAN Data analysis and processing I am a graphic designer Transformation between 2D and 3D Making my cartoon Entering the world of programs Doing scientific experiments with computers Experiencing the Internet of things Initial experience of open source robots	Exploring nutrition and cooking Colorful fabric world I am a fashion designer – Design and production of paper pattern clothing Create magical works of metal materials Design and produce personalized electronic works Intelligent brain: entering the world of single chip microcomputers Design and production of model projects Photography and electronic album production Preliminary application of 3D de sign and printing technology Understanding and using modern simple mental processing tools and equipment Creative design based on laser engraving Design & production of 3D paper art “Maker” space Bionic design in life Changes and innovation of tools in life
10-12	Incorporated into IT in senior secondary schools	Incorporated into GT in senior secondary schools

Content organizers of IT in senior secondary school

IT in senior secondary school is organized into 10 modules, among which there are two compulsory modules, two elective modules, and six more modules of two categories from which students are required to choose any one of two (Ministry of Education, 2017c), as is shown in Table 5.

Table 5. Content organizers of IT in senior secondary schools

<table>
<tr><th>Status</th><th colspan="2">Module</th></tr>
<tr><td>Compulsory</td><td colspan="2">Module 1: Data and computation
Module 2: Information and society</td></tr>
<tr><td>Optionally compulsory (Choose one of the two groups of modules)</td><td>Module 1: Data and its struc ture
Module 2: Foundation of networks
Module 3: Management and analysis of data</td><td>Module 4: Preliminary AI
Module 5: Innovative 3D design
Module 6: Design of open Resource hardware</td></tr>
<tr><td>Elective</td><td colspan="2">Module 1: Algorithms
Module 2: Design of mobile applications</td></tr>
</table>

Content organizers of GT in senior secondary school

The content of GT in senior secondary school is organized into 10 modules, among which there are two compulsory modules, four optionally compulsory modules for students to choose any two, and four more modules for students to choose any or none (Ministry of Education, 2017c). They are shown in Table 6.

Table 6. Content organizers of GT in senior secondary school

Compulsory		Optionally compulsory (Choose 2 out of 4)	Elective
Techno-Logy & Design 1	Techno-Logy & Design 2	Technology & Life Technology & Engineering Technology & Career Technology & Creation	Traditional Industry Arts and Practice Experience & Inquiry of new techno-logy Integrated application of technology Modern agriculture technology

General Characteristics of Technology Education in China

Relative emphasis on design and making in Grades 1-9

Design & Making is the focus of technology education in Grades 1-9. As illustrated above, Design & Making is actually one of the four fields integrated into IPA. While schools and teachers try to cram "knowledge" into students' heads and empower them to take pen-and-paper tests (*ying shi*) rather than boost their overall competencies, technology education is expected to resist this trend and bring back opportunities for hands-on work and happiness to children's education.

Relative emphasis on the integration of theory and practice in senior secondary education

Technology education in senior secondary education continues to focus on the practical use of technology and skills, but it simultaneously involves more theory learning. In this way, students learn to penetrate technological phenomena and seek more of the essence of technology so as to boost their technological literacy and lay a foundation for further study of technology engineering and in college or university, and prepare for the future working world.

Including both compulsory and elective programs

According to the regulations of the Ministry of Education (2017b, 2017c, 2017d), technology programs cover both compulsory and elective activities and modules. This is to ensure that technology education on the one hand guarantees all students' technological literacy, and on the other hand provides extra programs for those who are interested and/or talented in technology, and to select candidates who are likely to pursue further education of engineering/ technology in college or university.

Means of Recognition of Technology Education Achievement

Technology education achievement is recognized when students take tests and participate in competitions. Usually students are examined after they finish technology lessons and their results are recorded in electronic portfolios, which serve as learning evidence and recognition of their technology education achievement. Junior and senior secondary school students are required to take compulsory examinations for technology courses. There are also some technology-related contests for them to participate in through which they can gain recognition.

Assessment of students' achievement in technology lessons

All students in all grades should take technology education, and their achievements are recorded in their electronic portfolios. In addition to the summative evaluation, students' formative evaluation is also recorded.

All junior secondary school graduates in China should take *The Academic Test for the Junior Secondary School Students (Zhong kao)*, which has been organized by every municipality since 1980. The score of the test is the evidence to be admitted into senior secondary schools. In some provinces such as Ningxia, Hebei and Anhui, students are required to take the test of IPA and IT, but the other provinces allow their municipalities to decide if students should take technology-related tests.

All senior secondary students in China should take T*he Academic Test for the*

Senior Secondary School Students (Gao zhong hui kao). IT and GT are the two subjects that students take examinations for: IT is an academic examination that students take with pen and paper, but GT is an operational examination in which students show their competency through performing some kind of operation according to instructions.

Contests for interested and talented students

In China, there are some technology-related contests that students can participate in and through which they can gain recognition. *The Odyssey of the Mind program* (OM, called *Olympics of the Mind* in China), created by Dr. C. Samuel Micklus of New Jersey, United States in 1978, has been adopted by the Chinese educational system (Wu, 1991) since 1990. The first OM competition at the secondary school level in China was held in Beijing in March 1990 (Kong, 1990). It was broadcast throughout China via the National CCTV (i.e., Chinese Central Television Station) in 1990 and it has had an impact on technology education in China, developing positive attitudes toward technology education. Students are very interested in the OM program, the goals of which are to educate, foster, and observe students' abilities of actively and agilely solving problems (Wu, 1991).

National Computer Production Activities (NCPA) for elementary and secondary school students is one of the most influential and impressive official competitions in China. It has been held ever since 2000 by the National Center for Education Technology (NCET, *zhong yang dian jiao guan*) under the leadership of the Ministry of Education. This competition aims to popularize information technology education in elementary and secondary schools, promote the modernization of education with information technology, and realize a leap forward in the development of basic education. Actually, as early as in 1994, Mr. Deng Xiaoping stated that computer popularization should start with children. NCPA was therefore launched to popularize computer education, later developing into information technology. The philosophy (*zhi dao si xiang*) of

NCPA is to "enrich elementary and secondary school students' study and life, inspire students to participate and get involved in the process of production, stimulate innovation spirit, cultivate practical ability, and comprehensively promote quality education (*su zhi jiao yu*)" (NCET). The theme of NCPA is "Exploration and Innovation." NCET believes that the majority of elementary and secondary school students should be encouraged to actively participate in NCPA to explore, innovate, design and create computer works by means of information technology, and foster their ability to "identify problems, analyze problems and solve problems" (NCET).

Besides the OM and NCPA, there are some other technology program contests for elementary and secondary school students, for instance, model airplane competitions, technology camps, and computer application competitions. These contests are not only ways to recognize students' technology education achievements, but are also significant ways to recognize the technology education level of schools and districts.

Instruction in Technology Education

Technology teachers and teacher educators strive to find proper instructional approaches to boost all students' technological literacy, although today's instruction in technology education is still inevitably influenced by Chinese traditional teaching-centered and test-based practice. The following approaches are often applied to the current instruction of technology education in China.

Integrative-activity-based approaches

Integrative activities are the content organizers of IT and LT in elementary and junior secondary schools. Schools and teachers should give full play to the role of information technology in supporting all kinds of activities so as to effectively promote problem-solving ability, exchange and cooperation, and the display and sharing of results. Integrative-activity-based approaches mainly consist of the investigation & exploration activities and the design & making activities (Ministry of Education, 2017b).

The investigation and exploration approach is based on students' own interests and teachers' effective guidance. Students identify research topics out of the natural surroundings, social life and their own lives, carry out research activities, take the initiative to acquire knowledge, analyze problems and solve them by observing, thinking and recording. This approach focuses on the use of field observation, interviews, experiments, and so forth to collect materials and evidence and to form the spirit of rational thinking, critical questioning and bold exploration. The key elements of investigation and exploration include: identifying / initiating problems, putting forward hypotheses, selecting methods, developing tools, collecting evidence, putting forward explanations or ideas, exchanging and evaluating research results, and reflecting and improving (Ministry of Education, 2017b).

The design & making approach refers to the teaching and learning approach whereby students use various tools and processes (including information technology) to design and operate, put their ideas and schemes into reality, and transform them into objects or works, such as animation production, programming, and ceramics creation. It focuses on improving students' technological sense, engineering thinking, and hands-on making ability. In the process of activities, students are encouraged and expected to use their hands and brains, master the necessary knowledge and skills flexibly, raise their technological operation levels and knowledge transfer levels, and experience the whole design and making process with professional dedication. The key elements of the design & making approach are: creative design, selecting proper materials or tools, hands-on making, communicating / displaying works, reflecting and improving (Ministry of Education, 2017b).

Multi-discipline-based approaches

A growing number of technology teachers, teacher educators and researchers have recognized that technology in essence is not a sole discipline, but is involved with knowledge and the practice of multiple disciplines. Therefore, multi-discipline-based approaches to technology education are becoming increasingly popular in China. Among these approaches, the three most recognized are the project-based approach, the problem-based approach and the STEM approach.

The project-based approach was introduced from overseas thanks to cooperation between some international companies and China's education authorities. For instance, *Intel Teach to the Future* is a collaborative project of *working together to help students* between China's Ministry of Education and Microsoft. One more example is the China-Canada project *Strengthening the ability of basic education in Western China* (Zhong et al., 2015). Project-lead-the-way (PLTW) (Liu, 2014) has influenced the instruction in technology education in China to a great degree, because project-based learning provides students with the experience of engaging in real situations that can assist them in learning and that can also help them form a better and more realistic understanding of concepts in various fields (Chen, 2017). He (2006) argues that project-based instruction can integrate teaching resources of multiple disciplines and break the barriers between courses/subjects. Teaching and learning activities are designed as a process for students and teachers to overcome the segmentation between knowledge and skills that single subject teaching can cause.

The problem-based approach to technology education is also highly emphasized in technology education in China. Students are confronted with a hard problem and/or ill-structured situation where they need to identify and solve problems so as to develop their abilities of independent learning, problem-solving and meaning construction. Liang (2001) argues that problem-based learning can improve students' abilities and qualities in the following aspects:

a) problem-solving skills; b) thinking skills; c) teamwork skills that include appreciating and containing heterogeneous learning partners; d) time management skills; e) abilities of obtaining and evaluating information; f) communication of information; and g) computer application. Zhang (2013) applied the problem-based approach to an IT program in senior secondary school. His findings echoed Liang's opinion of the positive functions of the approach, but he found that the arrangement of separate school hours and evaluation might hinder the approach being put into practice. It was also challenging for teachers to identify the authenticity of the problem and to assess the students' performance.

The STEM approach has been attracting increasing attention globally. Separate STEM courses of Science, Technology and Mathematics in basic education are not new in China, but the integration of these courses plus engineering is still under exploration. What researchers and practitioners have noticed about STEM is its impact on curriculum integration and instruction. Yu (2015) claims that the nature of STEM education lies in the integration of multiple disciplines, which is an agreement most scholars and practitioners have reached. The STEM approach can not only make up for the shortcomings of seperate technology education and engineering education in elementary and secondary schools in China, but can also effectively promote the trend of curriculum integration (Zhong et al., 2015). The STEM approach is therefore specifically advocated in elementary Science education that covers the technology and engineering fields as a curriculum organizing form (*ke cheng zu zhi xing shi*) (Ministry of Education, 2017a).

Whole-task-based teaching and learning approach

The whole task-based teaching and learning approach is advocated to address the authenticity of general technology learning in senior secondary school (Guan, 2019). Contexts, tasks, activities and basic problems serve as the main ways to complete the whole task. Traditional teaching and learning models of technology education focus on task analysis and the teaching process, but the whole-task-based model focuses on task design, and emphasizes that the whole-task design is prior to the teaching process design. Whole-task-based instructional design is divided into three stages: a) initiating the task by analyzing program content and the literacy and competency embodied in the content; b) setting the objectives and performance gauges of the whole task; and c) designing the whole task in a detailed way. Guan's experiment (2019) found that the whole-task-based teaching and learning is not only able to boost students' design ability, but also assist teachers; however, it demands greater involvement of teachers to successfully conduct it.

STATE-OF-THE-ART TECHNOLOGY TEACHER EDUCATION

Technology teacher education in China is totally new, although China has had a tradition of Normal (*shi fan*) Education for more than 100 years, which has been gradually changing into Teacher Education (Gu, 2003). Technology teacher education started with the occurrence of technology education in elementary, junior and senior secondary schools as an independent learning field in the early 2000s.

Certification Requirements for Initial Technology Teachers

According to China's *Law of Teachers* (NPC Standing Committee, 1993, 2009), China practices a teacher qualification system. A Chinese citizen may obtain the teacher qualification if he/she passes the national teacher qualification examination and at the same time abides by the Constitution and laws, loves the cause of education, reaches the certain educational levels specified in the Law of Teachers, and demonstrates educating and teaching abilities.

Education level

A technology teacher must have a certain education level, as the *Law of Teachers* requires. To obtain the elementary school teacher qualification, one is supposed to have graduated from a secondary normal school (*zhong deng shi fan xue xiao*) or above; to obtain the qualification of junior secondary school teacher, one should have a diploma or above from a higher normal college (*gao deng shi fan xue xiao*) or other university; to obtain the senior secondary school teacher qualification, one must have a bachelor degree or above from a normal university (*shi fan da xue*) or other university.

Technology teachers' certification tests

The *Law of Teachers* requires that anyone who intends to be a teacher should get a teacher certification for a certain subject in elementary or secondary or tertiary schools. The qualification tests are nationally unified and organized by the provincial education administrative departments, but the standards of the tests are established by The Ministry of Education (2013). The tests consist of written examinations and interviews. Only those who pass their written examinations can participate in the following interviews. Written examinations are carried out on computer screens or on paper, and aim to assess teacher candidates' understanding of educational theories and practices. Interviews are usually conducted in groups of disciplines (*xue ke*) to assess if the teacher candidates have the required educating / teaching skills and attitudes. Each evaluation group for interviews is composed of at least three interviewers, one of whom serves as the main examiner. These interviewers are selected from experts in universities or teaching and research institutions and excellent teachers from elementary and secondary schools. The criteria of the selection are that interviewers should: a) be familiar with relevant policies of the teacher qualification examination; b) observe good professional ethics, being fair, decent and physically healthy; c) have solid professional knowledge, strong analysis and generalization ability, judgment ability and language expression ability; d) have more than 5 years of teaching or research work experience in related areas with professional and technical positions (titles) above deputy senior level; and e) have received training and certification of implementing teachers' certification tests from national or provincial organizations.

All candidates for elementary school teachers should take two written examinations: comprehensive quality (*zong he su zhi*) and *educating / teaching knowledge and ability (jiao yu jiao xue zhi shi yu neng li)*. Those who pass the written examinations are organized into groups for subsequent interviews according to the disciplines they specialize in. Candidates for IT teachers should take the interview of the group *of Elementary school IT.*

Candidates for junior and senior secondary school teachers should take three written examinations: *comprehensive quality (zong he su zhi), education knowledge and ability (jiao yu zhi shi yu neng li)* and *subject knowledge and teaching ability (xue ke zhi shi yu jiao xue neng li),* among which the content of the first and the second subjects is identical for all candidates, but the third are differentiated according to disciplines that candidates specialize in. Candidates for junior secondary school technology teachers take the discipline of Junior IT, while candidates for senior secondary school technology teachers can take either Senior IT or GT to obtain pertinent teaching certificates. Just as with the elementary school candidates, those who pass the written examinations are organized into groups for subsequent interviews according to the disciplines they specialize in.

Curriculum fields and credit hours for pre-service technology teacher education

The Ministry of Education (2011) issued *The Curriculum Standards for Teacher Education,* which sets the basic national requirement for teacher education curricula, and serves as the important foundation for formulating teacher education curriculum plans, developing teaching materials and curriculum resources, carrying out teaching and evaluation, and identifying teachers' qualifications.

Elementary school pre-service teacher education, as is required by the above standards (Ministry of Education, 2011), covers six compulsory learning fields: a) children's development and learning; b) elementary education; c) primary school discipline education and activity guidance; d) mental health and moral education; e) professional ethics and professional development; and f) elementary school educational internship. Pre-service teacher education should also provide the learning experience of pertinent electives modules, such as elementary school students' cognition and learning; education philosophy; curriculum design and evaluation; effective teaching; school education development; class management; school organization and management; education policies and regulations; elementary school curriculum standards and teaching materials research; elementary school teaching design; elementary school interdisciplinary education; and elementary school integrative practice activities. Among these elective modules, the interdisciplinary education and elementary school integrative practice activities (IPA) are very important for elementary school technology teachers. Minimum total credits for those pre-service teachers who study in 3-year colleges are 28, 32 for those in 4-year colleges, and 35 for those in 5-year colleges, where it takes a pre-service teacher 18 school hours to get 1 credit. Besides, every pre-service teacher should take an 18-week educational internship.

Curricula for secondary school pre-service teacher education required by the standards cover six compulsory learning fields as well. They are: a) children's development and learning; b) basis of middle school education; c) discipline education and activity guidance in middle school; d) mental health and moral education; e) professional ethics and professional development; and f) secondary school educational internship. Besides, the Ministry of Education (2011) recommends more modules for teacher education organizations, such as curriculum design and evaluation, effective teaching, school education development, classroom management, secondary school curriculum standards and teaching materials, secondary school teaching design, and secondary school Integrative practice activities (IPA). The IPA module is very important for secondary school technology teachers since technology education is an important part of IPA. Those pre-service teachers who study in 3-year colleges are required to earn at least 12 credits, and those in 4-year universities should obtain at least 14 credits. Just as with the elementary school pre-service teachers, secondary school pre-service teachers should spend 18 school hours to get 1 credit for the curricula, and they must also take an 18-week educational internship.

Curriculum fields for in-service technology teacher education

In-service teacher education curricula should meet the diverse needs of teachers' professional development, make full use of teachers' own experience and advantages, inspire teachers to deepen their professional understanding, solve practical problems, and improve their reflective thinking (Ministry of Education, 2011).

In the light of deepening in-service teachers' professional understanding, the Ministry of Education (2011) recommended teacher education subjects / modules such as contemporary educational thoughts, professional ethics of teachers, new progress in subject education, new progress in children's research, and new progress in learning science; some related topics in philosophy, humanities, and science & technology can also be selected. This coursework can empower technology teachers to better reach out to students and connect technology education to other subjects such as philosophy and the humanities.

In order to enhance in-service teachers' ability to solve practical problems within educational fields, the Ministry of Education (2011) recommended teacher education subjects / modules like subject teaching research, special education, youth development research, school curriculum leadership, school-based curriculum development, integrative practice activity design and guidance, portfolio evaluation, comprehensive quality evaluation of students, teaching diagnosis, classroom evaluation, classroom observation, academic achievement evaluation, and integration of information technology and curriculum. Among these subjects / modules, integrative practice activity design and guidance is directly related to technology teacher education, while others are indirectly related.

To improve in-service teachers' reflective thinking, the Ministry of Education (2011) recommended the subjects / modules of special research on teachers' professional development, educational experience research, reflective teaching, educational action research, educational case studies, and educational narratives.

Technology Teacher Education Programs

Technology teacher education programs vary with the purpose of cultivating pre-service teachers with academic degrees, or enriching those in-service teachers' experience and enhancing their practical abilities.

Programs with academic degrees

Colleges and universities in China provide science and technology education programs and educational technology programs for pre-service technology teachers to get Bachelor's degrees. Technology is the shared focal point of the two kinds of programs. The difference currently lies in the fact that science and technology programs usually prepare Science teachers, IPA teachers and General Technology teachers, whereas the educational technology programs mainly prepare Information Technology teachers. Science and technology programs usually cover the following courses: a) the theoretical foundation of teaching and education, such as advanced mathematics, college physics, college chemistry, life science and experiment, introduction to modern science and technology; and b) professional development for science and technology teachers, such as engineering drawing, applied mechanics, mechanical technology, electronic and electrical technology, technology design and production, information technology, and science and technology innovation education. Educational technology programs usually cover courses in three categories: a) Pedagogy, including principles of learning science, pedagogy, psychology, and research methods; b) Computer science, mainly including computer principles, database principles, C / C++, Java (optional), Python (optional), and data structure; and c) Media, mainly including photography, post production, and so on.

In addition to Bachelor degree programs, there are technology educational programs integrated with science for Master's degrees. Most normal universities (*shi fan da xue*) offer these programs. An increasing number of engineering universities have started to offer these programs as well. Take the pilot program of *cultivating high-level science popularization professionals* of Beihang University for example. It is a Master's degree program initiated in 2019. Only those undergraduates who have received their science or engineering Bachelor degrees are admitted. They take courses on educational principles, curriculum and teaching theory, psychological development and education, educational research methods, science and technology education curriculum and textbook research, science and technology education teaching design and implementation, scientific communication, digital popular science works planning and production, design research topics, and so forth. Postgraduates also need to take an internship for more than 6 months in a science and technology museum or relevant organization, and complete their degree thesis.

Programs without academic degrees

The National-level Teachers Training Program (NTTP, *guo pei ji hua*) has been conducted since 2010 with the Ministry of Education and the Ministry of Finance collaborating and implementing the national demonstration training (*guo jia shi fan pei xun*) for elementary and secondary school teachers in all provinces (districts and cities). This is an annual training program, mainly including demonstration projects such as training for backbone teachers in primary and secondary schools, distance training for teachers in primary and secondary schools, training for teachers in charge of classes, and training for teachers in weak subjects in primary and secondary schools. NTTP demonstrates training of backbone teachers in primary and secondary schools nationwide, and has developed and provides a series of high-quality training courses and teacher education resources to support the "Central and Western Rural Backbone Teacher Training Project," providing opportunities for professional development for primary and secondary school teachers (Ministry of Education, 2010).

The National Training Center for Senior High General Technology Teachers was set up in Nanjing Normal University (NNU) by the Ministry of Education, as NNU plays a leading role in academic research and practice of technology education in elementary and secondary schools. In September or October every year, approximately 50 selected general technology teachers around China gather in NNU to study the curriculum standards of general technology, attend lectures and visit Demonstrative Schools (*shi fan xue xiao*) of General Technology Education to learn about the design and implementation of technology programs. These trainees bring this experience back to their schools and their districts. They function as seeds of technology education throughout China, and gradually technology education takes shape.

Besides the National-level Teachers Training Program (NTTP), there are Provincial-level Teacher Training programs (PTTP, *sheng pei ji hua*) as well. NNU also serves as the training center for technology teachers within Jiangsu Province. Actually, teachers of the same or similar fields are often organized by schools, district or county authorities and municipal authorities to do "teaching and researching activities" (*Jiao yan huo dong*) together. Through these training programs and activities, teachers gain professional development.

Features of the Technology Teacher Education in China

A technology teacher education major did not exist at the university level within China (Wu, 1991) until the new millennium, but it has a long history in well-developed countries such as the United Kingdom and the United States. With the national policy of reform and opening up, China has learned a great deal from other countries and aims to develop suitable strategies and solutions to solve China's problems.

The first feature of technology teacher education in China is that it actively takes the dual perspectives of both globalization and localization. Today technology is given top priority, and great significance is attached to technology education. In China as well as in many other Asian areas influenced by traditional Confucian culture, technology used to be regarded as anything but noble. It was not until the most influential Chinese political leader Mr. Deng Xiaoping, advocated technology as the major productive force in the late 1970s and the early 1980s that China started to learn the world practice of technology education and tried to catch up with the international trend. With increasing mutual exchanges between China and overseas countries and areas, Chinese technology teacher educators are opening up their minds and bringing the internationally advanced technology curriculum standards, methodologies and other resources to the mainland. Meanwhile, they pay special attention to the reality of China and adopt a dual perspective of both globalization and localization.

The second feature of technology teacher education in China is that international talent is coming to China and boosting the whole professionalism of technology teacher education. On the one hand, an increasing number of technology education conferences are taking place in China, to which prestigious international professionals are often invited to deliver speeches. This opens up the audience's mind and boosts the professionalism of technology teacher education in China. On the other hand, as Wu anticipated (1991), Chinese students who study technology education overseas "affect the potential development of their motherland's technology education through communication with their universities, communities, or via suggestions to their educational systems and government."

CHALLENGES AND INNOVATION OF TECHNOLOGY TEACHER EDUCATION

Major Challenges

Lower status of technology education compared to other subjects in the school system

Technology is a new "small" subject compared to the classical "big" subjects like Chinese language and characters, mathematics, foreign languages, and even compared to science and the arts, which is mainly due to the test-oriented educational mode that does not include the subject of technology in the highly competitive college entrance examinations. Since technology is not a requirement in the college entrance examinations, schools pay less attention to technology teachers than to teachers of "big" subjects in terms of both quality and quantity, although schools understand that students' technological literacy is a basic competency in this highly technological world.

Insufficient provision for pre- and in-service technology teacher education

There are not enough universities or colleges to provide pre-service technology teacher education, nor is there a sustainable educational structure to encourage technology teachers to engage in lifelong learning in China. This problem is, to a certain degree, related to the low status of technology education, but in essence is due to the societal culture that does not give sufficient emphasis to technology.

Lack of candidates to receive technology teacher education

There are not enough candidates to receive technology teacher education. The number of professional and full-time technology teachers in a school might be minimal, with most technology teachers working part-time or transferring from other subjects.

Innovation and Strategies

Increasing provision for technology teacher education

Gu (2010) proposed measures to increase the provision of technology teacher education by setting up technology education programs in: a) the general normal colleges; b) the vocational normal colleges; c) engineering colleges with education discipline resources; d) educational technology departments in colleges with enough resources; e) Physics / Biology departments with a solid foundation; and f) international organizations that conduct collaborative programs with China.

Refining technology teacher education curricula

The research and development (R&D) of technology teacher education curricula needs to be refined. The R&D of the curricula should draw lessons from international technology teacher education and meet the urgent needs of technology teachers in China. It should also be based on the curriculum objectives, curriculum structure, curriculum content and specific characteristics of curriculum implementation in elementary and secondary schools, striving to achieve a high degree of unity of professionalism and practicality.

The core curricula of technology teacher education are composed of general pedagogy, study of technology and technology pedagogy (Gu, 2010). The curricula of general pedagogy are almost the same as those of other teacher education, such as educational psychology and educational measurements; the curriculum cluster of technology study covers the research and development of technology introduction, technology development history, technology aesthetics, technology sociology, technology foundation, technology design, technical drawing, CAD design and other basic technology courses; the curricula of technology pedagogy mainly consist of the development of the principles of technology education, technology curriculum theory, technology teaching method, technology education psychology, and technology education sociology. In addition, special projects such as technology experiments, technology exploration, technology production, technology culture and so on should be implemented so as to enhance technology teachers' practical ability and boost their teaching level (Gu, 2010).

Building a network of teaching-and-researching leaders (jiao yan yuan) with a disciplinary vision in provincial governments

The provincial-level network system of technology teaching and researching leaders (*jiao yan yuan*) with the disciplinary vision of technology education has been started in order to strengthen the guidance of technology curriculum development and teaching. Each province in China has at least one such kind of teaching-and-researching leader working in the provincial department of Education. In some provinces and urban areas, there is one teaching-and-researching leader to take responsibility for both the subjects of information technology and general technology, such as in Hainan, Jiangsu, Henan, and Sichuan; in some provinces and urban areas such as Shandong, Zhejiang, Ningxia, and Tianjin, there are two teaching-and researching-leaders: one for information technology and the other for general technology. According to a survey conducted in 2013 by the Institute of Technology Education of Nanjing Normal University among technology education teaching-and-researching leaders in 30 provinces and cities in Mainland China, there are seven provinces where one teaching-and-researching leader of technology covers all subjects relating to technology, that is, information technology, labor & technology and general technology; this accounts for 23.3%. There are 19 provinces where teaching-and-researching leaders cover information technology and general technology respectively, accounting for 63.3%. There are four provinces, accounting for 13.4%, with full-time teaching-and-researching leaders for information technology, but with no full-time leaders for general technology. Thus, there remains room for further work.

Enhancing the technology culture atmosphere

Technology culture is still vague, utilitarian and narrow in China (Gu, 2015) and there are many misunderstandings and prejudices about technology curricula, partially because there is a cultural tradition of discriminating against technology in the humanities, and a utilitarian tendency of only focusing on the college entrance examinations in the field of education. This situation may also be true in some other parts of the world where senior secondary students face highly competitive college entrance examinations.

Therefore, there is a great need for the construction of technology culture in schools as well as in families, communities and society as a whole. Special training programs should be provided for the personnel from education administration, teaching and research departments, examination departments, education equipment departments, secondary school principals, teaching directors and other leaders, so as to promote technology education related administrative decision making, education management, curriculum resource allocation and assessments. Besides, the research and achievement release of technology education should be strengthened to enhance the technology culture atmosphere and attract more people's concern about technology education and devotion to technology teacher education.

CONCLUSION

Technology education in China aims to boost all students' technological literacy. It is implemented in both separate and integrative ways. All students need to learn compulsory modules to guarantee a certain level of necessary technological literacy, and they can also choose elective modules according to their interest to lay a foundation for their further learning in tertiary education and to prepare for their future careers. Elementary school students learn Technology & Engineering (T&E) as a study field of Science, and they also take the courses of Information Technology (IT) and Labor & Technology (LT) integrated with Integrative Practice Activities (IPA); junior secondary school students continue to take IT and LT integrated with IPA; senior secondary school students take separate IT and General Technology (GT) courses respectively with LT incorporated. Comparatively speaking, technology education in Grades 1-9 emphasizes design and making, while in Grades 10-12 it emphasizes the integration of theory and practice. The curricula and teaching methodologies are developed according to students' psychological and mental development. Technology education achievement is recognized when students take tests and participate in competitions. Technology teachers and teacher educators strive to find proper instructional approaches to boost all students' technological literacy, such as a) the integrative-activity-based approach that includes investigation and the exploration approach and the design & making approach, b) multi-discipline-based approaches that consist of the project-based approach and the problem-based approach, c) the STEM approach and d) the whole-task-based teaching and learning approach.

Technology teacher education started when teacher educators managed to advocate technology as an independent learning field in elementary, junior and senior secondary schools in the early 2000s. China practices a teacher qualification system. A Chinese citizen may obtain the teacher qualification if he/she passes the national teacher qualification test and at the same time abides by the Constitution and laws, loves the cause of education, reaches the certain educational levels specified in the Law of Teachers, and demonstrates his/her ability of educating and teaching. *The Curriculum Standards for Teacher Edu-*

cation (Ministry of Education, 2011) sets the basic national requirements for teacher education curricula, and serves as an important foundation for formulating teacher education curriculum plans, developing teaching materials and curriculum resources, carrying out teaching and evaluation, and identifying teachers' qualifications. Technology teacher education programs vary with the purpose of cultivating pre-service teachers with academic degrees or enriching those in-service teachers' experience and enhancing their practical abilities. Technology teacher education is relatively new in China compared with that in many advanced countries and areas. However, with increasing international exchange, technology teacher education in China has actively taken the perspective of globalization to boost its professionalism to catch up with the world trend. Meanwhile, it has gradually formed the theory and practice of Chinese characteristics to meet the needs of the domestic economic and societal structure. However, it has encountered problems such as the lower discipline status of technology compared to other school subjects, insufficient provision of pre-service and in-service technology teacher education, and lack of candidates for technology teachers to receive teacher education. As such, the provision of technology teacher education needs to be increased, the technology teacher education curricula need to be refined, and a network of teaching-and-researching leaders with disciplinary perspectives needs to be built and a technology culture enhanced.

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TECHNOLOGY TEACHER EDUCATION IN HONG KONG

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ABSTRACT

In this chapter, the authors strive to report on the pre-service training programs for Technology Education teachers of both Information and Communication Technology (ICT) and Design and Technology (D&T) amid the influence of the Covid-19 lockdown in Hong Kong. By contrasting the discrepancy between the 2000 and 2017 versions of the Technology Education Key Learning Area Curriculum Guide, the scene is set to account for the insufficiency and even the missing practical components in the Post-Graduate Diploma of Education (PGDE) in D&T program, which has led to the difficult and undulating course of development of the D&T teacher training programs throughout the years. Features of the current situation of the teacher training in PGDE programs for both D&T and ICT are reported in terms of program structure/course of studies, credit points or units required for graduation, and the requirements to attain qualified teacher status. Both ICT and D&T stakeholders hold that the instantaneous introduction of STEM without consensus among stakeholders upon the purpose, pedagogies, planning of learning activities, etc. has posed challenges to the subject curriculum and thus the teacher training programs. The efforts and endeavors that teacher trainers in ICT undertake to cope with these challenges are discussed. In terms of D&T, besides the call to clarify the purpose of STEM education to build consensus, the authors also suggest that the practical essence of D&T necessitates that the teacher training program focus on the development of teachers' capabilities to perform the teaching of project-based learning with tangible outcomes. The discussion further extends to the exploration of the feasibility of introducing a licensing system to ensure the quality of teaching of practical activities in workshops to augment the existing preservice programs. This report also points out the need to forge a coalition of stakeholders including practicing teachers, tertiary education providers, officials of the central agency and emerging scholars and academics in D&T to build up synergy in pursuing desirable teacher training programs.

Keywords: Design and Technology, Post-Graduate Diploma in Education, STEMaker Education, project-based learning activities

INTRODUCTION

Education System in Hong Kong [1]

To understand the development of technology education, it is necessary to have a rough idea of the education structure. In Hong Kong, the education system consists of kindergarten, primary, secondary, post-secondary and vocational education.

Kindergarten (3 years)

In Hong Kong, kindergartens and child care centers provide services for children from 3 to 6 years old. The aim of kindergarten education in Hong Kong is to nurture children to attain all-round development in the domains of ethics, intellect, physique, social skills and aesthetics; to develop good habits so as to prepare them for life; and to stimulate children's interest in learning and cultivate in them positive learning attitudes in order to lay the foundation for their future learning.

Primary Education (6 years)

Primary schooling starts at the age of around 6 and there are 6 years of schooling at the primary level. There are three modes of operation in the primary schools, namely a.m., p.m. and whole-day. Encouraged by the government, most primary schools adopt whole-day operation. Chinese is the language of instruction in most schools, with English as the second teaching language.

The aims are to provide a balanced and diverse school education that meets the different needs of our students; to help them build up knowledge, values and skills for further studies and personal growth; and to enhance their bilit-

1 https://www.studyinhongkong.edu.hk/en/ and https://www.gov.hk/tc/about/abouthk/factsheets/docs/education.pdf are referred to in preparing this part of the report.

erate (i.e., English and Chinese) and trilingual (i.e., English, Putonghua and Cantonese) abilities.

Secondary Education (3+3 years)

Secondary schooling starts at the age of around 12 and comprises 6 years of schooling. There are three main types of local middle schools: government schools, aided schools and caput schools that are subsidized by the government, and schools under the Direct Subsidy Scheme (DSS). Besides the schools under DSS, the other two types of school provide free secondary education. Schools admitted to the DSS can charge school fees and also receive recurrent government subsidies on condition that 50% of the school fees will be set aside for fee remission and scholarship schemes.

Secondary schooling provides students with a broad and balanced curriculum in alignment with the seven learning goals. The school curriculum provides diverse learning experiences inside and outside the classroom, enabling students to realize their potential in the domains of moral, intellectual, physical, social and aesthetic development. Emphasis has been put on the implementation of the four key tasks for developing students' generic skills and self-directed learning capabilities, for example, information technology in education and STEM (science, technology, engineering and mathematics) education, to prepare our students for future challenges.

A 3-year new high school curriculum was implemented in the fourth grade of middle school in September 2009.This curriculum is designed to meet students' various interests, needs and abilities, and to cultivate students' overall development and lifelong learning ability. At the end of the sixth grade of secondary school, students will take the public examination, the Hong Kong Diploma of Secondary Education (HKDSE) examination, which has replaced the previous Hong Kong Certificate of Education Examination and the Hong Kong Advanced Examination. The first diploma examination was successfully held in 2012.

Post-secondary Education (4 years)

The Government provides multiple study pathways for secondary school leavers. Some of them will study bachelor's degree programs directly after completing the HKDSE, whereas some will choose to study sub-degree programs. For those who study sub-degree programs, upon graduation, they can pursue study in top-up degree programs (i.e., a "2 + 2" arrangement) to obtain their undergraduate qualifications.

The UGC-funded universities provide 15,000 publicly-funded first-year-first-degree intake places per annum. There are also around 9,000 self-financing undergraduate program places offered by various institutions. Besides, there are subsidized senior-year undergraduate places and self-financing top-up degree places for sub-degree graduates. At the sub-degree level, there are around 20,000 and 10,000 intake places for self-financing and publicly-funded sub-degree programs, respectively.

At present, there are 22 local degree-awarding institutions (9 publicly-funded and 13 self-financing) in Hong Kong. Apart from offering undergraduate programs, students can also choose a wide diversity of sub-degree programs as well as various continuing and vocational programs that best suit their interests and abilities.

Vocational Education

The Vocational Training Council (VTC) is a statutory body established to provide a comprehensive system of vocational and professional education and training (VPET) for school leavers and adult learners. It provides both full-time and part-time places. Courses offered through the VTC's member institutions are available from secondary 3 up to degree level, covering applied science, design, engineering, hotel, service and tourism, childcare, elderly and community services, business administration, information technology and other study areas.

THE PROFILE OF TECHNOLOGY EDUCATION

Technology Education Key Learning Area Curriculum Framework

In Hong Kong, all the subjects are grouped into eight different Key Learning Areas (KLA), namely Chinese Language Education, English Language Education, Mathematics Education, Science Education, Technology Education, Personal, Social and Humanities Education, Arts Education and Physical Education. The curriculum of these KLAs are from primary 1 to secondary 6.

Under each KLA, there may be one or more subjects. For example, in the Physical Education KLA, there is only one subject: Physical Education, whereas for the Science Education KLA, there are physics, chemistry, biology, integrated science and combined science. Table 1[2] illustrates the arrangement of the eight KLAs.

2 Retrieved from https://www.edb.gov.hk/en/curriculum-development/cs-curriculum-doc-report/8-key-area/

Table 1. The subjects in the 8 Key Learning Areas

Level	Key Learning Area							
P1 - 6	Chinese Language Education	English Language Education	Mathematics Education	Science Education	Technology Education	Personal, Social and Humanities Education	Arts Education	Physical Education
	Chinese Language Putonghua	English Language	Mathematics		General Studies		Music Visual Arts	Physical Education
S1 - 3	Chinese Language Putonghua	English Language	Mathematics	Science	Technology Education Key Learning Area Curriculum	Chinese History2 Geography History Life and Society3 Religious Education	Music Visual Arts	Physical Education
S4 - 6	Chinese Language Chinese Literature	English Language Literature in English	Mathematics	Biology Chemistry Physics Science (Integrated Mode; Combined Mode)	Business, Accounting and Financial Studies Design and Applied Technology Health Management and Social Care Information and Communication Technology Technology and Living	Chinese History Economics Ethics and Religious Studies Geography History Tourism and Hospitality Studies	Music Visual Arts	Physical Education
	Liberal Studies							

As stated on the latest TE KLA Curriculum Guide, the design of the TE curriculum follows the concept of "coherent, continuous and progressive, in accordance with the social cognitive and physical development of students" (CDC, 2017, p. 9). Therefore, there are different emphases in the TE curriculum at different key stages, as illustrated by the table inside the Guide which is extracted as follows.

Table 2. Different Emphases of the TE Curriculum at Different Key Stages

Primary Level **Key Stages 1 and 2**	**Junior Secondary Level** **Key Stage 3**	**Senior Secondary Level** **Key Stage 4**
Awareness & Exploration	Experiencing & Application	Orientation for Lifelong Learning and Specialization
⇧	⇧	⇧
Through strands in General Studies	Through the junior secondary subjects/core and extension modules in the TE KLA curriculum	Through the senior secondary elective subjects: BAFS, DAT, HMSC, ICT & TL

Table 3. Quick reference to ages of different key stages in Hong Kong:

AGE ON 31ST JANUARY	**CURRICULUM KEY STAGE**
3-5	Early Years Foundation Stage
6-7	Key Stage 1
8-11	Key Stage 2
12-14	Key Stage 3
15-17	Key Stage 4

The TE KLA curriculum aims at developing *technological literacy* in students through the cultivation of *technological capability, technological understanding* and *technological awareness*.

- Technological Capability to identify needs, problems and opportunities; communicate and evaluate solutions; and make informed decisions;
- Technological Understanding to understand the interdisciplinary nature of technological activities; the concepts, knowledge and processes of different technologies;
- Technological Awareness to be aware of the cultural and contextual dependence of developing technologies, and their impact on the society and the environment.

For Technology Education KLA at primary level, General Studies (GS) is the main vehicle for delivering the course content. However, GS serves the Science Education KLA, Technology Education KLA and Personal, Social and Humanities Education KLA. The total suggested time allocation for GS is 12% - 15% of the total curriculum.

For the junior secondary level, the TEKLA Curriculum accounts for 8%– 15% (about 220 to 413 hours) of the total lesson time over a course of 3 years from S.1 to S.3, whilst at the senior secondary level, each of the TE elective subjects of the senior secondary curriculum, namely Business, Accounting and Financial Studies, Design and Applied Technology, Health Management and Social Care, Information and Communication Technology, and Technology and Living, accounts for 10% to 15% of the total lesson time over a course of 3 years in KS4 (CDC, 2017, p. 119).

The above arrangement is a little bit tricky in terms of time allocation. Even though there is a solid "Technology Education Key Learning Area Curriculum"[3] stipulated for junior secondary, the implementation is largely school-based.

It is not uncommon that, at the S1 to S3 level, Hong Kong schools are domi-

3 Technology Education, Key Learning Area Curriculum Guide (Primary 1 – Secondary 3), EDB, 2002

nantly adopting a subject-based learning [4] approach, mainly, but not inclusively, through the following three subjects:

1. Computer Literacy (CL)Learning elements are covered under the Knowledge Context “Information and Communication Technology” in the curriculum
2. Design and Technology (DT)
   Learning elements are covered under the Knowledge Contexts “Materials and Structures,” “Operations and Manufacturing” and “Systems and Control” in the curriculum
3. Home Economics / Technology and Living (HE/TL)
   Learning elements are covered under the Knowledge Context “Technology and Living” in the curriculum

Technology Education in Senior Secondary

Information and Communication Technology[5]

As stated in the Information and Communication Technology Curriculum and Assessment Guide: Secondary 4– 6 (CDC & HKEAA, 2015), the senior secondary ICT curriculum aims to

- provide students with a body of essential knowledge, concepts and applications of information, communication and computer systems;
- equip students with problem-solving and communication skills, and encourage them to think critically and creatively;
- develop students into competent, effective, discriminating, ethical and con-

4 There are five modes of implementations states in the TEKLA Curriculum Guide (CDC, 2017, p.107), namely Subject-based learning, Aligning subjects/Knowledge Contexts, Collaborative teaching of subjects/Knowledge Contexts, Theme-based Learning and Life experiences of students.

5 CDC & HKEAA(2015) was referred to in preparing this part of the report.

fident users of ICT, so as to support their lifelong learning; and

- provide students with opportunities to appreciate the impact of ICT on our knowledge-based society, so as to nurture in them positive values and attitudes towards this area.

The compulsory part of the curriculum occupies 145 hours and spans approximately one and a half school years. It comprises a number of topics involving the fundamental principles in information and communication technologies, and provides students with a solid foundation and broad area of study in ICT. The Compulsory Part consists of five modules, namely Information Processing, Computer System Fundamentals, the Internet and Its Applications, Basic Programming Concepts and Social Implications.

Four options are offered in the elective part. Students are required to choose a specialized area for in-depth study. The options in the elective part can be broadly categorized as those illustrating applications of computers in specific areas, and those intended for students who will pursue further studies in ICT as a discipline in tertiary education. The options are Databases, Data Communications and Networking, Multimedia Production and Web Site Development and Software Development.

Starting from the 2018 HKDSE Examination, in the school-based assessment (SBA), students are required to complete two guided tasks focusing on "Design and Implementation" and "Testing and Evaluation" in the development of an information system. The context of the guided tasks is related to both the compulsory part and the elective part chosen by individual students.

Design and Applied Technology[6]

The subject Design and Applied Technology (DAT) is offered to secondary 4 to secondary 6 students, and is offered as an elective subject that continues the

6 CDC & HKEAA(2014) was referred to in preparing this part of the report.

studies of D&T at the junior secondary level.

The broad aims of the DAT are to enable students to:

- become independent thinkers and innovative problem-solvers;
- develop practical skills and knowledge in technology and design;
- identify needs, wants and opportunities for improving the quality of living, and develop design and technological responses as well as entrepreneurship, accordingly; and
- become discriminating, informed and responsible users of products, and develop their awareness of the interplay between technology and aesthetic, enterprise, social, cultural and ethical issues.

The total lesson time allocated to DAT is 250 hours, which includes approximately 80 hours for coursework. A rough estimation of the time allocation is:

- Compulsory: Technology, Design and Society (about 50%); and
- Elective: Technological Studies (about 50% for two optional modules of around 25% each)

The compulsory part consists of three strands, namely "design and innovation," "technological principles," and "value and impact." The elective part of the curriculum provides students with a choice of modules to suit their different interests and inclinations, while the content reflects the development of technology. These elective modules are: Automation, Creative Digital Media Design, Implementation and Material Processing

Besides sitting for the pen-and-paper examination, students studying DAT will have to undertake a SBA in their course of study which constitutes 40% of the final result. The components of the SBA include (HKEAA, 2014):

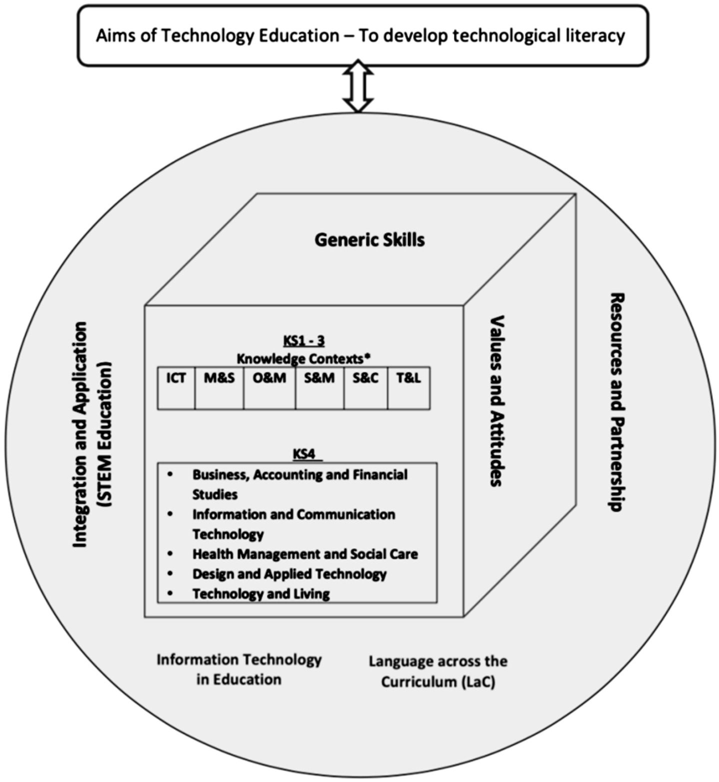
- Case studies which discern students' attainment in terms of:
  - analytical and critical thinking skills;
  - understanding of emerging technology; and

    - social, technological and entrepreneurship awareness.
- Technology exploration task:
    - In technological exploration assessment tasks students demonstrate a variety of "hands-on" practical, experimental and task-based skills.
- Students carry out a design project to reveal evidence of their ability to apply technological knowledge and generate ideas and solutions. The processes students have to go through are as follows:
    - clarifying the problem of the design task;
    - establishing a framework for the design;
    - finding out and selecting technologies and resources;
    - proposing solutions;
    - realizing the solution with tangible media; and
    - presenting ideas.
- Portfolios
    - This is a collection of students' work done during the course of study of the SBA, for example, design folders, artefacts, journals, and case study and fieldwork reports.

Discrepancy between the 2000 and 2017 TEKLA Curricula

It is worth noting that the 2017 Curriculum Guide is a complementary action to support the introduction of STEM education, with a peculiar zeal for enhancing the content of Knowledge Contexts. In so doing, the experiential emphasis of the TEKLA curriculum has undesirably been transformed from a descriptive framework guiding the development of broad and balanced learning experiences to a prescriptive plethora of content. This somewhat deviates from the original intention of the purposes and rationale proposed in the early stage of the establishment of the TEKLA (e.g., CDC, 2000).

Taking a glance at the 2017 Curriculum Guide might give raise to a question regarding Knowledge Contexts: do they represent six different subjects?



*The six Knowledge Contexts for KS1 - 3:

Information and Communication Technology (ICT)	Operations and Manufacturing(O&M)	Systems and Control (S&C)
Materials and Structures (M&S)	Strategies and Management (S&M)	Technology and Living (T&L)

Figure 1. Diagrammatic Representation of the TE Curriculum Framework as depicted in CDC, 2017.

In the table retrieved from the Education Bureau (EDB) webpages stating the subjects in the eight KLAs, there is a brief footnote purporting to explain what Knowledge Contexts are:

> "TEKLA Curriculum is fully implemented at the junior secondary level in the 2016/17 school year. It covers six Knowledge Contexts, namely "Information and Communication Technology", "Materials and Structures", "Operations and Manufacturing", "Strategies and Management", "Systems and Control", and "Technology and Living". Modular approach is proposed in the implementation of the curriculum"[7]

Looking at the latest Guide (CDC, 2017) in the section explaining the "Aligning subjects/Knowledge Contexts" mode of implementation, there is a statement that further perplexes the readers: "Teachers may plan and schedule the contents of different subjects/Knowledge Contexts in such a way that common learning objectives for students could be achieved and assessed in different TE classes." (ibid.)

Furthermore, given the plethora of objectives and content entailed from each Knowledge Context (ibid. pp. 55-95), it is not unsafe to claim the conception held by the composers of the TEKLA Curriculum Guide (ibid.) subscribes strongly to the notion that Knowledge Contexts are inherently a matter of content, not least being subjects in the school curriculum.

Unsurprisingly, the abovementioned paragraphs describing the Knowledge Contexts overshadows the founding aims of the TEKLA Curriculum (i.e., CDC, 2000).

7 Retrieved from https://www.edb.gov.hk/en/curriculum-development/cs-curriculum-doc-report/8-key-area/

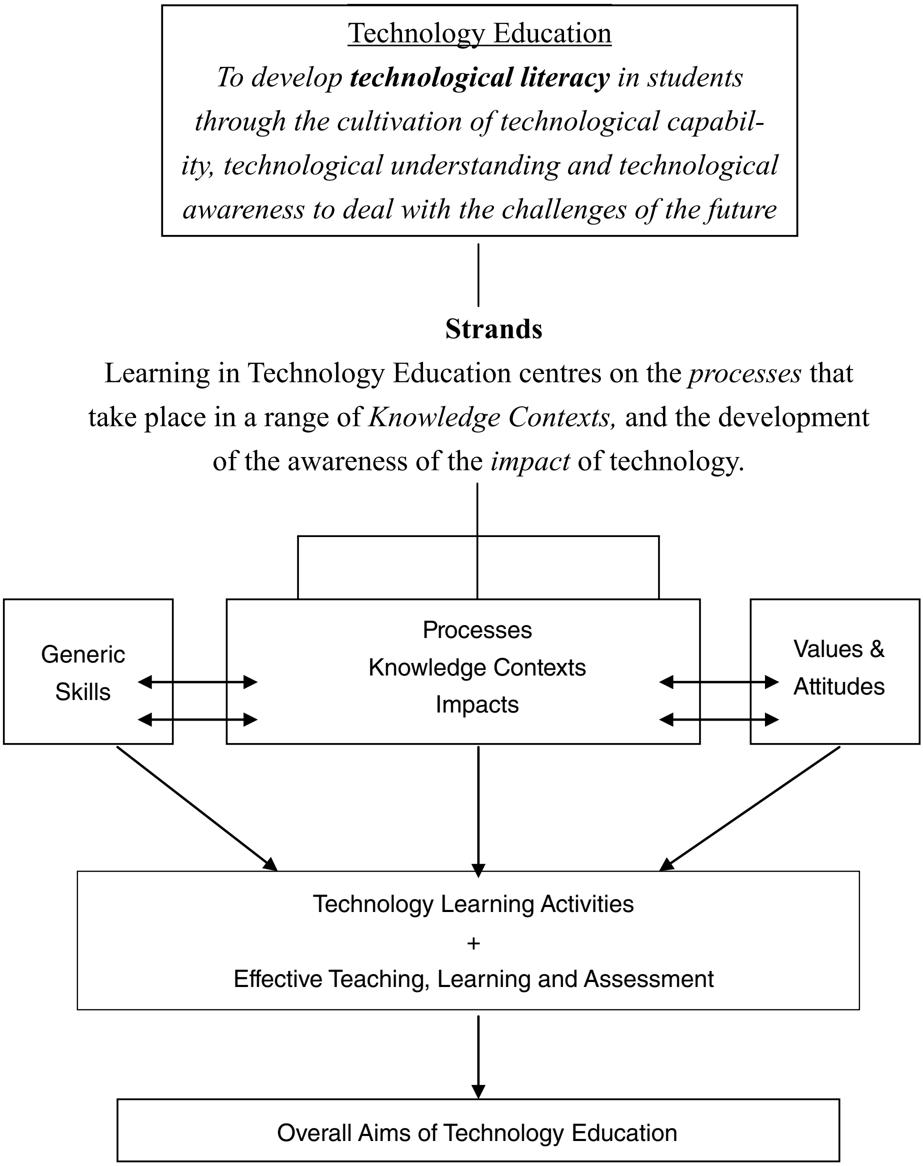


Figure 2. TEKLA Curriculum Framework (extracted from CDC, 2000b, emphases added)

The original aims of the TEKLA adhere to a high standard which “aims to develop *technological literacy* in students through the cultivation of” not only *technological understanding,* but *technological capability* and *technological awareness* as well. The lack of discussion and implementation of the last two literacy elements in the 2017 Curriculum Guide may reflect the downsides of insufficient teacher training in terms of offering practical learning activities. Besides, as not only stated in the latest TEKLA Curriculum Guide, but also in the former one in 2002, there are not one but three strands of the Curriculum, namely, *Knowledge Contexts in Technology, Process in Technology and Impact of Technology.*

As evidenced by the emphases in the 2000 document such as “hands-on,” “authentic,” “interdisciplinary nature of technology,” and “problem-solving learning activities as the vehicle to realize the aim of TE,” it is not difficult to realize that the core of the TE framework is technology learning activities [TLAs]. In brief, TLAs are “authentic hands-on problem-solving learning activities” (CDC, 2000c, 2001a) to develop students’ technological literacy. Teachers can select and organize TE learning experiences for students through the planning of TLAs. When carrying out TLAs, “…students are charged with a challenge or problem…manipulate materials and resources and equipment to meet perceived needs” (CDC, 2000c) with tangible deliverables, such as reports, artefacts, systems, etc.

Also, it is recommended that TLAs can be used to reflect the characteristics of technological activities in real-world situations (e.g., serving human needs, purposeful, interaction with materials and nature, interdisciplinary nature, etc.) as the problem-solving process that students adopt in TLAs “capture technology in action” (Lewis, 1999).

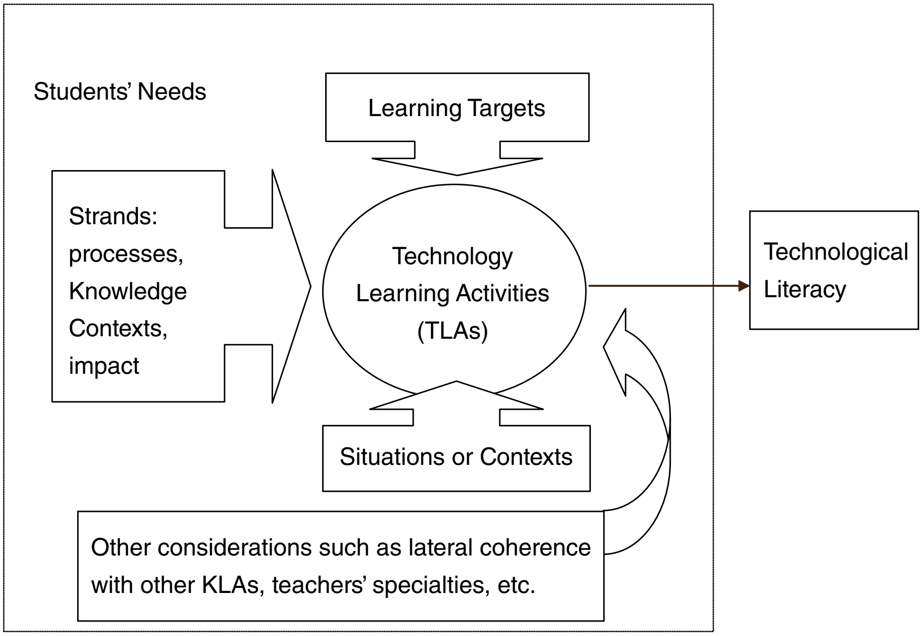


Figure 3. Schema for Formulating TLAs (Extracted from CDC, 2000b)

The TE Curriculum Framework (CDC, 2002) stipulates the above schema for teachers to formulate TLAs. It states the parameters to be considered in planning learning activities and also illustrates how they work together to contribute to the development of Technological Literacy.

The "processes" strand states the capabilities to solve technological problems. The totality of these capabilities is regarded as a "design process" or "design cycle," the widely used learning and teaching mode in D&T.

From the above schema, it is obvious that the "Knowledge Contexts" strand serves as the selection criteria and organizers of learning elements from the subjects in the TEKLA including D&T, CL and HK/TL. Table 4 further explains the relationship between these three subjects and the six Knowledge Contexts.

Table 4. Relationship between the three TEKLA subjects and the six Knowledge Contexts

	Information and Communication Technology	Materials and Structures	Operations and Manufacturing	Systems and Control	Technology and Living	Strategies and Management
CL	✓					
DT		✓	✓	✓		
HE/TL					✓	
Business						✓

Then, why is the Knowledge Context "Strategies and Management" in the junior secondary curriculum? In fact, it is not common for Hong Kong schools to offer Business at the junior secondary level. However, in order to ensure that the learning experiences can adopt a broader definition of technology, the learning elements of Business and related entrepreneurial understandings are provided through the "Strategies and Management" Knowledge Context. Together with the other five Knowledge Contexts and by means of the flexible selection and organization of the learning elements in formulating TLAs, the goal of TEKLA in the 2000 Curriculum Guide to develop students' Technological Literacy with broad and balanced learning experience can be achieved.

The above paragraphs aimed to illustrate the differences in the focuses of learning in TEKLA in the Curriculum Guides of the 2000 and 2017 editions. It is concluded that the unfortunate overstressing of the content of Knowledge Contexts in the latest TEKLA Curriculum Guide (CDC 2017) undermines the importance of the role of practical problem-solving activities, that is, TLAs. The consequence is reflected by the insufficient and even missing practical components in the Post-Graduate Diploma of Education (PGDE) in the D&T

program, as will be discussed in the latter sections.

THE STATE-OF-THE-ART OF TECHNOLOGY TEACHER EDUCATION- INFORMATION & COMMUNICATION TECHNOLOGY (ICT)

In the past, four universities provided PGDE in ICT programs in Hong Kong. They are the University of Hong Kong (HKU), the Baptist University of Hong Kong (HKBU), the Chinese University of HK (CUHK) and the Education University of Hong Kong (HKEdU).

Since the websites and PGDE program flyers of the HKU and HKBU do not list ICT as courses available after 2020, information is only available from the other two universities that will offer PGDE courses majoring in ICT in Hong Kong in this academic year. The two courses are operated by the Faculty of Education of the CUHK and the Department of Mathematics and Information Technology (MIT) of the HKEdU. The following will report on the CUHK PGDE in ICT programs.[8]

CUHK PGDE in ICT Programs

The Faculty of Education of CUHK offers both 1-year full-time and 2-year part-time programs for students majoring in ICT.

There are two types of part-time program: "Teaching" and "Non-teaching." For the "Teaching" program, the applicants have to be full-time serving teachers in secondary schools, whilst the "Non-teaching" program is purported to provide opportunities for applicants who have the aspiration to join the teaching profession.

The enrollment requirement is graduation with an honors degree. The major

8 https://www.fed.cuhk.edu.hk/pgde/cuhk_secondary_study_scheme.html was referred to in preparing this part of the report.

areas of study of students enrolled in the PGDE ICT programs are mainly Computer Science, IT, or related disciplines. They also have to fulfil the English language requirement prescribed by the Graduate Council of the CUHK before being admitted to the program.

The students usually serve as senior secondary level ICT subject teachers after graduation. Normally there are four to five students admitted to both the full-time and part-time programs respectively. Estimating the numbers of graduates from the PGDE in ICT programs of the other three universities, that is, HKU, HKBU and HKEdU, there used to be 24-25 ICT teachers trained in full-time programs and another 30-40 teachers trained in part-time programs.

Usually the lessons of the PGDE in ICT programs take place on weekday evenings and Saturday mornings for both full-time and part-time students.

Table 5. CUHK PGDE Program structure

I. Required Courses	**8 Units**
Curriculum and Instruction Domain (take 1 major Subject Curriculum and Teaching)	*3.5 units*
Educational Administration and Policy Domain	*1.5 units*
Educational Psychology Domain	*3 units*
II. Core Electives	**4.5 Units**
At least one course from each domain	
III. Electives	**4.5 Units**
3 other courses of any domain, can take core electives, electives or minor	
IV. Teaching Practice	**3 Units**
Total：	20 Units

Students admitted to the PGDE in ICT programs are required to complete all requirements for graduation within the maximum period of study, that is, 3 years for full-time students and 4 years for part-time students.

The graduation requirements that students have to complete are stipulated by the following program structure:

Description of the Courses Related to an ICT Major

A description of the courses related to the ICT Major is given as follows (as provided on the website of the Faculty of Education, CUHK[9]):

1. PGDE 5022 & 5122 Subject Curriculum and Teaching (SCT) Major: Information & Communication Technology.

This is a SCT course that provides the most important subject matter related to ICT learning and teaching such as basic teaching skills and pedagogical knowledge of the ICT subjects in secondary education. Topics include:

(1)The development of the curricula in Hong Kong, the aims, objectives, learning activities and assessments;

(2)Instructional plans, teaching methods, classroom and laboratory management; and

(3)Treatment of selected topics in the ICT curriculum in senior secondary education.

2. PGDE 5172 Teaching and Learning with Information and Communication Technology

This is an elective course open not only to ICT majors but to students from other majors as well. The topics in this course include:

(1)Development of multimedia and online resources for educational use;

(2)Integration of multimedia and eLearning into classroom teaching;

9 https://www.fed.cuhk.edu.hk/pgde/cuhk_secondary_course_list_and_descriptions.html was referred to in preparing this part of the report.

(3) Information literacy framework and development at secondary school; and

(4) Application of ICT in instructional design in the secondary teaching context.

Normally, attendance of lessons and completing the stipulated assignments are the requirements for students to complete a course, although in some cases (very likely in elective courses from other domains or majors) there may be tests, the results of which will contribute to the completion requirements.

It is worth mentioning that, as stated in the program structure, the three units of Teaching Practice (TP) are an essential requirement for students to complete the entire PGDE program. It serves as the main vehicle to facilitate student teachers' development of professional capabilities as well as their professional behavior and attitudes.

TP supervisors from the Faculty of Education will visit and assess the student teachers during their TP period in view of providing them with support.

Full-time Program students are required to complete two blocks of TP, with each block lasting 5 weeks (including a preparation week), throughout the study of the PGDE program. Each student will be assigned to a TP school by the Faculty of Education. One of the special features of the PGDE program of CUHK is that the Faculty of Education will invite experienced teachers in the TP schools to act as "Teaching Advisers" to support student teachers with guidance and supervision throughout the TP period.

Students in the "Teaching" Part-time Program will carry out TP at their serving schools throughout the 2 years of study with the same duration required for the full-time program students.

Part-time students admitted via non-teaching mode should complete two blocks of 4-5 consecutive weeks of TP within 2 years, and complete the first block in their first year of study. As students are not full-time serving teachers, the TP Office of the Faculty of Education will provide support by arranging TP schools for them.

As mentioned in the previous section, ICT is one of the Knowledge Contexts in the TEKLA Curriculum Framework. In the senior secondary curriculum, ICT is also an elective subject that students can choose to sit for the HKDSE.

As stated in the Information and Communication Technology Curriculum and Assessment Guide: Secondary 4–6 (CDC & HKEAA, 2015), the senior secondary ICT curriculum aims are no doubt in accordance with the aims of the TEKLA, that is, to develop technological literacy in students with particular focuses on the essential ICT-specific knowledge, problem-solving skills and the understanding of the impacts of ICT to the society.

Nevertheless, it would be a classic struggle for teachers of high-stakes subjects that will be counted in the university-entrance examination to strike a balance between the realization of the subjects' purposes of greater responsibility for the students (e.g., developing their technological literacy in a broad and balanced manner) on the one hand, while endeavoring to prepare and push them to excel in the public examination so that their university place could be more secure on the other.

In view of preparing student teachers to better cope with the challenges emerging from the daily school teaching, the CUHK PGDE in ICT program adopts a practice-oriented stance to plan the course matter. It is more subject-teaching-and-learning-focused rather than education-theory-inquiry-based in order to ensure that students are well-equipped with a good grasp of the subject matter and sound ITC subject-specific pedagogical content knowledge to support the learning of the students in secondary schools. Therefore small-class teaching/ micro teaching is an important feature of the program, especially in the SCT courses.

Furthermore, as a key measure to develop PGDE students' capability in lesson preparation, the SCT courses require students to compose two lesson plans that include elements of objectives, content, learning activities and pedagogical planning, and assessment. Therefore, students can realize these plans during their TP and equip themselves well with handy teaching programs that they can immediately implement in their job.

Another challenge posed to teachers in the TEKLA is the ever-evolving technological advancement. In order to have the students keep abreast of the latest developments, the CUHK PGDE in ICT program incorporates an IT Lab that features the latest technologies including VR, drones and Micro:Bit embedded systems, etc. These technologies are ready to be integrated into classroom situations so that they can enhance the learning experiences and the subject matter of student teachers in ICT.

CHALLENGES AND INNOVATION OF TECHNOLOGY TEACHER EDUCATION-ICT

In the discussion with teacher trainers of the PGDE in ICT program, two main challenges were identified. The first is the resource limitation due to the minor subject branch in the university, and the second is the issue of distinguishable subject status under the introduction of STEM education.

Although the importance and significance of ICT is widely accepted by the general public, the subject of ICT is not a mainstream subject at the senior secondary level. It is not as welcomed as those traditional science subjects and humanities subjects by students and parents. This can be attributed to its lack of competitive edge in comparison with mainstream subjects in the admission to business subjects, which are highly favored by the public in this commercial-dominant society.

When it come to the situation in the faculties of education in universities, ICT is not so popular as the core subjects of Chinese and English Languages and

Mathematics that will be likely to have more teaching vacancies in schools. Consequently, the resources allocated to the PGDE in ICT program is limited in terms of number of teaching staff and the student admission quota each year.

This limitation leads to two problems. Firstly, as the number of staff teaching the course is limited, it also means the professional experiences that the teacher trainers bring to the lessons are not of great volume and variety compared to those of major subject programs. It is a great burden to those trainers in the ICT program to equip the student teachers with adequate subject matter and pedagogical strategies to teach their students. Secondly, the small class size is not conducive to forging a sense of belonging to the "community of practice" (Lave & Wenger, 1991) of the ICT subject. The low number of "buddies" might reduce student teachers' sense of belonging and their professional morale. Besides, there will be a fear that given the constantly low number of teachers trained, the profession will vanish in days to come, which would further hinder the establishment of personal subject identity.

One of the strategies adopted by the PGDE in ICT program teacher trainers to cope with these challenges is to arrange school visits to outstanding ICT schools. Although these visits are arranged during school hours, requiring the student teachers to take leave from their work, they are very eager to join. It is evidenced that these visits can broaden student teachers' exposure to different teaching styles in the subject and a variety of good quality teaching programs. They can have first-hand experience of what excellence in ICT teaching pedagogy and innovative learning activities look like. Also, student teachers can take the chance to build connections with outstanding teachers. This is crucial to their professional development as they can participate in the ICT professional community to look for supports and assistance as well as exchange professional expertise with fellow teachers. More importantly, they will come to know that there are good fellow ICT teachers out there, and this is very helpful for them to forge a sense of subject identity

The second challenge to the PGDE in ICT originates from the introduction of STEM education in recent years.

The introduction of STEM education is a global phenomenon, but given the inconsistency and instability of its definition (e.g., Bybee, 2010; Wan et al., 2017; Williams, 2015) there exist issues in determining its scope and position in the school curriculum as well as what will be the appropriate learning experiences to achieve the purpose of STEM education, which is also yet to be defined, and how the subject works under the banner of STEM education.

To the teacher trainers of the PGDE in ICT program, this issue invites the question of what the role of ICT will be in STEM education. It would require a clear and distinguishable subject identity of ICT in STEM education before it can fully contribute to its development. The strategy employed to cope with this challenge is the endeavor initiated by the ICT professional community as well as the teacher trainers to promote learning experiences with ICT signatures, including coding, machine learning etc., with a view to reinstating the distinct contribution of the subject.

THE STATE-OF-THE-ART OF TECHNOLOGY TEACHER EDUCATION-D&T

The current teacher education of the D&T subject is not in a desirable state as there is no formal and sustainable full-time undergraduate preservice teacher education program entailed to the subject. Volk (2006) argues that one of the big lessons from the sudden collapse of the D&T BEd program in 2006 was the continued lack of public awareness. The authors would like to depict the evolving stages of the teacher training programs of the D&T subject in three episodes, which are characterized by the shift in government policy and public perception, but not least by the importance and significance of a subject in the curriculum. They are the "Down-the-wind" period, the "In-the-Doldrums" period and the "Catching-the-STEM-monsoon" period.

The authors must confess that due to difficulties which emerged during the Covid-19 lockdown period (including the need to social-distance), it was forbidden to conduct tête-á-tête exchanges with stakeholders involved in the offering of the current Post-Graduate Diploma of Education (PGDE) teacher training course. Until the time the report was finished, the authors could not approach or receive sufficient information from the staff of the HKEdU PGDE to furnish the report on the "State-of-the-art of the D&T teacher training course" section. Therefore, it is with regret that we can only provide the description of the situation with the information available to us at the time of writing.

The "Down-the-Wind" Period (Circa 1970s to 2006)

The policy of adopting compulsory education in Hong Kong dates back to 1965, the time of the White Paper "Education Policy" forging the plan for compulsory primary education for all. This plan was implemented in September 1971. By that time, technical schools and pre-vocational schools were established for preparing students who had finished their primary education for their career development. Before that, trade schools which trained labor for shoemaking, printing and carpentry had been established for decades. The turning point of transforming from craftsmen training to technician training came with the establishment of Morrison Hill Technical Institute (MHTI摩理臣山工業學院) in 1970. MHTI is also the first official technical teachers' training institute in Hong Kong. Hong Kong Technical Teachers' College (HKTTC香港工商師範學院) was established in 1974, and all the technical teacher training courses were absorbed from MHTI into this new college. By that time, courses on teacher training of Design and Technology had started to bloom.

From September 1978 onward, all children of the right age had the right to enjoy free education up to Secondary 3, and it became compulsory in 1980. In 1994, HKTTC was merged with another four teacher education institutes to form The Hong Kong Institute of Education (HKIEd). The setting up of the

Department of Engineering & Technology Studies (ETS) paved the way to the offering the Bachelor of Education (BEd) degree program majoring in D&T.

Over this period of time when the preparation of the BEd course was underway, the 2-year full-time to 3-year full-time Technical Teacher Certificate and then the following Certificate in Education (CE) specializing in D&T were gradually migrated to the 4-year full-time BEd degree majoring in D&T. Annually there were around 20 student teachers who graduated from the CE course in this period of time. When the ETS Department moved to the Tai Po Campus in 1997, the degree program was first offered in "mixed-mode" format to facilitate the holders of former CE to attain graduate status. The full-time 4-year BEd course received the first intake of around 20 students in 2000 and at the time of its cessation in 2006, approximately 60 student teachers received their preservice studies in the then HKIEd. Concurrently there was also the operation of the PGDE program.

The introduction and implementation of the compulsory education policy by the then colonial government gave a boost to the expansion of the entire education system and every teaching profession. Together in line with the then expansion and prosperity of light industries, the exponential increase in schools coupled with the expansion of technical subjects and the later D&T subject forged the once golden-age of the D&T teaching profession.

The "In-the-Doldrums" Period (Circa 2006 to 2016)

The hard time for the D&T educators began in 2006, from which time officially no formal or recurrent full-time preservice teacher training program was offered.

Unlike other Asian countries, for example Singapore, that adopt a "Masterplan" mentality to maintain a balanced economy, the voices of fading out technical schools and pre-vocational schools became louder in 1997 due to the economic shift of Hong Kong from an industrial and manufacturing economy to a financial economy. Starting from the 2006/2007 academic year, HKIEd ceased to run teacher training courses on technology education, reflecting this shift in the perceptions of the general public and the government alike.

Ten years after the return of sovereignty to China, The Government of the Hong Kong Special Administrative Region of the People's Republic of China (HKSAR) implemented 13 years of compulsory education up to Secondary 7, with the policy maintained until the present day. A new 3-3-4 schooling system was put in place, which denotes 3 years of Junior Secondary, 3 years of Senior Secondary and 4 years of Tertiary Education for Hong Kong students. At the same time, there are no longer technical or pre-vocational schools at secondary level as nearly all of these schools opted to rebrand into grammar schools with the technical and vocational labels removed. In the case of the grammar schools, many school principals and administrators took this rebranding as a reminder to rethink the value of placing the D&T subject in the school curriculum, with the preconceptions that it is inferior, involves handicrafts and is apprenticeship-like. The result was the declining numbers of schools offering D&T from around 300 at the turn of the century down to around 200 nowadays. Whilst the judgement of the value of the D&T subject contributed to a certain extent to this decline, the null supply of new D&T teacher was also problematic. The vicious cycle was perpetuated as fewer schools offered the D&T subject, thus suppressing the demand for preservice teacher training, and further discouraging other schools from considering offering D&T in view of the teacher-supply void.

It is amazing that there were still some new teachers who entered the D&T profession at this difficult time. A considerable number of schools managed to employ teachers to teach the subject due to their understanding of its value to the development of the students' creativity and technological problem-solving ability.

From the limited amount of information available to the authors, there was no obvious evidence that there were any PGDE in D&T programs available in this period. Therefore, it is quite certain that those D&T teachers who newly entered the profession in this period of time hold teaching qualifications of other subjects such as computer science or ICT.

From the communication between the authors and fellow D&T teachers through professional exchanges in the activities in the Hong Kong Technology Education Association (HKTEA), a rough roadmap of "entering the field" for teachers with non-D&T teaching qualifications is charted in the discussion that follows.

Given the absence of specifically D&T trained new teachers, principals would shortlist qualified candidates with engineering, design and architecture degrees. Under the endorsement of the school management and the Incorporated Management Committee of the school, and occasionally including the discussions and consultations with officers of the Regional Education Office or Curriculum Development Institute (CDI), teachers were employed to teach the D&T subject.

It should be noted that due to the diversity of their backgrounds and degrees held, the learning experiences that these teachers provide to their students are heavily dependent on the expertise and knowledge their background and undergraduate studies could support. This is time that "on-the-job" professional development comes into play. It is observed that "on-the-job" professional development is conducted in two main modes.

Firstly, the "in-house" mode whereby the new teachers receive their on-the-job training from fellow D&T teachers in the same schools. This training may include pedagogy and instruction, planning and offering of design projects, using tools, equipment and machines, workshop activity management, workshop safety and regulations, housekeeping, school administrative procedures related to the subject (e.g., the procurement process, academic policies), etc. In some cases, it is witnessed that the artisans or the workshop instructors [10] who take care of the workshop are also indispensable and valuable stakeholders in this teacher development.

Secondly, the new teachers resort to "informal training" offered by experienced teachers in the D&T educator community. Either this kind of on-the-job development is carried out in an ad-hoc manner, that is, new teachers identify experienced teachers through personal or social connections, or they join short courses in D&T professional development offered by the CDI or by the HKTEA.

Although on-the-job development can fulfil a great part of the professional knowledge demanded for offering the D&T subject, new teachers whom the authors had contacted raised their need for the introduction of the purpose, rationale, values and key concepts of the D&T subject. They deem these the essential conceptions for them to reflect on and to refine their practices.

The "Catching-the-STEM-Monsoon" Period (Circa 2016 to the Present)

It was not until 2016 that the HKEdU started to offer PGDE D&T full-time and part-time courses and that the supply of graduates to the profession was resumed.

STEM education was addressed in the government's Policy Address in 2015. HKIEd was renamed The Education University of Hong Kong (EdUHK) in the year 2016. The EdUHK reran the Postgraduate Diploma in Education (PGDE) program for Design and Technology Education again starting from

10 Workshop instructors are only available in previously technical or vocational schools. During the "rebranding" endeavors mentioned previously, those schools opted to retain these posts and staff in view of their contribution to the TE subjects.

2016, partly because of the trend of promoting STEM education. The authors hold that the reason may in fact be twofold.

Firstly, thanks to the promotion of the notion of "integrative STEM education" (Sanders, 2009) by the HKTEA, the education community came to realize that D&T design projects (i.e., Approach 2 in implementing hands-on STEM education as stated in CDC 2015) are a better way to achieve the goal of Hong Kong STEM education, viz. to unleash the creativity of Hong Kong students. This constitutes one of the incentives to rerun the PGDE in D&T program in order to supply teachers with D&T teaching capabilities.

Secondly, the rediscovery of the value of D&T in the integrative project approach caught the EDB and the education community by surprise as they found that a big chunk of D&T teachers will retire in the coming few years. Thus, the EDB promptly decided to commit the Department of Mathematics and Information of the Education University of Hong Kong (HKEdU) to offering the PGDE in D&T Course.

The PGDE in D&T Program

The academic entrance requirement to the PGDE program is a relevant honorary Bachelor's degree. It is observed that the majors held by students in the PGDE are fairly relevant to D&T including Product Design, Engineering, IT, Liberal Studies, etc. Besides, there is a requirement that, when applying to the part-time program, the candidates should preferably be serving teachers in local secondary schools.

It is observed that more and more students with engineering or design degrees have been admitted to the PGDE in D&T program in these 2 years, and that they are more able to fit the learning of the subject matter and the practice of D&T teaching.

There are two modes offered by the HKEdU[11] in terms of the PGDE in D&T program, viz. the 1-year Full-time (FT) and the 2-year Part-time (PT) modes. Although there are no accurate figures available, the authors came to realize that the PGDE course intended to offer around 10 places for each of the FT and PT programs.

The PGDE in HKEdU is a modularized program consisting of 30-33 credit points (cps). The program comprises a program orientation and the following components:

Major Subject Studies - Subject Methods 6/9 cps

Core courses on general method and elective courses in areas of technologies that are D&T-specific. The Major Subject Studies for Design and Technology include areas such as curriculum, learning and instruction. The topics are:

- Learning and Teaching of Selected Topics in Design and Technology; and
- Problem-solving and Assessment in Design and Technology.

Education Studies 12 cps

This part of the program provides student teachers with an understanding of foundational disciplines in education including psychology, sociology and philosophy of education, as well as those generic skills for planning, teaching and assessment.

The topics are:
- Foundations and Processes of Learning;
- Philosophical and Socio-cultural Issues in Education;
- Teacher Leadership and Professionalism in Changing Contexts; and
- Curriculum and Assessment.

11 https://www.eduhk.hk/acadprog/pgde/Secondary.htm was referred to in preparing this part of the report.

Elective Studies - Core and General 6/9 cps

The Elective Studies part of the program is divided into two parts: Core and General. The Elective Core course enables student teachers to fulfill specific subject requirements, while the Elective General is to allow them to have choices in directing their own professional development. Elective courses for D&T subject major students are the following, of which students select three:

- Computer-Aided 3D Design and Printing Technologies;
- Creative Multimedia and Design;
- Design of Innovative Learning Environments; and
- Introduction to Programming and Problem Solving.

Field Experience (FE) 6 cps

Field Experience or teaching practicum is the main vehicle for student teachers to engage and socialize in school situations, experience school life and work, and develop competence, readiness and professional attitudes to enter the teaching profession.

FT student teachers are arranged to undertake two blocks of teaching practice in local secondary schools to try out teaching, while PT students, who are serving teachers in schools, undertake Field Experience to broaden their experience in classroom practice, and to reflect on and improve their practice by testing out new ideas and applying pedagogical principles in classroom teaching.

Besides the level of language proficiency to be attained for respective medium of instruction (MOI) in Hong Kong schools, participants are required to fulfill the requirements including the duration of the FE, the number of periods the participants will normally have to undertake, arrangement for PT student teachers in case they are not serving teachers in school, etc.

Qualified teacher status

In order to apply for registration as a teacher in Hong Kong, the candidate should hold a teacher qualification (e.g., a local Teacher's Certificate or Post-graduate Diploma/Certificate in Education) and must be a Hong Kong permanent resident.

The PGDE D&T program is largely operated in taught-diploma format. Students in the program will work to pass all cps requirements (assignments and examinations), must pass in the practicums and also pass the Information Technology Competency in Education (ITCE) before graduation. In fulfilling the above, the student teacher attains the "Qualified teacher status" that enables him/her to apply for teacher registration.

It is worth noting that in Hong Kong there are preservice training entry requirements. There are no specified professional development requirements for in-service technology teachers except the requirements applicable to all teachers.

Features of the Technology Teacher Education in D&T

It is observed that theory and lectures contributed a great proportion of the course of studies of the PGDE. Volk (2006) reports the demolition of all the labs of the ETS Department of HKIEd in 2006. For the time being, it is reported that all that is available for the PGDE in D&T program students is a STEM lab equipped with 3D printers and laser cutters, but no benches for using hand tools to carry out practical work. Furthermore, given the lack of workshops or labs for the development of practical skills, reportedly lectures with videos become the main source of instruction materials for learning practical skills for making, for example, using a coping saw.

Not until last year were visits to the Arts and Technology Education Centre (ATEC) [12] arranged for student teachers taking the PGDE in D&T program to broaden their exposure to the practical aspects of D&T learning. However, students attend these visits solely on a voluntary basis, as it does not constitute a course-completion requirement.

The demolition of all the D&T labs in 2006 resulted in the deprivation of training facilities in the HKEdU for the PGDE in D&T program, except for a STEM lab. It invites questions regarding the extent of the effectiveness of developing student teachers' capabilities and knowledge of conducting practical activities required in D&T design projects with the current facilities. It would not be unreasonable to maintain that practical skill development under these conditions is somewhat beyond the satisfaction of student-teachers and professional D&T teachers alike. The current situation illustrates the urgent need for on-the-job professional development for graduates of the PGDE programs as well as serving D&T teachers.

CHALLENGES AND INNOVATION OF TECHNOLOGY TEACHER EDUCATION-D&T

From the authors' observation in the latest developments in D&T education and related teacher training programs, two issues/ challenges are identified:

- Introduction of loose and ill-defined STEM education has led to an "anything goes" approach that downplays the significance of practical learning

12 The ATEC, which is operated by the EDB, offers D&T, Technology & Living and Visual Arts courses for Secondary 1 to 3 students for schools which lack venues and facilities for these subjects. From 2002, ATEC started to offer senior secondary subjects including Visual Arts, Applied Learning, Music, Design and Applied Technology. A "Makerspace" was to be established in October 2017 to promote STEM education and to be open for all secondary and primary schools.https://www.atec.edu.hk/index2.html

experiences in problem solving; and

- Teacher training for D&T will cease, again.

A loose STEM led to "anything goes"

It is interesting to find that both ICT and D&T educators regard the swift introduction of STEM education as problematic. By nature, STEM education development involves many stakeholders. As discussed previously, the definition of STEM is not stable; there is yet to be a common understanding of its purpose and nature.

From the authors' observation of the current practices of HK teachers, it is recognized that they regard STEM as:

- After lesson activities to reinforce learning;
- Post lesson activities to arouse interest;
- Traditional craft skill drilling;
- Something that can be put into other subjects but which is related to Science and Mathematics (S&M);
- An extension of the discovery approach;
- Making something based on S&M concepts; and
- Coding.

In particular, existing practices on implementing STEM in Hong Kong schools mostly include:

- More emphasis on hands-on experiments, or enriching the apparatus and equipment with digital or even DIY equipment;
- Introducing the discovery approach in making things ➪ dismantle things, observe and rebuild;
- Fun science product making, e.g. solar cars, manual generators, etc.;
- Employing smart devices to aid teaching, for example, using a digital pulse meter to measure heart beat rate, weather stations with digital logs, etc.;

- Simple coding. App building using GUI with stress on computational thinking; and
- Robotics: Treating robots as a vehicle for putting S&M learning elements into lessons.

Barlex comments that inherently “[T]he curriculum experienced by pupils in school will be the result of power struggles between vested interests” (Barlex, 2012). Therefore, it is not unnatural for every party involved to strive to define STEM education in accordance with the agenda favorable to their own subject characteristics. So “anything goes!”

In the case of Hong Kong, while STEM development is not under the helm of the D&T educators, STEM without practical elements but favoring investigation for the enhancement of understanding is deemed acceptable. In short, the challenges of STEM education come from the misunderstandings and misinterpretations of STEM. Its introduction obscures the crucial role of D&T design projects with diversified goals and learning and teaching demands of science, mathematics, and engineering education. In view of this, the authors would argue that it is more beneficial to the students’ learning if STEM is implemented using the problem-solving project approach, viz. design projects in D&T, through the integration and application of knowledge and skills from different STEM subjects.

Teacher training for D&T will cease, again

With regret, the authors would have to pronounce that there might come about the fourth episode of the course of development of D&T teacher training: “Tide over[13] - The beginning of the end.”

13 Tide-over: ‘When there was no wind to fill the sails, sailors would float with the tide until the wind returned. They would “tide over.”’ From https://oceanservice.noaa.gov/navigation/nautical-terms.html

There are clues that the PGDE might cease to be offered in the coming few years. One of the clues is that in the 5-year period from 2016 to 2021 there may be in total around 100 D&T PGDE graduates. Given that the total number of schools offering D&T is around 200, this figure is likely to offset the professional drain caused by the wave of teacher retirement. In terms of policy performance, it is a success since the PGDE program almost entirely settled the complaints about the shrinking in number of D&T teachers who are valuable in undertaking the conduct of practical problem solving learning activities for students. Given that a “balance” in the number of D&T teachers supply has been attained, it would not be unnatural to cease to or limit offer the program in view of cost-effectiveness of public money spent.

Secondly, there was a decline in the in-take number down to five in the part-time course in the 2020 academic year. In view of the utilization rate of the course facilities, it would very likely lead to the reckoning of the value and existence of the program.

Although the authors could not find any clues about the fate of the PGDE in D&T course, as they were not able to contact the relevant staff before the finalizing of this report, given the track record of the cessation of the BEd Course D&T major in 2006, it is not unrealistic to conclude that D&T teacher training could come to an end with the above two observations.

Volk (2006) argues that resembling the first closure of the BEd D&T program, the cessation of the PGDE in D&T program might be due to the fact that the D&T program has continually lacked public awareness and it “…is a big mistake…[that] the prospect of developing any new D&T teachers and continuing programs in schools is doubtful.” (ibid.)

As far as public money is concerned, it is unquestionable that the existence and sustaining of teacher training programs shall be blessed by policy-wise support from the central agency. It would be adorable if the formulation of the education policy related to D&T teacher training would take into consideration the role the subject plays in nurturing the competitiveness of the younger generation, and its characteristics and resources that enable it to attain the former.

Nevertheless, the authors concluded in the previous section that the Curriculum Guide (CDC, 2017) lays erroneous emphasis on the content matter of the Knowledge Contexts but not on the holistic, integrative, hands-on problem-solving TLAs, which deviates from the rationale compared with the original aim and objective of the TEKLA Curriculum Framework (CDC, 2000). Therefore, it is not frivolous to conclude that there is an urgent need for the central agency to have a good grasp of a clear vision of TE and the unique role that D&T can play in achieving the desirable outcome of TE, which could subsequently entail a sustainable and stable supply of high caliber D&T teachers to serve the subject aims. Any ill-informed planning if not short-term goals such as "filling up the place of teachers to be retired" would be sterile and in fact detrimental to the development of creativity and innovation capability in Hong Kong students. It would be even more devastating if the above-mentioned absence of foresight and vision leads to the instantaneous decision to ask any tertiary institution handy to offer teacher training courses that might not have practical workshop experiences for student teachers. Adding to the concern that Volk (2006) voices regarding the lack of scholar critical mass of D&T lecturers, there are chances that it might be run by non-D&T academics. This "anything-goes" mentality in the name of a broadest-sense of technology could certainly miss out the core capability of D&T project pedagogy that develops students' problem solving with tangible outcomes, which may result in teacher training programs that are far from desirable.

Innovation to cope with challenges: In search of the ideal D&T teacher training amid the STEM Challenge

As discussed above, STEM itself, unlike other disciplines, does not have a well-defined curriculum framework. Amidst the multitude of explorations and endeavors by schools and stakeholders at that time, the authors put forward under HKTEA the notion of "STEMaker" to conceptualize the vision and the strategies to implement STEM education in Hong Kong.

Suggestions regarding the purpose and content of the teacher training program based on the STEMaker education Curriculum with the following components are listed as follows:

- Vision: Nurture STEMaker through STEMaker Projects to engage in Small Innovation Enterprises (SIE)[14];
- Goal: Universal STEMaker Education for ALL students and to develop in them the qualities of an **"Anthropocentric perspective," "Technology literacy"** and an **"Entrepreneur mindset";**
- Curriculum organization: STEM in Edu+ Maker Culture = STEMaker Education;
- Pedagogy and learning experience: STEMaker Projects--authentic, hands-on, purposeful and user-oriented problem-solving learning activities. The concepts of **"4 types of Problem," "8 levels of STEM activities"** (Leung, 2019) [15] and the considerations in scaffolding a **"creativity space"** (ibid.);

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14 Small innovative enterprises normally comprise several young entrepreneurs who

- focus on the design and development of client-oriented products involving a range of technologies and related science and mathematics concepts and understandings.
- raise capital through cloud-funding
- depend on the collaboration and effective communication among members to operate and flourish
- are flexible in making timely adjustments to cope with the challenges and fluidity of the global market

15 The 4 types of problems are: Title-based Problem, Task-based Problem, Problem-based Problem and Theme-based Problem. The 8 Levels of STEM activities are: Craft skill project, Scientific investigation, Model making, Project using kits, Pro-

- Support: 4D Curriculum planning Tool & School-based curriculum development cycle; and
- Venue recommendation: STEMaker Space layout & equipment (科藝創建空間規劃).

The implication of the suggested components is the need to re-think what the teacher training course should look like in order to develop potential D&T teachers' knowledge, capabilities and values in teaching the subject.

Following an interpretive perspective, the situated-learning (Lave & Wenger, 1991) tradition, and based on the finding of a longitudinal study of a pre-service Graduate Diploma of Teaching course for secondary TE teachers, McGlashan and Wells (2013) suggest that "programmes that signpost pitfalls while building on students' own strengths and those of the curriculum to cope with the wide variety of interpretation and pedagogical approach of school communities" and "not only prepares teachers for teaching the pragmatics of the curriculum, but also concentrates on building a student teachers' own persona as a teacher."

Elsewhere, Banks et al. (2004) argue that in a good teacher training program, teachers have to go through the transition of subject knowledge into "school knowledge," that is, they have to transform their understanding of the knowledge and their capabilities acquired in the teacher training programs into their own set of practices, subject matter and wisdom that are compatible with the real-life school situation (Banks 2004). In accordance with this, pre-service teacher training should place a strong emphasis on promoting reflection.

In an evaluation of the TE teacher training in South Africa, Pool, Reitsma, and Mentz (2013) point out the same problem that Hong Kong is facing, namely

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gramming project, Project on embedded system, Problem-based project and Career orientated project.

that there is great demand for pre-service teacher training for potential teachers. By laying out a tripartite model of the professional competencies of the technology teacher, they put forward the consistent essential elements in the TE teacher training program that consists of knowledge (including subject knowledge and pedagogical content knowledge), skills (that is, subject-related skills and pedagogical subject skills) and values and attitudes (Pool, Reitsma, & Mentz 2013).

Suggested Teacher Training Course for D&T

Taking into consideration the characteristics of the learning and teaching in the D&T subject as well as the peculiar challenges that emerge in the Hong Kong context, the authors suggest that for a more desirable teacher training program for D&T, the components would be preferable to include:

- a broader understanding of the TEKLA curriculum and subject knowledge
- the development of master knowledge and skills required for practical work with a wide range of tools, equipment and materials
- TLAs lesson planning knowledge and skills
- understanding and reflection on the core values of TE and enhanced awareness of technological issues
- development of professional identity and career insights

Further, the authors would like to refer to the Framework of the Technology Education Professional Development Course (TEPDC) as proposed by the HKTEA under the finding of the **Technology Education ENrichment Initiative** (TEEN) (HKTEA, 2015) to illustrate the organization of the program:

Fundamental Work

1. To understand the TEKLA curriculum, its direction and purpose, especially the D&T curriculum
2. Technology - Technological Process & Skills, Technological Knowledge,

Technology & Society

3. Subject skills – Design concepts, basic knowledge of common tools, apparatus and equipment in a workshop or a design studio.
4. Subject knowledge - to have a comprehensive knowledge of D&T.
5. Health and safety requirements in a workshop and a studio
6. Knowledge of Technology Learning Activity
7. Subject-specific classroom/workshop management

Advanced Study

1. Technology Learning Activity (in particular the pedagogical content knowledge and assessment for learning practices required to support students' learning)
2. Designing and planning TLA
3. Activity planning strategy (School-based curriculum development)
4. Further subject knowledge such as design, animation, electronics, etc.
5. Administrative skills:
   - Procurement Procedures
   - Budgeting
   - Setting up a TE Workshop/Design Studio
   - Sourcing equipment, tools, apparatus and materials
   - Managerial Skills for running TE facilities such as a workshop
6. Designing programs for SEN students

Professional Requirements for Teaching in Workshops

As mentioned previously, the introduction of STEM education also raised the education community's awareness of the value of the workshop practices that the D&T subject can offer. However, at the same time it brings into focus the issue of workshop safety and thus invites the question of whether any professional qualification is required for teachers teaching in workshops.

In the era of "Teacher Certification" (circa 1970s to 2006), workshop safety was a core and essential component of the D&T teacher training course. Therefore, it is assumed that the holder of a Teacher Certificate in D&T is licensed to teach practical activities in a workshop situation. But could one apply the same level of confidence of “licensed to teach” in workshops to teacher training programs that fall short of practices of using tools and machines to work with materials? It is known to the authors that some school administration’s response to this practice-deprivation is to rename their workshops with other labels, so that teachers with less practical training can perform teaching there. But the trade-off will be the sacrifice of the authenticity and comprehensiveness, let alone the extent of the challenge of the learning activities offered.

Therefore, the authors would like to put forward the notion of a “Practical Teaching License” to augment the current teacher training qualification with a view to regulating teachers who can or cannot undertake the teaching of practical project-based learning activities (e.g., TLAs) in a workshop. It is preferable that the license would have a renewal mechanism, which requires license holders to be put under review in an interval of time, for example, 10 years, to ensure the integrity of their professional capability. The authors are well aware that the “Practical Teaching License” concept is out-of-the-blue to not just the general education community but to the D&T teachers as well. We are well aware that further serious deliberations on the focuses, components and aspects to be included in the license requirement are imminent for the license system to be substantiated and operationalizable.

CONCLUSION

The authors have done their best to compose this report, although the outcome is somewhat compromised by the obstruction resulting from the Covid-19 lockdown restrictions in Hong Kong. Without the chance of tête-á-tête exchange, the authors were deprived of not only access to some stakeholders, but also certain aspects of the information about the TE teaching training program. Under these constraints and with all the information available, the authors report the current situation, the challenges posed and responding innovative measures of the teacher training programs of TE, in particular ICT and D&T to the best of our ability.

The moral of the story distilled from this report is the need to forge a coalition of stakeholders including practicing teachers, tertiary education providers, officials of the central agency and emerging scholars and academics in D&T to build up synergy in pursuing desirable teacher training programs. Taking into consideration the special features and characteristics and the contribution of design projects to students' creativeness, these programs should enable potential teachers to undertake practical, project-based learning activities in workshops.

Foreign experiences show that the ideal program should not be narrowly focused on theories and lecturing, but should provide ample experiences of undertaking hands-on activities in design and making, as well as understanding and knowhow, mindsets that are cardinal in planning and conducting design projects. Moreover, the training should facilitate the student teachers' reflection in view of the need "to assist in the transition from specialist practitioner to developing teacher persona" (McGlashan & Wells, 2013).

Stakeholders in both ICT and D&T teacher training are aware of the influence of the introduction of STEM to the profession. The swift introduction of STEM in the school curriculum is yet to be accompanied with a clear and common understanding of its aims, purpose, principles governing the planning of learning experiences, conducting of learning activities and assessment. This lack of consensus leads to the danger of an "anything-goes" situation in the school curriculum and in the teacher training program as well. Co-efforts of the stakeholders in STEM should be called upon to work towards a consensus on the way it is to be implemented so that the training need of preservice teachers could be better defined and catered to.

Volk (2006) argues that the public awareness and understanding of the subject nature of D&T / TE are important in the struggle for the development of the subject and also the continuation of teacher training programs. It is because these can be translated into community and, hopefully, central agency's support that can eventually affect resources and funding and the continuation of the training program.

In accordance with this, the authors suggest a framework of a desirable D&T teacher training program that reflects the value of D&T in developing students' problem-solving and innovation capabilities through practical project-based learning activities. A licensing system is also put forward to highlight the importance of workshop practices in the learning of TE/D&T.

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TECHNOLOGY TEACHER EDUCATION IN JAPAN

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ABSTRACT

Facing the current and future Fourth Industrial Revolution and super smart society (society 5.0), it is questioned what technology education should be included in school education according to the stages of children's development. This includes an understanding of the roles that technology education has played, and the issues which should be addressed in the future. With the ideal of technology education for long-term "immutability and fluidity" (keeping the historical good points, working on new issues), this paper explains the history and the current situation of technology education in Japan from the viewpoint of educational content, educational methodologies and teacher education, and then reviews the existing issues and the strategies to address those issues. Furthermore, it is considered what future technology education should be like, while partnership with other countries and related issues are also mentioned.

Keywords: Technology Education, Teacher Education, Course of Study, Japan

INTRODUCTION

In Japan, in accordance with the spirit of the Constitution of Japan established in 1947, the Fundamental Law of Education is designated. This is the basic law on education which designates the educational goals and principles. The School Education Law, which designates the specific content of the Fundamental Law of Education, presents the organization and management of the school education system. In addition, government ordinance is established to enact educational laws, and detailed standards on school establishment and the Course of Study, which is the standard for educational curricula, are designated in ministerial ordinances and public notices by the Ministry of Education, Culture, Sports, Science and Technology.

Currently, Japan consists of 47 prefectures that include 1,724 municipalities. Those prefectures and municipalities are municipal corporations endowed with autonomy. In this situation, they have a nationally unified school education system. This is based on a 6-3-3-4 school system, that is, 6 years for elementary school, 3 years for lower secondary school, 3 years for upper secondary school and 4 years for university. Compulsory education consists of the 9 years of elementary school and lower secondary school. In addition to this, there is kindergarten prior to elementary school, and after lower secondary school, there are technical colleges, vocational schools and special training schools. Technology education is provided in many kinds of schools, but this paper discusses elementary schools, lower secondary schools and upper secondary schools which have technology education as part of general education. Specific data show that there are 19,892 elementary schools, 10,270 lower secondary schools, and 4,897 upper secondary schools in Japan (2020). Local residents elect members of their local council and the head of their local administration (prefectural governors, mayors, town managers, or village headmen), and committee members of the board of education are appointed by the head of their local administration based on the consent of the board. Although municipal corporations are endowed with a broad jurisdiction in terms of the local administration, the main functions of branch offices of the national administration organs are to provide the municipal corporations with advice and aid. Therefore, national ministries exert great influence on local administrations through the establishment of ordinances and standards. Similarly, school education is nationally unified, and one kind of school education system is provided by the Ministry of Education, Culture, Sports, Science and Technology in Japan.

The relationship so far discussed can also be understood in terms of the national aid system in the school education. For example, one-third of teachers' salary in compulsory education schools is supported by the nation, and two-thirds is supported by the municipalities. Besides, the nation provides financial support for half of the expenses including the construction of school buildings, teaching materials/teaching tools, economic aid for attending school, and educational promotion in remote places. This means that the nation, prefectures and municipalities take cooperative action. Therefore, a teacher certificate is systematized according to the Educational Personnel Certification Law by the Ministry of Education, Culture, Sports, Science and Technology.

This paper reviews technology education as a part of general education executed within the above-mentioned system and background, and the state of implementation of technology education, history, teacher education, issues and challenges of teacher education.

THE PROFILE OF TECHNOLOGY EDUCATION

Types of Schools and Subjects

Regarding where technology education is provided, it is in arts and crafts classes. In this subject, art content including drawing is provided in art classes, whereas technology education including making things is provided in craft classes. However, most of the time is actually spent on art classes and little time is spent on craft classes. It can be said that teachers do not offer craft classes partly because classes regarding technology education are seldom provided in elementary school teacher education.

At lower secondary school, technology education is provided in Technology and Home Economics, which is a required subject. In recent years, since 2002, the number of class hours for this subject has been 70 hours in the first school year, 70 hours in the second school year and 35 hours in the third school year. The subject name, Technology and Home Economics, was previously handled within a single framework under the policy that boys took technology education and girls took home economics education. This led to the combined name of Technology and Home Economics. Today, however, all students take the same curriculum without distinction of gender. Therefore, the number of hours spent on technology and on home economics is 35 hours each in the first school year, 35 hours each in the second school year and 17.5 hours each in the third school year. In the previous curriculum, the number of class hours was 70 hours in the first school year, 70 hours in the second school year and 70 to 105 hours in the third school year, resulting in the number of hours for Technology and Home Economics in the third year being significantly reduced. Moreover, at lower secondary schools, as a possibility of technology education in addition to this required subject, there was also the subject of technology as an elective subject. This used to be the subject to study in accordance with the community and school situation and the actual situation of the students, but this subject no longer exists.

However, in the new educational curriculum introduced in 2002, classes of integrated studies have been established, and are taught 70-100 hours in the first school year, 70-105 hours in the second school year and 70-130 hours in the third school year. The main educational content of these classes include information, environment, international understanding and welfare, and emphasis is placed on hands-on learning as seen in manufacturing. Therefore, it is quite likely that technology education is promoted within this subject, being extremely significant in light of both the educational content and the educational methods.

Furthermore, technology education in upper secondary schools is divided into general education (general course, 3,755 schools) and professional education (industrial course, 1,987 schools). The general course is for students who wish to proceed to higher education or who have not decided on specific vocational areas after graduation. Regarding technology education, this general course includes the subject “information” which started in 2003; however, a technology teacher cannot take charge of this information subject directly without obtaining another certificate.

On the other hand, the industrial course is divided into many vocational areas including industry, agriculture, business and fisheries. With the certificate of industrial education, which is obtained by many technology teachers when they obtain the certificate of technology education, they can get involved in all industry-related education including the machine course, the electricity course and the architecture course. Approximately 20% of upper secondary school students across Japan are enrolled in the industrial course.

In addition to the general course and industrial course, the integrated course (375 schools) was established in upper secondary school in 1994; it provides both general education and professional education. Although this integrated course has a characteristic of selecting subjects out of a wide variety of subjects in order to correspond to students' diversified interests/concerns, ability/aptitude, and desired future courses, the present number of schools that offer this course is still small; future increase is expected.

Textbook of Technology Education

In accordance with the public notice of the new Course of Study, textbook companies develop new textbooks and provide them to students. This process takes approximately 4 years from the notice, and the details including the former and the latter related content are shown as follows.

1. The Minister of Education, Culture, Sports, Science and Technology consults the Central Education Council on what new education should be provided in accordance with the needs of the next generation. Generally, this is executed every 10 years.
2. Each committee is held under the control of the Central Education Council with various discussions.
3. The Central Education Council submits a proposal to the Minister of Education, Culture, Sports, Science and Technology.
4. The Course of Study for each type of school and each subject is notified,

reflecting the content of the proposal.

5. Textbook companies edit and develop textbooks, following the Course of Study.
6. Textbook companies submit textbooks to the Ministry of Education, Culture, Sports, Science and Technology, then the Ministry inspects the textbooks.
7. Each board of education selects and adopts textbooks from the authorized textbooks (inspected textbooks). National schools and private schools select textbooks on their own.
8. The adopted textbooks are distributed to students and are actually used in classrooms.

Thus, samples of textbooks used by students are prepared by textbook companies based on the Course of Study notified by the Ministry of Education, Culture, Sports, Science and Technology and are inspected by the Ministry. Only textbooks that pass inspection are permitted to be sold. Adopted textbook companies start sales work for adoption. Although the adoption of textbooks is left to the discretion of boards of education of prefectures or municipalities, the expenses for the textbooks are all borne by the nation (the Ministry of Education, Culture, Sports, Science and Technology) in compulsory education. Then, they are used in lower secondary schools. Therefore, all textbooks used in all schools all over Japan have been authorized by the Ministry of Education, Culture, Sports, Science and Technology, meaning that uniform education is provided all over Japan.

Incidentally, the above-mentioned authorized textbooks of technology are provided by three textbook companies. Each company takes measures for adoption, considering textbook shape, color and design, organizing methods to interest students, and changes in social situations and lifestyles regarding technology. Taking this into account, it can be said that the editors from the textbook companies have profound knowledge of the technology subject. Currently, one company accounts for more than half of the textbooks in use.

Content of Technology Education

In this section, the educational content of technology education in the new curriculum and in the previous curriculum are compared. The six areas that comprised the previous curriculum until 2001 – “woodworking,” “metalworking,” “electricity,” “machines,” “cultivation,” and “fundamental education of information processing” – were integrated into two content areas in the new curriculum from 2002, that is, “technology and manufacturing” and “information and computers.” The content of the new educational curriculum consists of the following items:

“Technology and Manufacturing”
1. Roles of technologies
2. Design of manufactured articles
3. Material processing technology
4. Mechanism and maintenance of devices
5. Energy conversion
6. Cultivation of crops

The content of the latter area consists of the following items:
“Information and Computers”
1. Roles of information means
2. Bases of computers
3. Use of computers
4. Telecommunication networks
5. Use of multimedia
6. Program and instrumentation/control

From this, it can be found that “fundamental education of information processing,” which was one of six areas in the previous curriculum, is the main focus of the new curriculum, with the remaining five areas integrated into one area. This structure of the curriculum reflects the advent of the information society which changed the society and the living environment. However, considering that Japan achieved the present economic growth by manufacturing after World War II and that it will continue to be a nation active in manufacturing, this way of curriculum composition will remain an issue. Nevertheless, it is encouraging that the number of hours in terms of the teaching program is left to the judgment of the school or the discretion of the teacher, and there are reportedly many schools in which much time is allocated to the subject "Technology and Manufacturing."

Followed this, the next educational curriculum, starting in 2012, consists of the following items:

A. Technology concerning materials and processing
B. Technology concerning energy conversion
C. Technology concerning raising organisms
D. Technology concerning information

In addition, the next educational curriculum, which starts in 2021, will consist of the following items and textbooks provided to students.

A. Material and processing technology
B. Raising organisms technology
C. Energy conversion technology
D. Information technology

Thus, it is likely that the item category of the educational content from 2002 is fixed, but each educational content is selected (as a tradeoff) based on the ideal of "immutability and fluidity." Although the second and third items are exchanged in the table of contents of the textbooks from 2021, it seems that each lower secondary school takes the same content and methods as before. This is basically because the content and methods of the technology subject in Japan rely on classroom teachers.

Technology classes in schools are introduced here. Teachers decide on manufacturing subjects based on the main theme of technology education within annual allocated hours and the available budgets. Then, students formulate plans for manufactured articles (works) of manufacturing subjects, study the materials of the subjects, organize the plans, and work on designing and drafting. Following this, they work on manufacturing, in studying the tools, and devices and technological skills. Finally, they carry out self-evaluation and evaluation by others. These steps are carried out with lectures and practice. For example, when the total hours are 35, 15 hours are used for lectures and 20 hours are used for practice. In other words, technology classes are usually organized as manufacturing subjects, which is a project type.

Manufacturing articles are generally called teaching materials in Japan, but actually, the correct name is subject. Therefore, when two kinds of subjects are used, they are sometimes called the main subject and the sub-subject. Regarding teaching materials in technology class, the main material is the textbook and other materials include reference books, study notebooks, actual objects, models, audio-visual material and software material. By using many of these materials, effective and efficient education is provided in order to learn the knowledge and skills of technology.

Next, the evaluation of technology education is outlined. As previously mentioned, the educational curriculum will be renewed in 2021. Educational evaluation involves inspecting students' learning progress and guaranteeing the maintenance and improvement of educational standards in terms of the results. In addition, in subjects, it is carried out as "evaluation based on goals" which evaluates and rates the educational condition in each setting perspective according to the goals in the Course of Study, and it is expected to aim for fulfillment of intensive educational guidance and certain establishment of educational content for each student. Currently (2020), four perspectives of educational evaluation are "interest, motivation, attitude" "thought, judgement, expression" "skill" and "knowledge and understanding," whereas from next year (2021), they will be organized into three perspectives: "knowledge and skill" "ability to think, ability to judge, ability to express" and "attitude to take initiative in learning." It is necessary to improve the guidance format. Within the basic structure of this evaluation, learning is rated from stages 1 to 5 by judging with three perspectives in lower secondary schools. Especially with regard to "attitude to take initiative learning," it is introduced that teachers consider some aspects for evaluation, including descriptions in notebooks and reports, remarks in classes, behavior observation by teachers and self-evaluation and interactive evaluation by students. This is a recent issue for technology teachers.

History of Technology Education

The source of the present technology and home economics education goes back to the Fundamental Law of Education and the School Education Law that were established in 1947. The new-education-system lower secondary school was established with the extension of school age and the 6-3-3-4 school system, and the "vocational course" started as a subject corresponding to the "cultivation of the ability to select the future course in accordance with basic knowledge and skills in occupations needed in the society, an attitude respecting labor and the personality," provided in Article 36 (2) of the School Education Law. This vocational course consisted of five subjects - agriculture, industry, business, fisheries and home economics, and students were expected to take one or several subjects to study as required subjects for 140 hours.

From 1951 onward, the formerly separated home economics, which was one of the above-mentioned subjects, was integrated into a single subject with the name altered to "vocational/home economics." In the Course of Study, the content of the course consisted of four classes and 12 items: the first class (cultivation, breeding, fisheries, food processing), the second class (handicrafts, machine operation, drafting), the third class (paperwork, business book-keeping, calculation), and the fourth class (cooking, sanitation and child-care), and it was mandated that students study for 140 hours in every school year.

From 1957 onward, the content was divided into six groups, 22 fields and 52 items: the first group (agriculture), the second group (industry), the third group (business), the fourth group (fisheries), the fifth group (home economics) and the sixth group (vocational guidance). Regardless of gender, it was mandated that students spend 35 hours studying content in all groups except for the fourth group, and the remaining hours were spent studying content in selected groups among the first to fifth groups. In 1957, the rapid scientific and technological advances brought about economic stability and abundance to Japan, and the public calls for the promotion of scientific and technological education intensified.

From 1962 onward, “vocational/home economics” was reformed to establish “technology and home economics” comprising male-oriented technology and female-oriented home economics. This was the start of technology education as general education. The male-oriented education assigned comprehensive practice, in addition to designing/drafting, woodworking, metalworking, cultivation, machines, and electricity. The female-oriented education consisted of cooking, clothing manufacturing, household handicrafts, household machines, household electricity and childcare, with the individual details specified by grade. The number of class hours was 3 hours per week and 105 hours per year in every school year, totaling 315 hours in 3 years.

From 1972, for “technology and home economics,” in order to cope with the scientific and technological advances and the rapid economic, social and cultural progress, it presented that “the nature of the practical subject be clearly defined” in terms of the goal, and “the male-oriented education and the female-oriented education be associated with each other and basic items be carefully selected with the range and the degree clearly defined” in terms of the educational content. For the male-oriented education, the comprehensive practice was abolished, designing was studied in each area, and drafting was left as a separate area. As for the female-oriented education, dwelling was newly established, clothing manufacturing was changed to clothing, and cooking was changed to food. The number of class hours was the same as in the previous Course of Study.

Although the goal of “technology and home economics” from 1981 basically remained unchanged, the educational content that supported the goal changed significantly. The conventional male-oriented and female-oriented educational groups were abolished, and the new educational groups were composed of 17 areas: woodworking, metalworking, machines, electricity, and cultivation for males, and clothing, food, dwelling and childcare for females. It was decided that a school should select seven areas in total to offer to its students on the so-called mutual entry basis based on its judgment: six areas or more from the technology group and one area or more from the household science group for male students; and five areas or more from the household science group and one area or more from the technology group for female students. The number of class hours changed to 70 hours for the first school year, 70 hours for the second school year and 105 hours for the third school year, totaling 245 hours in 3 years.

From 1993 onward, woodworking, electricity, home life, and food were designated to be required subjects, out of the six areas of the technology group consisting of woodworking, metalworking, machines, electricity, cultivation, and newly established information processing, and the five areas of the home economics group consisting of clothing, food, dwelling, child care and newly established home life. They were designated to be taught under the same curriculum for male and female students. In addition, it was mandated that students study seven out of the 11 areas, with the number of class hours being 70 in the first school year, 70 in the second school year and 70-105 in the third school year. Besides, in order to deal with the newly established information processing education, teacher education has been actively carried out by the

Ministry of Education, Culture, Sports, Science and Technology, prefectures, municipalities, research organizations and local companies.

Technology and home economics from 2002 onward reflected trends in advancing technologies, informatization in society and daily lives, internationalization, aging society and progress of the time. Woodworking and electricity, which were required areas in the previous Course of Study, and metalworking, machines and cultivation, which were selective areas, were integrated into “technology and manufacturing,” whereas fundamental education of information processing, which was a selective area, became independent as “information and computers.” The number of class hours was reduced in the third school year, with 70 hours in the first school year, 70 in the second school year and 35 in the third school year.

From 2012 onward, various technologies used in the current society were organized in terms of four points: technology concerning materials and processing, technology concerning energy conversion, technology concerning raising organisms, and technology concerning information. It was decided to learn basic knowledge and technologies through practical and hands-on learning such as manufacturing assigned to all students; in addition, there was a focus on deepening the understanding of the relationship among technology, society and environment, and on developing abilities and attitudes to evaluate and use technologies properly for the establishment of a better society.

From 2021 onward, in addition to the diversification of family and family life, and changes in consumption, it is aimed to take the initiative in social rapid changes in the future such as globalization, progress of an aging society with a low birth rate, establishment of a sustainable society, and to develop students' skills to support technological progress and to take the initiative in technological innovation. Moreover, the aim is to develop students' skills to establish better lives and a sustainable society with technology by exerting the ways of viewing and thinking about technology, through practical and hands-on activities regarding technology such as manufacturing.

However, the number of hours in 2012 and 2021 is the same as that of 2002. This shows that the number of allocated hours for technology education in Japan is much less than in other countries. Furthermore, considering the future of Japan as a technology-driven nation, this is a big obstacle.

TECHNOLOGY TEACHER EDUCATION

Overview of Technology Teacher Education

Technology teachers are trained mainly in national universities in Japan, that is, technology teacher education is provided in the departments of teacher education in universities and teachers colleges. Furthermore, technology teachers are trained in the engineering and agricultural departments of national and private universities. These organizations provide credits in all required subjects based on the Educational Personnel Certification Law. However, in the former organizations, there is a case that credits cannot be provided by specialized instructors in all subjects of woodworking, metalworking, electricity, machines, cultivation and information, due to the decrease in the number of students in the departments of teacher education and teachers colleges, and to the lack of instructors for the fulfillment of other educational content. In this case, the credits are complemented by support from part-time or non-specialized instructors. Students who aim to be technology teachers need to study various specialized fields with a small number of credits from colleges of engineering, agriculture, science and education in which their university faculty have graduated from. Therefore, it is difficult for them to understand the content in all specialized fields, and as a result, they have no choice but to study broadly and shallowly.

On the other hand, in the latter organizations, those students who obtain a teacher's certificate in such faculties as electrical or mechanical engineering, or timber engineering in the agricultural department, study deeply in the specialized fields but relatively shallowly in terms of other fields. In other words, students who aim to be technology teachers from those faculties study the content of technology education deeply and narrowly.

In general, there are two processes in becoming a technology teacher: One is to enter a university with the objective of becoming a technology teacher in lower secondary school from the beginning, and the other is to obtain the technology teacher certificate as a second teacher certificate in addition to the first objective of becoming a teacher for elementary school or another school or subject. At the time of their graduation, it cannot be said sweepingly which students are better or which students recruiters think are appropriate. However, the latter students mostly graduate from their universities with a small number of credits in specialized content areas associated with the industrial arts, or graduate from their universities with a second class certificate (this is mentioned later), and as a result, some of them lack expertise or skill. In addition, many female students have recently entered universities with the objective of obtaining the teacher certificate for technology education; however, most of them tend to become teachers for elementary school as a result of the recruitment test, and the teacher certificate for technology education is not useful in this case.

The number of students in the departments of teacher education in universities and teachers colleges is small. This resulted from the fact that technology education as a part of general education is only provided in the subject of technology at lower secondary schools in school education, and that there are fewer technology teachers than teachers of other subjects in small-sized schools in Japan. Comparing urban and rural areas, in Tokyo or Osaka for example, the number of graduates from departments of teacher education in universities and teachers' colleges is small and the number of graduates from specialized departments is large, whereas the opposite trend is found in other areas.

Next, professional training of teachers after employment is regarded as important in every country and it has also become an important issue in Japan recently. The boards of education in prefectures and municipalities have provided training programs for beginning teachers in their first year and for teachers who have 10 years' experience. Now, as it is aimed to improve guidance such as subject guidance and student guidance, and to develop specialties by providing training programs according to each teacher's ability and aptitude, training for teachers who have 10 years' experience has been offered since 2003. Japan does not have a kind of point system whereby achievement is reflected in teachers' salaries every certain number of years, as is found in other countries. Therefore, once they become teachers, they are employed almost permanently, and self-improvement mostly depends on the discretion of the teachers. Active teachers belong to a regional, national or international research institute or professional organization to attend workshops or conventions to have discussions and make presentations. Incidentally, there is a nationwide organization for teachers of technology and home economics for lower secondary schools in Japan, which holds workshops in different prefectures every year. This is a place for technology teachers to share information on practical education and to have interactive communications.

On the other hand, there is a research institute mainly composed of university instructors for technology teachers. It is called the Japanese Society of Technology Education (JSTE), and it works on ideals and practices regarding education and comparative education research. This institute has maintained a long and deep historical relationship especially with educating technology teachers in lower secondary schools and industrial schools. The goal of this institute is "Research on technology education, work on its promotion and spread, keeping ties between members and contributing to the development of technology education," and its slogan is "Technology education is the key to reviving Japan as a technology-driven nation." This is the only institution of technology education and a cooperative academic research institute of the Science Council of Japan working on the following activities.

- Branch activities
- Group activities
- Holding national conventions once a year
- Publishing academic journals four times a year

As this involves teacher education, these matters are discussed here in detail. The Japanese Society of Technology Education has regional branch activities in nine branches: Hokkaido, Tohoku, Kanto, Hokuriku, Tokai, Kinki, Chugoku, Shikoku and Kyushu. Each region holds branch meetings and research workshops to promote the development and fulfillment of technology education in regions. Members are mainly university teachers. This is a place of activities for members who are interested in technology education including lower secondary school teachers and office workers in regions.

Next, this academic institute consists of specialists in various fields including engineering, agriculture, science and education. In order to make use of their specialties, the following groups have been organized for each field.

- Technology education group
- Material processing group (Wood processing)
- Material processing group (Metal processing)
- Energy group (Machine)
- Energy group (Electricity)
- Nurturing organisms group
- Information group

Meetings and research workshops are actively held by each group.

The national convention of this institute is held in each region every year, and universities in the region take charge of it. As Japan consists of 47 prefectures, each prefecture takes charge once every 47 years.

This is a research institute; therefore, it is important to work on various types of research and to present research papers. For this, the Japanese Society of Technology Education Academic Journals (ISSN 2434 6101) are published four times a year. In May 2020, volume 62 No.1 issue was published, that is, the journal has been published for 62 years. In order to be a member of this institute, the annual membership fee is 9,000 yen for a regular member, 3,500 yen for a student member, and the admission fee is 1,000 yen for only a regular member. This JSTE has been a cooperative organization of ICTE since the early years.

On the other hand, there is an organization called Japan Association of Universities of Education, consisting of 56 national teachers' colleges/departments. This divides the nation into nine regions and organizes 20 research departments and eight sections. The goal is "Improve the quality of universities and departments, promote academic development on education by interactive cooperation among members, and contribute to educational promotion in Japan." It is stated that "it consists of universities and departments mainly working on academic research on education and teacher education among national universities."

In this association, it is designated to place "all Japan research departments" with the approval of the board of directors in order to promote Association projects, comprising 20 subject departments and eight sections for each type of school. Besides, in regional meetings, teachers who are regional members work on projects based on the goals of the Association such as research on the theory and practical aspects of teacher education, and research departments can be established to promote regional projects. This association has a technology education department, and this greatly contributes to the development and fulfillment of technology as well.

Structure of Technology Teacher Education

The requirement for technology teachers in Japan is to study at a higher educational institution for 4 years after graduation from an upper secondary school, and to graduate from the university to obtain a Bachelor's degree. The number of national educational institutions to educate technology teachers in Japan is 42 in total, consisting of 10 single-department teachers' colleges and 32 departments of teacher education in universities. The number of private universities to educate technology teachers in the departments of engineering and agriculture is 21. There are 281 instructors in technology education courses to educate technology teachers. In terms of their educational background, there are 196 experts in technology (instructors for specialized content including engineering and agriculture), 47 experts in technology as well as technology education (instructors for methodologies of technology education) and 38 experts in technology education. In the meantime, the number of students who graduated from the universities is 329, including 250 males and 79 females. The number of students in graduate school Master's courses is 85 males and 11 females. The sum of graduates from universities and graduate schools is 425 (the data in 2003 is presented here as there is no current official data). Generally, the current number is said to be 70% of the above-mentioned number, although this is not recent data. The previous graduate school used to be called the Graduate School of Education with research purposes, whereas the current graduate school is called the Professional School for Teacher Education which works as a training center for those wishing to become teachers or to retrain in-service teachers.

Since the education system in Japan is uniform all over the nation, the educational content provided in teacher's colleges/departments is mostly the same. However, the abovementioned 42 educational institutions have common characteristics and originally improved characteristics in the content of teacher education. Here, the case of Aichi University of Education where the author previously worked (currently a professor emeritus of this University) is introduced as an example.

The subjects in the course intended for fostering technology education teachers of lower secondary schools and their numbers of credits (in parentheses) are as follows.

- Common subjects
  - Liberal arts
    - Constitution of Japan .... (2)
    - Basic subject. ....(6)
    - Theme subject ....(8)
  - Introduction of information education ....(2)
  - Foreign language subjects
    - First foreign language ....(4)
    - Second foreign language.............(2)
    - English communication ....(2)
  - Sport subjects ....(3)
- Professional education subjects (83)
  - Introductory Subject for Professional Education .... (2)
  - Common major subject .... (2)
  - Course study subject... (2)
  - Course major subject..(a)(34)
  - Teaching profession subjects
    - Course educational subject ..... (b)(8)
    - Educational subject ....(25)
  - Subject related to the course or teaching profession .... (4)
  - Graduation study ....(6)
- Independent subject ....(16)

Total number of credits ....(128)

In recent years, the subject for the development of practical skills is adopted to improve abilities as a teacher. The aim of this subject is to develop rich humanity and experts who can deal with various contemporary issues by experiencing lifestyles of diverse children and refining the senses through school activities. In order to achieve this aim, some activities are prepared including the introduction of school support activities, nature experience activities, multicultural experience activities and internship activities.

Next, the unique subjects for technology teachers are course major subjects to learn specialized fields, course education subjects to learn educational methodologies, and educational subjects. These are described in detail as follows.

(a) The course major subject provides breadth in specialized fields related to technology, and targets the following six areas required to obtain the teacher certificate. The course offers 18 required subjects with 20 credits and 24 selective subjects with 31 credits, totaling 51 credits. These are offered on the basis of the Educational Personnel Certification Law.

- Woodworking (drafting, lectures and practices on woodworking)
- Metalworking (lectures and practices on metalworking)
- Machines (lectures and practices on machines)
- Electricity (lectures and practices on electricity)
- Cultivation (lectures and practices on cultivation)
- Information and Computers (lectures and practices on computer)

(b) The course education subject provides the methodologies for technology education. This includes the following four required subjects with 2 credits each, 8 credits in total.

- Technology Education I
- Technology Education II
- Technology Education III
- Technology Education IV

Each subject is explained individually.

The goal and overview of Technology Education I are to take up current topics in relation to individual, social and natural environments surrounding technology education and to study them from a broad perspective. The plan and content of this course include the educational administration in technology education, the history of technology education, the value of technology education, the environment and technology education, computerization and technology education, internationalization and technology education, psychology of learning and technology education, and teaching materials and technology education.

The goal and overview of Technology Education II include instructional plans, learning processes, various tests, preparation of survey forms, selection and development of teaching materials, development of learning processes, usage of teaching materials, analysis of classes, and cultivating a sense of reality through the simulation of teaching practice. The plan and content of this course are the development of instructional plans and learning processes, the development of pre- and post-tests, preparation of survey forms, the selection and development of teaching materials, and the analysis of classes.

The goal and overview of Technology Education III are comprehensive studies on the goals, content, methods and assessment of technology education while associating the past research results and the actual teaching practice. The plan and content of this course are to analyze past research results relating to the goals, methods, content and assessment of technology education, and also to pursue various issues relating to the selection, development, arrangement and application of teaching materials used in industrial arts, and several issues relating to instructional design and educational guidance including its arrangement and use, and lastly, to study theories and methods to address those issues.

The goal and overview of Technology Education IV are to study intensively important environmental conditions in implementing industrial arts and various assessments concerning the class in a practical manner. The plan and content of this course deal with facilities and equipment, safety guidance, methods for educational assessment, assessment of content/methods of learning and assessment of content/methods of teaching.

(c) In the educational subjects, students carry out practical training to teach in a lower secondary school, and the following teaching practices are offered.

- Teaching Practice 1—basic practice
- Teaching Practice 2—major practice
- Teaching Practice 3—practice in other types of schools
- Teaching Practice 4—applied practice

Each practice is explained individually. The goal of the basic practice is to deepen the understanding of basic activities of school education through observation and participation in classes and school events, to deepen the understanding of children/pupils and to cultivate positive attitudes toward the teaching profession through communication with children. This subject is optional and worth 1 credit.

The goal of the major practice is designed to understand the work and the mission of teachers, to recognize the overall structure of school education, to learn the methods and techniques to understand and guide children, and to further deepen the study in the student's course or major. This subject is mandatory and worth 5 credits.

The goal of the practice in other types of schools is to learn the differences, characteristics, and continuity between school types through participation in a different type of school from the school type where the student implemented his/her major teaching practice. This subject is optional and worth 2 credits.

The goal of applied practice is to cultivate the professional competence, research and development capabilities for a teacher through such activities as TT (Team Teaching) and TA (Teaching Assistant), in order to further deepen the practical instructional capabilities. This subject is optional and worth 1 credit.

Teacher License for Technology Teachers

Teachers from kindergartens to upper secondary schools all over Japan must possess a teacher certificate granted by a prefectural board of education in accordance with the Educational Personnel Certification Law established by the nation. Teacher certificates are largely divided into three categories according to the school type – a regular certificate, an advanced class certificate, and a temporary certificate for assistant teachers. The teacher certificate for lower and upper secondary school is a certificate for each subject. A teacher who possesses a teacher certificate for kindergarten or elementary school can take all subjects, and a teacher who possesses a teacher certificate for lower or upper secondary school can teach the subject in which he or she was granted the certificate. Technology teachers of course follow this system as well.

Teacher education for regular certificates is offered in universities, and other schools such as junior colleges. Teachers who wish to obtain certificates need a basic qualification such as a Bachelor's degree from a university, and credits in subjects relating to a prescribed course and the teaching profession in a curriculum authorized by the Minister of Education, Culture, Sports, Science and Technology. The regular teacher certificate is categorized into the advanced class certificate, the first-class certificate and the second-class certificate. Basic qualifications for teacher certificates are: acquisition of a Master's degree, or more than 1 year of attendance in a specified department in university with the acquisition of more than 30 credits for the advanced class certificate; a Bachelor's degree for the first class certificate; and an associate's degree from a junior college for the second class certificate. The number of credits in subjects relating to the course and the professional qualification required to obtain a regular teacher certificate are stipulated by laws and regulations in accordance with the type of certificate. For example, one who wishes to obtain a first class certificate for lower secondary school teaching in technology needs to acquire 20 credits of course-related subjects, 31 credits of subjects related to the teaching profession, and 8 credits of subjects relating to the course or the teaching profession. Incidentally, 5 out of 31 credits related to the teaching profession are allocated to teaching practice.

It was decreed in April 1998 that it was necessary to take a 7-day nursing care course at a special education school or a social welfare institution in order for students who enter the university to acquire a regular teacher certificate for elementary school or lower secondary school. On the other hand, in-service teachers who have already obtained a teacher certificate can obtain a higher class of certificate by acquiring prescribed credits after working at a school for a certain period of time with acceptable levels of competency. A special certificate is granted to a member of society with professional expertise or skill (such as a computer-related worker) who has a Bachelor's degree, to enable them to be employed as a teacher. While regular teacher certificates are valid for life in all prefectures, the special certificate is valid for a period of not more than 10 years, and only in the prefecture where the certificate is granted.

A temporary certificate is a certificate for an assistant teacher, which is granted only in the case that a teacher with a regular teacher certificate cannot be employed. The temporary certificate is valid for 3 years in the prefecture where it is granted.

According to the establishment of the Revised Educational Personnel Certification Law in June 2007, the renewal system of teacher certificates was introduced on April 1, 2009. The aim, content and methodologies of this system are presented here. The aim of the renewal system of teacher certificates is that teachers engage in education with confidence and pride, and acquire social dignity and trust by obtaining the latest knowledge and skills regularly, in order to keep the necessary qualities and abilities of the time for teachers. It is not aimed to eliminate unqualified teachers. Next, regarding the basic design of this system, it is necessary to apply to a certificate manager (prefectural board of education) within 2 years after taking 30 hours or more of workshops for certificate renewal held by universities. If a certificate holder applies to extend his/her certificate before it expires is approved for a certain reason, or workshops are exempted, it is necessary to follow some procedures. Workshops of certificate renewal are intended for in-service teachers.

CHALLENGES AND INNOVATION OF TECHNOLOGY TEACHER EDUCATION

National universities of Japan, which had been formerly and directly governed by the Ministry of Education, Culture, Sports, Science and Technology, were converted to individual national university corporations in April 2004. Although they continue to be operated under the national budgets as in the past, competition among universities for research and teaching is intensified, and independence in fund raising is emphasized, due to the continuous constant reduction in the budgets. On the other hand, integration of national universities is demanded as part of the recent national university reform in Japan. As a result of voluntary integration, the number of national universities decreased from 89 in 2004 to 86 in 2020. In addition, the plan to integrate departments of education and teachers' colleges by region was realized, and some departments and universities have already been integrated and are executing roles shared among them. These situations mean that it will become impossible to carefully foster technology teachers by individual prefecture. This definitely poses a serious issue not only to all instructors in teachers' colleges/departments but also to the people of Japan.

In particular, because the technology education course is generally smaller in terms of the number of instructors but needs more facilities, equipment and a bigger budget for research and education than other subjects, the situation is much more serious. Paying attention to the current trend in the school situation in Japan, there is the fact that other subject teachers teach technology classes in small-scale schools instead of technology teachers, and it is a concern that qualitative and quantitative fulfilment of technology education in specialized aspects might be lowered. Educational statistics show that the number of schools with technology teachers is 7,774 out of 9,982 lower secondary schools in Japan, and the number of teachers with a certificate of technology education is 6,833, whereas those without a certificate is 750 (2017).

The current situation of this statistic in school education has led to a decrease in the number of technology teachers employed and a further decrease in the number and morale of students who aim to be technology teachers.

Once teachers in Japan pass the employment examination and are employed as teachers, their employment is extended unless they cause a scandal. Their salary is relatively high, and regular inspection of teacher qualifications is not strict. Therefore, training for self-improvement by in-service teachers mainly relies on their personal intention to undergo training and pursue research. For those who are positive about their improvement, it is considered to be important that instructors in universities and departments of teacher education offer training content to meet their requests and needs, and create opportunities for them to learn various specialized content and to provide information.

In these situations of universities and school education, and social background, the previously mentioned JSTE (the Japan Society of Technology Education) plans the following events and promotes the further development and fulfillment of technology education.

- Examination certifying teaching ability of technology teachers

"Examination certifying teaching ability of technology teachers" was established in 2008, and it is the first examination that this academic institute has provided to certify teachers' teaching ability. Focused on special knowledge and an understanding of technology, skills of design and manufacturing (including production, operation and development) and teaching students in classes, abilities or skills are measured with a writing test, a practical test and a trial lesson, then pass or fail is determined. This examination is administered once a year, and there are two levels: the standard level which is the minimum required level as a teacher, and the advanced level which a teacher with a position of leadership is expected to attain. Following "the standard for educating technology teachers" developed by each group of JSTE: technology education, material processing (wood and metal processing), energy (machine and electricity), nurturing organisms and information, this examination covers reference materials developed by selected members of those groups. Thus, the “Examination certifying teaching ability of technology teachers” is designed to evaluate the abilities of teachers in charge of the subject “technology.” Approximately 150 people have been certified so far.

- Contest on technology works with energy

JSTE consists of teachers of elementary, lower and upper secondary schools, technical colleges and universities, and people concerned in companies, who are involved in technology education including manufacturing and information. Every year it hosts the “Contest on technology works with energy” (abbreviation: Ene-Con). This contest aims to provide an environment (opportunity) in which students work on manufacturing with technological views, and to foster national understanding of technology (manufacturing) education. Specifically, use of energy which is important for utilizing technology as a main theme, and works using each source of energy are comprehensively evaluated according to some perspectives such as the aims of manufacturing and its functions, materials and processing methods used in manufacturing, mechanisms and mechanical knowledge, and creativity and originality. Ene-con has been held once a year since 1998, 22 times in total so far, and has been recognized widely by many institutes, organizations and individuals.

- Promotion and enlightenment on technology education

In addition to the abovementioned branches and groups, JSTE holds various committees including the elementary school committee, the upper secondary school committee, the technological knowledge investigation committee and the international relation committee, with each playing its respective role. What is equally important is public relations activities by means of newspapers. There are many public relations materials appealing to school education, society, companies and ordinary people. For example, “Technology education in the 21st century – illustration of technology education content as general education in each development stage,” and leaflets “How is technology education in the world now?” “Toward understanding and promotion of technology education” and “Technology education starting in elementary school.” All of these promote technology education in Japan and greatly contribute to educating technology teachers and developing students’ technological knowledge.

The author often gives lectures at prefectural education centers or public workshops and gets hints on what is needed by in-service teachers (educational content and educational methodologies). With these hints as a reference, projects that the author has continuously worked on are introduced as follows.

These projects have been implemented after the Ministry of Education, Culture, Sports, Science and Technology approved the application made by the author through the university. The titles and content of open workshops for in-service teachers, and content implemented in cooperation with others are presented. The overarching theme consistently remains “Course for the Development of Teaching Materials for Technology Education” and various types of content are offered every year with the following sub-themes added under the name.

(1) 1997: “Manufacturing of Wooden Products Using Thinned Wood”
The mountains of Japan consist of natural forests and artificial forests, and some of the artificial forests need to be thinned periodically; however, actually thinned artificial forests are no more than a half of the artificial forests in need of thinning. Furthermore, the quantity of thinned wood that can be actually used in the society is limited even if thinned. This is why an attempt was made to find if thinned wood could be used in school education along with the issue of the forest environment.

(2) 1998: “Manufacturing of New Practice Work Materials Using Wood and

Metal"

This is an attempt to manufacture new practice work materials by using two types of materials—wood and metal. Manufacturing of creative products with previously unseen applications, designs and combinations was attempted.

(3) 1999: "What Teaching Materials ought to be toward a New Course of Study and Assessment"

The new Course of Study states that it is important to manufacture products not only by using a single material but also by using multiple materials. This course dealt with manufacturing of products using three materials — wood, metal and plastic — that had never been previously attempted.

(4) 2000: "Robot Contest – Concept and Approach"

Robot contests have been held in various types of schools in recent years. This course suggested that, in order to implement a robot contest more effectively, it is important to push forward with the manufacturing of robots and contests after steadily mastering the fundamentals of the materials.

(5) 2001: Toward a New Course of Study "Information and Computers"

The new Course of Study provides that much time should be allocated to "Information and Computers." This course guided the curriculum from fundamental required content to selective areas for the development or applications for the sake of smooth execution of the class.

(6) 2002: Teaching Materials for "Technology and Manufacturing" Linked with Integrated Study

This course studies the methodology to link effectively and efficiently the industrial arts as required subjects, the industrial arts as selective subjects and the industrial arts in the course Integrated Study through the manufacture of practice work materials.

(7) 2003: Technology Education Advanced Theory I to Acquire the Advanced Class Certificate

In-service teachers who possess a first class regular certificate can acquire the advanced class certificate by acquiring the prescribed number of credits for lectures offered in graduate schools. This course was established to permit relevant teachers to acquire the credits through open lectures.

These open lectures were offered by the author in collaboration with teachers and researchers outside of the university. Many recent open lectures have been offered through cooperation with instructors involved in technology education courses within the university. The content has received high evaluation inside of the university as well.

(8) 2005: Manufacturing Event in Aichi Expo

A manufacturing event was held in the 2005 World Exposition, Aichi, Japan (Aichi Expo), making use of the above-mentioned experiences. The Expo was held for six months in Aichi prefecture with the slogans "Dialogue with Nature," "Experiencing Today's Technology" and "Exchange among the People of the World." Many exhibitions and events related to the environment were held there. "Manufacturing with Thinned Wood and Contest" was held by the author and other technology teachers at the civil pavilion in the Seto area, where we presented the importance of thinning and the use of thinned wood to visitors as a theme.

(9) 2005 – present: Manufacturing Workshop

With the Aichi Expo as a turning point, and adopting its slogans, workshops for children who are the next generation were proposed and have been developed so far in the Toyota Commemorative Museum of Industry and Technology. The project "Let's make things with thinned wood" was established with the approval of the author and other collaborators. This project provides activities to gain knowledge of artificial forests and manufacturing skills by touching, experiencing and getting familiar with thinned wood.

(10) 2011 - present: Toward Joining UNESCO Schools

It was decided that the UNESCO World Conference on ESD (Education for Sustainable Development) was going to be held in Nagoya, Aichi prefecture in 2014, and then, Aichi prefecture kicked off the movement to increase the number of UNESCO Schools that year. The author worked in Aichi University of Education at that time; however, at the request of the governor of Aichi prefecture, the author plays an important role in working for school education in Aichi. The number of UNESCO Schools in Aichi reached 50, which was the goal, and the current number is now 170.

(11) 2014: "UNESCO World Conference on ESD"

"The Decade of the United Nations ESD" (2005-2014) was adopted in the United Nations, and in 2014, which was the 10th anniversary year of this adoption, the World Conference was held. In this Conference, the symposium "Manufacturing and ESD" was held as a side event. In this symposium, an in-service technology teacher gave a presentation on ESD and technology education. Based on this Conference, the future policy was decided.

(12) 2014 - 2020: Toward Development and Fulfillment of ESD/SDGs Activities

Toward the development and fulfillment of UNESCO Schools as a base of ESD activities since 2014, consistent activities on ESD/SDGs (Sustainable Development Goals) have been carried out with in-service teachers: support for joining UNESCO Schools, support for fulfillment after joining UNESCO Schools, exchanges of ESD activities, forums in the Chubu bloc area, and presentations on the achievement of ESD activities at the end of fiscal years.

(13)1999 - 2020: JICA "Industrial Technology Education"

For approximately 20 years, the JICA training course "Industrial Technology Education" has been carried out, as technology education has played a central role which is the basic theme of this training course. This has been carried out thanks to many people, including technology teachers in lower secondary schools, instructors in departments and universities of technology teacher education and researchers from other countries. It is considered that these projects have definitely contributed to the development of technology education.

Looking back on these projects, it is clear that many of them involve activities with thinned wood and activities for sustainable development; in other words, ESD activities have been carried out by the author himself. It is clear that this leads obviously to the 15th goal of SDGs "Protect the richness of the land." Furthermore, in collaboration with other technology teachers, it is realized that this leads to the new development of technology education.

CONCLUSION

The current and future lack of labor is a serious issue in Japan due to the low birthrate and the decrease in the number of young workers. Therefore, some measures and systems are reviewed including various supports for children and young people, maintenance of working conditions, and elimination of sexual inequality. Furthermore, issue-solving is practically carried out for opening up the labor force and working content to foreign workers. Japan is a country of processing trade, importing ingredients and materials, making things (products) and exporting products. Although the importance of technology education seems to be the same in every country, Japan particularly needs processing technology due to its resource situation. In addition, it is important that technology education is greatly reflected in school education, and for this, it is necessary to address the specific issues that are being faced.

In order to achieve this, it is definitely essential to have an active attitude toward confronting the content and methods of technology education, reserving good old things (immutability) and adopting new effective and efficient things. Currently, in Japan, as presented in the proposal of the establishment of the third term basic plan on educational promotion, it is necessary to work on the direction and strategies of human resource development for the society from 2030 onward, in other words, a super smart society. Probably in historical changes, it is necessary to deal with all countries and regions in the world, regardless of whether they are developed or developing countries. Technology education is deeply involved with the basis of this, and researchers and educators need to take the initiative in international exchanges, such as sharing and exchanging information. Fortunately, the ICTE organization exists with a central focus on East Asia. This paper states how Japan is involved with technology education, especially the current situation of technology teachers and future issues. However, as mentioned in the next Course of Study, it is necessary in the future to review stances in terms of international cooperation and international collaboration as common issues, with ESD activities and 17 perspectives in SDGs which are the goals of ESD.

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TECHNOLOGY TEACHER EDUCATION IN KOREA

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ABSTRACT

The purpose of this chapter is twofold: (1) to provide an overview of the current status of technology education in the National Curriculum and, (2) to introduce a framework and major characteristics of technology teacher education and its challenges in South Korea. Technology education is an indispensable part of general education, and was first implemented under the title of Technology for both junior and high school students in 1970 in the Republic of Korea. The separate subject, Technology was integrated with Home Economics into one single subject in 1997.Unfortunately, the first institution of technology teacher education was not established until 1981, 11 years after the start of technology education. The following is discussed in the chapter. First of all, the current status of Korean technology education along with the school system in Korea is introduced. Second, the teacher education system for elementary and secondary schools is introduced. Third, the qualifications of technology teachers and the curricula of technology teacher education institutions are analyzed. Finally, challenges to overcome in technology education and technology teacher education in South Korea will be discussed.

Keywords: technology teacher education, Republic of Korea, technology education in South Korea, pre-service technology teacher, challenges of technology teacher education.

INTRODUCTION

South Korean children between the ages of 6 and 15 are required to attend school. The Korean educational system has adopted a school ladder that would follow a singular track of 6-3-3-4; that is, 6 years of elementary school followed by 3 years of middle school, which is junior high school, 3 years of high school, which is senior high school consisting of general high school, vocational high school and special purpose high school, and 4 years of college and/or university. Figure 1 shows the 6-3-3-4 school system in South Korea. The Korean educational system comprises a variety of national, public, and private schools.

All formal schools in South Korea abide by a national curriculum framework developed by the Ministry of Education. This standardized national curriculum in Korea has been revised every 5 to 10 years since the establishment of the government of the Republic of Korea after World War II. The Korean education system is highly centralized in general. For instance, the Korean Ministry of Education dictates the national curriculum along with regional guidelines. Only individual schools have the autonomy in part to add learning experience for students to the curriculum to stress the specific needs of the school.

The school year in South Korea is divided into two, spring and autumn, semesters. The spring semester extends from March through July (1^{st} semester) and the autumn semester from September through February (2^{nd} semester). There are summer and winter vacations between semesters. Attendance requirements in Korean schools call for a minimum of 220 days at all three levels including primary, middle, and high school.

Around 95% of students complete senior high school in South Korea, about 80% of whom attend general high schools, which are college bound, and about 20% attend vocational high schools.This represents a significant decline in the percent of the student population in vocational schools, as about 40 percent of students attended vocational schools as of the late 1990s (National Center on Education and the Economy, n. d. a, Para. 1, System Structure).

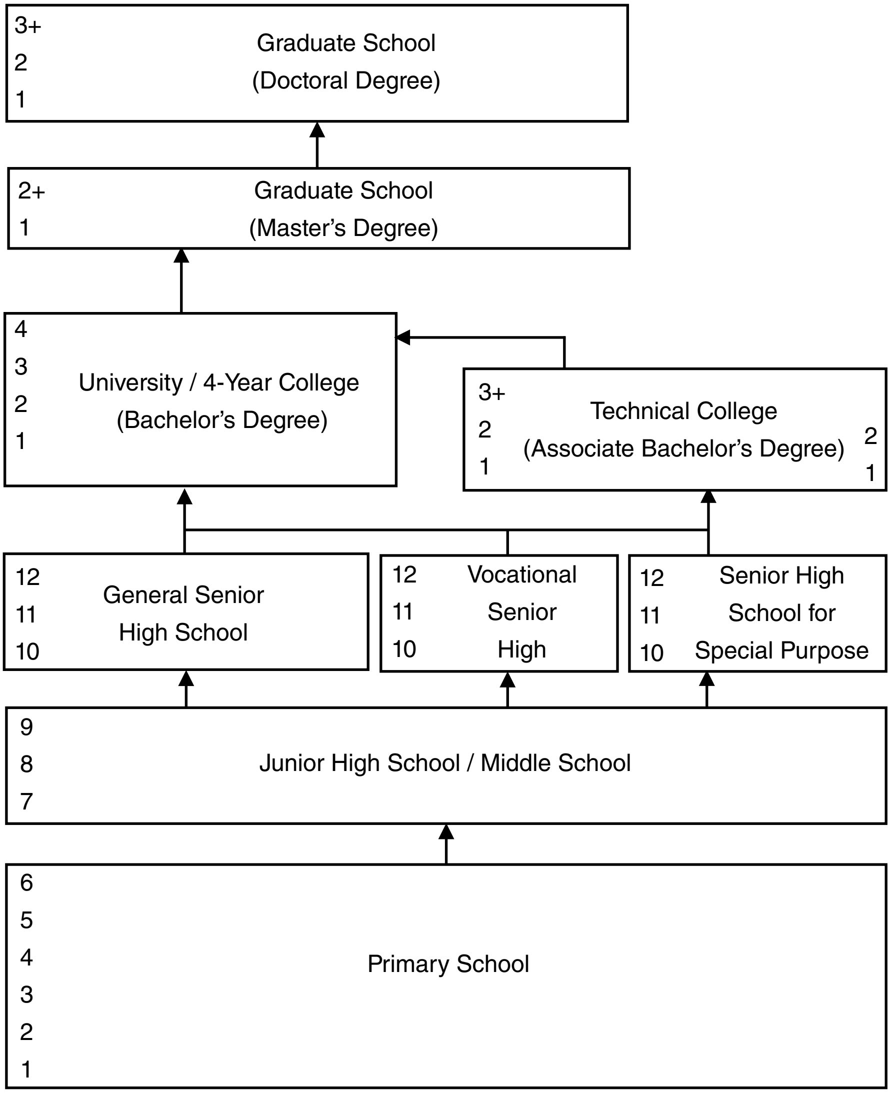

Figure 1. Educational System in South Korea

THE PROFILE OF TECHNOLOGY EDUCATION IN SOUTH KOREA

Korean technology education as an integral part of general education began to be offered to all students at the secondary level as a required and separate subject under the name of *'Gisul'* (literally meaning 'technology') from the seventh National Curriculum in 1970. All students in South Korea learned Technology in every grade of middle school and general high school from 1970 to 1996 (Yi, 1997, p. 42)

In 1997, the separate subject Technology was integrated with Home Economics into one single subject, Technology-Home Economics when the seventh National Curriculum was revised. Technology-Home Economics is a required subject for all students in middle school, while the integrated subject in general high school is an elective subject offered to all students usually in 10^{th} grade.

Application of this integrated subject in schools has caused a number of conflicts in the process of merging the two subjects into one, including organization of the curriculum, hours of instruction, teacher education, and so on.

A major goal of technology education in the current Korean National Curriculum introduced in 2015 is helping students to cultivate technological competence. Figure 2 shows the goal and major purposes of Korean technology education in the current national curriculum.

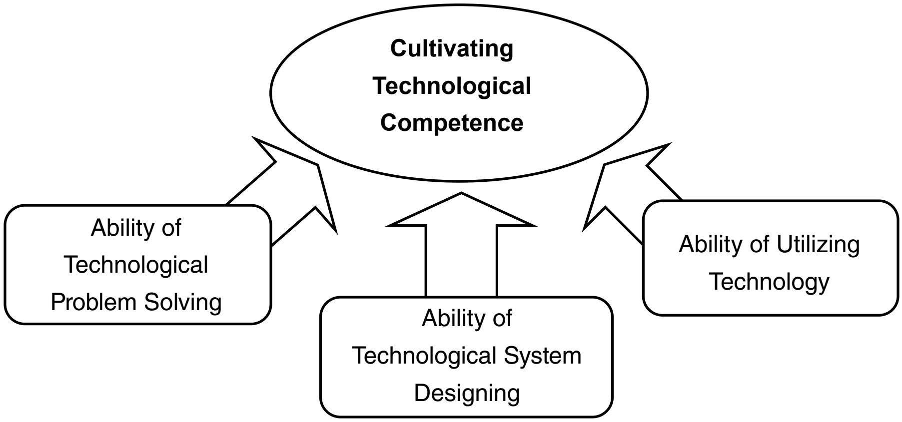

Figure 2. Goal and purposes of technology education in the 2015 revised national curriculum in Korea

The following two areas as major curriculum organizers of technology education were suggested in the current Korean national curriculum in 2015: (1) Technological systems including production, transportation, & communication technology, and (2) Utilization of technology including standardization, invention, and sustainability. Figure 3 shows the framework of technology education in the 2015 revised national curriculum in Korea.

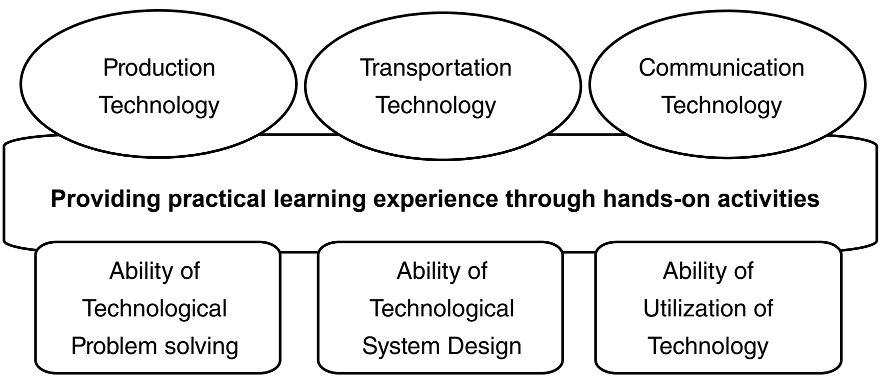

Figure 3. The Framework of technology education in the 2015 revised national curriculum in Korea

Six generalized areas of knowledge, namely production technology, transportation technology, communication technology, standardization & invention, adapting to the rapidly changing technology, and sustainability, were suggested as the major curriculum content areas of technology education. More elaborate descriptions of the six generalized areas of knowledge are presented in Table 1.

Table 1. The framework of the Technology Education Curriculum in Korea

	Area	Core Concept	Content (Generalized Knowledge)
Home Life (50%)			
World of Technology (50%)	Technological system	Creation	• Production technology uses a variety of resources to produce useful goods for human life.
		Efficiency	• Transportation technology improves the efficiency of space transfer for humans or objects.
		Communication	• Communication technological systems produce and process information and share it in various way and via devices which transmit it.
	Utilization of Technology	Adaptation	• Through rational decision-making processes, humans design their future and respond to advances in technology and social change.
		Innovation	• The inventions in the problem-solving and standardization in the development technology contribute to the innovation and development of the nation and society.
		Sustainability	• Humans predict changes in life according to technology development and keep society sustainable.

Adapted from Mimistry of Education, 2015c, pp.6-7.

The six areas of curriculum content of Korean technology education consist of content elements for each school level. They were placed in each school curriculum according to the scope and sequence of learning experiences of the six content areas. Table 2 shows the scope and sequence of content elements in the technology education curriculum by school in the current national curriculum.

Table 2. Content elements of technology education by school in South Korea

<table>
<tr><th rowspan="2"></th><th rowspan="2">Area</th><th rowspan="2">Concept</th><th colspan="3">Content Elements</th></tr>
<tr><th>Primary School</th><th>Middle School</th><th>High School</th></tr>
<tr><td>Home Life (50%)</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td rowspan="2">World of Technology (50%)</td><td rowspan="2">Technological system</td><td>· Production technology</td><td>• Bio-technological system
• Cultivation of plants.
• Breeding of animals</td><td>• .Manufacturing technological system
• Manufacturing technological problem solving
• Construction technological system
• Construction technological problem solving
• Future Technology and biotechnology</td><td rowspan="2">• Cutting edge manufacturing technology
• Cutting edge construction technology
• Cutting edge bio-technology
• Cutting edge transportation technology
• Cutting edge communication technology</td></tr>
<tr><td>· Transportation technology</td><td>• Transportation technology and life.
• Safety management of transportation means</td><td>• Transportation technological system
• Transportation technological problem solving
• New/renewable energy</td></tr>
</table>

(continued)

	Area	Concept	Content Elements		
			Primary School	Middle School	High School
World of Technology (50%)	Technological system	• Communication technology	• Understanding of software • Stages of problem-solving. • Elements and structure of programming	• Communication technological system • Communication technological problem solving • Media & mobile Communication	
	Utilization of Technology	• Adaptation	• World of work and vocation • Self-understanding and exploring vocation	• Development of technology • Technology & social changes	• Technology and vocation • Industrial accident • Safety of automobile
		• Invention & standardization	• Invention and problem-solving. • Protection of personal information and intellectual property • Function and structure of robots	• Technological Problem solving • Realization of ideas for invention • Technology Utilization & Standardization	• Creative engineering design • Invention and business starter-up • Technological development and standards
		• Sustainability	• Future Eco-agriculture • agriculture experience in life	• Appropriate technology • Sustainable technology	• Sustainable technology

Adapted from Mimistry of Education, 2015c, pp.6-7 & p.34.

The primary school curriculum in South Korea consists of the following nine subjects: Moral education, Korean language, social studies, mathematics, science, physical education, music, fine arts, practical arts and English. Table 3 shows these nine subjects including Practical Arts.

Table 3. Primary school curriculum in South Korea

<table>
<tr><th colspan="2" rowspan="2">Classification</th><th colspan="3">Grade</th></tr>
<tr><th>1~2</th><th>3~4</th><th>5~6</th></tr>
<tr><td rowspan="8">Subjects (Subject Cluster)</td><td>Korean</td><td rowspan="7">Korean 448
Mathematics 256
Disciplined Life 128
Intelligent Life 192
Pleasant Life 384</td><td>408</td><td>408</td></tr>
<tr><td>Social Studies/ Moral Education</td><td>272</td><td>272</td></tr>
<tr><td>Mathematics</td><td>272</td><td>272</td></tr>
<tr><td>Science & Practical Arts</td><td>204</td><td>340(Practical Arts 68)</td></tr>
<tr><td>Physical Education</td><td>204</td><td>204</td></tr>
<tr><td>Art (Music & Fine arts)</td><td>272</td><td>272</td></tr>
<tr><td>English</td><td>136</td><td>204</td></tr>
<tr><td>Sub total</td><td>1,408</td><td>1,768</td><td>1,972</td></tr>
<tr><td colspan="2">Creative Experiential Activities</td><td>336 Safe Life (64)</td><td>204</td><td>204</td></tr>
<tr><td colspan="2">Total hours of instructions</td><td>1,744</td><td>1,972</td><td>2,176</td></tr>
</table>

① In this table, one instructional hour is equivalent to 40 minutes of teaching. This time, however, can be adjusted according to weather and seasonal conditions, degree of students' development, the nature of the content to be learned, school circumstances, and so forth.

② Time allocation for each grade cluster and subject (or subject cluster) is the total number of instructional hours for 2 years, which is based on 34 weeks of teaching per year.

③ The total instructional hours for each grade cluster indicate the minimum number of instructional hours.

④ The instructional hours for Practical Arts are only applied to Science/Practical Arts for grades 5 and 6.

Source: Ministry of Education, 2015a, p. 10.

Technology education in primary school in South Korea is implemented through the subject, Practical Arts, for 5th and 6th graders. In other words, technology education in Korean primary school is a part of Practical Arts. The curriculum content of Practical Arts consists of technology, home economics, and agriculture. Technology education accounts for more than one-third of the whole Practical Arts curriculum. Practical Arts has 68 hours of instruction for 5th and 6th graders, meaning 2 hours of instruction per week.

The homeroom teacher (or class teacher) at Korean primary schools has a lot of work to do. He or she is in charge of starting the day with students, giving their classes, and ending their day at school. The primary school students in South Korea are taught all subjects through the homeroom teachers. In other words, there are no technology teachers who are responsible for teaching & learning technology at the primary school level.

Middle school in South Korea, which is lower secondary school, includes the following subjects: Korean, English, mathematics, science, social studies/moral education, technology-home economics, information, physical education, music and the arts, as well as some elective courses. Middle school students in Korea also have a special semester, what we call an "Exam-Free Semester." This unique semester gives pupils time each day to study either a course for exploring careers or to design their own independent study course based on learning by doing philosophy. During this semester, traditional paper-and-pencil tests are not allowed, even for regular classes, so as not to distract attention from the non-traditional activities. Table 2 shows subjects and allotted time by grade respectively in Korean middle school.

Table 4. Middle school subjects and allotted time in Korea

Classification		Grade7~9
Subjects (Subject Clusters)	Korean	442
	Social Studies, Moral Education	510
	Mathematics	374
	Science, Technology-Home Economics & Informatics	680 (Technology-Home Economics 272, Informatics 34)
	Physical Education	272
	Art (Music & Fine arts)	272
	English	340
	Electives	170
	Sub-total	3,060
Creative Experiential Activities		306
Total hours of instructions		3,366

① IIn this table, one instructional hour is equivalent to 45 minutes of teaching. This time, however, can be adjusted according to weather and seasonal conditions, degree of students' development, the nature of the content to be learned, school circumstances, and so forth.
② Time allocation for each subject (or subject cluster) is the total number of instructional hours for 3 years, which is based on 34 weeks of teaching per year.
③ The total number of instructional hours is the minimum number of hours for 3 years.
④ The standard instructional hours for organizing and implementing Informatics is 34.

Source: Ministry of Education, 2015a, p. 14.

Korean middle schools provide all students with Technology-Home Economics for 272 hours, which is 8 hours per week for the three grades. Typically, Technology-Home Economics is offered for 2 hours in 7th grade, 3 hours in

8th grade, and 3 hours in 9th grade. Technology education occupies half of Technology-Home Economics and therefore, for example, Technology is offered for 1 hour in 7th, 2 hours in 8th, and 1 hour in 9th grade.

Application of the following is strongly recommended in Korea for classroom teachers to help students cultivate technological competence: Project- (or problem-)based learning and cooperative learning in middle school. Overall, middle school teachers employ assessment using course portfolios, checklists, scoring rubrics, students' work as well as paper and pencil tests as a means of recognition of students' achievement in the two areas of technological systems and utilization of technology in daily life.

General high school in Korea is college bound and is an academic upper secondary school. Required subjects in general high school include Korean, English, mathematics, Korean history, science, science exploration and experiments, social studies, physical education and arts. Electives include Technology-Home Economics, Chinese characters, a second foreign language, and others.

Korean general high schools provide all students with Technology-Home Economics as an elective for three units. A unit is a period of 50 minutes per week during 17 weeks of one semester. Typically, Technology-Home Economics in general high school is offered as one of the general electives for 3 hours (units) for 10th graders.

Technology-Home Economics is divided equally between the two topics. Therefore, for example, Technology in general high schools is offered for 1 hour a week and for 2 hours the following week, alternately with Home Economics for 10th graders. As we need to secure self-sufficient time allotment for both theory and practice lessons in technology education, the shortage of teaching hours of technology lessons results in unqualified technology education at the secondary level in Korea.

An advanced subject of technology for 11th and 12th graders, General Engineering, is offered as an optional subject in general high schools. Unfortunately, the percentage of schools that choose to offer General Engineering is less than 1%.

Table 5. General high school subjects and allotted units in Korea

	Subject Areas	Subjects (Subject Clusters)	Common Courses (Units)	Required Units	Autonomous Implementation Units
Subjects (Subject Clusters)	Foundation	Korean	Korean(8)	10	Individual schools construct the curriculum in consideration of students' aptitudes and career plans.
		Mathematics	Mathematics(8)	10	
		English	English(8)	10	
		Korean History	Korean History(6)	6	
	Inquiry	Social Studies (including History/Moral Education)	Integrated Social Studies(8)	10	
		Science	Integrated Science(8) Science Laboratory Experiments(2)	12	
	Physical Education∗Arts	Physical Education		10	
		Arts		10	
	Life∗Liberal Arts	Technology-Home Economics/ Second Foreign Language/ Classical Chinese/ Liberal Arts		16	

(continued)

	Subject Areas	Subjects (Subject Clusters)	Common Courses (Units)	Required Units	Autonomous Implementation Units
	Subtotal			94	86
Creative Experiential Activities				24(408 hours)	
Total Units				204	

① One unit is equivalent to taking 50 minutes of teaching for 17 classes.
② One instructional hour is 50 minutes of teaching. This time, however, can be adjusted according to weather and seasonal conditions, degree of students' development, the nature of the content to be learned, school circumstances, and so forth.
③ Units assigned to common courses can be reduced by up to two units. However, Korean History must be implemented for more than six units and more than two semesters.
④ Science Laboratory Experiments, as a rule, must be organized and implemented without reducing the given units. However, high schools specialized in science, physical education, and art may implement this course with flexibility based on school circumstances.
⑤ The number of required units indicates 'the minimum requirement' which includes the units of common courses. High Schools with Special Purposes and autonomous private high schools are encouraged to allocate more than five units for the Arts subjects (or subject clusters) and more than 12 units for Life/Liberal Arts.
⑥ The total number of units in the Foundation may not exceed 50% of the total number of completed units in three years of high school.
⑦ The units for Creative Experiential Activities represent the minimum units, and the number in the parentheses indicates the equivalent instructional hours.
⑧ The total units indicate 'the minimum requirement' for students to complete during the 3 years of high school.

Source: Ministry of Education, 2015a, pp. 19-20.

Application of project-(or problem-)based learning and cooperative learning in general high school is also strongly recommended in Korea for classroom technology teachers. General high school teachers also employ assessment using course portfolios, checklists, scoring rubrics, students' work as well as paper-and-pencil tests as a means of recognition of learning achievement in the two areas of technological systems and utilization of technology in the real world.

■ STATE-OF-THE-ART TECHNOLOGY TEACHER EDUCATION

The Teacher Education System in South Korea

The National Center on Education and the Economy (NCEE) explains teacher recruitment and status in the Republic of Korea as follows:

> Teaching is a high status and well-paid job in South Korea. Recruitment of teachers is very different for primary and secondary teachers, however. South Korea has regulated the supply of primary school teachers, who are trained in only 13 institutions in the country, whereas it has not closely regulated the supply of secondary school teachers who are trained at a much broader set of institutions and programs. This has resulted in very competitive admission to primary school teaching programs and high job placement rates and less competitive (and more varied) admission to secondary teaching programs and a much lower job placement rate. Indeed, only about one in five trained secondary school teachers work as teachers. In addition to the oversupply of secondary school teachers, the licensing exams for secondary school teachers are very difficult, making licensing a key selection point rather than admission to initial training. (n. d., Para.1, Teacher Recruitment and Compensation).

The classification and qualifications of teachers in South Korea are defined in the Act on Primary and Secondary School Education. Teachers including technology teachers are classified into "Grade I and Grade II. They are required to meet the specific qualification criteria for each category and be licensed by the Deputy Prime Minister and Minister of Education as regulated by Presidential Decree" (Ministry of Education, n. d., Para. A. Teacher Education System).

The Korean teacher education system is divided into two forms by target students: pre-service teacher education which is a teacher preparation program for students who want to become teachers, and in-service teacher education for practicing teachers who are working in primary, junior high and senior high schools.

The former is offered in general at the 4-year undergraduate programs within a university. After students acquire a teacher's license upon graduation from the university or college, they must undergo the national screening process, what we call the "teacher recruitment examination" conducted by city/provincial education offices and local education authorities.

The latter is for the professional development of pedagogy and/or content knowledge of the subject.

Pre-service education including technology teachers for secondary schools in Korea are educated at 4-year universities or graduate schools of education.

The NCEE continues to sum up Korean pre-service teacher education as follows:

> Primary teacher candidates in South Korea are trained in undergraduate programs at ten national universities of education, two public universities, and one private university. Secondary teacher candidates have more training options: undergraduate programs in a broader range of colleges and universities or at graduate schools of education. Most are prepared in undergraduate programs. The

South Korean government has set up an accreditation system for teacher preparation programs to try to maintain quality across the system. As part of this system, it has required all programs to adhere to national curriculum standards and conducts periodic program evaluations of these programs, tied to program funding.

Every teacher in South Korea is required to have a subject major, which is listed on his or her teaching certificate. Teachers must earn about two-thirds of their credits in their subject majors and one-third of their credits in the teaching profession. Subject major courses include content knowledge and content-specific pedagogy, while courses in the teaching profession include educational theory and courses tailored to current social issues, as well as a practicum requirement. For primary teacher candidates, the practicum component is typically nine to ten weeks long and includes observation practice, participation practice, teaching practice, and administrative work practice. For secondary teachers, the practicum requirement length varies, but undergraduate programs typically include four week practicums. Once teachers have completed training programs, they receive a Grade II certificate, which allows a teacher to be hired by a school.

Teachers then must take a national employment exam before applying for a teaching position. This is a very competitive exam, which functions as a screening tool for teaching. Teachers are ranked based on their scores. Once teachers are hired, there are three stages of school-based induction: pre-employment training, post-employment training, and follow-up training… Pre-employment train-

> ing typically lasts for two weeks and focuses on the practical elements of job preparation, like classroom management. This is followed by six months of post-employment training, which is typically provided by principals, vice principals, and teacher mentors and involves instructional guidance and evaluation, classroom supervision and instruction on clerical work and student guidance. Finally, during two weeks of follow-up training, new teachers share what they have learned through presentations, reports, or discussion with peers. Teachers can be upgraded to Grade I certificates after three years of experience and required in-service qualification training. A Grade I certificate allows them to apply for more advanced positions, such as principal or Master Teacher. (n.d., Para. 2, Teacher Initial Education and Training).

Technology Teacher Education in South Korea

Even though the need to establish institutions of technology teacher education had been raised in South Korea, departments of technology education at teacher's colleges were not established until 1981, 11 years after the start of technology education. The absence of technology teacher education institutions in the opening years of technology education as general education has long caused numerous problems of identity of technology education and unqualified technology teachers in Korea.

There are two types of pre-service educational institutions of technology teacher in South Korea. The first type is departments of technology education at universities including Chungnam National University, Korea National University of Education and Daebul University. The second type is a Department of Technology and Home Economics education at the Kongju National University.

The license of technology teacher can only be given if "basic areas (or courses) of study to be completed" to acquire the technology teacher's license are provided in the institutions of technology teacher education. In other words, students must finish basic courses or areas of study in order to qualify for the license of technology teacher. The "basic areas (or courses) of study to be completed" stipulated by the Ministry of Education for each subject teacher such as English, History, Technology, and others as Korean national curriculum is revised. Current basic areas (or courses) of study to be completed for the technology teacher's license were stipulated in 2008.

The basic areas (or courses) of study to be completed to acquire a technology teacher's license consist of the following two main parts: (1) pedagogy of technology education, and (2) the content of the subject, which is technology. The subject content is subdivided into five areas, namely manufacturing technology, construction technology, transportation technology, communication technology, and bio-technology. The reason why the subject content comprises five areas is that they were the five major curriculum contents and/or organizers of technology education in the Korean National Curriculum at that time. Table 4 shows the basic complete areas and courses of study to acquire a technology teacher's license in South Korea.

Table 4. The basic areas (or courses) of study to be completed to acquire the technology teacher's license

Time	Basic area (or course) of study to be completed for the technology teacher's license	Note
Ministry of Education Notice No. 2008-119(2008.1.8)	(1) Pedagogy of Technology Education (2) Manufacturing Technology(Technical Drawing, Machinery) (3) Construction Technology(Civil Engineering, Architecture)	Should complete one or more courses in each area of (1) through (6)

(continued)

Time	Basic area (or course) of study to be completed for the technology teacher's license	Note
	(4) Transportation Technology (Energy, Automotive Engineering) (5) Communication Technology (Electrics, Electronics, Computer, Information Communication) (6) Bio-technology (Cultivating & Breeding, Foundation of bio-technology)	

Source: Ministry of Education, Science and Technology, 2009, p. 12.

These basic areas (or courses) of study to be completed for the technology teacher's license are offered as compulsory areas or courses in each institution of pre-service technology teacher education. Table 5 shows the full curriculum for specializing in technology education of technology education departments excluding liberal arts at colleges of education in Chungnam National University.

Table 5. Curriculum of Technology Education Department in Chungnam National University

Specialty Area	Courses for specializing in Technology education
Pedagogy of Technology Education	Introduction to Technology Education -Research method on Technology Education -Practical instructional design of Technology Education -Practical Cases of Technology Education -Teaching Method and Evaluation of Technology Education -Logical description on Technology Education -Research on Curriculum & Instructional Materials of Technology Education - The latest Trends in Technology Education

(continued)

<table>
<tr><th colspan="2">Specialty Area</th><th>Courses for specializing in Technology education</th></tr>
<tr><td rowspan="5">Subject content</td><td>Manufacturing Technology</td><td>-Mechanical Technology
-Manufacturing Technology
-Manufacturing Technology Practice
-Educational Robot Practice
-CAD Practice</td></tr>
<tr><td>Constructional Technology</td><td>-Civil Engineering
-Construction Technology
-Construction Technology Practice
-Construction Materials and Building</td></tr>
<tr><td>Transportation Technology</td><td>Transportation Technology
-Transportation Technology Practice
-Thermo-fluid Engineering
-Energy & Power</td></tr>
<tr><td>Information & Communication Technology</td><td>-Information & Communication Technology
-Computer Technology
-Electronic Technology
-Internet Technology Practice
-Computer Programming
-Foundational Practice for Electric & Electronic
-Advanced Practice for Electric & Electronic</td></tr>
<tr><td>Bio-technology</td><td>-Bio-technology</td></tr>
<tr><td colspan="2">Others</td><td>-Education and Computer
-Sustainable Development and Technology Education
-Wood Working Practice
-Educational Statistics and Computer Data Analysis
-Invention & Patent
-Vocation and Care
-Industrial Physics
-Industrial Mathematics
-Technical Drawing & Design
-Information Technology Practice
-Introduction to Creative Engineering Design
-Counseling for Future Design 1~6</td></tr>
</table>

(continued)

Specialty Area	Courses for specializing in Technology education
Others	-Case study of technology education -The latest Trends of Integrative Technology -Capstone design Technology Project -Utilizing Information & Communication Technology for Education -History of Science and Technology -Technology and Society -Integrative Technology Project -Introduction to Intellectual Property -Engineering Mechanics

Source: Chungnam National University, (n. d.), from http://english.moe.go.kr/sub/info.do?m=020109&s=english.

Table 6 shows the basic areas and compulsory courses offered in the Technology Education Department in Chungnam National University.

Table 6. The basic areas and compulsory courses offered in the Technology Education Department in Chungnam National University.

Area	Offered Courses as Compulsory	Credit	Method of completion
(1) Pedagogy of Technology Education	Introduction to Technology Education	3	Should get more than 21 credits for the courses by completing one or more courses in each area of (1) through (6).
	Teaching Method and Evaluation for Technology Education	2	
(2) Manufacturing Technology	Manufacturing Technology	3	
	Engineering Drawing	2	
(3) Construction Technology	Construction Technology	3	
(4) Transportation Technology	Energy & Power	3	
	Transportation Technology	3	

(continued)

Area	Offered Courses as Compulsory	Credit	Method of completion
(5) Information Communication Technology	Computer Technology	3	
	Information Communication Technology	3	
	Electrical& Electronic Technology	3	
	Electrical Technology	3	
	Electronic Technology	3	
(6) Bio-technology	Bio-Technology	3	

Source: Chungnam National University, (n.d.), p. 63.

Table 7 shows the curriculum of the Technology Education Department excluding liberal arts at the 3rd college in Korea National University of Education.

Table 7. Curriculum of Technology Education Department in Korea National University of Education

Specialty Area		Courses for specializing in Technology education
Pedagogy of Technology Education		Introduction to Technology Education -Curriculum & Facilities of Technology Education -Instructional Methods & Assessment for Technology Education -Research & Development of Instructional Materials for Technology Education -Logical description of Technology Education
Subject contents	Manufacturing Technology	Mechanical Technology -Technical Drawing and Design -Manufacturing Technology Practice -Application of Mechanical Technology

(continued)

<table>
<tr><th colspan="2">Specialty Area</th><th>Courses for specializing in Technology education</th></tr>
<tr><td rowspan="4">Subject con-
tents</td><td>Constructional Technology</td><td>-Architectural Technology
-Civil Engineering Technology
-Civil Engineering Practice
-Architectural Technology Practice</td></tr>
<tr><td>Transportation Technology</td><td>-Energy Technology
-Thermo-Fluid Dynamics
-Automobile Technology
-Thermal Engine
-Thermal Engine Practice</td></tr>
<tr><td>Information & Com-
munication Technol-
ogy</td><td>-Electrical Technology
-Information and Communication Technology
-Computer Technology
-Computer Practice
-Electrical Technology Practice
-Electronic Communication Technology
-Application of Information and Communica-
tion
-Electronic Technology Practice</td></tr>
<tr><td>Bio-technology</td><td>-Cultivation and Breeding Technology</td></tr>
<tr><td colspan="2">Others</td><td>Understanding of Technology and Technol-
ogy Education
Technology and Invention
Engineering Mathematics
Career Guidance
Technology-Centered STEAM
Engineering Mechanics
Understanding of Physical Computing</td></tr>
</table>

Source: Korea National University of Education, 2020, February 28, p. 122.

Table 8 shows the basic areas and compulsory courses offered in the Technology Education Department in the Korea National University of Education.

Table 8. The basic areas and courses of study to be completed for the technology teacher's license offered in the Technology Education department in the Korea National University of Education.

Area	Offered Courses as Compulsory	Credit	Method of completion
(1) Pedagogy of Technology Education	Introduction to Technology Education	3	hould complete one or more courses in each area of (1) through (6).
(2) Manufacturing Technology	Manufacturing and Design	3	
	Mechanical Technology	2	
(3) Construction Technology	Architectural Technology	3	
	Civil Engineering Technology	3	
(4) Transportation Technology	Energy Technology	3	
	Thermal Engine	3	
	Thermo-Fluid Dynamics	3	
(5) Information Communication Technology	Electrical Technology	3	
	Electronic Communication Technology	3	
	Computer Technology	3	
	Information and Communication Technology	3	
(6) Bio-technology	Cultivation and Breeding Technology	3	

Source: Korea National University of Education, 2020, February 28, p. 58.

The courses relating to pedagogy of technology education in technology teacher education institutions shown in above table 5, 6, 7, and 8 are taught by profession with specialization in technology education. The profession with specialization in technology education have a full understanding of technology education as an integral part of general education.

By the way the courses relating to subject content, namely technology in the technology teacher education institutions are instructed by profession with specialization in engineering, in other words engineer. The engineers in technology education have a lack of understanding of technology education as an integral part of general education. These engineers as instructor and curriculum organizer in the technology teacher education institutions are in charge of offered courses and/or areas relating to technology as subject content including manufacturing technology, construction technology, transportation technology, information communication technology, bio-technology, invention and/or standardization, and sustainable technology listed above tables. They like to stick to their own engineering-based nature of the body of knowledge when they both organize curriculum and teach. This subjective point of view of engineering have been in discord with curriculum of technology teacher education. Technology teacher education in South Korea is in need of not engineering but technology from a holistic point of view in order to cultivate technology teachers with qualitative professional knowledge, attitude and skills to effectively facilitate students' learning activities relating to technology.

In-service education of teachers including technology is offered to provide education for certificates and professional job training to establish a firm basis in education theory and methodology, while enhancing the ability to perform efficiently in the classroom. Educational programs are available for Grade I and Grade II teachers including technology and others. Each program lasts 30 days (180 hours) or longer. Educational programs are categorized according to the purpose: information digitalization, curriculum formulation training, general training, and teaching training. The head of the program may determine the course, content, and period of training contingent on the purpose of the training (Ministry of Education, n. d., Para. B. In-Service Training of Teachers).

Teachers' performance on training programs is quantified and managed for the purpose of utilizing such data in the promotion of teachers and wage increases. An assessment is conducted on those who complete 60 hours or more of the training program. Institutes providing teacher training are primary education training institutes, secondary education training institutes, educational administration training institutes, comprehensive education training institutes and distance education training institutes. Teacher training institutes are established at universities, teacher's colleges, local education offices or other organizations designated by the Ministry of Education (Ministry of Education, n. d., Para. B. In-Service Training of Teachers).

The following illustrates the professional development of teachers in South Korea:

> Teacher professional development is a key element of the Teacher Competence Development Assessment, implemented in 2010. Through this system, teachers' performance is evaluated by teacher peers, school leaders, students, and students' parents; evaluation results then inform individualized professional development plans. The highest-scoring teachers are eligible for research sabbaticals of up to one year, while struggling teachers may be required to pursue a certain number of hours or type of professional training.
>
> Professional development is offered through both public and private providers, with private courses subject to government approval. Courses include training for specific qualifications, as well as in-service training and special training opportunities that can include research sabbaticals or study abroad. Recently there has been an emphasis on expanding teacher-led professional development. For

example, in order to prepare teachers to implement the 2017 revision of the national curriculum, the Ministry of Education trained 13,000 teachers to facilitate professional development sessions at the school level. As of 2017, the government had also budgeted a total of □4 billion (US$3.8 million) to support professional learning communities across the country. Because training is worth points for teacher promotion, there is a direct connection between teachers' participation in professional development and advancement on the career ladder.

The national Professional Development Master Plan, developed in 2015, lays out a comprehensive structure. It recommends specific professional development opportunities for educators according to their stage of career development, from beginning teachers to Master Teachers and school leaders. Principals can also provide teachers with professional development support by recommending particular programs and using school funding to subsidize training (National Center on Education and the Economy, n. d., Para. 4, Teacher Initial Education and Training).

CHALLENGES AND INNOVATION OF TECHNOLOGY TEACHER EDUCATION

There are new challenges to overcome in technology teacher education in South Korea. First of all, there is a discrepancy between current basic courses or areas of study for the technology teacher's license and the technology education curriculum content. The current basic areas and courses of study for the technology teacher's license were stipulated by the Ministry of Education in 2009. The current curriculum of technology education has been revised twice since then. Therefore, current basic courses or areas of study for the technology teacher's license should be stipulated in accordance with the current 2015 revised national curriculum. Especially, utilization of technology including standardization, invention, and sustainability should be placed in the basic courses or areas of study for the technology teacher's license.

Another problem still facing the Korean technology teacher education system is the lack of qualified technology teacher educators. In teacher education, quality in the long run should be controlled and maintained more so than in any other profession. Technology teacher educators in Korea are divided into the following two groups according to their academic background: major in technology education and engineering. Technology teacher educators who have a Ph.D. in engineering have shown a lack and/or misunderstanding of technology education as an integral part of general education. In the South Korean technology teacher education profession, engineering majors outnumber education majors by five to one. In fact, lack and/or misunderstanding of the profession with specialization in engineering in technology teacher education about technology education has been a serious obstacle for technology teacher education to overcome.

There are only four departments of technology education in Korean universities. The enrollment quota is only 80, and faculty members are only 23 for the departments in total in South Korea. Currently South Korea is in need of quantitative enlargement of institutions of pre-service technology teacher education at the undergraduate program level at universities.

CONCLUSION

Technology education as general education began to be offered in both middle schools and general high schools in 1970 in Korea. The Korean technology education curriculum is related to the appreciation of industry and technology, vocation and career guidance, consumerism, and so on. Recently the technology education curriculum has reflected an increased emphasis on technological literacy and capability including creative problem solving, or what we call 21st century skills.

Technology education as general education in South Korea is a part of 'Practical Arts' at the primary level and a part of 'Technology-Home Economics' at the secondary level. In others words, Technology education has been offered not a separated subject but a part of integrative subject both primary and secondary schools since 1997. Technology education in South Korea under this reduced situation has a lot of problem including insufficient organization of curriculum, lack of instruction hours, securement of technology teacher, and so on.

Despite all of the achievements of technology education since 1970, some distinctive problems still face the Korean technology teacher education system. The educational institutions of technology teacher in South Korea need a lot of improvement in terms of both quality and quantity.

'Basic areas (or courses) of study to be completed' are required in the institutions of technology teacher education in Korea. The basic areas (or courses) of study to be completed to acquire a technology teacher's license consist of the following two main parts: pedagogy of technology education, and the subject content, which is technology including manufacturing, construction, transportation, communication, and bio-technology.

According to the saying, "the quality of an education system cannot exceed the quality of its teachers," the major determinant of technology teacher education will be the quality of technology teacher educators. Technology teacher education in South Korea is in dire need of quality technology teacher educators with a Ph.D. in technology education to establish the identity of technology education as an integral part of general education in terms of quality. More technology teacher preparation programs are needed at undergraduate schools in terms of quantity.

This chapter has described and discussed a variety of features and challenges of technology education and technology teacher education in South Korea. The issues raised from the chapter may be important in that the quality of technology teacher education is regarded as present among global technology education society. This chapter of Korean technology education and technology teacher education may offer insight into dealing with each country's own problems and challenges in consideration of its unique societal and/or cultural background. Further review of the different contexts of technology teacher education such as in South Korea may afford global insight into the fundamental works of recruiting and retaining high quality technology teachers. I wish this chapter may contribute to enlarging our collective understanding of technology education and technology teacher education in an absence of any definitive and comprehensive view of technology teacher education around the globe.

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TECHNOLOGY TEACHER EDUCATION IN NEW ZEALAND

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ABSTRACT

Undertaken in universities and other approved private providers, technology teacher education in New Zealand involves students in theory and practice. The New Zealand Teaching Council, the teaching professional body, regulates and approves courses and programs. Based on Constructivist principles situated within Sociocultural theory, teacher education in New Zealand focuses on meeting students' individual learning needs, and is founded on the principles of equality and inclusion, guided by the Te Tiriti o Waitangi, The Treaty of Waitangi, ensuring the specific rights of Māori and the New Zealand Curriculum.

Technology, briefly defined as "Intervention by Design", occurs through a range of contexts across three strands for learning: Technological Practice, the Nature of Technology, and Technological Knowledge, and within five technological areas: Designing and Developing Materials Technologies, Designing and Developing Processed Technologies and Designing and Developing Digital Technologies, Design and Visual Communication and Computational Thinking.

Technology in New Zealand, although world leading, faces a number of challenges. These include a lack of understanding of the philosophy and key ideas that underpin technology, low subject status based on its predecessor, technical education, and the lack of time and facilities available in teacher education programs. Many currently practicing specialist technology teachers struggle with the philosophical changes needed to move technology from a technical, skills-based program to the needs-based student-centered program outlined in the current curriculum. Over recent years in primary education in New Zealand, the Ministry of Education's focus on literacy and numeracy has led to the marginalization of technology education in schools and teacher education programs. It is hoped that recent revisions to increase the presence of digital

technologies in the technology curriculum, and the move to teaching through inquiry, whilst acknowledging students' lived experiences facilitates the consolidation of technology education as a learning area of status incorporating the duality of practical and academic thinking.

Keywords: New Zealand, Technology education, teacher education, curriculum pedagogy

INTRODUCTION

Aotearoa New Zealand is a democratic nation in the South West Pacific with a resident population of around 4.8 million. Nearly three quarters of the population identify as having European heritage, 15% as Māori, 12% as Asian and 7% as Pacific peoples. As the indigenous people of New Zealand, Māori have particular statutory rights under Te Tiriti o Waitangi, The Treaty of Waitangi, signed in 1840 between the British Crown and over 500 Māori rangatira (chiefs). This broader socio-political context is important because of its impact on educational policy and practice. For example, the Native Schools Act of 1867 significantly failed Māori students and communities by introducing English as the sole medium of instruction. The Waitangi Tribunal addresses violations such as these. One important change has been the recognition of te reo Māori, the Māori language, as an official language since 1987, and the emphasis in current education policy on the importance of Māori succeeding *as* Māori. In practice, this means there is an emphasis on culturally responsive pedagogies by the Ministry of Education. Teachers' practice in this context is critical since the majority of Māori tamariki and rangitahi (children and young people) attend English-medium schools, with only a very small percentage (2.5% of the total school population) taught in Māori Immersion settings.

To become a teacher of technology education, individuals must undergo formal Initial Teacher Education (ITE) programs (also known as pre-service teacher education). Teachers undertaking professional learning and development (PLD) after ITE can be referred to as *in-service* teacher education. There are 156 approved ITE programs in New Zealand, delivered as 80 qualifications by 25 providers. In New Zealand, both state and private institutions offer training programs. Seven of the nine universities have teacher education programs. These are the Universities of Auckland, Waikato, Canterbury and Otago, Victoria (in Wellington) University, Massey University, and Auckland University of Technology. Other pathways occur through private training institutions and are usually employment-based. Initial Teacher Education institutions offer programs for teaching in the sectors of early childhood education (ECE), primary, secondary, Māori and Pasifika education (New Zealand Teaching Council, 2020).

During teacher education, student teachers need to develop an holistic view of the nature of technology and how technology impacts and influences our world, people and the environment. There is also a need for student teachers to understand the role of content, pedagogical, and pedagogical content knowledge. They must also gain a thorough understanding of the values, principles and competencies that underpin and inform teaching in New Zealand. The way that teaching *looks* may differ slightly between ECE, Primary and Māori sectors, but practice is derived from a philosophy that respects and honors the Treaty of Waitangi (ToW). Signed in 1840, the ToW is an agreement between the British Crown and Māori that upholds the rights of New Zealand's Māori people, ensuring all New Zealanders have a right to fair and equitable educational opportunities to meet their future needs, thus enabling them to be confident, connected, actively involved, life-long learners (Ministry of Education, 2007).

This chapter is written from the perspective that student teachers' educational experience is closely related to their beliefs and values as professionals, which translates directly to their perceptions of the nature of technology, curriculum, pedagogy, assessment, and cultural ways of knowing. Both ITE and PLD teacher education need to focus on ways to influence teacher beliefs and values, as well as understandings of conceptual and pedagogical knowledge, with a view to enacting procedural knowledge (technological know-how) in classroom practice. The context for technology teacher education in New Zealand is described, including consideration of the influencers from the wider educational context. The profile of technology education in New Zealand is discussed, with reference to contextually relevant teaching and learning theory.

PROFILE AND STATUS OF TECHNOLOGY EDUCATION

The role and status of technology education has evolved, but its cross-disciplinary nature means that there is no single theoretical perspective to define it (Pacey, 1992). This presents a confusing professional climate for some technology teachers, who are required to navigate some uncertain challenges within their professional practice. Technology education yields unique opportunities to engage students in their learning – through both practical and innovative means. There are various types of differing and equally important understandings applied to the subject, including practical, conceptual, and tacit knowledge (Hill, 2003). For example, De Vries (2005) suggests that early philosophers about technology focused on the relationship between technology and people, or society, but more recently, conceptions of technology have focused more on what technology is. Both aspects are important and need to be understood in order to teach technology education effectively.

When asked what technology is, many people refer to technology as artefacts such as high-end electronic and digital technologies and align with a view that technology is a relatively recent phenomenon. However, an holistic view of technology education requires teachers to have a broader view of the nature of technology. Technology is an innate human endeavor. If you watch a group of pre-school children with a set of blocks and sticks – the way that they interact to build a structure illustrates this. Since the dawn of time, humans have intervened in the natural world by designing and modifying their environment, to make life easier or to increase their capability. They have identified and deployed a range of resources and materials to make tools, clothes, develop processes, and have manipulated materials to solve practical problems.

Technology education is briefly referred to as "Intervention by Design" in the New Zealand curriculum (Ministry of Education, 2007, p. 32), which involves the identification of a problem, issue, or the recognition of an opportunity to address. Technologists, or people who design and develop technologies, then undertake technological practice, with a view to developing an outcome to solve the identified problem or address an identified opportunity. This process can include the development of artefacts or products, systems, and processes.

For teachers of technology, there is a need to develop a deep understanding of technology. For example, as people become aware of a range of medical issues caused by exposure to certain materials, as global warming increases and other environmental issues arise, we begin to understand that people and technology are having a devastating impact on the planet and those who live within its bounds. The technological innovation of plastic is a case in point. Plastic was once hailed as a miracle material, known for its strength, variety, flexibility, and longevity. We are now coming to realize its long-term impact on the environment, and are becoming more aware of this pact, such as the Pacific garbage patch – a giant ocean gyre in which all dumped plastic debris has accumulated over the last 60 years. Over time, this plastic debris breaks down into small particles and is ingested by marine life, thus entering the food chain. Many people are now becoming more discerning about their use of plastic and some have made a decision to avoid the use of plastics in their everyday lives. In New Zealand, single-use supermarket plastic bags are prohibited and have been replaced with reusable fabric bags. Paper straws are slowly returning, sandwiches wrapped in wax-covered fabric, and many of the plastics used are recycled. These changes all involve technology in some way.

Technology is not just about designing and making "stuff" – technologists must be more deliberate in their decision-making. Technology includes understanding the impacts that decisions have on people and their environment. Technologists need to understand that they should not always design and develop anything they or others desire. A research-informed perspective is a critical part of the process. Understanding current and future societal impacts are vital factors in the nature of technology education.

The Nature of Technology Education in New Zealand

Technology education in New Zealand emerged from technical education. The 1877 Education Act provided the framework to introduce technical studies into New Zealand classrooms. In New Zealand, technical education was introduced as a compulsory subject in the school curriculum in 1890, giving it a long history. The 1900 Manual and Technical Instruction Act introduced technical education with the sole intent of increasing students' manual skills, by focusing on woodwork and metalwork for boys, and cooking and sewing for girls. At this time in the secondary context children from working class backgrounds and those considered to be "non-academic" were encouraged to attend technical schools, which focused on the continued development of technical education (Harwood, 2003). It is from these roots that technology education emerged, and although it was one of the (then) seven learning areas in the New Zealand Curriculum Framework (Ministry of Education, 1991), many people still perceived technology as a practical subject of lower status than other subjects.

The 1980s saw a shift towards a more integrated curriculum and greater development of the "whole person." The New Zealand Curriculum Framework, published in 1993, identified technology as one of seven essential learning areas. A curriculum document, *Technology in the New Zealand Curriculum* (Ministry of Education, 1995), identified the overarching aim as being "to develop technological literacy …to enable and empower students with the know-how they will need to make informed choices about technology, and to be the technological innovators of the future" (p. 5). In other words, both vocational and general education aims were included. Three strands: technological knowledge and understanding, technological capability, and technology and society, taught across a range of technological areas are chosen by teachers and schools to "best help their students achieve the objectives of this curriculum" (p. 12). The technological areas included biotechnology, electronics and control technology, food technology, information and communication technology, materials technology, production and process technology, and structures and mechanisms. The Hangarau (Māori technology) curriculum was also published, although the identification of appropriate technical terminology was problematic. At the same time, the Workshop Craft and Home Economics syllabi were revoked, with some of these teachers unclear about their role in the face of extensive change.

At the time of implementation, the 1995 *Technology in the New Zealand Curriculum* had not previously been taught, so it made sense that a review was undertaken in a relatively short time. In 2003, this review was initiated, not just of technology but of the whole school curriculum. Targeted empirical classroom-based research informed thinking about technology education. This revision resulted in the new 2007 curriculum document *The New Zealand Curriculum* with a restructuring of the curriculum strands to technological knowledge (*know-that*), technological practice (*know-how*), and the nature of technology (*know-why*). The technological areas were modified and included structural, control, food, and information and communication technologies, and biotechnology. Both vocational and general education purposes were retained, as was the focus on technological literacy because "In technology, students learn to be innovative developers of products and systems and discerning consumers who will make a difference in the world" (Ministry of Education, 2007, p. 17). This curriculum revision attempted to draw together some of the lessons learned from the 1993 curriculum roll-out, and the need to refine teachers' understanding of the key curriculum concepts was recognized.

It was, and still is, perceived by some as a subject suitable for non-academic and/or disengaged students. Those who understand the academic and practical duality of the subject challenge this perception. The status for the subject is slowly improving. In 2017, the 2007 iteration of technology education (Ministry of Education, 2007), which is now one of eight learning areas, was revised to emphasize digital technologies. In this version there are five technological areas in the learning area of technology education. These include the designing and developing material outcomes, designing and developing processed outcomes, design and visual communication, the design and development of digital technologies, and computational thinking. Student teachers should be exposed to learning in all of these technological areas, to be well prepared for the profession. Full implementation of the revised technology curriculum was expected to occur from February 2020.

Program Titles and Time Allocation

In New Zealand, education is compulsory for all children aged between 6 and 16, although most children enroll at school on their fifth birthday. Since 2007, government policy also provides funding for all children to attend 20 hours of free early childhood education from the age of 3. The years of schooling are variously grouped, including contributing primary school (Years 1-6; ages 5-10), full primary school (Years 1-8; ages 5-12), intermediate school (Years 7-8; ages 11-12), middle school (Years 7-9 or 10; ages 11-14), secondary school (Years 7-13 or 9-13; ages 11-18), or area school (Years 1-13; ages 5-18). In general, primary school teachers are generalists and teach across the curriculum, whereas secondary school teachers are subject specialists. Most intermediate and middle school teachers tend to be generalists. However, specialist teachers, often in a classroom dedicated to the subject, offer some subjects, like technology education. When intermediate and middle schools do not have specialist resources, partnerships may be developed with local secondary schools and students have classes there, usually for a half a day a week. Students in Years 7 & 8 in full primary schools also travel to specialist technology centers also for half a day per week or 1 day every 2 weeks in rural areas. Whilst technology education is a compulsory subject in the schooling sector (Years 1-10), the time allocated to its teaching depends on the school context, collective staff focus, or teacher's interest. For example, in a primary school, concepts for technology education can be taught through inquiry learning, meaning curriculum intentions are not always fully realized. In a secondary school context, technology education usually has the same timetabled time as other curriculum subjects from Years 9-10.

In the schooling sector, all students study programs developed from the New Zealand Curriculum (Ministry of Education, 2007), or Te Marautanga o Aotearoa (Ministry of Education, 2008). These policy documents specify a curriculum framework that outlines, in very broad terms, the knowledge and skills students are to acquire within eight essential learning areas, including technology education. Across this framework, the key competencies identify capabilities for living and lifelong learning (thinking; using language, symbols, and texts; managing self; relating to others; and participating and contributing). Values that are to be encouraged, modelled and explored include excellence; innovation, inquiry and curiosity; diversity; equity; community and participation; ecological sustainability; and integrity. Individual schools are responsible for developing their local curriculum, with each school operating autonomously under the guidance of a Board of Trustees – consisting of community representation with responsibility for setting the direction of the school, within the parameters of regulation. An independent audit agency, the Education Review Office, evaluates and reports on school performance, on average, once every 3 years.

Major Objectives

Technology education is positioned to assist learners' preparation for life, both in the current and future technological world. Barlex (2006) suggests that a major educational goal of technology is to teach students the capability to operate effectively and creatively in the made-world. There is also the opportunity to prepare students to participate in rapidly changing technologies, and to intervene creatively to improve their quality of life. Teachers' pedagogies need to evolve to be responsive to such requirements. For example, when designing technological outcomes, students should have ownership of their design ideas, become knowledgeable in the aspects of their technological practice, and make key decisions, from an informed perspective. Barlex (2006) stated that from a pedagogical perspective, this is fascinating, because "it is the pupil who has the knowledge and expertise in this situation, only he/she knows about his/her design" (p. 193). More recently, Barlex (2017) indicated that there are similarities between New Zealand and England, whereby the necessary change in pedagogy has been hindered by a significant and continuing need for professional development and learning, to focus on specialist knowledge and pedagogy, and with a view to modernizing the curriculum area's profile and becoming more effective teachers.

The notion of "effective pedagogy" presented in the New Zealand curriculum states, "there is no formula that will guarantee learning for every student in every context" (Ministry of Education, 2007, p. 34). It suggests students learn best when they feel supported and safe in their school or classroom. Teachers are encouraged to reflect on and consider their own actions, understand the focus of the learning, support students' collaborative practices, recognize their experiences, and offer substantive learning opportunities.

Teachers in New Zealand are encouraged to inquire into their practice and be adaptive in their teaching approaches (Timperley & Alton-Lee, 2008). This requires quite a different role *for* and approach *from* teachers than previously. This is particularly pertinent in technology education, where teachers and other experts must facilitate students' learning to enable progression of the intended design, to develop knowledge and understanding of the wider social, cultural, ethical and environmental considerations that impact or influence design. This includes teachers' critical reflection on their practice through a range of strategies and activities, to motivate, engage, develop, and challenge students' thinking.

Education in New Zealand has traditionally focused on the development of students' competencies, in particular their understanding of knowledge and skills. It should, however, also develop students' capability to adapt to a changing world where new knowledge is generated (Fraser, 2000). To foster a climate of innovation in technology education, teachers are likely to be required to encourage creative and critical thinking and reflection about the factors that can inform future technological developments. Such practice is significantly different to teaching students about the stages of production in a replicated product.

In technology education, students learn to be "innovative developers of products and systems and discerning consumers who will make a difference in the world" (Ministry of Education, 2007, p. 17). Technology in The New Zealand Curriculum (Ministry of Education, 2007) is defined as:

> … intervention by design: the use of practical and intellectual resources to develop products and systems (technological outcomes) that expand human possibilities by addressing needs and realizing opportunities. Adaptation and innovation are at the heart of technological practice. Quality outcomes result from thinking and practices that are informed, critical, and creative. (p. 32)

In New Zealand, the aim of technology education is the development of technological literacy (Ministry of Education, 2007; Moreland & Cowie, 2007). Technological literacy is demonstrated when students have a broad understanding of the ways that made products work or are developed as a result of societal intervention, needs, or opportunities (Technology Online, 2010).

Also viewed as a means to support students to function in a technological and future-focused society, technological literacy is understanding of how to undertake holistic technological practice knowledgeably and skillfully within the bounds of the learning context, and to address concepts presented in the New Zealand Curriculum (Ministry of Education, 2007, 2017).

Content organizers

New Zealand is one of a number of countries who have technology as a separate learning area in the curriculum. In other countries, there is a move towards joining or embedding it into other subjects (science, social science, environmental studies, life studies, and craft) or learning in technology has a sole focus on digital or information and communication technologies. The commonality for all nations is that technology is a relatively recent addition to the curriculum (post 1980s) and that it has experienced constant change and revision as nations come to develop their understanding and rationale for its place in the curriculum (Benson & Lunt, 2011).

In 2017, the technological areas were modified considerably in New Zealand, following a Ministry of Education directive to enhance the presence of digital technologies within the technology curriculum. The new technological areas are designing and developing materials outcomes, designing and developing processed outcomes, and design and visual communication, and two new areas specific to digital technologies: computational thinking for digital technologies, and designing and developing digital outcomes. There are generic concepts taught across all technological areas, within three strands: *Technological Practice,* the *Nature of Technology,* and *Technological Knowledge.* Together, these strands provide opportunities for learning, which develop students' abilities to critique technology, and to understand its complexity. Contextualized student learning addresses the following components.

Table 1. The eight technology curriculum components (adapted from The New Zealand Curriculum, MoE, 2007)

Technological practice	Technological knowledge	The Nature of Technology
Planning for Practice	Technological Modelling	Characteristics of Technology
Brief Development	Technological Products	Characteristics of Technological Outcomes
Outcome Development and Evaluation	Technological Systems	

Technology education in New Zealand is different to other countries because of the universal inclusion of foods, textiles and biotechnology in the curriculum. New Zealand is an agriculture-based country with its primary produce contributing significantly to the Gross Domestic Product (GDP). The recent revision to the technology aspect of the New Zealand curriculum sees textiles, woodwork, and metalwork situated within the Designing and Developing Materials Outcomes technological area. Food technology and biotechnology are currently situated within the Designing and Developing Processed Outcomes technological area. The study of food and nutrition has also remained in the Health and Physical Education learning area.

General Chatacteristics of Technology Education in New Zealand

Contemporary approaches to learning in New Zealand are regularly associated with sociocultural theory (Schepens et al., 2007), which is of particular relevance to technology. Sociocultural theory considers the role of action and tools in the construction of knowledge (Wertsch, 1998) and posits that children's cognitive development is dependent upon individual responses to cultural and societal influences. The goal of the sociocultural approach to learning is to understand the relationships between human action and mental functioning, as well as the cultural, institutional, and historical context in which this action occurs (Wertsch et al., 1995). In New Zealand, technology students develop technological outcomes to meet authentic needs or realize opportunities, often situated within local communities. This involves an oscillation between critical thought and practical enactment as student work through design processes appraising practice and outcomes as they go.

According to Vygotsky (1978), human learning is an "outside-in" process described as internalization and externalization, where knowledge transforms from a social context to an inner psychological conception. Internalization is "related to reproduction of culture; externalisation, the creation of new artefacts, makes possible its transformation" (Engeström et al., 1999, p. 10). Murphy and Hall (2008) suggest that Vygotsky's account of fundamental psychological functions, such as perceptions and memory, is that they appear first as elementary functions, such as rote learning times tables, then as higher functions, such as understanding and using multiplication. These functions occur through assimilation into sociocultural practices that occur when people live, work, or study together. There are two key ideas in sociocultural research that are pertinent here, especially for technology: action and mediation. One of the fundamental claims Vygotsky made was that human activity is mediated by tools and signs (Wertsch, 1981). The underlying assumptions are that humans have access to the world only indirectly or mediately rather than directly or immediately – therefore external tools mediate action allowing the internalization of that action (Zinchenko, 1985).

Today there is a need for students to understand, appreciate and engage with the world in which they live – technology plays a major part in this learning. Students need to become familiar with the diverse range of complex communities in order to meet the requirements of sustained learning and effective participation in society. Learning to appreciate these environments and communities of practice, along with developing a mind and responsibility for the future means learners must continually be involved in meaningful and authentic learning and practice. Renzulli et al. (2004) stated, "it's the application of knowledge in authentic learning situations – not the perpetual memorisation and testing – that characterises a progressive education system" (p. 74). Education must actively engage students in the ways of life *beyond the school* (Newmann, 1996). Technology education is, by definition, future-focused.

Future-focused Approaches to Technology Education

The term future-focused is used here to recognize the evolution of technology education in New Zealand and to describe the government-advocated pedagogical practice. Teachers in New Zealand are encouraged by government to adopt a future-focused approach to education within learning communities, which are sufficiently flexible to accommodate students' learning needs, are situated within open and adaptable teaching spaces, and harness the use of digital technology (Leggat, 2015; Ministry of Education, 2016).

No generation can escape the responsibility of deciding what students should learn (Bellanca & Brandt, 2010). Learning today presents teachers with the daunting task of equipping students with the knowledge and skills necessary to survive their unknown future. Contemporary ideas about learning challenge past educational assumptions and so schools must change significantly to meet the emerging social and academic needs of today's students (Reinsfield, 2019). Reinsfield (2019) states that in the secondary school sector in New Zealand, many technology teachers still view their subject as a means to predominately develop student skills and specialist content knowledge. She asserts an urgent need to challenge teachers' views and teaching practices which negate or marginalize curriculum policy and intent, and recommends that to support the development of students' technological literacy, there needs to be an alignment of both technical and technological ways of thinking and practicing in secondary technology education.

Many education programs are out-of-step with students' current lives and seem irrelevant to their future lives (Fox-Turnbull, 2003; Reinsfield, 2018a).

Skills supporting innovation, creativity, critical thinking, and problem solving need to fulfill the expectations of the future economy (Compton, 2010). Wagner (2008), in The Global Achievement Gap, advocated for the development of seven survival skills for the future, including:

- curiosity and imagination
- critical thinking and problem solving
- initiative and entrepreneurialism
- collaboration, learning by influence
- agility and adaptability
- accessing and analyzing information
- effective oral and written communication

In considering future educational approaches, Claxton (2007) identified the need for diversity when fostering students' learning capacity. He called for an epistemic culture change in schools, to replace stand-alone courses that offer a discrete focus with teachers identifying learners' needs. Aspects of such an epistemic culture might focus on the ways teachers and learners collaborate, the range of activities and methods they will engage in to support learning, the ways students can transfer their thinking, and how teachers might model learning to support successful participation in a future-focused society.

Technology education is a subject that can accommodate Claxton's aspects, whilst also including a diverse range of academic and social needs through creative, critical, and problem solving approaches (Reinsfield, 2015; 2016a; 2016b). This includes those students with a preference and abilities for practical activities who can also be creative and solve problems. Concerningly however, a sole focus on technical approaches can often equate to learning where students manufacture outcomes through a series of predetermined stages (Reinsfield & Williams, 2017). The tension for technology teachers is how they manage such traditional perceptions of the subject to interpret the curriculum and respond to the changing context of global, social, and technological need in their classrooms, from a future-focused perspective.

Taught in a variety of ways, technology education is a distinct learning area sometimes delivered within an integrated curriculum model. Teaching approaches that best support future-focused ways of learning are interdisciplinary, integrated, inquiry, problem or project-based, values and competency driven. Approaches are learner-centered and should prepare students for life in the real world, and generate curiosity, excitement and increase engagement.

Student engagement is a concept that has historically focused on teachers' need to increase achievement, encourage positive behavior and a sense of belonging within the classroom (Parsons & Taylor, 2011). Whilst important concepts, there has also been a focus in New Zealand on developing students' lifelong learning capabilities to support their ability to function in a knowledge-based society (Gilbert, 2007). Student engagement has evolved as a notion which is viewed as a means to cater to students who may be "at risk" of underachieving or disengaging from school altogether (Finn & Zimmer, 2012). In technology education, this might equate to placing students in programs that support pathways in the Trades or to learning facilitated through authentic contexts. Regardless of the program afforded to learners in technology education, it is essential that the teacher establishes an environment where, in Claxton's words, "students' questions are welcomed, discussed and refined, so the disposition to question becomes stronger – more and more robust; broader – more and more evident across different domains; and deeper – more and more flexible and sophisticated" (2007, p. 120).

Learning in technology education can take the form of problem-based learning (PBL), inquiry learning, and experiential learning, leading towards an environment where there is less intrusive teacher guidance (Kolb & Fry, 1975; Lombardi, 2007; Papert, 1980; Peacock, 1997; Snape & Fox-Turnbull, 2013). In such learning contexts, teachers provide opportunities for students to construct their own knowledge, as the result of their experiences (Kirschner, 1992).

Students' own lived experiences or funds of knowledge make a valuable contribution to technology practice, as well as giving value to often-marginalized understanding and practices (Fox-Turnbull, 2015).

Funds of Knowledge

Funds of Knowledge is a theory situated with a sociocultural paradigm, which draws on the perspective that learning is a social process bound within a wider social context (González, Moll, & Amanti, 2005). Funds of Knowledge are the developed bodies of skills and knowledge accumulated by a group to ensure that they can function appropriately within their social and community contexts (Lopez, 2010). Such thinking is pertinent because if teachers know about students' home and cultural activities, and experiences, they will be better informed to maximize learning opportunities and to make the most of the knowledge and skills already established or accessible to some students (González et al., 2005).

As such, technology education provides opportunities for students to be exposed to learning about the changing nature of knowledge, technology, society, and global issues through the means of problem solving activities, which create critical and creative thinking opportunities (Education Gazette, 2017; Lai & Hong, 2015; Lewis et al., 1998; Ministry of Education, 2016b, 2017b; Wright, 2010). Students' funds of knowledge assist contributions to their own and others' technological practice, and frequently validate their cultural knowledge. Students can deploy funds of knowledge gained from passive observation and participatory enculturation. Participatory enculturation involves students being enculturated into an activity and engagement results in transferable knowledge. This engagement includes both active participation and peripheral participation, where students might be on the periphery of an activity but can still engage through the use of questioning and/or conversation. An alternative approach may be engagement through passive observation, which refers to learned knowledge obtained through passive means, when learners are non-participatory observers. For example, learning can still occur through watching movies, television or reading books - involving no direct interaction with knowledge sources. Deploying their own funds of knowledge can provide students with deeper understanding of the value of diverse cultural knowledge (Fox-Turnbull, 2015).

Experiential Learning

Experiential Learning provides opportunities for students to be exposed to phenomena through real world experiences rather than hearing about it or learning in the traditional classroom setting. Such learning is enhanced and continuous, through critical reflection of and inquiry into the experiences - leading to what Kolb (2015) describes as "spirals of learning," thereby ensuring continuing engagement and learning. Educational institutions frequently deploy this approach by engaging their students in Work Integrated Learning (WiL) and Project-based Learning (PBL). Experiential Learning has obvious links to technology education as the practical nature of technology facilitates students' engagement in solving real-world technological problems through the process of inquiry, as informed by critical reflection.

Inquiry Learning and Guided Inquiry

During Inquiry learning students are encouraged to construct their knowledge and understandings, as situated within their own cultural lens. The process enables them to take ownership of and responsibility for their learning. Inquiry learning encompasses a wide range of skills and processes in active learning, leading to a much broader understanding of the world. One Inquiry learning strategy that focuses on the facilitation of developing independent knowledge is Guided Inquiry. The guided inquiry approach reflects the belief that, for students, active involvement in construction of their knowledge is essential for effective learning (Kuhlthau et al., 2007).

Guided Inquiry is systematic learning which proceeds through a number of teaching and learning phases within a predetermined context. It involves students engaging in deep learning, through the process of self-motivated inquiry, with several distinct phases. A teacher using an Inquiry approach to learning strives towards students' development of wider or rich concepts, or learning that endures – about the world and how it functions (Blythe, 1998; Kuhlthau et al., 2007; Murdoch, 2004). Guided Inquiry is very different from an open approach to discovery learning as teachers have a continuing responsibility to structure a range of activities, which are sequenced to maximize the development of learners' thinking processes and skills.

During the first phase, the teacher usually announces a topic of study that requires thorough research, thus initiating the inquiry process. During this time, students are prepared for selecting a topic of research through a variety of immersion activities. The second phase involves the selection of a topic of study, and questioning is used to support the direction of their work. Exploration is the third and most difficult phase, and involves sifting through available information to find a specific focus. Students need to be well informed about the general topic, in order to find an appropriate area to focus on. In the fourth phase, formulation, students identify ways to focus and organize their topic, thus providing a degree of clarity. The next phase, collection, follows with an extended focus on how to present new understandings. Once students have gathered all the required information, they consider the nature of the presentation with which to share their findings. The presentation phase may consider a range of styles from informal to formal outcomes. The assessment phase concludes the project as both teachers and students judge content and skills learned throughout the process. This provides a time to critically reflect and evaluate on the inquiry process as a whole. Such reflection is not to be confused with formative assessment of content and process, which is ongoing throughout the project (Kuhlthau et al., 2007).

Guided Inquiry offers students an opportunity to build on what they already know and to gain new knowledge through active engagement in and reflection on a learning experience. Students develop and use higher-order thinking skills, with teacher guidance at critical points in the learning and development process. It allows for different modes of learning, and facilitates learning through social interaction with others (Kuhlthau et al., 2007). The Guided Inquiry process reflects authentic technological practice as identified by Kimbell and colleagues (Kimbell et al., 1991). The Assessment of Performance (APU) Model (Figure 1) illustrates a technology design process, providing a succinct overview of the iterative process of thought in action, where interactions between mind (Imaging and Modeling) and hand (Confronting Reality) are formulated, tested and reformulated as design activity progresses (Stables & Kimbell, 2000). The Guided Inquiry process also reflects the Technology learning area as it is organized in The New Zealand Curriculum (Ministry of Education, 2007), as illustrated in Figure 2.

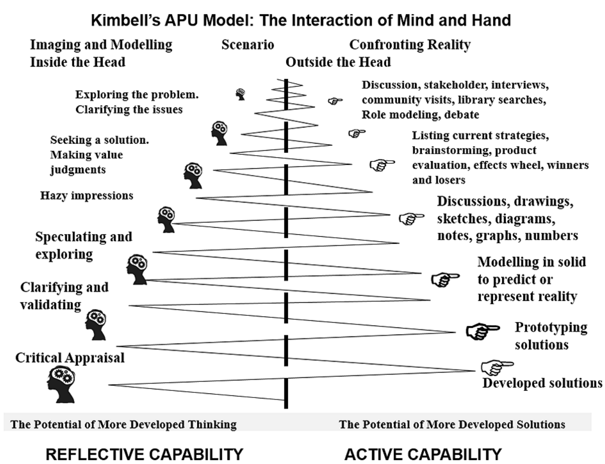

Figure 1. Kimbell and Colleagues APU Model of Technology Practice modified by W Fox Turnbull

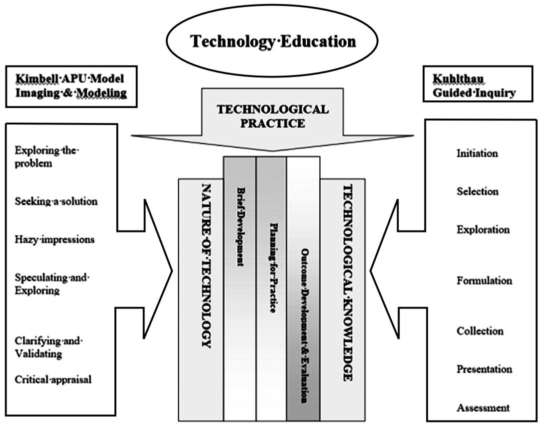

Figure 2. Technology Education and Guided Inquiry Nexus (Snape & Fox-Turnbull, 2011)

Talking for learning

The ways that teachers talk about and facilitate students' learning is key to successful outcomes in technology education. Talk plays an important role in contemporary approaches to learning and is particularly important in technology education in New Zealand because learners often work in groups to develop outcomes in response to an issue. Mercer and Dawes (2008) suggest that educational talk is either symmetrical or asymmetrical. Asymmetrical talk is the talk between teachers and students where one person takes the lead, usually the teacher. Symmetrical talk is talk between students where participants have equal status and control, which is more likely to happen when students are working in pairs or small groups. Scott (2008) uses different terms: Interactive or Non-interactive. Interactive talk includes verbal participation of all participants; non-interactive talk usually only involves one person - typically the teacher or one student who dominates the conversation and decision-making. Traditionally much educational talk in the classroom was asymmetrical; teachers acted as arbiters of knowledge and therefore acted with authority by leading conversations through the transmission of facts, demonstrating, explaining to or correcting students. Symmetrical or Interactive talk is more congruous with new ways of learning, but asymmetrical or non-interactive talk do still have a place in the classroom – at times.

Talk is given prominence in Alexander's (2008) dialogic teaching, which is a pedagogical approach where teachers need to "provide and promote the right kind of talk" (p. 10) to ensure that students learn more effectively and efficiently. Dialogic teaching demands both student engagement and teacher intervention through talk and can occur in any organizational context, whether it is whole class teaching, or during small group collaborative discussion. Argument as a tool can be effective in this space. Mercer (2006) suggests that argument is characterized by three specific types of talk: disputational (mainly Asymmetrical), cumulative, and exploratory (Symmetrical). Disputational talk is prevalent in but by no means restricted to an aggressive type argument and is characterized by participants' unwillingness to understand another person's point of view – with a constant reassertion of his or her own. Collaborative activity becomes almost impossible in such circumstances, as participants vie to have their views adopted. Defensive and uncooperative behavior typifies this type of talk where participants seek control of the discussion and aim to hold the power.

Within exploratory symmetrical talk, two subsections emerge: cumulative (Mercer & Dawes, 2008) and Intercognitive (Fox-Turnbull, 2013). Cumulative talk occurs when speakers build on each other's contributions and are supportive but uncritical; thus, shared understandings do not develop with individuals retaining ownership of their own unchanged understandings. Intercognitive talk describes talk within which participants value and build on each other's contributions and developing understandings. Participants are supportive and critical, but in a constructive manner. Used when students are working collaboratively on the development of a single outcome or project, Intercognitive talk is perfectly suited to technology education. To achieve the design and possible development of a successful technological outcome when working with others, students must find common ground when they experience differing ideas and solutions – thus demonstrating sociocultural conflict.

Sociocultural conflict theory is relevant to authentic technology practice. It is a means to acknowledge that discrepancy or conflict leads to cognitive development. A subset of sociocultural theory, with a focus on the use of language as a tool, sociocultural conflict theory identifies conflict as an essential component of any joint endeavor – to bring about cognitive change. This thinking translates to both pre- and in-service teacher education. Doise and Mugny (1984) demonstrated that when working in pairs to solve problems, learners advance to a higher level of learning than for those working by themselves. Alternative points-of-view during problem solving can force a learner to adjust his or her own viewpoint to align to that of another. The conflict can only be resolved if cognitive restructuring takes place and therefore mental change occurs because of social interaction. Language as a tool is a key component of such interactions.

Language can be a tool of intellectual adaptation within the context of teacher learning. Vygotsky (1978) described two relevant forms of language. Firstly, the nature of social speech as a means of communication with others, as described above. Secondly, as represented through private speech during teachers' engagement with professional learning – assuming that private speech connects thought with words, as internalized, self-regulating, thinking, in action. An example of language as a tool of intellectual adaptation might be that a teacher has their own belief about the way that the technology curriculum should be enacted, but they regulate their thoughts and language to communicate an alternative, more socially acceptable perspective during class, or when engaging with colleagues. Alternatively, a teacher might disagree with the social speech represented in a professional context and choose to ignore it. Teachers' actions can align with or be disparate to their espoused theories of technology education, and represent multiple perspectives, customs and motivators. This is particularly evident by the differing representations of discourse in senior secondary school contexts in New Zealand (Reinsfield, 2018a).

General Pedagogical Principles

Technology Education offers rich contexts for study, including the social construction of outcomes, cooperation and collaboration with others, and practical engagement in worthwhile and real-world activities (Snape & Fox-Turnbull, 2011). Technology projects are frequently collaborative, requiring shared processes. This requires significantly different approaches to work than the frequently seen desk-confined, textbook and whiteboard techniques often used in traditional classrooms. The New Zealand curriculum seeks to establish the direction for student learning in schools, to provide guidance, and allow schools to shape pedagogy within their own context (Ministry of Education, 2007), with a view to "build[ing] an education system that equips New Zealanders with twenty-first century skills. It also strives to reduce underachievement in education" (Cubitt, 2006, p. 196). With the implementation of the 2007 curriculum, New Zealand education refocused efforts towards developing human capability, with a view to supporting the structure of a prosperous and inclusive society. There were more explicit connections between learning, pedagogy, and assessment. Positioned as empowered professionals and legitimate decision makers, teachers had the ability and autonomy to design appropriate learning for their students within their school context.

Teachers in New Zealand are expected to be lifelong learners who are committed to developing their understanding of contemporary pedagogy (Ministry of Education, 2007). Enabling factors include collaborative communities, with a focus on continuous improvement, internal and external partnerships, and effective leadership. Time to reflect and critically analyze one's own practice, having a sound knowledge of pedagogical practice for application in differing learning contexts, and a safe environment to take risks are critical (Fullan, 2002; Hargreaves & Fink, 2004; Koehler & Mishra, 2009; Shulman, 1986, 1987; Timperley & Philips, 2003). Teachers of technology need to combine skilled expertise in their specialist area with strong academic understanding of underpinning technology practice and design principles. They need to be able to develop strong relationships with all students, understanding their different starting places and cultural backgrounds. Most importantly, they need to be passionate about technology and learning.

Technology emerges from within social context and does not occur in isolation from values, beliefs and social life – constructed in response to the social and cultural needs of the society in which the technological outcomes are developed (Fleer & Jane, 1999; Siraj-Blatchford, 1997). Technological solutions developed within the context of the community, within which the needs arise, and those that use local skills, resources and existing technologies, are likely to be the most successful. It is essential that pedagogical approaches in technology reflect and facilitate this thinking. Teaching today's students through yesteryear's pedagogies is no longer acceptable. The "graveyard model of teaching" (everyone in rows, passively accepting instruction) needs to be replaced with students interacting, solving problems, applying skills, and making decisions about meaningful issues (Gordon, 1998). Practices should be real to the student, and their current or possible future lives (Hennessy, 1993). As these practices are undertaken, students gain an appreciation of the bigger picture of technology (Blythe & Associates, 1998; Murdoch & Hornsby, 1997), utilize key competencies and values, create, innovate and work with various media and educational technology. The socially embedded nature of technology integrates a variety of skills, ethics and cross-cultural themes, offering opportunities for students to participate in, and understand many local, national or global community issues. The review of the technology curriculum in 2017 (Ministry of Education, 2017) provided an opportunity to conceive pedagogy differently and re-position students' learning so that it can be inclusive of creative, innovative, and critical thinking approaches in a more purposeful manner. To develop innovative technological outcomes for example, students need to understand the nature of materials or systems and be exposed to experiences where they can manipulate and adapt resources to represent and realize their ideas. The nature of technology education in New Zealand continues to change, and teachers should be providing opportunities for students to explore conceptual, partially modelled, digitally realized or fully realized outcomes. Assessment is an important aspect of learning in any educational setting. Both assessment of and for learning impacts and influences technology education in New Zealand schools.

Assessment *of, for* and as Learning in Technology Education

Meyer and Land (2003) argue that teachers "perceive, apprehend, or experience particular phenomena [which] might lead to a privileged or dominant view and therefore a contestable way of understanding something" (p. 1). This perspective suggests that the core concepts presented within the technology curriculum, communicated as Achievement Objectives, and within the Indicators of Progression documentation (Ministry of Education, 2007, 2010, 2017) might be interpreted according to their dominant worldview. To make judgments about students' learning progressions, teachers need to be aware of their own bias, have sound knowledge of their students' worldviews, and be conversant with the notion of formative assessment or assessment for learning (Black & Wiliam, 1998). The principles of collaborative professional learning can support approaches, which ensure accurate and unbiased assessment. According to Earl (2011), assessment as learning provides an opportunity for students to self-regulate and challenge their own and others' ideas for application in their future learning.

Another way of assisting fair formative assessment practices is by assisting students to undertake peer and self-assessment. Clarke (2005) and Clarke et al. (2003) support the view that such approaches ensure that students take greater responsibility for their learning. To enable this process however, students must be informed of or negotiate learning intentions, which communicate very clear and specific success criteria – coupled with effective questioning from their teachers. Such practices are more likely to make students aware of the purpose, intent and scope of their learning. At this time, teachers need to be responsive in planning, teaching, and resource development to reflect curriculum concepts (Allen et al., 2013). Technology teachers must also have sound pedagogical knowledge and a commitment to a constructivist approach to teaching (Saxton et al., 2014). Brooks and Brooks' (1993) four principles of a constructivist approach to learning include

1. the seeking and valuing of the learner's point of view
2. the ability to challenge learners' suppositions by either validating or transforming their truths
3. discussing emerging issues or relevance of the learning to support the creation of personal meaning
4. contextualizing learning within the wider scope of individual understandings.

In New Zealand, curriculum documentation provides a means for teachers to plan and structure students' evolving understandings, but there are existing tensions when learners enter the latter stages of their school study. New Zealand's main secondary school qualification is the National Certificate in Educational Achievement (NCEA) (New Zealand Qualifications Authority [NZQA], 2012). Within this assessment framework, students progress from Level 1 in Year 11 to Level 3 in Year 13. Students accrue credits at each Level, to progress to the next. Students are able to choose learning programs from a range of subjects, which are assessed against either Achievement or Unit Standards. In Achievement Standards, students demonstrate understanding or mastery at Achieved, Merit, or Excellence levels – of identified knowledge and skills (e.g., Brief Development). Unit standards are competency based and students are assessed on an Achieved or Not Achieved basis. All NCEA Standards are currently under review. Some examples are outlined in Table 2 for a

Year 11 student (age 16).

Table 2. Example of Achievement and Unit Standards

Standard	Title	Assessment criteria
AS90144 NCEA Level 1 4 credits	Undertake brief development to address a need or opportunity	Undertake brief development to address a need or opportunity involves: • identifying a need or opportunity as a result of exploring the given context and issue • reflecting consideration of the social and physical environment • reflecting key stakeholder's opinion • describing the outcome to be developed • identifying the physical and functional attributes needed for the outcome • producing a final brief comprised of a conceptual statement and specifications.
US24352 NCEA Level 1 2 credits	Demonstrate knowledge of and apply safe work practices in the construction of a Building Construction Allied Trades (BCATS) project	Students need to • Demonstrate knowledge of safe working practices for the construction of a BCATS project • Select, maintain and use personal protective equipment (PPE) during the construction of a BCATS project.

The complex and sustained relationship between vocational (trades) and (general) technology education in New Zealand presents a duality between the two philosophical approaches. Unfortunately, in many schools, these programs are often taught in the same environment, by the same teachers, and to the same students (Williams, 2015). Williams states the pragmatics of such enactment means that the separation of teaching into different concepts or pathways is not always straightforward, nor possible because technology education and vocational education have differing purposes and contrasting pedagogical approaches. Thus, by blending the philosophies, a teacher is likely to be less effective or empowered to teach in a future-focused manner, to address the concepts presented within the New Zealand curriculum (Ministry of Education, 2007). Such diverse understandings about the nature of technology education have implications for student teachers' developing understandings.

TECHNOLOGY EDUCATION: A CHANGING ART

Student teachers can experience learning in technology in their undergraduate, graduate, or postgraduate study. Most undergraduate and graduate courses have 15 points associated with them. One point is the equivalent of 10 hours of study. Typically, for undergraduate and graduate primary teacher education, there will be one 15-point course with 16-36 hours of technology contact learning supplemented with additional hours allocated for thinking time, independent reading, coursework, and assignment work. The exact number of hours allocated is dependent on whether the courses are shared with other learning areas, such as science. For secondary teacher education programs in New Zealand, contact hours can range from 36-72. Even in programs with subject endorsement, which draw on learners' previous work experiences, there are time pressures, which impact the ability to address the diversity of knowledge required to adequately prepare student teachers for the profession. Developers of the pre-service technology education framework (PTTER) 2013 suggested that

> Pre-service educators can realistically only prepare teachers to recognize, understand and plan good technology teaching practice. Teacher competencies to deliver technology programs will therefore evolve through their teaching practice and involvement in continued teacher education programs. (p. 483)

The PTTER resource provides a framework for ITE programs in technology

(Forret et al., 2013), which is partially based on findings from a questionnaire investigating student teachers' beliefs and views about technology education. The authors, all ITE educators in technology, one from each of the six New Zealand universities with ITE programs, also drew on experience and recent literature to identify four cornerstones of learning. These four cornerstones: Philosophy, Rationale, Curriculum and Implementation, considered chronologically, can assist the framing of balanced programs of work in technology education. This approach is also beneficial to student teachers' wider programs of study, where they learn about and can make connections to content such as teaching and learning theory, education in the New Zealand context, or te reo and tikanga Māori (Māori language and traditions).

The PTTER questionnaire recognized the importance and persistence of student teachers' values and beliefs, and shaped subsequent program development. As a result, student teachers in primary technology teacher education programs typically undertake a number of small tasks that are applicable to their future school settings, and are reflective of a range of technological areas. Links made to the technology curriculum and implications for teaching, learning and assessment are highlighted. For secondary student teachers, similar ideas are explored, but more often, in one or two technological areas. The learning at both levels prioritizes an approach to pedagogy that is learner-centered and authentic, with a view to developing student teachers' ideas about both the nature of technology and how this translates to technology education in New Zealand.

Authenticity in technology occurs through specific links to students' context and real technological practice. Learning is predominantly based on connecting students' understanding to meaningful and real-world situations, and their involvement in technological practice that is similar to practicing technologists, while using authentic tools and processes where possible. Hennessey and Murphy (1999) explained that authentic practice involves situations that are real to the student, their lives, and situations they may encounter in the future workplace. Activity embedded in authentic technological practice is more likely to produce greater understanding and provide the opportunities for students to identify, simulate, and relate to the tacit knowledge of technologists. Snape and Fox-Turnbull (2011) suggested three dimensions of authenticity to enhance learning in technology: pedagogy and instruction, teachers and learners, and activities. Learning should closely resemble everyday situations, and provide students with opportunities to make decisions about the nature, content and pace of their learning (Petraglia, 1998).

Authentic teachers take responsibility for remaining current and aware of the variety of possible opportunities that exist for student involvement and engagement (Kreber et al., 2007). As professionals, teachers must ensure that their practice pays particular attention to what is best for the students and their understanding, to help them make better sense of the world in which they live. Cranton (2001, cited in Kreber et al., 2007, p. 34) argued, "the authentic teacher cares about teaching, believes in its value, wants to work well with students, and has a professional respect for students."

Students' ownership and self-regulation is necessary if enduring learning is to take place (Murdoch & Hornsby, 2003; Reinsfield, 2018a). Riggs and Gholar (2009) focus on the role that students can play themselves to accomplish their dreams and aspirations. They describe this as the conative domain or conation, the will, drive or determination to achieve a goal – also sometimes labelled in the literature as self-actualization, self-efficacy or individuation (Kreber et al., 2007; Tessmer & Richey, 1996).

Conative learners are self-regulated, confident, diligent, and resourceful; they know what they can do and are proactive to seek support, as they require it (Zimmerman, 1990). Zimmerman argued that these learners can problem-solve, take responsibility for their learning, plan, set goals, reflect, and action the need to change their thinking. This term is also applicable to how teachers think and how their pedagogies foster students' agency in the classroom. Conation can be compared to Freire's (2005a, 2005b) construct of conscientisation in which an individual deeply understands their place in the world (Nevin & Cardelle-Elawar, 2003). For example, a teacher's concept of technology education can be determined through their espoused perception and manifesting practice, as mediated by past or present professional experiences (Harding et al., 2001).

Conative teachers and students present as motivated learners, who have high self-efficacy and intrinsic motivation and with appropriate support find a learner-centered approach to technology education an experience that affirms their confidence. This will however depend on the professional skill of the teacher to organize the learning process appropriately.

Entry requirements

In New Zealand, entry into teacher education programs is restricted. The New Zealand Teaching Council, mandates that all students must be interviewed and deemed "suitable for the profession of teaching." A police screen is also conducted before admission. As signaled earlier, teacher education occurs at two levels, one in pre-service or Initial Teacher Education (ITE) programs, where students are taught the fundamentals of teaching to early childhood, primary and secondary school aged children. The other type of teacher education is in-service or professional learning and development (PLD), targeted at maintaining the currency of practicing teachers.

In ITE programs, primary teacher education students experience teaching and learning in technology education, along with all other curriculum areas. Some institutions have separate courses for technology; in others, technology is clustered with other subjects such as Science. Bachelor's degree and graduate diploma are the two predominant programs where students can become primary teachers. Bachelors programs are currently 3 years in duration, with some institutions offering a further 4th "honors" year of study. The 3-year duration of the degree is somewhat controversial, with many teacher educators espousing a need for a 4-year program. Graduate Diploma programs offer an intense year of study, undertaken over an extended university year - beginning in January and finishing in November or December, depending on the location (Note: our academic year is the same as the calendar year).

In secondary ITE programs, students cannot generally gain entry unless they have a Bachelor's degree, and some higher level papers, to support their teaching subject. For technology, this has proved problematic, as previously those with an Advanced Trades Certificate were also eligible for entry. The shift to degree level entry has contributed to a shortage of teachers who have strong practical backgrounds. The University of Waikato currently offers a 2-year pathway for those students with extensive Trades experience, which leads into a Graduate Diploma. Within the Graduate Diploma (secondary) students experience more time studying technology than their primary colleagues, however time is still of the essence so the nature of technology programs is focused on curriculum and pedagogical knowledge and skills, because students who enter the program have the expertise to ensure they have the necessary practical skills within their specialist technological areas. Within New Zealand, there is disparity in the nature and time allocated to technology teacher education across the country, as reflected in other countries.

TECHNOLOGY TEACHER EDUCATION IN NEW ZEALAND COMPARED TO OTHER COUNTRIES: CHALLENGES AND INNOVATION

These changes bring unique challenges for teacher educators in New Zealand. Current ITE courses need to be adjusted, and academic staff need to become cognizant of and respond to the changes and/or additions to the curriculum. Similar needs are represented in schools where changes to the curriculum also require considerable time and investment in teacher Professional Learning and Development (PLD). Reinsfield's research (2018b, 2018c) has identified persisting challenges for teacher education, particularly for technology teachers in New Zealand. She indicates an urgent need for secondary school teachers to move away from traditional approaches to technology education, which emphasizes practical outcomes and safety rather than fostering students' critical and creative thinking. To enable such a change, practicing teachers need to move from a sole focus on specialist knowledge, towards the interpretation of the curriculum and/or assessment standards, and towards a student-centered approach, where teachers are positioned to guide rather than instruct their learners. Such practice reflects the authentic actions of technologists, where learning is open-ended and divergent.

There is a continued need for student teachers to reflect upon their own and others' perceptions of technology education, and it is the responsibility of ITE programs to prepare them to professionally critique (but not be explicitly critical of) the way that technology education is taught in schools. During their initial education programs, all students undertake practicum experiences in classrooms with experienced Associate Teachers, who model and guide their student teachers. This presents a number of challenges for technology teacher education in New Zealand. In the secondary sector, students undertake a practicum within technology departments, taking a range of classes with students aged from 10-18 years of age. Student teachers are taught how to foster and implement learner-centered and future-focused learning contexts so that they can remain committed to these pedagogies, particularly as what they may observe in schools may not always correlate with best practice recommendations.

TEACHER PROFESSIONAL LEARNING AND DEVELOPMENT

Professional learning and development (PLD) structures in place (to support teachers' evolving practice) are variable in quality in New Zealand, and sometimes discount individual learning needs, especially as Ministry of Education PLD funding and provisions are targeted to the government of the times' wider educational goals rather than teachers and schools' specific needs. In a climate where teacher learning is expected to be a continuous process, an inquiry-based or collaborative approach to professional development provides a means to recognize existing experiences and understanding, and to situate the learning process as being social in nature and directly connected to practice (Webster-Wright, 2017).

In 2019, the Mātanga (Māori word for expert) project was conceptualized to offer a new approach to professional learning and development (PLD) for technology teachers in New Zealand. Its design acknowledged yet challenged traditional approaches to PLD, where teachers were positioned as the receivers of information (Granshaw, 2010). The New Zealand curriculum (2007) outlines that teachers should use an inquiry-based approach to their professional development, which is needs-based, and has the potential for a collaborative approach to learning.

Engagement with online professional learning was also a pertinent area for technology teachers because recent changes to their learning area implied that practitioners needed to be or become confident users of digital pedagogies (Ministry of Education, 2017). The principles of connectivism were used to support teachers to think differently about their learning, or to foster new understandings through the use of digital technology (Siemens, 2014). An online platform (Zoho Connect) provided discursive learning contexts, to accommodate the sharing of diverse views from colleagues outside of teachers' immediate school communities, thus extending the scope of their evolving understandings (Lai et al., 2013). This model was suited to teachers in remote areas, or for those who had limited access to curriculum support. The overarching, long-term goal of the Mātanga project is to provide self-sustaining PLD, based on community needs, and to position the agency of the learning within the community. The provision of easily accessible professional development, supported through the Technology Education New Zealand (TENZ is a professional association for technology education) network of regional meetings and conferences, has also helped to ensure its sustainability.

Teaching of Teaching and Learning

As we have identified, there is a continued need for student teachers to reflect upon their own and others' perceptions of technology education, and it is the responsibility of Initial Teacher Education programs to prepare them to professionally critique the way that technology education is taught in schools. For example, student teachers in New Zealand become conversant with formative assessment (Black & Wiliam, 1998) and the principles of active learning (Newmann et al., 1995). Clarke (2005) and Clarke et al. (2003) state that a greater role in their learning facilitates students' learning success. The same applies to student teachers who are taught about the sharing of learning intentions, questioning, self and peer assessment – all strategies of formative assessment to make learning more explicit. Student teachers are also taught to identify appropriate success criteria for the learning. When highlighted or co-constructed, learning is even greater. The identification and writing of clear, measurable learning intentions in technology clarifies aspects of technological knowledge and skills within any one lesson. Conceptual, procedural, societal knowledge and technical and information skills need to be articulated to students before the lesson commences. Teachers need to be able to identify and articulate key learning to students. Each learning intention is subsequently associated with planned learning experience/s to facilitate that learning. Student teachers are taught to purposefully plan and logically sequence these experiences. This ensures relevant information about the context of study, and relevant technological knowledge and skills are available to learners to enable the development of intended technological outcomes while being cognizant of societal, environmental and global issues influencing decision making.

When implementing technology in the classroom, each learning intention and associated experience produces some form of tangible (e.g., written, oral, visual, dramatic, graphical) evidence of learning with the potential for formative assessment opportunities. Student teachers learn how to plan, implement and assess such activity, and are encouraged to plan for the production of variety within the evidence of learning produced by their students. This evidence might take the form of things such as posters, charts, interviews, written summaries/reviews, products, systems, environment plans, discussion or oral explanations, concept maps, annotated sketches, 2D and 3D detailed drawings, functional models, prototypes and final technological outcomes. Proof of learning outcomes can be evidenced and used formatively or summatively for assessment when clear specific criteria are identified. Table 3 shows examples of muddled and context-free learning intentions in technology.

Table 3. Examples of learning objectives and contexts (adapted from Fox-Turnbull, 2012)

Context & Technology *Component*	**Unclear learning intention *(to be avoided) Students are learning to…***	**Context-free learning intention *(desirable) Students are learning to…***
School senior ball gown/ prom dress *Technological Modelling*	Understand why making a mock-up of their ball gown is necessary to ensure quality	Understand the importance of making a mock-up has on the quality of a final outcome
Meals for the elderly living at home *Planning for Practice*	Develop a critical path to plan meal preparation for elderly living at home	Plan technological practice through the development of a critical path to ensure maximizing all team members' use of time
Wooden jigsaw puzzles for an early childhood centre *Characteristics of Technological Outcomes*	Understand how the physical and functional nature of wooden jigsaw puzzles for an early childhood centre impacts performance	Understand how the physical and functional nature of an outcome impacts on performance
Cell phones *Characteristics of Technological Outcomes*	Explore critical environment issues and impacts of cellphones	Explore critical environment issues and impacts of a commonly used technology

Context & Technology ***Component***	**Unclear learning intention** ***(to be avoided) Students are learning to...***	**Context-free learning intention** ***(desirable) Students are learning to...***
A hutch for a rabbit *Outcome Development and Evaluation*	Use a digital tool to draw 3D detailed plans of their rabbit hutch	Use a digital tool to draw 3D detailed plans of a structure
Webpage for Hamilton Hawks Running Club *Outcome Development and Evaluation*	Construct a user-friendly website for Hamilton Hawks	Construct a quality, safe, user-friendly digital outcome for a specific client

One strategy taught to student teachers is to write learning intentions that are free from the context of learning. Clarke (2008) suggests that separating the context from the learning intention can have a dramatic effect on teaching and learning. This strategy clarifies the intended learning and enables focused feedback to students. When teaching specific technological knowledge and skills, it is easy to muddle context with technological learning, so that neither become clear – developing a "mucky brown paint" rather than a clear pool of "curriculum color." There is a risk in this situation that the rich technological learning might get buried in the business of the context (Fox-Turnbull, 2012). The context or "vehicle" through which learning occurs is vitally important and must be engaging and authentic to students (Clarke, 2005, 2008). This process also facilitates opportunities for the transfer of skills and knowledge to other contexts within and across curriculum learning areas (Clarke, 2008).

CONCLUSION

Technology education in New Zealand has evolved and changed regularly since its inception into The New Zealand Curriculum Framework in 1993 (Ministry of Education, 1993). Key organizers such as curriculum strands, technological areas, and achievement objectives are currently on their third iteration. These changes have influenced the practice of teachers, students and teacher educators alike.

Initial teacher education in New Zealand currently prepares student teachers to teach in student-centered innovative learning environments. Constructivist principles situated within Sociocultural theory underpin the education system that values excellence, innovation, inquiry and curiosity, diversity, equity, community participation, ecological sustainability and integrity (Ministry of Education 2007). ITE programs prepare student teachers to teach technology through experientially-based inquiry learning approaches to design and develop technological outcomes, systems or products, to meet identified needs within social, cultural and sustainable parameters. Courses in technology education teach technological content, pedagogical, and pedagogical content knowledge, but time does not allow for the development of physical and technical skills related to individual technological areas.

Many currently practicing specialist technology teachers struggle with the philosophical changes needed to move technology from a technical, skills-based program to the needs-based student-centered program outlined in the current curriculum. In the primary sector, challenges remain but for different reasons. Over recent years in primary education in New Zealand, the Ministry of Education's focus has led to the marginalization of technology education. These challenges mean that although student teachers are learning up-to-date practice and pedagogy while at university, they rarely see quality technology education being modelled in the classroom. However, not all is lost. The recent revisions to increase the presence of digital technologies in the technology curriculum, and the move to teaching through inquiry whilst acknowledging students' lived experiences, offers exciting opportunities to consolidate the status of technology education in the future.

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TECHNOLOGY TEACHER EDUCATION IN TAIWAN

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ABSTRACT

In Taiwan, the curriculum guidelines adopted in 2019 for the technology domain, which comprises both living technology and information technology, mainly aim to equip students with computational thinking and design thinking skills. The guidelines do not apply to elementary schools, but require two mandatory technology curriculum classes per week for six semesters in junior high school. For senior high school, the mandatory courses provide 4 credits, while the elective courses have up to 8 credits. In the curriculum guidelines, considerable revisions have been made to learning content compared to previous guidelines. In terms of technology teacher education, many revisions and adjustments have also been made accordingly. This chapter presents details of programs designed for preparing technology teachers in Taiwan, covering Content Knowledge (CK), Pedagogical Knowledge (PK), and Pedagogical Content Knowledge (PCK). It then discusses potential challenges in developing technology teachers, including their insufficient number, inconsistent quality, and lack of content knowledge, owing to the impact of emerging technology issues. In addition, it also describes several innovative measures, including the launching of maker education and technology centers, the promotion of integrative STEM/STEAM education and robotic teaching, implemented by Taiwan in recent years, as well as the effects on preparing technology teachers. It is hoped that by elaborating Taiwan's endeavors to promote technology education, including recent developments, challenges, and opportunities of technology education, this chapter can help Taiwan to engage with the rest of the world in order to expand the reach of technology education.

Keywords: Technology Education, Teacher Education, Taiwan

INTRODUCTION

In the 21st century, as a consequence of the new way of life brought about by rapid technological development, skills for understanding, analyzing, and applying technologies are fundamental for everyone who aspires to succeed. To aid the development of students' technological literacy, the Ministry of Education in Taiwan announced the curriculum guidelines of the technology domain for its 12-year basic education in 2018. By providing technology tools, materials, and resources, the courses offer students opportunities to both gain hands-on experience and increase their capabilities in designing and creating technology tools and information systems. The courses could also improve students' higher-order thinking skills, such as creative thinking, critical thinking, problem solving, logical and computational thinking (Ministry of Education, 2018).

Taiwan's current 6-3-3-4 system of education comprises the 12-year basic education which constitutes compulsory education, and a college/university education (typically 4 years). The first part is divided into three stages, namely, 6 years of elementary education, 3 years of junior high school education, and 3 years of senior high school education (including general senior high schools and technical schools). The second part is for students who have completed compulsory education and want to continue their studies.

According to the curriculum guidelines for 12-Year Basic Education, there is no technology curriculum included in the elementary school educational stage. For junior high school, there is a mandatory technology curriculum of two classes per week, and for senior high school, the mandatory courses provide 4 credits, while the elective courses offer up to 8 credits. The senior high schools can be divided into several categories according to their characteristics: general high schools that focus on basic disciplines; technical high schools that give priority to vocational and practical subjects; and comprehensive high schools that have the characteristics of both general and technical schools. The teaching time of the technology curriculum is mandatory only for general senior high schools, while for the other three types of high schools, technology curricula are only provided on the basis of flexibility and electives. Therefore, the high schools referred to in this chapter are general senior high schools.

THE PROFILE OF TECHNOLOGY EDUCATION

The Evolution and Ideas of the Technology Curriculum

Figure 1 presents the evolution of the technology curriculum in Taiwan. This curriculum can be traced back to the industrial arts curriculum in the 1960s, which developed under the influence of the industrial arts education offered in the United States. At that time, these courses aimed to provide students with the opportunity to familiarize themselves with the concepts of industrial civilization, prepare for an industrialized society, develop creative thinking, and explore the industrial world, at the same time, focusing on design and using hands-on tools. Therefore, subjects covered in the early industrial arts curriculum included the trades of carpentry, metal work, electrical work, ceramics, and plastics. The industrial arts curriculum was renamed as the living technology curriculum in 1992, and this name has been used ever since. Meanwhile, it was included in the Grade 1-9 curriculum guidelines in 2001, together with biology, physics and chemistry, and earth sciences, as part of the science and living technology domain. The living technology curriculum focused on the technologies of communication, manufacturing, construction, and transportation. In addition to the original subjects of carpentry and metal work, additional subjects, such as film editing, seismic protection structure, and energy and power transportation were also incorporated. Until 2018, the curriculum guidelines for 12-Year Basic Education grouped the living technology and information technology subjects into the new technology domain, which encompasses the current technology education curriculum in Taiwan. The new technology domain stresses the integration among disciplines. For example, in order to make a robot to perform a specific task, students need to integrate the skills of mechatronics and control application, digital processing, as well as programming.

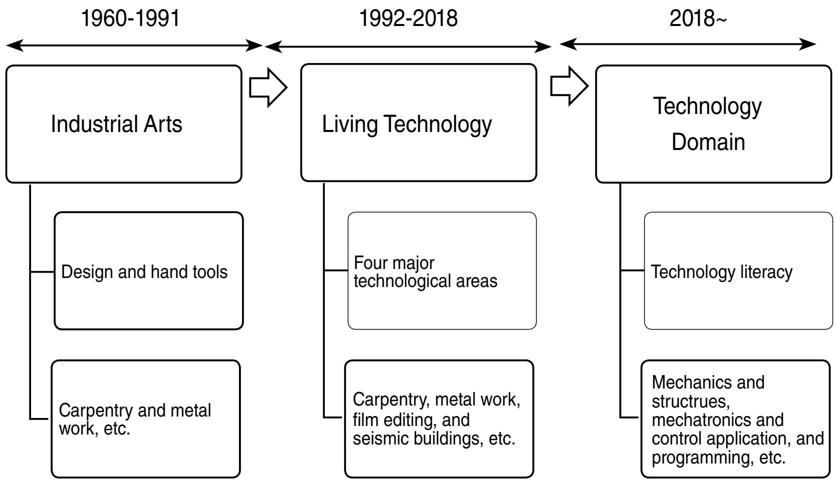

Figure 1. Evolution of the technology curriculum in Taiwan

In Taiwan, the curriculum guidelines are reviewed every 10 years and the Ministry of Education (MOE) is the agency responsible for developing the curriculum guidelines for each educational stage which provide the basis for curriculum design and textbook preparation. The curriculum guidelines for 12-Year Basic Education adopted in 2018 are the latest version, in which the purposes and objectives of the new technology domain curriculum is to be accomplished through two subjects: Information Technology and Living Technology. The Information Technology course covers knowledge and skills related to computer science, with the focus on computational thinking, including logical and systematic thinking. Under these principles, the designs and practice activities in the course are also instrumental in enhancing students' ability to put computational thinking into practice, as well as to develop their problem solving, teamwork, and creative thinking skills. Figure 2 lists the curriculum idea of the Information Technology course at different educational stages. For junior high schools, the key purpose is “integration of information technologies for creation,” focusing on helping students acquire basic knowledge of information technology, integrate information technologies for communication and creation, and solve problems with computational thinking. As for senior high schools, the key purpose is “gaining insights into information technology,” highlighting the importance of assimilating computational thinking for developing the abilities of creative thinking and teamwork. In addition to information technology knowledge and skills, another goal is to improve students’ moral values and the sense of responsibility required by the information society. Generally, the key objectives of the Information Technology course are to equip students with the main concepts, principles, and methodologies of information technology, enabling them to sharpen their computational thinking skills for applying technologies effectively when solving problems. Consequently, the goal is to help students become positive and responsible citizens who can both excel in creative thinking and are open-minded regarding communication and cooperation.

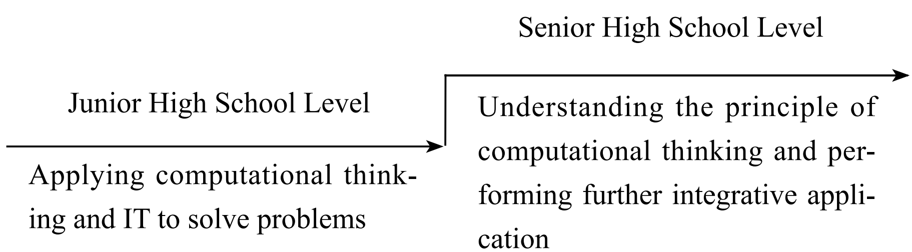

Figure 2. The idea of the Information Technology course
Source: Fujita & Lee, 2018.

The Living Technology course takes “design thinking” as the basic concept, and emphasizes the cultivation of students’ abilities to “do” hands-on practice, the “use” of technological products, as well as design and critical “thinking” (Ministry of Education, 2018). The curriculum idea in each educational stage of the Living Technology course is shown in Figure 3. Among them, it can be seen that the junior high school educational stage focuses on “creative design” and emphasizes the use of technological tools and materials processing to develop the knowledge and skills for designing. In addition, it also helps students understand the development of technology and the relationship between technology and society in the junior high school educational stage. At the stage of senior secondary school education, it focuses on “engineering design” and emphasizes the integration of interdisciplinary knowledge through engineering design projects, such as Science, Technology, Engineering, and Mathematics (STEM), and aims to develop higher order thinking skills, innovation, and critical thinking in the fields of technology and engineering.

In conclusion, the concept of the Living Technology course is based on hands-on practice, and focuses on cultivating students’ hands-on abilities and design knowledge. Furthermore, it helps increase students’ understanding of curiosity about technology topics and constructing comprehensive knowledge of technology, and finally achieve the cultivation of technology literacy.

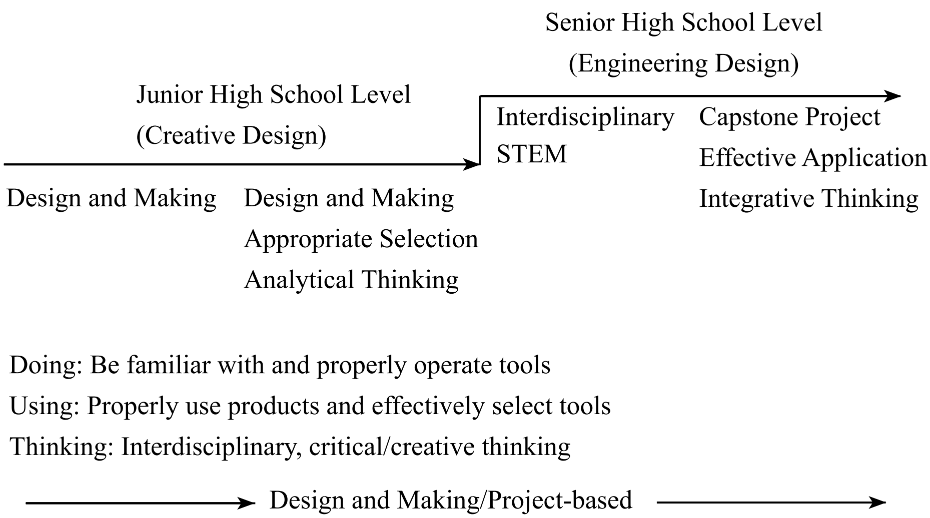

Figure 3. The idea of the Living Technology course
Source: Fujita & Lee, 2018.

Curriculum Guidelines

As mentioned above, the 12-year basic education can be divided into three stages. This is planned according to the system of education, including 6 years of elementary school, 3 years of junior school and another 3 years of senior high school. On the other hand, according to the students' physical and mental development level, it can also be divided into five learning stages: the first stage represents the first and second grades in elementary school, the second stage represents the third and fourth grades, the third stage represents the fifth and sixth grades, the fourth stage represents the seventh, eighth, and ninth grades in junior high school, and finally, the fifth stage represents the 10th, 11th, and 12th grades in senior high school. According to the curriculum guidelines for 12-Year Basic Education, elementary schools can provide the technology curriculum on a flexible basis; that is, they can incorporate, at their own discretion, topics related to living technology or information technology into learning activities. However, in junior and senior high school, with required teaching hours, the technology curriculum is part of the domain-specific curriculum (as shown in Table 1).

Table 1. Time allocation and subject combination in the technology domain

Educational stage		**Junior high school**			**Senior high school**		
Learning stage		Fourth learning stage			Fifth learning stage		
Grade		7	8	9	10	11	12
Required course	Information Technology	1	1	1		2	
	Living Technology	1	1	1		2	
Elective course	Enrichment and expanded elective courses	-	-	-		8	

Source: Ministry of Education, 2018.

A comparison of the requirements of the earlier Grade 1-9 curriculum guidelines and those of the current curriculum guidelines for 12-Year Basic Education shows substantial changes to both teaching hours and learning content for Information Technology and Living Technology courses. In the Grade 1-9 curriculum guidelines, the information technology course is not included in the domain-specific curriculum, while in the senior high school educational stage, it belongs to the living domain. Although it is not a compulsory subject for Grades 1-9, because it is classified as the main subject, teachers can incorporate it into other courses at their discretion. The Living Technology course forms part of the science and technology domain in the Grade 1-9 curriculum, but falls within the living domain in senior high school. In terms of teaching hours, there is no required number of hours for Information and Living Technology courses in elementary school. For Grades 7-9 in junior high school, of an overall total of 32-35 classes per week, there must be two technology course classes each week, with one class for Information Technology and the other for Living Technology. In Senior high school, students usually need a total of 180 credits in 3 years. Among 180 credits, Information Technology and Living Technology courses, as mandatory courses, each provide 2 credits, while the additional 8 credits are provided by elective technology domain courses.

Students who complete the 12-year basic education can pursue post-secondary education in colleges/universities. In the near future, the most common way to enter a college/university will be to apply for admission, which currently accounts for 57% of the admitted students. Although the technology curriculum is not included in the entrance examination, the latest statistics from the agency of the Joint Board of College Recruitment Commission show that by 2022, about 30% of the departments will consider the high school academic portfolio of the technology curriculum. In other words, learning records of the technology curriculum in senior high school are one of the key factors influencing a senior high school student's admission to a college/university. Such a description shows that both the details in the curriculum guidelines and the admission requirements for further education reflect the importance of technology education in Taiwan.

Curriculum Goals and Content

The curriculum goals of the technology domain are listed as follows:

(1) Acquire basic technological knowledge and skills, and develop appropriate concepts, attitudes, and work habits; (2) Become proficient in the use of technological knowledge and skills to carry out creative, design, critical, logical, and computation thinking; (3) Integrate theory and practice to solve problems and meet needs; (4) Understand the technology industry and its future development trends; (5) Cultivate an interest in technological research and development, regardless of gender, and engage in relevant career exploration and preparation; (6) Understand the interactions between technology and individuals, society, the environment, and culture, and reflect on ethical issues related to its use (Ministry of Education, 2018).

With such goals, Information Technology and Living Technology courses include two aspects, “learning performance” and “learning content,” which respectively express the course goals and the course contents. Details are described as follows.

Learning performance

The learning performance of the technology curriculum includes two dimensions, computational thinking and design thinking, and the details are presented in Table 2. The learning performance of computational thinking focuses on training students to apply information technology tools to solve problems, cooperate, interact and communicate with others, as well as establish a positive attitude and concern about related issues. In addition, the learning performance of design thinking focuses on guiding students to observe and discover the needs in life, to learn and think in the process of design and making, while training hands-on abilities, the ability to use technology products and critical thinking.

Table 2. The learning performance of the technology curriculum

Dimension	Performance	Explanation
Information Technology	Computational thinking and problem-solving	Be able to use computational tools to analyze problems, develop methods and make effective decisions.
	Collaboration and creativity around computing	Be able to use computational tools to collaborate with others.
	Communication and presentation about computing	Be able to use computational tools to present ideas and communicate with others.
	Attitudes toward computing	Be able to establish positive attitudes towards and habits of computing.
	Computational representation and procedures	Be able to present problems in computational form or transform data into suitable structured tables; be able to solve problems with programming and algorithms.
	Design and implementation of computational artifacts	Be able to create and solve problems with computational thinking.
Living Technology	Technological knowledge for everyday life	Be able to understand the nature of technology, concepts and knowledge of technology, procedural knowledge, and conduct impact assessment of technology development.
	Attitudes toward everyday technology usage	Be able to establish positive attitudes toward using technology, to enhance interest in learning, and to develop the habits of hands-on practice.
	Hands-on skills for everyday technology	Be able to operate technological tools, use technology products, and maintain these technology products.
	Integration of technological competency	Be able to integrate technological knowledge with practical design and making, as well as communicate and cooperate with others.

Source: Ministry of Education, 2018.

Learning content

The learning content of the Information Technology course includes six themes, namely Algorithms, Programming, System platforms, Data representation, processing & analysis, Application of information technology, and Information technology, humans, & society. There are four themes included in the Living Technology course, specifically Nature of technology, Design & making, The application of technology, and Technology & society. Tables 3 and 4 show the details of the learning content for each course.

Table 3. Learning content of Information Technology in required courses

Themes	Educational stage	Learning Content
Algorithms	Grade 7	- Basic concepts of algorithms
	Grade 8	- Concepts and application of the array data structure
		- Introduction to basic algorithms
	Senior High	- Concepts and application of important data structures
		- Concepts and application of important algorithms
		- Performance analysis of algorithms
Programming	Grade 7	- Basic concepts, functions, and application of programming
		- Structured programming
	Grade 8	- Hands-on programming with arrays
		Concepts of modular programming
		- Hands-on problem solving with modular programming
	Senior High	- Concepts and hands-on practice of textual programming
		- Hands-on programming of the array data structure
		- Hands-on programming of important algorithms

(continued)

Themes	Educational stage	Learning Content
System platforms	Grade 9	- Important developments and evolution of system platforms
		- Basic concepts of architecture and operation of system platforms
		- Concepts and introduction to computer networks
		- Concepts and introduction to network services
	Senior High	- Fundamental algorithms and operation of system platforms
		- Future development trends of system platforms
Data representation, processing, and analysis	Grade 9	- Principles and methods of data digitization
		- Representation of digital data
		- Concepts and methods of data processing
	Senior High	- Concepts of Big Data
		- Basic concepts of data mining and machine learning
Application of information technology	Grade 7	- Data processing project
	Grade 9	- Information technology project
	Senior High	- Concepts and tools of digital collaboration and co-creation
Information technology, humans, and society	Grade 7	- Personal data protection
		- Fair use principles for information technology
		- Information security
	Grade 8	- Social issues related to the media and information technology
		- Information ethics and law
	Grade 9	- Impact of information technology on human life
		- Characteristics and types of common computer industries
	Senior High	- Fair use principles for information technology
		- Personal data protection
		- Influence and impacts of information technology on humans and society

Source: Ministry of Education, 2018.

Table 4. Learning content of Living Technology in required courses

Themes	Educational stage	Learning Content
Nature of technology	Grade 7	- Origin and evolution of technology
	Grade 8	- Systems of technology
	Grade 9	- Relationship between technology and science
	Senior High	- Relationship between technology and engineering
		- Integration and application of engineering, technology, science, and mathematics
Design and making	Grade 7	- Methods of creative thinking
		- Creation of design drawings
		- Operation and usage of hand tools
	Grade 8	- Process of design
		- Material selection, processing, and handling
		- Operation and usage of common tools
	Grade 9	- Design and development of products
	Senior High	- Engineering design and hands-on activity
Application of technology	Grade 7	- Selection of everyday technological products
		- Mechanistic and structural applications of everyday technological products
	Grade 8	- Maintenance of everyday technological products
		- Energy and power applications of everyday technological products
	Grade 9	- Electrical and control applications of everyday technological products
		- Application of emerging technology.
	Senior High	- Design and application of mechanisms and structures
		- Design and application of mechatronics and control

(continued)

Themes	Educational stage	Learning Content
Technology and society	Grade 7	- Interactions between technology and society
	Grade 8	- Influence of technology on society and the environment
	Grade 9	- Investigation of issues related to technology
		- Development of technological industries
	Senior High	- Investigation of issues related to engineering technology

Source: Ministry of Education, 2018.

As listed above, Information Technology focuses on problem-solving, emphasizing the cultivation of students' ability to use information technology and computational thinking to solve problems at the stage of junior high school. In the senior high school stage, Information Technology places more emphasis on the integration of information technology and computational thinking, whereby the exploration of computer science enables students to further understand the relevant principles of computational thinking. The learning content of living technology in the junior high school educational stage emphasizes the training of students' ability to process materials and produce with simple tools. At this stage, it focuses on developing students' creative and design abilities for solving technological problems in real life; hence most of the learning content at this stage is based on hands-on practical activities. Unlike in junior high school, Living Technology emphasizes engineering design projects in senior high school. By integrating interdisciplinary knowledge learning (such as science, technology, engineering and mathematics) and applying technology tools, higher order thinking skills such as design, and innovative and creative thinking, can be cultivated. From the perspective of the learning content details, we can find that the curriculum of technology education in Taiwan not only connects the domain concepts and curriculum goals, but also sees its continuity. For example, in the junior high school educational stage, students learn to understand “Mechanistic and structural applications of everyday technological products” and “Electrical and control applications” in Living Technology courses. After entering the senior high school educational stage, they must learn the design and application of the concepts of “mechanisms and structures” and “mechatronics and control.” Through complete arrangements, these courses are closely related to the goals of technology education in Taiwan. At the same time, with these arrangements, it is expected that students can observe and learn basic concepts, and begin to solve problems through design and making in their life.

The enrichment and expanded elective courses of the technology domain are offered at the senior high school educational stage, including advanced programming in Information Technology; an engineering design project for Living Technology; and a robotics project and an applied technology project for the domain-specific curriculum. The details are presented in Table 5. The aim of the advanced programming in Information Technology is to increase students’ interest in technology through understanding and integration of applied technology knowledge. Therefore, the learning content includes four topics: Programming language, Data structure, Algorithms, and Project implementation. The engineering design project in living technology is based on the needs of career and social development, and focuses on cultivating students’ ability of interdisciplinary integration, and emphasizes project-based learning to allow students to experience engineering-oriented design and making. Through advanced project-based courses, the robotics project and the applied technology project in the domain-specific curriculum cultivate students’ integration of the knowledge of Information Technology and Living Technology. For example, the robotics project requires students to apply practical skills in programming, as well as mechatronics and control ability integration.

Table 5. Learning content of enrichment and expanded elective courses

Subjects	Courses	Themes	Learning Content
Information technology	Advanced programming	Programming languages	- Concepts and application of programming languages
			- Development of programming languages
		Data structure	- Principles and application of common data structures
			- Hands-on programming of common data structures
		Algorithms	- Principles and application of key algorithms
			- Hands-on programming of key algorithms
			- Performance analysis and comparison of algorithms
		Project implementation	- Hands-on programming project
			- Program debugging
Living technology	Living technology engineering design project	Design and making	- Advanced engineering design and hands-on practice
		Application of technology	- Spatial and structural design
			- Engineering materials and application
			- Product design and making
			- Making of transport vehicles
			- Application of emerging technologies
Domain-specific curriculum	Robotics project	Robot development	- Types and application of robots
		Robot control	- Usage methods of robot program development tools
			- Control methods of various motorized devices in robots
			- Data access methods for various sensors in robots

(continued)

Subjects	Courses	Themes	Learning Content
		Hands-on implementa-tion	- Hands-on robotics programming
		Design and making	- Advanced mechatronics design and hands-on practice
	Applied technology project	Principles of applied information technology	- Computational principles of ap-plied information technology
		Hands-on implementa-tion of applied information technology	- Methods of applied information technology
			- Performance evaluation of applied information technology
		Design and making	- Advanced programming and hands-on practice

Source: Ministry of Education, 2018.

The enrichment and expanded elective courses planned for the technology domain include four courses, and each of them is assigned 2 credits. After completing the required courses, students at the senior high school educational stage can choose the enrichment and expanded elective courses according to their interests. Furthermore, in the domain-specific curriculum (including the "robotics project" and "applied technology project"), Information Technology and Living Technology teachers can carry out collaborative teaching to guide students in project activities. These elective courses are mainly based on hands-on practical projects, and the purpose is to cultivate students to integrate the acquired technology knowledge to solve observed problems. Meanwhile, through the process of design and making, it helps students understand the development and nature of technology, which should enable them to explore and develop the technological expertise required for their future careers.

To sum up, the development of the technology education curriculum in Taiwan has been planned according to a systematic and complete approach. Whether in Information Technology or Living Technology, there are detailed curriculum goals and learning content that teachers can follow when designing the activities. In addition, there are specialized classrooms, managed by the teachers themselves, for both Information Technology and Living Technology which include the software and hardware required for teaching, such as computers, software, hand tools, power tools and digital tools. In terms of assessment, the assessment in the field of technology education in Taiwan covers different aspects such as technological knowledge, attitudes, practical skills and comprehensive capabilities. Not only formative but also summative assessment is used, with attention paid to gender equality and individual differences when processing assessment. Therefore, it is mentioned in the curriculum guidelines of 12-year Basic Education for the Technology domain (2018) that the assessment of technology knowledge should emphasize students' thinking and expression skills with open-ended questions; the assessment of technology attitudes can be conducted through interviews, student self-assessment or peer review; the assessment of practical skills can be examined via students' performance and interests through implementation or portfolio assessment; the assessment of integration ability, including design, innovation, problem solving, teamwork, and critical thinking should be assessed through different methods, such as implementation, interviews, and self-assessment. For teachers, it is important to understand students' learning effectiveness and improve their teaching through assessment, and at the same time help students reflect on their performance. In summary, the curriculum of technology education in Taiwan is able to give technology teachers a clear direction and suggestions for implementing assessment to facilitate teaching and learning.

THE STATE-OF-THE-ART OF TECHNOLOGY TEACHER EDUCATION

Technology Teacher Education in Taiwan

According to some education scholars in the United States, such as Beeby (1966) and Cochran-Smith (2012), teacher quality has a significant effect on both quality of teaching and students' learning results. In addition to having knowledge of a specific subject, effective teaching also requires a positive attitude and proper values and beliefs (Amirshokoohi, 2016; Bame et al., 1993). Therefore, in many countries, a high priority has been placed on teachers' professional development, which is critical to both the realization of educational theories and the improvement of teaching results (Blank et al., 2007; Fishman et al., 2003).

In terms of pre-service teacher education, since 2018, an individual who has: (1) graduated from a college or university, (2) completed a pre-service teacher education program, (3) passed the teacher qualification examination, (4) finished the educational practicum, and (5) met the teacher selection requirements (refer to Figure 4 for the detailed process) could be qualified as an elementary or secondary school teacher in Taiwan. As mentioned above, the MOE is responsible for planning teacher education, and there are several educational institutions, including normal/education universities, as well as universities with teacher education programs or centers (collectively, teacher education universities), providing teacher pre-service education programs. According to the statistics, there are 49 teacher education universities in Taiwan, with 27 providing programs to prospective high school teachers, nine educating K-6 teachers, and 13 educating teachers for different stages of education (Ministry of Education, 2019). This paper mainly focuses on technology teacher education, and since there is no program dedicated to the technology domain curriculum for educating teachers at the K-6 stage, discussions will center on secondary school teachers. As a result, National Taiwan Normal University (NTNU) will be used as an example in order to introduce the teacher education systems in Taiwan.

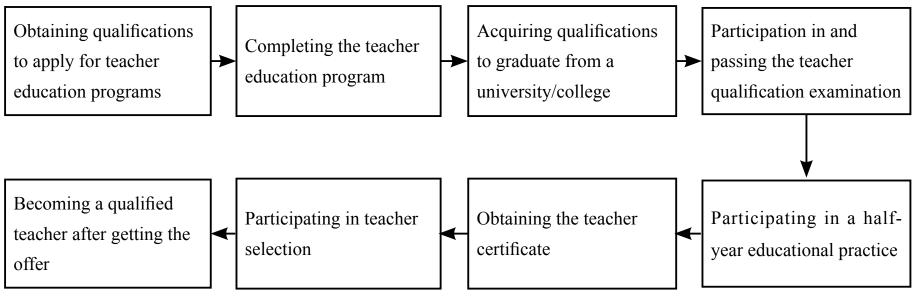

Figure 4. Process for becoming a qualified elementary or secondary school teacher
Source: Ministry Education, 2017.

Students studying in teacher education departments of NTNU, including those with Bachelor's, Master's or a doctoral degree, can participate in the teacher education programs after completing the selection process. To finish the teacher education programs, the students must complete all the teacher pre-service education courses, which include general courses, subject-specific courses, and professional education courses. The general courses must be completed by all students from each of the departments, for example, a Living Technology teacher must complete the general courses, such as Introduction to technology education, Electronic circuits, and Basic design, and the subject-specific courses, covering content knowledge that a teacher must acquire, including Mechanical design, Structural design, Engineering graphics, etc. The professional education courses that must be completed by all students are provided by teacher education centers.

Any student who has completed the teacher education programs and has been accredited with a certificate can take the teacher qualification examination which is held once a year. This examination takes place in June from 2020, covering four subjects; that is, a Chinese competency test, Educational principles and systems, Teenager development and guidance, and the High school curriculum. After passing the examination and meeting the requirements for graduation, a student must then participate in a half-year educational practicum. During this period, the students will work in a secondary school to practice teaching in their own subject areas and get a sense of the administrative and class management responsibilities in the actual working environment. Pre-service teachers who have finished the educational practicum will be accredited by MOE with a teacher qualification certificate, based on which they are entitled to be selected as an official secondary school teacher.

Pre-service Technology Teacher Program in Taiwan

To be successful, teacher professional development programs must be founded upon an empirical knowledge base that links different forms of professional development to either teacher or student learning outcomes (Fishman et al., 2003). Among relevant studies conducted outside Taiwan, Bybee and Loucks-Horsley (2000) identified four key areas in technology teacher professional development: (1) learning about technology; (2) learning to teach technology; (3) self-assessment and continuous improvement; and (4) sustained professional development. Furthermore, Engelbrecht and Ankiewicz (2016) propose that an effective teacher professional development program should enable technology teachers to learn about content knowledge, pedagogical knowledge, and school knowledge (understanding of the role of the taught subject in school education, or the knowledge between content and pedagogical knowledge), as well as to improve their skills, attitude, and values. In addition, the course content in the teacher professional development program should be designed based on teachers' existing knowledge and experiences, including theoretical foundations and practical experiences, as well as their reflections on those experiences.

In Taiwan, the Department of Teacher and Art Education of the Ministry of Education under the Executive Yuan is responsible for the system of technology teacher education. Specifically, it is responsible for harmonizing, planning, and supervising technology teacher education with the assistance of the entrusted teacher education universities. The required pre-service technology teacher program mainly covers Content Knowledge (CK), Pedagogical Knowledge (PK), and Pedagogical Content Knowledge (PCK), as discussed in detail below.

Content knowledge

CK represents the technology knowledge required for technology domain teachers. For example, an Information Technology teacher's CK should include subjects related to algorithms, such as data structure and discrete mathematics. For Living Technology, a teacher's CK should cover basic technology and engineering theories (including introduction to engineering; areas of engineering and their definitions; integration of engineering, technology, science, and mathematics and their applications; procedural knowledge about engineering design and practices, including predicting and analysis, testing, revising, and optimizing models/prototypes). Designing appropriate teacher education programs is also crucial for ensuring that technology teachers can both acquire CK and apply it in their teaching. In designing the programs, consideration is given to a range of factors, such as global trends in information and living technology education, the curriculums of teacher education institutions, and the necessary conditions of a technology teacher for implementing Taiwan's new curriculum.

1. Information Technology

Many countries have revised their curriculums regarding information technology in order to keep up with the rapid development both in this area and in related teaching theories, and with this trend, Taiwan also adopted a new curriculum for designing suitable information technology courses in 2019. Since preparing teachers to have sufficient core capabilities in CK and PK is critical for ensuring a smooth implementation of the new curriculum, it is necessary to redesign the Information Technology teacher pre-service education program. Thus, Table 6 presents the subject-specific courses in the program and their credits required for pre-service Information Technology teachers. According to the learning content in the curriculum guidelines, the Information Technology teacher pre-service education program is designed to include eight mandatory subjects, namely, algorithms, programming, data structure, discrete mathematics, computer structure, operating systems, computer networks, and information security. In addition, another 11 elective courses, specifically machine learning, artificial intelligence, data mining, linear algebra, database systems, probability, embedded systems, software engineering, image processing, computer graphics, and introduction to computers, are also included.

Table 6. Subject-specific courses for the Information Technology teacher education program

Type	Subject-specific courses	Credits	Remarks
Mandatory	Algorithms	3	
	Programming	3	
	Data structure	3	
	Discrete mathematics	3	
	Computer structure	3	
	Operating systems	3	
	Computer networks	3	
	Information security	3	
	Technology systems and social development	2	
	Total credits for mandatory courses	26	
Elective	Machine learning	3	One of the two subjects must be completed
	Artificial intelligence	3	
	Data mining	3	

Type	Subject-specific courses	Credits	Remarks
	Linear algebra	3	
	Database systems	3	
	Probability	3	
	Embedded systems	3	
	Software engineering	3	
	Image processing	3	
	Computer graphics	3	
	Introduction to computers	3	
	Total credits for elective courses	9	

Source: National Taiwan Normal University, 2019.

In general, pre-service Information Technology teachers must complete eight mandatory courses (with 26 credits) and three elective courses (9 credits) for a total of 35 credits. These courses aim to develop teachers' capabilities in various areas, such as understanding of computational concepts, solving problems with computational thinking and information technology, presentation with appropriate data, solving problems with processing and analysis methodologies, system planning and designing, understanding and application of network technologies, and understanding of the relationships between information technology and human society. Only upon gaining these capabilities is a teacher capable of teaching effectively by using his/her knowledge and skills as needed. To ensure that the pre-service teachers obtain the teaching strategies of information technology teaching and establish a positive attitude towards teaching, there are two compulsory courses, the "Information Technology Teaching Strategies and Methods" course and the "Teaching Practicum," which help them to develop PCK. By participating in these courses, the pre-service Information Technology teachers are trained in the overall knowledge of professional disciplines, programming, computational thinking, teaching methods and strategies.

(2) Living Technology

With the rapid development of modern technology products and applications, technology has become an indispensable part of our lives. Therefore, modern citizens need to be technologically literate; in other words, individuals are required to possess the capability to understand, utilize, and realize technologies for solving technology issues. In order to keep up with emerging technologies on fast-tracking and solving the difficulties experienced over the past 10 years regarding teaching Living Technology courses, Taiwan moved the Living Technology curriculum into the technology domain as part of its latest curriculum guidelines, which were revised based on both the needs of students and practical teaching activities. To equip Living Technology teachers with sufficient capabilities, the education programs for the teachers have also been adjusted accordingly in the new curriculum guidelines. Table 7 outlines the subject-specific courses for Living Technology teacher pre-service education programs for a total of 39 credits, including 31 credits for mandatory courses, such as introduction to technology and engineering education, engineering graphics, basic design, engineering design, material processing, mechanics design, structural design, energy and power, electronic circuits, and electromechanical integration, as well as 8 credits for elective courses.

Table 7. Technology subject-specific courses for the Living Technology teacher education program

Type	Subject-specific courses	Credits	Remarks
Mandatory	Introduction to technology and engineering education	2	
	Engineering Graphics	3	
	Basic design	3	
	Engineering design	3	
	Material processing	3	

Type	Subject-specific courses		Credits	Remarks
	Mechanics design		3	
	Structural design		3	
	Energy and power		3	
	Electronic circuits		3	
	Electromechanical integration		3	
	Technology systems and social development		2	
	Total credits for mandatory courses		31	
Elective	Related to “technology teaching capabilities”	Design and management of technology classrooms	2	At least one must be selected
		Occupational health and safety	3	
		Design and development of multimedia materials	3	
	Related to “design and making capabilities”	Product design	3	At least one must be selected
		Manufacturing	3	
		Computer multimedia	3	
		Computer-aided design	3	
		Computer-aided design and manufacturing	3	
		Model making	3	
	Related to “application of technologies”	Introduction to computers	3	At least one must be selected
		Human factor engineering	3	
		Programming	3	
		Practical project	3	
		Automatic control	3	
		Engineering mathematics	3	
		Total credits for elective courses	8	

Source: National Taiwan Normal University, 2019.

All of the mandatory courses listed above are mapped to the subjects included in Living Technology courses according to the technology domains curriculum guidelines. Elective courses, such as those provided by the department of NTNU dedicated to preparing secondary school Living Technology teachers, include three items. First, "technology-teaching capabilities" includes three courses, helping them understand the essential requirements of the technology domain curriculum guidelines, developing standard-specific courses and materials, effective utilization of various teaching strategies and diversified assessment strategies and tools, and designing, managing, and maintaining technology classrooms. Second, the item "design and making capabilities" is critical for living technology teachers. Thus, six elective courses are provided in this item, focusing on designing products for practical projects, engineering design processes, and solving technology and/or engineering problems, including plotting and reading graphs, the application of tooling equipment, and procedural knowledge about material processing and treatment. Lastly, in terms of "application of technologies," a total of six elective courses are provided for equipping Living Technology teachers with critical content knowledge, including the design of mechanics and structures and their application, electromechanical integration, and other forms of professional knowledge. In addition, the department for teacher education has at its discretion the right to design elective courses of up to 6 credits. Generally, these courses aim at preparing pre-service teachers with basic and core technology capabilities; therefore, they are designed based on the measurements of the capabilities. In order to improve the outcomes of technology education, Living Technology teachers in the new era should have not only content knowledge, but also the practical skills and positive attitude needed for technology learning.

Pedagogical knowledge

Pedagogical Knowledge (PK) refers to the means by which a teaching process is implemented, as well as the general teaching objectives and values covered in it, for example, students' learning methods, classroom management skills, and capabilities in both developing course plans and assessing students' learning performance. Teachers should have sufficient PK, understand the strategies through which students can construct knowledge, and adopt an attitude for developing good practices and positive interests. All the pre-service technology teachers must develop their PK by taking professional education courses, including the "basic pedagogical course," "pedagogical methodology course," and "common elective courses" provided by teacher education centers. The information technology and living technology sections each have a "Teaching strategy and method course" and a "Teaching practicum course" for developing students' Pedagogical Content Knowledge (PCK) (as shown in Table 8). A pre-service technology teacher must complete pedagogical professional courses with a total of 26 credits before graduation. In addition to the mandatory courses that account for 20 credits, a student also has to obtain 6–8 credits from subjects grouped into a "basic pedagogical course," a "pedagogical methodology course," and "common elective courses," which should be completed in at least 2 years (4 semesters).

Table 8. Professional education courses and credits

PK/ PCK	Category	Mandatory/ Elective	Required credits	Courses
PK	Basic pedagogical courses	Mandatory	At least 4 credits	Conception of education, educational psychology, educational philosophy, and educational sociology
PK	Pedagogical methodology courses	Mandatory	At least 10 credits	Principles of education, course development and design, learning assessment, classroom management, principles and practices of instruction, and teaching media and their application

PK/ PCK	Category	Mandatory/ Elective	Required credits	Courses
PK	Common elective courses	Elective	6–8 credits	Including emerging educational topics, educational principles and systems, students' development and instruction, and courses, teaching, and assessment, etc.
PCK	Teaching strategy and method course and Teaching practicum	Mandatory	4–6 credits	Teaching strategy and method course and Teaching practicum for each subject
		Total credits	26 credits	

Source: College of Teacher Education, 2018.

For the category of "basic pedagogical courses," a technology pre-service teacher must complete at least 4 credits (two of the four courses); under the category of "pedagogical methodology courses," 10 credits (five of the six courses) must be completed; and the remaining 6-8 credits for elective courses can be obtained from courses in the above two categories or from the "common elective courses" chosen by the student. Common elective courses can be further grouped as emerging educational topics, educational principles and systems, students' development and instruction, and courses, teaching, and assessment, etc. The first sub-category covers courses such as environmental education, information education, and gender education; the second includes education history, education administration, and high school education, etc.; the third consists of courses like remedial education and adaptive teaching; and the fourth comprises educational statistics, computers and teaching, and educational service. It is evident that the pedagogical professional courses provided by teacher education centers can help pre-service technology teachers to cultivate PK, which is instrumental to their teaching activities in educational premises.

Pedagogical content knowledge

Pedagogical Content Knowledge (PCK) focuses on the linkage between professional knowledge and teaching, such as designing bridging courses based on students' existing knowledge, adopting and adjusting alternative teaching strategies, and providing assessments and feedback tailored to students' individual differences. In other words, PCK aims at achieving the optimal combination of PK and CK. In professional education courses, the "Teaching strategy and method course and Teaching practicum" course is responsible for equipping pre-service technology teachers with PCK (see Table 8). According to the course objectives and capacity in the curriculum guidelines, PCK courses should equip information technology teachers with the teaching capabilities, such as those for solving problems based on computational thinking, creative thinking, teamwork cooperation, interdisciplinary integration (including STEM and STS), and project-based teaching strategies. As for living technology teachers, the required capabilities include teaching strategies for solving problems (cooperative problem solving), creative thinking, cooperative learning strategies, critical thinking, interdisciplinary integration (such as STEM and STS), and engineering design thinking, as well as project-based learning strategies. These capabilities are increased by the teaching strategy and method course and teaching practicum courses for each specific subject.

The teaching strategy and method course for a particular subject focuses on presenting teaching strategies and relevant theories on teaching and cognitive psychology. It aims to enable teachers to design learning activities that can be adopted for suitable teaching strategies, which could have a more significant outcome on improving students' outcomes. By contrast, the teaching practicum course for a subject is designed to prepare pre-service technology teachers' PCK in areas like lesson plan design and development, practical teaching, classroom management, and teaching assessment through observation, simulation, and actual teaching experience. Taking a famous institution for preparing technology teachers as an example, NTNU equips pre-service Living Technology teachers with PCK through the courses of teaching strategies and methods, teaching practicum I, and teaching practicum II (three courses for six credits). For Information Technology teachers, the teaching strategies and methods course, as well as the teaching practicum course, with a total of four credits, are required.

In-service Technology Teacher Program in Taiwan

In teaching, a professional teacher functions as an instructor, learner, and researcher. Efforts for improving teachers' professional development center on enabling continuous self-learning of teachers and examinations, as well as reflection on and improvement of their teaching as a way to improve their professionalism and teaching outcomes (Burke, 1987). In terms of the differences in course objectives and syllabuses between the new and previous curriculum guidelines, in-service technology teachers can improve themselves through the training programs in the technology domain. The training programs are mostly provided by teacher education universities with dedicated courses for pre-service teachers. The practice activities and workshops included in the courses are beneficial for improving both the professional knowledge and skills of in-service teachers. Currently, there are seven universities providing training programs for information technology, and three providing programs for living technology.

Information technology in-service training program

In terms of information technology, the training program includes two mandatory and two elective courses. The mandatory courses cover: "New themes in information technology" (1 credit and composed of 4 themes) and "Pedagogy for information technology" (1 credit and composed of 5 themes). Meanwhile, the elective courses include: "Algorithms" (2 credits) and "Programming and data structure" (2 credits). Table 9 summarizes their key topics.

Table 9. Training programs for in-service Information Technology teachers

Course	Mandatory/Elective credits (hours)	Themes and key points
New themes in information technology	Mandatory 1 credit (18 hours)	- Internet of Things
		- Data science
		- Topics on information technology and human society
		- Concepts for computational thinking
Pedagogy for information technology	Mandatory 1 credit (18 hours)	- Teaching on problem solving based on computational thinking
		- Teaching on creative thinking and information technology
		- Teaching on cooperative creation and information technology
		- Teaching on interdisciplinary integration (STEM) and information technology
		- Teaching on project-based information technology
Algorithms	Elective 2 credits (36 hours)	- Theories and methodologies for major algorithms
		- Practices for major algorithms
		- Efficacy assessment for algorithms
Programming and data structure	Elective 2 credits (36 hours)	- Concepts and practices in programming
		- Concepts, theories, and practices of basic data structures

Living Technology in-service training program

For Living Technology, the training programs include mandatory courses of 6 credits: "Engineering design and teaching: integration of mechanics and electronics and control of mechatronics" (36 hours), "Engineering design and teaching: mechanism and structure" (36 hours), and "Computer-aided design and manufacturing" (36 hours). In addition, topics such as introduction to technology and engineering and related teaching methods, as well as teaching strategies, are embedded into the above courses in order to better meet the teaching requirements. Table 10 summarizes their key themes and topics.

Table 10. Training programs for in-service Living Technology teachers

Courses	Credits (Hours)	Contents
Engineering design and teaching: Integration of mechanics and electronics and control of mechatronics	2 credits (36 hours)	- the introduction of electronic circuit design
		- the system design and application of microcontrollers (such as Arduino)
		- the introduction, control, and application of sensors, communication equipment, and technology of electromechanical control
Engineering design and teaching: mechanism and structure	2 credits (36 hours)	- mechanical and structural design
		- engineering materials and their application
		- product development and making
		- application of new technology
Computer-aided design and manufacturing	2 credits (36 hours)	- basic principles, theoretical bases, and application methods of CAD and CAM systems
		- three-dimensional (3D) drawing techniques
		- the management, operation, application, and maintenance of common tools and equipment, such as laser mixers, 3D printers, and three/four-axis computer numeric control (CNC) machines

Specifically, the computational thinking capabilities, as stressed in the new curriculum guidelines for Information Technology, mean that in-service teachers urgently need to refresh the following CK: advanced algorithm design and programming, and data analysis and processing. In terms of PCK, the required capabilities according to the conceptual design of the new curriculum guidelines include understanding the concepts in computational thinking and related teaching ability, teaching on creative thinking, teaching strategies for cooperative creation, teaching on interdisciplinary integration (including STEM and STS), and projects-based teaching strategies. For Living Technology, in line with the concepts highlighted in the new curriculum guidelines for creative design, practice, and engineering design thinking, the CK to be refreshed by in-service Living Technology teachers should include the following: understanding of engineering design processes and design thinking, mechanics and structures, electricity and control, and related CK on implementing engineering design projects or robot electromechanical integration projects. In terms of PCK, the priorities should be placed on problem-solving strategies, inquiry learning strategies, interdisciplinary integration teaching strategies (including STEM and STS), teaching strategies for engineering design thinking, and project-based learning strategies. The training programs mainly target in-service teachers and standby teachers (those who have been qualified but have not assumed the role of official junior or senior high school teachers).

In addition, teachers can also visit the in-service training website for updates on further learning activities and can participate in such processes. In countries like the United States and the United Kingdom, dedicated education associations are responsible for organizing further learning courses for technology teachers, such as the International Technology and Engineering Education Association (ITEEA) and the Design and Technology Association (DATA). Such institutions assume the greatest responsibility for promoting technology education and designing further learning courses for technology teachers in their respective countries. The DATA even designed the curriculum guidelines for the “design and technology” domain in the United Kingdom by working in collaboration with professional teams for developing textbook resources. By contrast, the activities and courses for in-service teachers in Taiwan are mostly provided by individual institutions. The information of these activities and courses are listed on the sso.inservice.edu.tw/, enabling interested teachers to enroll and participate on a voluntary basis. Generally, in-service technology teachers have multiple means through which to enhance their professionalism in order to cope with rapid technological development. Their efforts in self-renewal also facilitate the realization of concepts and spirits of the new curriculum guidelines in their teaching activities.

CHALLENGES AND OPPORTUNITIES OF TECHNOLOGY TEACHER EDUCATION

Challenges of Technology Teacher Education

Insufficient number of technology teachers due to the reduced number of pre-service teachers

Over the past few years, in addition to the reduced demand for technology teachers as a result of the inclusion of Living Technology courses under both the science domain of the previous curriculum guidelines and the effects of the falling birth rate, the number of technology teachers in the pipeline has also dropped substantially. Although the new adopted curriculum guidelines for the technology domain have quickly increased short-term demand for technology teachers in schools at various educational stages, the reduced number of available teachers has led to a persistent shortage of teachers in the technology domain. In order to meet the demand, some cities/counties have urged other non-traditional education institutions to provide in-service further learning courses in Living Technology or Information Technology. In this way, in-service teachers can obtain the certificate for the technology domain and thus teach the technology curriculum legally. However, in comparison with dedicated technology domain teachers, teachers from other domains may be understandably less satisfactory in terms of their professional capabilities, especially considering the short duration and incompleteness of the courses designed for them.

Inconsistent levels of professionalism among technology teachers due to diversified educational channels

Since Taiwan lifted restrictions on institutions that could provide teacher education programs in 1995, many traditional teacher education universities have been transformed into comprehensive universities, while other general universities have also applied for the establishment of teacher education centers designed to educate technology domain teachers. However, diversified channels for educating teachers have led to a less rigorous education process, an imbalanced supply and demand for educated teachers, poorly implemented internship programs, and paralyzed motivation and evaluation mechanisms for teachers' professional development (Ministry of Education, 2012). Facing these issues, which have been caused by the diversified education system, and given the forecast that more universities may apply for educating technology domain teachers, less prudent oversight and qualification criteria will result in inconsistent capabilities in teaching the technology curriculum, as well as a failure to implement the intentions of the technology domain's curriculum guidelines.

The technology teacher education programs are impacted by emerging technology topics

Given both the wide coverage of the Internet and the rapid development of technologies, Taiwan revised its technology domain's curriculum guidelines with an eye on international trends and current technological developments, designing the learning content of Living Technology and Information Technology accordingly. At the same time, the pre-service education programs for technology teachers were also adjusted in line with the learning content of the new curriculum guidelines. However, the technology teacher education programs are inherently incapable of keeping up with emerging technology topics generated from continuously evolving and developing technologies. For example, topics such as “maker movement,” “STEM education,” and “robotic education,” which have gained increasing popularity in recent years, could bring numerous impacts on the CK designed for teacher education-related courses, which need continuous revision and adjustment to stay relevant.

Opportunities of Technology Teacher Education

Even while taking into account the above issues in current developments and systems of technology teacher education, innovative measures adopted by Taiwan in the technology domain are strong enough to promote their healthy development.

Maker movement

Following the trend of the global maker movement, the first opportunity is to both raise national awareness of teaching in the technology domain and to take initiatives in developing hands-on capabilities. Setting itself apart from many other nations, Taiwan employed a top-down approach to promote Grade 1-12 technology teacher education, as well as to develop courses and activities designed for the maker movement in schools. In order to upgrade technology education at the county and/or city levels, as well as to promote implementation of technology education programs, a total of 100 maker education and technology centers have been established at local levels. The activities of a maker education and technology center include developing courses, educating teachers, and promoting materials-based education, mostly aiming at enabling nearby schools to offer technology domain courses under the new curriculum guidelines. Therefore, the centers play a critical role in implementing the new curriculum guidelines for the technology domain.

STEM/STEAM education

In recent years, the need to promote STEM education has gained increasing global attention, with many nations committing considerable efforts to equip students with critical capabilities in the 21st century through STEM education (Brown et al., 2011; The White House, 2014; Voogt & Roblin, 2012) and developing students' STEM literacy. In order to develop technologically innovative talents with interdisciplinary capabilities, Taiwan's new curriculum guidelines for the technology domain include STEM issues in Living Technology courses for senior high schools.

Robotics competition

Over the past few years, a focus has also been placed on robotics teaching, as this can provide not only hands-on experience, but also interest in interdisciplinary learning (Alimisis, 2013). In addition, several international robotics competitions, such as the FIRST Robotics Competition (FRC) organized in the United States, which encourages senior high school students to learn as much as they can about science and technology, have attracted players from around the world, including Taiwan. Such international events not only generate great motivation and an interest in learning, but also provide an international arena in which to showcase Taiwan. In addition, Taiwan also hosts several competitions related to robots, such as the senior high school living technology competition and the national Brain Go competition for innovative technology products. Besides the robot competitions, senior high school students can also learn more about robots by taking elective courses under the technology domain curriculum guidelines. In order to meet emerging demands for robotics education, teacher education programs have already incorporated courses related to robotics, such as mechanical design, structural design, electrical circuits, and electromechanical integration.

CONCLUSION

Given the rapid technological development that has been witnessed over recent years, technology literacy, which involves the ability to utilize technology to both improve standards of living and solve problems, has become indispensable for everyone who aspires to succeed. Nations worldwide are attaching great importance to technology education, and Taiwan has followed this trend by combining the Living Technology and Information Technology courses into a new technology domain in its latest curriculum guidelines. The Information Technology courses prioritize the capabilities of computational thinking, while also applying information technologies. The Living Technology courses focus on hands-on experience and capabilities for solving problems by guiding students through the journey from conceptual design to engineering design. The curriculum guidelines not only set out the curriculum objectives, but also design learning performance and learning content at different learning stages. The concepts of engineering design and interdisciplinary thinking and application are also incorporated into the teaching activities for equipping students with interdisciplinary capabilities. The curriculum guidelines have designed technology education for all stages of learning, from elementary school through to high school. For elementary school, the technology curriculum is offered on a flexible basis, while secondary school students should complete the required hours and credits in specified themes and subjects. For example, the Living Technology courses for Grade 7 in junior high school focus on mechanical and structural design, those for Grade 8 prioritize energy and power design, while those for Grade 9 focus on electricity and control design. In senior high school, students are expected to integrate and apply their knowledge and skills as the course progresses.

It is said that teacher quality has important effects on students' learning results. Therefore, in promoting technology education, providing pre-service teacher education for technology teachers is as important as developing well-thought-out curriculum guidelines. In Taiwan, an individual who aspires to become a technology teacher must first pass through a rigorous process that involves enrolling in a pre-service teacher education program, obtaining a university degree, passing the teacher qualification examination, finishing the educational practicum, meeting the teacher selection requirements, etc. The pre-service education programs enrolled in by technology teachers cover CK, PK, and PCK, and by participating in professional courses, they can equip technology teachers with sufficient professional knowledge and skills to effectively guide students' learning activities. In addition, in-service technology teachers can also participate in either training programs offered by teacher education institutions or the workshop events organized by schools, both of which are designed to improve their professional knowledge and skills.

For technology education, Taiwan now faces various challenges, such as an unsustainable quality of technology teachers due to diversified channels for educating teachers, an insufficient number of technology teachers and less satisfactory professionalism among teachers from other domains, and the potential impact on current technology teachers' CK from emerging technology topics. Even with these issues, Taiwan has been active in promoting technology education through several measures, including incorporating STEM into the curriculum guidelines for the technology domain and stressing the importance of developing interdisciplinary talents, encouraging the development of robotics competitions and equipping technology teachers with the ability of robotic teaching, and establishing 100 maker education and technology centers at local levels. As a result of these efforts, it is evident that technology education courses have acquired nationwide attention.

In line with the global trend, and by leveraging the opportunities in designing the new curriculum guidelines, Taiwan has adjusted its technology teacher education programs in a way that is both more targeted and more rigorous. Taiwan has a vision to expand its technology teacher education programs into an international program, to design the STEM interdisciplinary learning courses and topics based on international issues, and to equip technology teachers with a more diversified and wider vision, while also strengthening their capabilities.

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TECHNOLOGY TEACHER EDUCATION IN THE UNITED STATES OF AMERICA

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ABSTRACT

Technology Education (TE) courses in America have typically been offered to public school students at the middle school and high school levels. Recently, an increasing trend has been to offer TE activities at the elementary level where they are often integrated with core content. Education in America is a state's right, and not the responsibility of the federal government, so it is not possible to have a national curriculum for TE or any other subject. Some states require TE to be taught to all students at the middle school level. Others have a requirement at the high school level, but many states do not have a requirement that TE be taught at all. Even so, TE courses often exist as elective courses taught at the secondary level. Goals for TE programs are typically drawn from the Standards for Technological Literacy that were recently revised and are now referred to as the Standards for Technological and Engineering Literacy. A significant recent trend in America has been to embrace the engineering movement within TE. This movement resulted in a name change for the International Technology Education Association to the International Technology and Engineering Educators Association in 2010. Although TE course offerings vary widely, they are often characterized by hands-on learning as an instructional methodology, and by the making of a useful product as a deliverable. Content organizers for TE have become increasingly broad-based and expansive over time. Additionally, the spans between major curriculum movements have shortened over time. TE teacher preparation programs also vary based upon philosophy. Some are more traditional, while others take a progressive approach addressing more engineering content. Despite a documented need for teachers, TE teacher preparation has been in a state of decline in America for decades. This trend has spawned a need for innovative teacher preparation programs.

Keywords: Technology Education in America, Technology Education Teacher Preparation, Model Technology and Engineering Programs

INTRODUCTION

Historically, technology education programs in the United States have been oriented toward the secondary level of education. In America, this is defined as middle school and high school. Technology Education (TE) traditionally begins in middle school and addresses students 11 to 13 years in age. Education in America is a state's right and not the right of the federal government. As a result, technology education programs and requirements can vary widely, not only from state to state, but from district to district within a given state. Some states require TE to be taken by all students at the middle school level, but in many states the offering is purely elective. Other states have a requirement that TE be offered at the high school level, and many states have no TE requirement at all, relying on the local school districts to determine their required and elective course offerings. Instruction in TE typically progresses through high school levels in America as a series of elective offerings completed by students 14-18 years in age. More recently, the current trend in America is to deliver TE as an integrative subject at the elementary level. Instruction in technology & engineering at the elementary level has been experiencing significant growth in many states throughout the country. As evidence of this trend, the Virginia Children's Engineering Convention was recently held in early February of 2020 in Roanoke, Virginia. The convention attracted approximately 700 participants, and this is a regional conference that only draws attendees from Virginia and a handful of surrounding states.

THE PROFILE OF TECHNOLOGY EDUCATION

TE in America, like technology itself, is in a state of ever-changing flux. Over the past two decades more emphasis has been placed on digital technologies like web design, CADD and coding of robots and CNC machining devices. Videography has become quite popular, with many TE programs delivering school news programs and making documentaries, and Rapid prototyping or 3D printing is also tremendously popular in America at this time. However, traditional material processing courses and graphics courses remain quite popular with students at the high school level as well. At the middle school level, the trend for the past two decades has been to offer broad-based courses that allow for explorations in multiple technologies. Typical course titles for middle school TE programs in America could be Applying Technology, Creating Technology, or Explorations in Technology. Some are simply referred to as Technology Education. This section of the paper explores the major objectives for TE in America, along with program titles and a bit of history that helps to explain the current content organizers used for TE in America, and how those content organizers have evolved over time.

Major Objectives of TE

The primary objectives of technology education in America are drawn from the Standards for Technology & Engineering Literacy (STEL) as recently released by the International Technology & Engineering Educators Association (ITEEA). Eight core standards are presented to be addressed at the K-12 levels. The core standards are as follows:

1. Nature and Characteristics of Technology & Engineering
2. Core Concepts of Technology & Engineering
3. Integration of Knowledge, Technologies, and Practices
4. Impacts of Technology
5. Influence of Society on Technological Development
6. History of Technology
7. Design in Technology & Engineering Education
8. Applying, Maintaining & Assessing Technological Products and Systems

Benchmarks are also provided within the STEL. These benchmarks are associated with various grade levels to help determine if these standards are being adequately addressed.

Program Titles for TE

A review of the 2019/2020 Technology & Engineering Teacher Education Directory (Rogers, 2019) yields some interesting information about program titles. Although these titles identified are for post-secondary teacher preparation programs, they are likely a reasonable representation of public school program titles as well. The directory lists at least 40 programs, but some programs only exist at the graduate level so their titles were not recorded. There are many variations for program titles as seen in the example in Appendix A.

The most frequently used program titles by far were simply Technology Education or Technology & Engineering Education. Several of the other variations in title were only slightly different from the two most popular titles. At the time of this writing, 14 of the 38 programs identified had chosen to include some reference to the term Engineering in the title of their programs. This is a growing trend and is in keeping with TE in America's move toward embracing engineering in some cases as a profession, but often as a process, that will be briefly described within this paper.

Time Allocation for Technology Education

Given the varied nature of educational requirements in the United States, discussing time allocation for school subjects can be challenging. Many factors contribute to how much time a student spends in the TE classroom. Chief among them is whether states require technology education to be given as part of graduation requirements. According to Moye et al. (2015), when surveying state supervisors about the state of TE in the United States, the authors found that only seven of the thirty-nine states that responded had a requirement for TE in their schools. Some states also only require a certain number of completed classes, and some mandate that TE is either to be offered at the middle or high school level and no more. This lack of widespread adoption of TE requirements and varied approaches to required implementation greatly inhibits the number of hours that American students are exposed to TE.

Another factor that contributes to difficulty of assessing time allocations is the idea that schools do not have a uniform structure across all states, counties, or even districts. Scheduling in schools, even within the same school district fluctuates. An example of this can be seen when comparing the class times in middle schools and high schools. Often middle school students have eight class periods in a day that last roughly 45 minutes. Additionally, some of those classes rotate on a weekly cycle (i.e., five different classes that students attend once a week in a specific time slot in their day). This rotating period is often where TE finds itself, along with music, art, and other courses that are not assessed by mandatory state testing. In contrast, high schools often use a system known as block scheduling, where students have five periods a day that last roughly an hour and twenty minutes each. Students across the country could have several classes in TE, no classes in TE, required classes at one schooling level or elective courses at another and that total time in the classroom could be different than someone in the next school district.

History of Content Organizers for TE in America

Content organizers for technology education have evolved significantly over time. Original content organizers were organized around technical subjects primarily associated with the predecessor of Technology Education in America that was known as Industrial arts. Those original content organizers included woods, metals and drafting. Later additional content organizers such as printing and power mechanics evolved. A number of major curriculum development efforts in the 1960s moved the field toward broader content organizers such as Manufacturing and Construction and Communication. Two popular industry-based curriculum development efforts of that period were known as the American Industry Project conducted by Face and Flug (1965) at the University of Wisconsin-Stout in 1965 and the Industrial Arts Curriculum Project (IACP). The IACP was funded under the Vocational Education Act of

1963 and was a joint project between the Ohio State University and Illinois State University. This grant funded project to develop a curriculum to reflect modern industry resulted in the most extensive curriculum development effort the field had ever seen. Products produced as a result of the IACP included textbooks and activity guides known as the World of Manufacturing and the World of Construction. There were other competing philosophies emerging in the 1960s. One really unique philosophical approach was advocated by Donald Maley at the University of Maryland. This came to be known simply as the Maryland Plan. Maley's unique approach placed individual development as the primary outcome of any industrial arts program. He advocated for individual and group work, investigation and interaction with the industrial world outside of school. According to Householder (1979), content organizers were secondary to Maley, who placed more emphasis on processes like problem solving and research and experimentation.

Throughout the 1960s, the study of technology and its influence on society as a major organizer for the field was beginning to take hold. Early primary advocates of this approach according to Householder (1979) in his yearbook chapter on curriculum Movements of the 1960s included Donald Lauda and Delmar W. Olson. By the 1980s a major shift toward technology education was evolving. A curriculum summit for the field was held with a select group of 20 of the nation's leading philosophers in the field. This gathering resulted in a white paper known as the Jackson's Mill Industrial Arts Curriculum Theory (Snyder & Hales, 1982). Jackson's Mill represented a further broadening of curriculum organizers to address "human adaptive systems" such as Manufacturing, Construction, Communication and Transportation, but perhaps more importantly, it marked the beginning of the end to industry as the primary organizer for the content of the field and ushered in a new era using technology as a major content organizer. Among the most influential leaders at Jackson's Mill was Paul DeVore, Chairman of the Program for the Study of Technology at West Virginia University. An industrial arts educator, Paul DeVore had changed the focus of the program at West Virginia University to reflect technology many years earlier. Just 4 years after the Jackson's Mill curriculum theory document was published, the American Industrial Arts Association (AIAA) voted for a change in name to the International Technology Education Association (ITEA). In the early 1990s, Ernest Savage of Bowling Green University and Leonard Sterry of the University of Wisconsin-Stout set out to recreate the Jackson's Mill study using a similar Delphi technique to identify participants for what came to be known as A Conceptual Framework for Technology Education. Twenty-five leaders were chosen from across the United States to participate in the study. Among other innovations, the Conceptual Framework ushered in the concept of bio-related technologies as a body or content for the field in addition to common organizers such manufacturing, construction, communication and transportation.

The Technology Standards Project was the brainchild of Dr. William Dugger who sought to create national standards for the study of technology in the early 1990s. Academic standards for other subjects had become prevalent in the United States by this time, and mainstream subjects such as mathematics and English had already gone through evolutions of standards development. The Technology Standards Project was funded by a large National Science Foundation grant and resulted in a 1996 publication known as A Rationale and Structure for Technology Education. The actual standards themselves were published in 2000 and are known as the Standards for Technological Literacy: Content for the Study of Technology (SfTL). These standards came to identify both content and process organizers for the field of technology education, and represented a further broadening of the content base for technology education. The content standards identified within the SfTL included the study of some content organizers that had become more familiar over time such as energy & power, transportation, communication, manufacturing, and construction, along with the study of medical and biotechnologies. These standards were reprinted by the International Technology Education Association in 2002 and 2007.

The most recent influence on content organizers in the field of technology education has been the engineering movement. This movement has been advanced in large part by the influence of a private organization known as Project Lead the Way (PLTW). The purpose of PLTW is to encourage more students to pursue engineering as a career in the United States, and the premise is that as a nation we are not producing enough engineers. PLTW does not identify content organizers as such, but rather provides course offerings for the elementary, middle and high school levels. The engineering movement has been so prevalent within the United States that the ITEA changed its name to include engineering education in 2010. The organization is currently referred to as the International Technology & Engineering Educators Association (ITEEA) and produces its own curriculum known as Engineering by Design. ITEEA has recently completed an update of the SfTL. This set of academic standards is now known as the Standards for Technological and Engineering Literacy (STEL) and is helping to define and explain the role of technology and engineering in the realm of STEM education. Content, or rather context organizers as defined in the STEL include Material Conversion & Processing, Transportation & Logistics, Energy & Power, Information & Communication, The Built Environment, Medical & Health-related technologies, and Computation, Automation, Artificial Intelligence and Robotics (ITEEA, 2020). Additional organizers related to the processes used in Technology Education are referred to as Practices. These practices address items such as Making by Doing, Systems Thinking, Creativity, Collaboration, Communication, Optimism, Critical Thinking, and Attention to Ethics. With regard to content organizers for technology education in America two conclusions can be drawn. The first is that the content base for technology education has been expanding over time. The second is that the spans between major curricular shifts that influence those organizers have been shortening over time.

General Characteristics of TE Programs

Characteristics of TE programs in the United States vary widely, but most TE classes also have two common themes. They are often characterized by the use of hands-on learning as a primary means of instruction, and the creation of some form of product as an outcome. Those products can be quite different, based upon the nature of the class, and some are no longer even physical in nature. For instance, the development of a webpage to market a product, or a computer program to make a robot perform specific tasks. In the elementary grades, it is common to link technology & engineering activities to more traditional content that would naturally be addressed. This type of thematic learning often serves to reinforce traditional lessons in history or science. Historically, technology education programs had leaned with much greater emphasis toward hands-on learning, with a 20% lecture, 80% lab balance in many courses. In recent decades, the shift toward digital technologies and the teaching of software packages and programming has resulted in technology education courses becoming more cerebral. Many technology education courses could likely be characterized as having anywhere from a 30% lecture, 70% lab split to an even greater balance between the two methods of teaching and learning. At the risk of making a potentially gross overgeneralization, rural communities in America tend to offer programs with greater emphasis on hands-on learning and more robust laboratory equipment and hands-on experiences than urban programs. In the big cities throughout the United States a lot of equipment has been removed from laboratories due to safety concerns, technological obsolescence, budget cuts or lack of competent technology education teachers with equipment familiarity. Even so, there are still many quality programs that exist in urban environments, and many robotics teams and engineering courses offered to students within some of those environments.

Means of Recognition of TE Achievement

The International Technology & Engineering Educators Association (ITEEA) has a robust Teacher Excellence Awards program and a Program Excellence Awards program as well. The Program Excellence Award is designed to recognize superior K-12 Technology and Engineering Education programs across the United States. The awards program is co-sponsored by ITEEA and Paxton/Patterson, an American equipment and supply company that caters to the field of TE. Similarly, the ITEEA's Teacher Excellence Award program is co-sponsored by the ITEEA and Goodheart-Willcox, an American textbook publisher that also caters to the field of TE. Both the Teacher Excellence Award Program and the Program Excellence Award are regarded as one of the highest honors given to technology & engineering education programs and teachers at the elementary, middle, and high school levels in America. Annual awards can be issued to one teacher and one program from each level (elementary, middle school & high school) in each of the 50 states. International programs are sometimes recognized as well. Teacher Excellence and Program Excellence award winners serve as a standard for comparison and as models for fellow TE teachers and the development of TE programs. Provided below is a brief explanation of eligibility criteria for the ITEEA's Program Excellence Award.

- Technology teacher/ or school at the elementary level must be a member of ITEEA and their state association or become a member of these organizations prior to recognition
- Program must reflect high quality technology & engineering education (Integrative STEM education) philosophy and curriculum structure while also employing effective teaching strategies
- State level Program Excellence Awards Committee (or ITEEA Board Representative in the case of international nominees) reviews application materials and forwards results to ITEEA. State award recipients are sometimes honored at state or local conferences prior to recognition at the annual ITEEA conference.

The criteria for the Teacher Excellence awards are quite similar, as shown below:

- The teacher must be (or become) a member of ITEEA and their respective state/province Association.

- The teacher must be incorporating technology and engineering content and principles into the curriculum
- The teacher must have a minimum of 3 years of teaching experience.

Teacher Excellence Award winners can be nominated by colleagues, parents of students, principals, and even through self-nomination. Program Excellence and Teacher Excellence award recipients from each state at the elementary, middle school and high school levels are recognized at the annual ITEEA Conference each year.

Instruction in Technology Education

Instruction in TE in America may be easier to define and describe than the content base for TE in America. In 2018 the ITEEA published a study entitled Learning Better by Doing (Moye et al., 2018). The study surveyed almost 6,000 K-12 Science Technology, Engineering and Mathematics (STEM) teachers. Over 99% of those teachers surveyed indicated that their students benefit from doing activities in the classroom. Regardless of subject matter, whether it be graphics or drafting or manufacturing or robotics, TE teachers believe in learning by doing as an underlying pedagogical principle of the field. Second to learning by doing would be the use of the technological problem-solving method, sometimes referred to in the United States as the design method or the engineering method. There are many different versions of this problem-solving methodology, but all employ the most basic elements of addressing a challenge, researching solutions, proposing multiple solutions, prototyping a solution, and refining a prototype into a working product. More complex versions sometimes include additional steps such as mathematical modeling and optimization of a product. Since TE courses are typically taught in a laboratory environment in America, at the secondary level chances are students will have access to tools, equipment, computers and consumable materials. Assessment in technology and engineering education courses may not take the form of traditional quizzes and tests. Many technology educators would prefer not to test through conventional means, rather relying on rubrics for projects, portfolios that document student work, and other forms of authentic assessment that they find to be more accurate and meaningful than multiple-choice tests.

THE STATE-OF-THE-ART OF TECHNOLOGY TEACHER EDUCATION

In the United States the education of the populace is deemed the responsibility of each individual state. To accomplish this, each state has its own governing entity that sets out rules, regulations, and standards for knowledge for each Local Educational Agency (LEA), otherwise known as school districts. The state governing bodies also set the standards for teacher preparation programs, located within colleges and universities, and issues teaching licenses to qualified candidates. At the national level, the United States Department of Education (USDOE) exerts its influence through the allocation of funding to states for education purposes through categorical grants. The federal policy makers will place certain requirements or stipulations on funding that states can apply for (Jaroscak et al., 2020). These requirements reflect the opinions and ideas of the administration and are the main way that the federal government impacts educational policy.

While the autonomy that this creates for individual states has its advantages, a side effect of this is that each state has a different set of rules, regulations, and traditions for education. This has led to great diversity and uniqueness in requirements for certification to be a practicing teacher and what content teachers learn in their undergraduate programs. This section illustrates, using several states as examples, how the certification process is unique in each state. Additionally, an analysis regarding how technology teacher education programs within the United States are unique will occur. When describing teacher licensure, it should be noted that many states offer interstate reciprocity with regard to teacher licensure certifications in all subjects, not just TE. This is particularly true with neighboring states.

Technology Teacher Certifications

As a means of developing an understanding as to the uniqueness of individual states' approaches to certification requirements for TE teachers, three neighboring states were selected for analysis. These states were New Jersey, Ohio, and Pennsylvania. These states all feature TE standards set forth by their state education governing body (New Jersey Department of Education, 2014; Ohio Department of Education, 2017; Pennsylvania Department of Education, 2002). They also feature at least one higher education institution that is home to some form of a TE teacher preparation program (International Technology and Engineering Educators Association, 2020). Lastly, those programs are members of the most prevalent technology and engineering education professional organization in the United States, the International Technology and Engineering Educators Association (ITEEA). These factors were seen as important because they represented similarities between the states that can be used as a baseline to illustrate the idea that, despite foundational similarities, each state is unique in their processes.

New Jersey Certification Requirements

In the state of New Jersey, there are paths to certification for two categories of educator. One path is for those individuals who have not completed a formal teacher preparation program, the Certificate of Eligibility (CE), and one for those who did, the Certificate of Eligibility Advanced Standing (CEAS) (New Jersey Department of Education, 2019a). These two paths fall under the same general process towards permanent certification, known as the Provisional Teacher Process (PTP). The PTP is broken down into three stages, establishing eligibility, becoming employed in a school district and completing the provisional teaching period, and being recommended for permanent certification (New Jersey Department of Education, 2019b).

During the PTP, both CE and CEAS teachers are to be mentored by an experienced teacher for a minimum of 30 weeks. The teachers must then meet evaluation requirements for their teaching. Once per year the educator must be evaluated and obtain two effective or highly effective final ratings. These ratings must be within 3 consecutive years and adhere to state-wide evaluation system (New Jersey Department of Education, 2017). CE teachers must complete a formal instruction program in teaching and 50 hours in a pre-professional experience as well.

Upon completion of the PTP, eligible candidates may apply for permanent licensure. As a means of continually improving as professionals, licensed teachers and their supervisors are to create individualized professional development plans. These plans help to assess the strengths and weaknesses of the teacher and create a pathway to improvement. This improvement works in conjunction with state-mandated requirements that each licensed teacher complete at least 20 hours of professional development per year (New Jersey Department of Education, 2014b).

Ohio Certification Requirements

The state of Ohio maintains licensure tracks for several different educational professionals. Most germane to the current conversations are those that pertain to teacher applicants seeking licensure. In the TE field the specific licensure falls under the "Career-technical resident educator" license. For new teachers who complete an approved teacher preparation program, the state of Ohio maintains a 4-year licensure program called the Resident Educator License (REL). There is an alternative pathway for those who did not complete a teacher preparation program but have completed a Bachelor's or Master's degree that involves additional coursework before joining the REL program (Ohio Department of Education, 2020b).

This multi-year process begins with two mentoring years. In these mentoring years, the novice teacher works with a mentor to "…engage in activities that use self-assessment, goal-setting, and reflection to demonstrate effective use of authentic teacher work such as lesson planning, data analysis, and analysis of student work and assessments" (Ohio Department of Education, 2020c). In the 3rd year, teachers may take the Resident Educator Summative Assessment (RESA), administered by a private company in partnership with the state of Ohio. This summative assessment "consists of one Lesson Reflection that requires Resident educators to demonstrate reflection and decision making of their instructional practices" (Ohio Department of Education, 2019). In the 4th year, the candidate is asked to explore and think about leadership, the fine details of which each LEA determines for themselves. Additionally, if the candidate did not pass the RESA in the preceding year, they are required to attempt the assessment again in their final year.

Upon completion of the REL, eligible persons may apply for a professional educator license. This license is valid for 5 years in the state of Ohio and must be renewed to continue teaching. A condition of license renewal is the completion of professional development plans and engagement with continuing education activities. Educators wishing to renew their license must complete 6 semester hours of coursework related to teaching and/or their area of licensure, 18 continuing education units (180 contact hours), or equivalent activities related to classroom teaching. All coursework must be dated after the issuance of the license they wish to renew, and any licenses that lapse require additional semester hours of coursework to renew (Ohio Department of Education, 2020a).

Pennsylvania Certification Requirements

As with the other example states, Pennsylvania provides pathways to licensure for both the "approved" (graduate of approved, 4-year, teacher preparation program) and "alternative" (those who have not completed an approved teacher preparation program) applicants for teacher licensure. In the case of those pursuing alternative certification, there are several program providers approved by the Pennsylvania Department of Education designed to provide the necessary instruction to prepare the applicants for the teaching profession (Pennsylvania Department of Education, 2020a).

Upon completion of an approved or alternate certification program and passing of required certification tests, educators apply for certification. If approved, they are granted a level I instructional certificate. This certificate is considered valid for 6 years of service and must be converted to a level II certificate in that time. To accomplish this there are several steps that must be taken by the educator. They must accrue 24 graduate or undergraduate level credits at an approved degree-granting institution or approved intermediate unit, with a minimum of 6 of those credits being in the content area of the level I certification. Educators must also accumulate 3 years of satisfactory service in a Pennsylvania public school entity. During the 3 years, educators must receive six semi-annual satisfactory ratings on assessments by their employer. A final evaluation must occur with a state approved evaluation form as well. Finally, all educators must complete an induction program that includes a mentoring component (Pennsylvania Department of Education, 2020b). After completing all of the requirements, the educator's level I instructional certificate converts to a level II. To maintain this certification, educators must complete 6 credits of collegiate study, approved professional education courses, or 180 hours of continuing professional education programs, activities or experiences every 5 years (Pennsylvania Department of Education, 2020c).

Similar but Unique

After analyzing each sample state's certification processes, two key points can be drawn. The first key point is that each state follows a broadly similar process. Each state has certification paths for individuals who have completed an approved collegiate level program and those who did not. Upon initial approval and hiring at an LEA, educators must complete certain tasks to further their training in their profession. Finally, upon final approval and issuance of a permanent licensure, the educator must engage with continuing education activities to maintain their status. The broad similarities of the sample states can be due, at least in part, to the idea that when creating these processes, the persons in charge researched what other states were doing and its relative effectiveness and modeled their own processes after what they had found.

The second key point that can be drawn is that, despite similarities, each state's certification process is still unique. An example of the unique aspects of each state's process can be seen in their requirements for permanent licensure. Each state may have a mentoring component, an assessment component, and a continuing education component, but they are all different in the details. New Jersey, for example, requires 30 weeks or mentoring, whereas Ohio mandates 2 years and Pennsylvania does not put a specific numerical mandate on time of mentoring. For assessment purposes, Ohio partners with a private company while Pennsylvania uses a proprietary instrument generated at the state level.

This uniqueness is not limited to the three states used for comparison. Given the fundamental framework and breakdown of responsibilities between the state and federal levels of the United States, all states handle certification of teachers differently than their neighbors. As evidenced by the prior examples, even the uniqueness of processes can lead to some level of similarities between states. As states periodically review their practices and align them with current best practices, they look amongst themselves and analyze what makes for great teacher preparation and they begin to emulate one another in broad ways. This leads to, over time, the spreading of best practices and alignment by states to those practices to better serve and educate their population.

Technology Teacher Education Programs

Much like certification requirements, technology teacher education programs and the colleges and universities that house them are all unique. This uniqueness is reflected in the personality of the programs, admission and graduation requirements, and what content is explored by the students in their programs of study. To shed light on the diversity that exists in American technology teacher preparation, four universities and their technology teacher preparation programs will be discussed. This discussion is centered around admission and graduation requirements, what they offer with regard to training, and finally the features of the American system and how it compares to other paradigms.

For the purposes of the current discussion, the four schools that were chosen were Brigham Young University (BYU), located in Provo, Utah; Millersville University of Pennsylvania (MU), located in Millersville, Pennsylvania; North Carolina State University (NCSU), located in Raleigh, North Carolina; and The State University of New York at Oswego (SUNY), located in Oswego, New York. The four schools were chosen based on the region of the country they are located in, size of institution, and standing as a publicly-owned or privately-owned institution. Additionally, each institution is a participating member of ITEEA and is home to a TE teacher preparation program. These factors were chosen as a means of establishing common threads among schools that served as the foundation for analysis and comparison.

Admissions Requirements

The admissions requirements for the four example institutions provide an interesting glimpse into the variety that exists in American technology teacher preparation. MU and SUNY, both regional, publicly owned by the states in which they are located, reflect the idea that publicly owned and funded educational institutions should be accessible to as many students as possible while upholding rigorous academic standards. According to common data sets published by SUNY and MU, the average high school GPA of enrolled, degree-seeking, first-time, first-year freshmen at SUNY in the 2018-2019 academic year was a 3.49 (State University of New York at Oswego, 2019) and 3.36 at MU (Millersville University of Pennsylvania, 2020). Additionally, both schools profile their first-year students as having SAT evidence-based reading and writing scores roughly between 500 and 600, and SAT math in a similar range. In terms of importance in the application process, both schools rank rigor of secondary school record and academic GPA as very important factors in the decision-making process while factors such as test scores and application essays are less highly ranked.

Oftentimes, larger institutions have differing goals than do regional institutions. Some look to serve specific populations, based on academic interest, academic achievement, or religion. BYU and NCSU are interesting to compare because of their missions and ownership status. BYU is a faith-based, privately owned institution that focuses on undergraduate education and research. NCSU is a publicly owned, land-grant research university with a split emphasis on undergraduate and Master's degrees. These differences lead to differing admissions requirements. BYU, according to their common data set, having incoming first-year students with an average high school GPA of 3.86, SAT scores between 600 and 700, on mathematics reading and writing and rank not only GPA and secondary school rigor as very important, but also talent, character/personal qualities, and religious affiliation/commitment as very important factors to admissions decisions (Brigham Young University, 2020). Similarly, NCSU reports an average high school GPA for its first-year students of 3.80 with SAT scores in the 600 to 700 range. The major difference between the two larger schools is that while BYU places a heavy emphasis on non-academic factors (character, religious preference/commitment), NCSU, being a publicly owned institution, places their admissions emphasis solely on academic factors (GPA, secondary school rigor, standardized test scores) (North Carolina State University, 2020a).

Graduation Requirements

Graduation requirements for the four example institutions and their technology teacher education programs, in broad terms, were similar in framework. Each program featured a diverse offering of technical classes, ranging from materials processing, to visual communications, to computer-aided drafting (CAD) classes. This broad technical offering reflects a point made in Litowitz (2013) that “many institutions have designed their curriculum to reflect the Standards for Technological Literacy… specifically the portion of the SfTL referred to as the Designed World” Litowitz continues, “The Designed World identifies sectors of technology and the economy as communication, transportation, manufacturing, construction, energy & power, and biological, agricultural, and medical technologies that are worthy of study toward the goal of technological literacy” (pg. 6). In addition to the technical component, all of the universities required general education courses, professional courses meant to instruct students in core concepts of teaching, and all students are required to complete a student teaching experience.

Despite the broad similarities in graduation requirements for the four institutions, there are also unique aspects as well. One example of this relates individual state-level differences, as discussed previously in this section. To complete the Technology and Engineering Education major program of study at MU and graduate with an entry level, K-12 teaching certification, a student must complete 129 semester hours (Millersville University of Pennsylvania, 2019), while the other three institutions require 120. The 9 additional semester hours originate from Pennsylvania Department of Education requirements for teacher certification of any subject area that added an additional three courses to all programs to address topics like exceptional children in the classroom, differentiated instruction techniques, and the teaching of English Language Learners.

Another example of differences in requirements can be traced to institution-specific nuances. BYU, for example, follows a similar framework to the other institutions but also requires four courses in religion. These courses, known as the “religion cornerstones” (Brigham Young University, 2019, pg. 1) reflect a unique part of the culture of the university and its mission. A final example of this can be seen in the curriculum at NCSU (North Carolina State University, 2020b). There is a slight emphasis on graphic communication courses in the technical requirements, as students are required to take three graphic communication classes as opposed to other technical subjects. This emphasis can be explained because there is a second track within the Technology, Engineering, and Design Education department centered around graphic communications. Owing to this, there are more graphic communication technical courses offered and therefore taken by the students. This kind of subtle emphasis is by no means unique to NCSU, as programs across all of academia develop different identities within the content area they teach.

Technology Teacher Training Offerings

Technology teacher training in the United States, as previously discussed, is quite varied from program to program. According to Rogers (2019), there are 40 degree-granting technology teacher education programs active in the United States. As discussed previously, each with a unique blend of course work and perspectives that make compiling a unified and nuanced understanding of their offerings difficult. However, Litowitz (2013) describes a composite curriculum made up of a compilation of 24 program's curriculums that could represent a pseudo-national curriculum. Table 1 summarizes the composite curriculum.

Table 1. Composite TE teacher preparation program

General Education (45 Credits) Including:	Professional Studies (33 Credits) Including:	Technical Studies (44 Credits) Including:
College Algebra and 1 additional College Mathematics course	At least 2 teaching methods courses addressing topics such as instructional techniques, curriculum, and assessment	2 courses in Energy & Power including Electricity/ Electronics and Transportation

(continued)

General Education (45 Credits) Including:	Professional Studies (33 Credits) Including:	Technical Studies (44 Credits) Including:
1 Physics course	At least 1 methods course specifically in technology & engineering education (most programs require 2 such courses)	1 course in Manufacturing
	1 course in Educational Psychology	1 course in Communication
	1 course in Special Needs children in the classroom	1 course in Construction
	Full semester student teaching experience	1 course in Design
		1 course in Material Processing
		1 course in Drafting/CAD

Note. Reprinted from "An Analysis of Undergraduate Technology & Engineering Teacher Preparation in Programs in the United States" by Litowitz, L., 2013, *Journal of Technology Education, 25*(2), p.81.

This curriculum features a similar broad structure (general education, professional studies, technical studies) while also leaving room for state and institution-specific needs. In terms of technical courses, the composite curriculum features classes in Energy & Power (including electricity and transportation), Manufacturing, Communications, Construction, Design, Materials Processing, and Drafting/CAD. The professional studies component calls for two teaching methods classes, at least one class in TE methods, educational psychology, special needs children in the classroom, and a full semester student teaching experience. In terms of general education, the curriculum calls for a college algebra class, a college-level mathematics class, and a physics course (Litowitz, 2013, pg. 81). This composite curriculum represents something of a general overview of what specific content and training is offered in the United States within technology teacher preparation programs.

Features of Technology Education in the United States

Technology teacher education in the United States, for all of its variety, finds itself with a few defining features. The first of these features is the broad-based nature of the body of knowledge. By covering such diverse topics as materials processing, bio-related technologies, graphic communication, design, robotics and transportation, a technology educator in the United States is well-prepared to teach students about the physical and digital world around them. Understanding one aspect of technology often means needing to understand several others, and with the broad knowledge base that American technology educators become versed, they are that much better prepared to help mold generations of technologically literate citizens.

Another feature of the American technology teacher education landscape is that it does not look at technology in a vacuum, but rather from a holistic point of view. The Standards for Technological Literacy (SfTL) (International TE Association, 2000) contain within them several signposts for the study of technology and its impact on the context it is/was developed in. SfTL provides guidance for the instruction of students on the impacts that technology has on: culture, society, economic systems, political systems, the environment, and how technology has influenced human history. As discussed by Litowitz (2013), many institutions pattern their curriculum after SfTL, meaning that technology educators are likely being given instruction in these concepts. By doing so, the educator's perspective of technology is open to the idea that technology does not exist by itself. By having this idea trickle down to the students, a wider audience begins to understand that technology is not in isolation but impacts many facets of life. This is a key aspect of technological literacy and one that is more valuable today than ever.

A third feature of technology teacher education in America is the emphasis placed on learning by doing. The one ubiquitous trait that programs have is a predilection toward using a hands-on approach to learning and teaching the study of technology. The ethos of learning by doing fits and is applied to nearly every corner of the body of knowledge, and plays an integral role in constructing the knowledge through use of multiple modalities of learning in classrooms nationwide.

The final feature of technology teacher education in America is the flexibility that is inherent to it. It is often not possible for a single educator to cover all of the content they would like to in the time that most working professionals have with any one student. While an educator may not be able to cover everything, they can maximize the time they have by creating a curriculum that is timely, and germane to their students. This is a positive in multiple ways; first is that it allows the educator to customize the learning to what is important today and what will be important in the future of their student, thus making the learning agile and responsive to student needs. This is also positive because in a more vocationally directed curriculum, the study of technology can be shaped to support the needs of the local economy which, in turn, boosts the student's knowledge and employability.

The American Model Compared to Other Models

It should be noted that the great variety and flexibility that is inherent to the current way America technology teacher education operates is not the only way. Other nations conduct this training in different ways; one example of this is through the use of a standardized national curriculum. While there are features and challenges in every education model, the flexibility of the American model does allow for certain freedoms and an agility that is desirable. As discussed, because of the flexibility brought on by state-centered educational authority, states and LEAs can decide for themselves what is more important for their populations to learn. This is a benefit to the students, as they can engage in modern and timely coursework that boosts their understanding of the modern world and boosts their employability. This also benefits the local businesses of the area, as through partnerships with the schools, they can be a partner in the process of creating a 21st century workforce.

Another model of TE that is appropriate for comparison is the British method. Much of the British tradition of TE relies heavily on design and conservation of materials. Students are asked to engage in heavy planning and design phases before being given materials and access to means by which the materials are shaped. This is in contrast to a more hands-on approach where students learn the fundamental concepts and are asked to apply them in a structured way, often through pre-designed plans. Once the student has achieved competency in the requisite techniques, they are allowed to engage in projects of their own design that incorporate a combination of learned techniques and new techniques. The hands-on approach used in America, generally speaking, is less efficient in terms of material consumption, however students come away with a larger set of practical skills.

CHALLENGES AND INNOVATION OF TECHNOLOGY TEACHER EDUCATION

Much like every other facet of academia, there are challenges that inhabit the world of technology teacher education. These challenges stem from certain historical perceptions of this field of study context and the inability, to this point, to amend them in modernity. However, given the critical nature of these issues, the members of the TE field of study are working to meet these challenges head on through research and implementation. In this section, a discussion will occur surrounding the challenges faced by the American technology teacher education field and how the members are working to address it.

Challenges

Among the most important challenges to be addressed is the decline in enrollment in technology teacher education programs. Discussing trends in enrollment over a 25-year period (1970-1995), Volk (1997) concluded that without giving attention to the issue, the demise of technology teacher preparation programs would occur in the year 2005. Moye (2009) added to this idea of a downward trend, “Data indicated that the number of TE teacher graduates had decreased by 68.35% between the years of 1995/1996 and 2007/2008” (pg. 31). This trend continues at the time of this writing, wherein the number of programs with 20 or more active undergraduate-level students is 20 (Rogers, 2019), down from 24 at the time of the Litowitz (2013) study.

Another challenge facing technology teacher education is a shortage of in-service teachers. Ndahi and Ritz (2003) discuss an overall shortage of teachers in the United States and within the field of TE, “It is clear that there is a shortage of teachers, especially technology teachers, and the shortages will continue to increase” (pg. 28). Moye (2009) discusses this trend and forecasts potential shortfalls thusly, “When estimating the supply and demand of TE teachers in the United States, there will be an estimated shortfall of 2,799 teachers between the fall of 2009 and 2014” (pg. 34). This shortage could be considered self-feeding, as Wright and Custer (1998) point out that, based on their study, the most influential factor in a student being motivated to become a technology teacher was encouragement from a high school TE teacher (pg. 67).

A third challenge that is faced by the technology teacher education field is an inequity in terms of gender, race, and ethnicity among technology educators. In 2015, Moye et al. reported that “Those supervisors reported that approximately 6,029 (77.2%) male and 1,376 (22.8%) female technology and engineering education teachers in their states. Data show female teachers comprise fewer than one quarter of the technology and engineering teacher population” (pg. 35). These figures are supported by Ernst and Williams (2015) who report a 75.6 /24.4 split between male and female teachers (pg. 51). In addition to gender statistics, Ernst and Williams reported that, of their respondents, 91.9% self-reported as white.

Innovations and Strategies

Challenges, especially those as critical as the ones outlined in the previous section, must be met with a great deal of thought. Challenges such as declining enrollment, teacher shortages, and race/gender inequity are usually identified through analysis of data. Whether that be for the purposes of research or as an analysis to gauge the state of a program or profession, much of this is born from data analysis. While challenges such as this can be overwhelming because of the magnitude and scope of the problem, it is often a better strategy to triage the problem and solve smaller problems that lead to bigger solutions.

In the case of declining enrollment, one may begin to solve the problem by bringing in students for workshops in fun and interesting subjects, and gather data in the form of an exit survey. This survey could ask questions about how they felt about the physical space, their thoughts and experiences about TE, and what would motivate them to become a teacher. This data, born of research and development of classes and workshops, could then be used to fine-tune marketing and develop an understanding of what modern students look for in their education. These findings and the results of the improvements could be shared through professional activity such as journals and conference presentations so that other programs can intake the strategy and decide if it would help them. This is just one example of how dividing up larger-scale issues into manageable pieces can help solve problems.

Most of the innovations in TE teacher preparation in America at present have to do with finding ways to certify more technology & engineering teachers through alternative means. A recent innovation proposed at Millersville University seeks to attract secondary social science or elementary education teacher preparation candidates to complete the equivalency of a minor in technology & engineering education in order to prepare for the TE Praxis specialty area examination. In Pennsylvania, like many other states, if a teacher or teacher candidate is certified to teach any subject, they may become certified to teach other subjects simply by passing a subject area specialty test. This method of certification does not take into account safety training on the use of equipment, knowledge of instructional methodologies that are specific to a particular subject area, or familiarity with and history of a given profession. Even so, it is a valid method of entering the profession in many states like Pennsylvania. If someone has a teaching license in any subject, and they can pass a paper-and-pencil test, they can become a technology and engineering teacher in many states in America. Given this reality, and a serious shortage of technology teachers to fulfill the void of retiring teachers in the field, offering a minor in Technology & Engineering Education teacher preparation may be the best compromise between expedience and developing some level of technical competence for teachers seeking to enter the technology & engineering profession via an alternative route to traditional teacher preparation. The minor is not billed as a replacement for the major. Rather, it is being marketed as a way to prepare for the Praxis subject area specialty test in Technology & Engineering education with the intent to allow those pursuing the minor to develop enough technical competence to be able to teach broad-based introductory courses in the field that are typically offered at the middle school level. Additional training would likely be necessary to develop the appropriate depth to teach high school courses that tend to be much deeper and subject-matter specific. These are the types of innovative programs that are surfacing to meet the demand for technology & engineering teachers in America.

There are several obstacles to innovation and to the example research and development scenario. A major obstacle is time. Many faculty members are incredibly busy with families, teaching, research, committee work, advising, etc. This time crunch makes it difficult to put in the requisite effort without taking away from another important aspect of their day. Another factor is availability of funding and other resources. Exciting programming can be expensive to pull off, especially when considering the cost of materials and assistance from trained personnel to assist with the delivery. Even when using student volunteers, the costs can be prohibitive, especially when the workshop has a large number of attendees. A final potential obstacle is low attendance and poor outcomes. It can be very disheartening for organizers when they put in the hard work and the workshop was not well attended, they received minimal data, and did not garner much interest in the profession of technology teacher education. This can lead to giving up on pushing forward with recruitment research and a jaded attitude about the health and future of the profession.

CONCLUSION

TE in America cannot be easily explained because education is a state's right in America and cannot be federally mandated. Some states have requirements for TE coursework at the middle school level, some have requirements for TE to be taken at the high school level, and many states have no requirement for TE courses to be offered or completed whatsoever. The vast majority of TE programs in America exist as purely elective courses at the secondary level. TE teacher licensure requirements also vary from state to state, although many states offer interstate reciprocity with regard to licensure. Even though there is not a national curriculum, most TE state associations reference the International Technology & Engineering Educators Association and the Standards for Technology & Engineering Literacy (STEL). This set of academic standards, formerly known as the Standards for Technological Literacy, identify eight core topics that TE courses should incorporate and address. In addition to publishing the STEL the ITEEA also co-sponsors an outstanding Program Excellence and Techer Excellence Awards recognition ceremonies at its annual conference for programs at the elementary, middle school and high school levels in all 50 states. International programs are sometimes recognized as well.

Program titles for TE programs in America vary widely as well. Most programs and even some middle school courses are simply referred to as TE, but many others have included engineering in the title of their programs as well. This change in title reflects a turn toward engineering in the field of TE in

America. The content organizers for TE that humbly started out as names used to represent different subject areas taught have broadened and expanded the content base for TE over time. As the content base has expanded, major shifts in curricular philosophy have occurred with shorter spans of time in between them. Through all of these changes, one aspect of TE in America has remained remarkably consistent, and that would be the methodology of learning by doing that is prevalent in TE classrooms throughout the nation. Significant challenges facing the field of TE in America include the decline in TE teacher preparation programs throughout the nation and a shortage of qualified teachers. Another challenge has been a lack of ability to significantly increase females and ethnically diverse candidates to enter the teaching profession. More than 75% of all TE teachers are male, and most of those are Caucasian. These challenges have spurred some innovative solutions toward attracting a greater diversity of people to become TE teachers. Alternative licensure methods now appear to be one of the best means of meeting the needs of TE teachers in the near future because few institutions in America are graduating significant numbers of TE teachers via traditional methods of teacher preparation. One area of significant growth in the field of TE in America has been at the elementary level. TE is not always typically taught as a stand-alone subject area at the elementary level, but rather integrated into the curriculum through hands-on experiences that complement existing content. This is consistent with research that has long indicated that learning by doing is a highly effective means of teaching and learning that leads to greater knowledge retention than traditional instructional methods like listening and note-taking.

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Appndix A. Technology education program and course titles in school districts in Lancaster

School District	Name of Middle School	Name of T&E Program	Course Names (If available)
Cocalico	Cocalico Middle School	Technology Education – Required at Grades 6,7, & 8	Material Technology Design and Engineering Technological Design
Columbia	Columbia Middle School – Hill Campus	Technology Education	Unavailable
Conestoga Valley	Gerald G. Hueskin Middle School	Technology Education	Unavailable
Donegal	Donegal Junior High School	Technology Education (within the Unified Arts Team)	Unavailable
Eastern Lancaster County School District	Garden Spot Middle School	Technology Education (Listed within the Humanities)	Unavailable
Elizabethtown Area School District	Elizabethtown Area Middle School	Technology Education (Published offerings for grades 1-12)	See Link Below

(continued)

School District	Name of Middle School	Name of T&E Program	Course Names (If available)
Ephrata Area School District	Ephrata Middle School	Technology Education (Grade 8)	Technology Education with subject headings (Architecture/CAD, Bridge Building, Manufacturing)
Hempfield	Centerville Middle School Landisville Middle School	Technology and Engineering Education (7^{th} and 8^{th} Grade)	Exploring Technology Applying Technology
Lampeter-Strasburg	Martin Meylin Middle School	Technology Education (6^{th}, 7th, & 8^{th})	Foundations of Technology Exploring the Physical and Informational Systems of Technology Applying the Physical and Informational Systems of Technology
School District of Lancaster	Hand Middle School Lincoln Middle School Martin Middle School Reynolds Middle School Wheatland Middle School	Was unable to find information about MS T&E on their sites	Unavailable

(continued)

School District	Name of Middle School	Name of T&E Program	Course Names (If available)
Manheim Central	Manheim Central Middle School	Technology Education (Grades 5-8)	PLTW – Launch PLTW – Robotics & Automation Challenge PLTW – Design & Modeling PLTW – Automation & Robotics
Manheim Township	Manheim Township Middle School	Technology Education Grades 7 & 8	Unavailable
Penn Manor	Manor Middle School Marticville Middle School	Technology Education Grades 7 & 8	Seventh Grade Technology Education Eighth Grade Technology Education
Pequea Valley	Pequea Valley Intermediate School	Referred to as Agricultural Science and Technology Education on the high school page. No academic sites set up for MS.	Unavailable
Solanco	George A. Smith Middle School Swift Middle School	Technology Education Grades 6,7, & 8	Unavailable

(continued)

School District	Name of Middle School	Name of T&E Program	Course Names (If available)
Warwick	Warwick Middle School	Technology Education Grades 7 & 8	Seventh Grade Technology Education Eighth Grade Technology Education

Source: Gathered from IU13 https://www.iu13.org/community/public-schools/

A COMPARISON OF TECHNOLOGY TEACHER EDUCATION IN THE ASIA-PACIFIC REGION

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ABSTRACT

The technology education (TE) and technology teacher education (TTE) from eight countries/areas in the Asia-Pacific Region (APAC) are presented in the former eight chapters of this book. This chapter summarizes the TE profile, state-of-the-art of TTE, and the challenges and innovations of TTE presented in these chapters. Similar trends and unique characteristics are also raised for further discussion. Consequently, the main conclusions are as follows: (1) TE programs are common at the lower secondary education level. (2) The profile of TE varies by country/area, but the role of TE in helping students develop technological literacy is widely recognized. (3) The TE content in the eight cases could be roughly grouped into three approaches: the first approach places more emphasis on Design and Technology (D&T), as in the cases of Australia, New Zealand and Hong Kong; the second puts more stress on Technology and Engineering (T&E), as in the United States, Japan, Korea and Taiwan; and the third underlines labor technology more than others topics, as in China. (4) For most cases, the minimum education level for initial technology teachers is a Bachelor degree. (5) Pre-service technology teachers are usually required to complete pedagogical courses and technology/relevant subject coursework and to pass the teacher qualification/licensing examination. (6) Each country/area has its own unique features of TTE—for example, in New Zealand, initial teacher education programs prepare student teachers to teach technology through experientially-based inquiry learning approaches. (7) A shortage of qualified technology teachers, insufficient pre-service technology teacher education programs and the lower subject status of technology compared to other school subjects are three major problems/challenges of TTE. (8) A number of innovations and strategies are raised in each country/area to deal with the common and individual challenges—for example, in Australia, it has been suggested that more scholarships be offered by universities and be potentially funded by government departments to encourage both school leavers and tradespeople to consider teaching as a career.

Keywords: technology education, technology teacher education, comparative analysis, Asia-Pacific region

INTRODUCTION

This book compiles articles about the technology education (TE) and technology teacher education (TTE) from eight countries/areas (i.e., cases) in the Asia-Pacific (APAC) Region, specifically Australia (AU), China (CN), Hong Kong (HK), Japan (JP), Republic of Korea (KR), New Zealand (NZ), Taiwan (TW) and the United States (US). TE here refers to the technological literacy education as a realm of general education in primary and secondary schools. It includes both Design and Technology (D&T)/Technology and Engineering (T&E) and Information and Communication Technology (ICT). Due to differences in the educational systems for each case, nationwide TTE may be narrowed down to the most representative statewide TTE. Following are summaries of the TE profile, state-of-the-art of TTE, and the challenges and innovations of TTE in this region. Similar trends and unique characteristics are raised for further discussion.

Table 1 shows a summary of the schooling systems within which TE programs are placed, and the types of institutes offering TE programs. For the eight countries/areas, most cases provide TE programs from the primary through to the secondary education levels. In AU, TE starts earlier than in other countries (from kindergarten), while the TE program in TW is provided relatively late (flexibly offered in elementary schools and formally starting at lower secondary education). In the US, the schooling system varies by state and local government. Some have integrative STEM programs at the elementary level, but the others do not provide TE courses in primary education. It can be concluded that nowadays TE programs are common at the lower secondary education level (such as junior high school, middle school, lower secondary school, etc.) Most countries/areas have extended the programs to upper secondary school level and primary education level, and a few even to kindergarten level.

As for the types of institutes offering TE programs, TE is provided either in general/academic high schools or vocational/ technical/comprehensive high schools. CN and TW are examples of education systems that track students into different groups according to their academic aptitude and interests in the secondary education stage. TE is provided in both school institution tracking types. In AU, institutional types are quite unique, including the government public school system, the Catholic school system, and independent schools. They all offer TE programs for students.

THE PROFILE OF TECHNOLOGY EDUCATION (TE)

Table 2 presents a summary of the profiles of technology education in the Asia-Pacific Region. Nine comparative points were proposed for further discussion across the countries/areas, including TE program status, title, time allocation, major objectives, characteristics of the target group, content organizers, general characteristics, means of recognition of TE achievement, and instruction. All of the descriptions focus on the primary and secondary education levels.

Point 1: Program Status

This section discusses whether the TE program is required/elective, separate/integrated, or considered as a vocational/general subject. At the primary education level, TE programs are integrated and compulsory courses in CN, HK, JP, and KR. These courses are a part of Practice Activities (CN, KR), the General Studies subject (HK), and Practical Arts (KR). In JP, TE is integrated into arts and crafts classes. As for AU and NZ, technology is a required/separate learning area that focuses on cultivating students' broad technological literacy. In the US, although TE status varies by state or local school district, it is a recent trend that it is provided via integrative subjects at elementary schools.

At the lower secondary education level, it is common to see TE as a required and separate subject in this region. As for upper secondary education, the TE program in most cases is elective and general-oriented, except for AU where

Table 1. A summary of the schooling system and institute types regarding TE programs in the Asia-Pacific Region

	Australia (AU)	China (CN)	Hong Kong (HK)	Japan (JP)	Korea (KR)	New Zealand (NZ)	Taiwan (TW)	United States (US)
Schooling system (place of TE)	From Kindergarten to secondary education (K - 12)	All elementary and secondary school students	Primary education and secondary education (junior & senior)	Elementary school, lower secondary school, and upper secondary school: divided into general education (general course) and professional education (industrial course)	Elementary education (only for 5th and 6th graders); Secondary education	Technology education is a compulsory subject in the schooling sector (Years 1-10)	Secondary education	Integrative STEM at the elementary level; Secondary level of education
Types of institutes offering TE programs	Government public school system, Catholic school system, & independent school	Elementary school, junior high school, technical and vocational schools, & academic senior high schools	Primary school, local middle schools (government schools, aided schools and caput schools)	Elementary school, lower secondary school, & upper secondary school	Primary school, middle school, & general high school	Primary school, full primary school, intermediate school, middle school, secondary school, & area school	Junior high school & senior high school (divided into general high school, technical high school, & comprehensive high school)	Elementary school, middle school, & high school

TE in Years 9-12 has a more vocational focus that aims at preparing students for entry into the workforce or university.

Point 2: Program Title

Some cases which have a national curriculum have a nationwide TE program. Examples of their program titles include: Design and Technologies and Digital Technologies in AU; Practice Activities (IPA), General Technology (GT), and Information Technology (IT) in CN; Technology Education (TE), Business, Accounting and Financial Studies, Design & Applied Technology, Health Management & Social Care, Information & Communication Technology, and Technology and Living in HK; Technology and Home Economics, and Information in JP; Practical Arts and Technology-Home Economics in KR; Technology in NZ; and Information Technology (IT) and Living Technology (LT) in TW. As for the US, program titles are very diverse across states, including: Applying Technology, Creating Technology, Explorations in Technology or Technology Education in middle schools; and Material processing, Graphics, Digital technologies (like web design, coding of robots and CNC machining devices), Videography, Rapid prototyping or 3D printing in high schools.

Point 3: Time Allocation

The time allocation of TE programs for the eight cases is too diverse to generate a common pattern. What we found interesting is that in some countries such as AU, CN, KR, and TW, the recent revision of the curriculum guidelines has highlighted the importance of TE and has allocated more time to the program compared to the past.

Point 4: Major Objectives

There are a number of similar major objectives of TE programs in this region. Most cases recognize that the major objectives are to help students develop technological literacy in order to be well-prepared for participating in changing technologies in their current and future life. More specifically, technological awareness and understanding are common factors, and technological problem solving, innovative making, and applying are highlights in countries such as AU, CN, KR, and TW.

Point 5: Characteristics of the Target Group

In AU, CN, and HK, students can access TE programs from Years 1 to 12 and in NZ from Years 1 to 10. In KR, the TE program starts from Grade 5 and extends to all students in middle school. For the other cases of JP, TW, and the US, most students access the TE program from the junior high school/middle school level.

Point 6: Content Organizers

The content organizers of TE in each country/area are quite diverse due to their TE program development history and current focus. However, some popular components are observed in this region, such as Design and Technology (D&T), Home Economics (HE), Living Technology, Technology and Engineering (T&E), Information Technology (IT), and Information and Communication Technology (ICT). In AU, a number of traditional TE content organizers (such as Textile technology, Woodwork, Metalwork, etc.) are maintained in the current program. Overall, the TE content organizers have changed in recent decades; in the early stage more time was allocated to traditional craftsmanship learning, while nowadays it has started to shift to living technology, information technology or engineering. For the eight cases in APAC, the TE content could be roughly grouped into three approaches: the first approach places more emphasis on D&T, as in AU, NZ, and HK; the second puts more stress on T&E, as in the US, JP, KR, and TW; and the third underlines labor technology more than other topics, as in CN.

Point 7: General Characteristics

The general characteristics of TE among the cases have similar and unique points. Some similar characteristics include the focus on knowledge as well as practice/hands-on skills learning (AU, CN, TW, US), paying attention to the relationships among human action, technology, society, and the environment (JP, NZ), and utilization of technology in the real world (AU, JP, KR, TW, US). It is worth noting that the HK authors proposed that the recent TE program revision in HK overstresses the content of knowledge, which might undermine the role of practical problem-solving activities. More attention to further adjustment is warranted.

Point 8: Mean of TE Achievement Recognition

All of the cases in this region adopt varied types of school-based assessment to evaluate student TE achievement in terms of knowledge, skills and attitude. The common means are interviews, student self-assessment, peer review, portfolios, paper-and-pencil tests, checklists, scoring rubrics, posters, projects, and videos. An authentic assessment approach is used in which students are asked to perform real-world tasks to demonstrate meaningful application of what they learned about TE knowledge, skills, and attitude. These school-based assessments are usually used as formative and summative assessments during students' learning period. Besides, some countries conduct unified tests or issue national certificates or awards to recognize achievement. For example, CN has the Academic Test for the Junior Secondary School Students on IPA and IT, and the Academic Test for the Senior Secondary School Students on IT and GT. In addition, CN holds competitions (such as Olympics of the Mind, National Computer Production Activities, etc.) that also provide access to understanding students' performance. In NZ, the National Certificate in Educational Achievement secondary school qualification can assess students' progress from Level 1 in Year 11 to Level 3 in Year 13. It assesses against either Achievement Merit or Excellence in Achievement Standards (pass/fail in Unit

Standards). In the US, the Teacher Excellence Award and Program Excellence Award programs sponsored by the International Technology & Engineering Educators Association (ITEEA) are powerful means of recognizing achievement.

Point 9: Instruction

There are some popular teaching and learning pedagogical principles or approaches used in this region, such as the problem-based/ problem-solving approach, project-based learning and learning by doing/ hands-on experience. In addition, some unique approaches are highlighted in individual cases. For example, besides the earlier mentioned approaches, AU also emphasizes the design-based approach; CN stresses the integrative-activity-based approach which incorporates the investigation and exploration approach, and the design and making approach. In NZ, inquiry learning, talking for learning, and the future-focused approach are highlighted; their use is flexible in order to accommodate students' learning needs.

Table 2. A summary of the profiles of technology education in the Asia-Pacific Region

	Australia (AU)	China (CN)	Hong Kong (HK)	Japan (JP)	Korea (KR)	New Zealand (NZ)	Taiwan (TW)	United States (US)
Program status-required or elective-separate or integrated-vocational or general	1. A Technologies learning area required from Kindergarten to Year 8 with an option in Years 9-10. 2. From K-8, TE is truly general (broad, relevant to technological literacy); in Years 9-12 TE is not compulsory and has a more vocational focus, preparing for entry into the workforce or for university	1. Both compulsory and elective programs. 2. Both integrated and separate: embodied as a part of Integrated Practice Activities (IPA) from Grades 1 to 12. Technology and Engineering is integrated with science in elementary schools; separate subjects of General Technology (GT) and Information Technology (IT) in senior high schools.	1. Primary level: part of the General Studies subject 2. Junior secondary level: required and separate subject 3. Senior secondary level: compulsory and elective subjects	1. Required/ separate subject in lower secondary school 2. General courses in general education & vocational in professional education	1. Integrated, a part of 'Practical Arts' in primary school 2. Integrated, a half of 'Technology-Home Economics' and required in middle school 3. Integrated, a half of 'Technology-Home Economics' and selected in general high school	1. Separate learning area 2. Compulsory subject in the schooling sector (Years 1-10)	1. A mandatory/ separate technology curriculum in junior high school 2. Mandatory and elective in senior high school	1. Varies by state/ local school district 2. Recent trend: integrative subject at elementary level

	Australia (AU)	China (CN)	Hong Kong (HK)	Japan (JP)	Korea (KR)	New Zealand (NZ)	Taiwan (TW)	United States (US)
Program titles-course titles	A national technologies curriculum, encompassing two subjects: Design and Technologies and Digital Technologies	1. Technology & Engineering (T &E) in Science (Integrate for Grade 1-6) 2. Labor & Technology (LT) in IPA (Integrate for Grade 1-12) 3. IT (Integrated for Grade 1-9; Separate for Grade 10-12) 4. GT incorporating IPA (Separate for Grade 10-12)	1. TE is one of 8 Key Learning Areas in the Curriculum Framework 2. Subject title in TE KLA: Primary Edu 1-6: General Studies (GS); Secondary Edu 1-3: Technology Education (TE); Secondary Edu 4-6: Business, Accounting and Financial Studies, Design & Applied Technology, Health Management & Social Care, Information & Communication Technology, & Technology and Living	1. Elementary school: arts and crafts classes 2. Lower secondary school: Technology and Home Economics 3. Upper secondary school: Information in general education	1. Primary school: Practical Arts (national curriculum) 2. Middle school: Technology-Home economics (national curriculum) 3. General high school: Technology-Home economics (national curriculum)	Technology (Intervention by Design)	Technology domain curriculum, including two subjects: Information Technology (IT) and Living Technology (LT)	1. Middle school: Applying Technology, Creating Technology, Explorations in Technology, or Technology Education 2. High school: Material processing, Graphics, Digital technologies (like web design, CADD and coding of robots and CNC machining evices),Videography, Rapid prototyping or 3D printing

	Australia (AU)	China (CN)	Hong Kong (HK)	Japan (JP)	Korea (KR)	New Zealand (NZ)	Taiwan (TW)	United States (US)
Time allocation	Notional hours recommended by ACARA: K-12 (60), Year 3-4 (80), Year 5-6 (120), Year 7-8 (160), Year 9-10 (optional, 0-160), Year 11-12 (optional, per subject 200-240)	1. T&E: 18 hrs./ per year 2. LT:17.5±hrs./ per year 3. IT: 17.5± hrs./per year (integrate) 126 hrs./3 years (separate) 4. GT: 144 hrs./3 years	1. Primary GS serves Science Edu, TE, & Personal, Social and Humanities Edu KLAs. The total time allocation is 12-15% 2. TE KLA: 8–15% (220 to 413 hrs) for junior secondary level 3. Senior secondary level: all TE subjects (which ar electives subjedts) accounts for 10-15% of the total lesson time	1. Lower secondary school: 70 hrs in the 1st school year, 70 hrs in the 2nd, and 35 hrs in the 3rd	1. Primary school: 68 hours for 5th and 6th graders 2. Middle school: 272 hours 3. General high school: elective courses for 3 hours/ per week for 10th graders	1. Depends on the school context, collective staff focus, or teacher's interest 2. In primary school, taught through inquiry learning; from Years 9-10, same timetabled time as other subjects	1. For Grades 7-9 in junior high school, each IT & LT has one class (45mins) per week 2. In Senior high school: each IT & LT has 2 credits (100mins)/ per week in one semester (mandatory courses), and 8 credits for elective courses	Varied by state/ local school district

	Australia (AU)	China (CN)	Hong Kong (HK)	Japan (JP)	Korea (KR)	New Zealand (NZ)	Taiwan (TW)	United States (US)
Major objectives	1. Design and Technologies: students use design thinking and technologies to generate and produce designed solutions for authentic needs and opportunities. 2. Digital Technologies: students use computational thinking and information systems to define, design and implement digital solutions	1. General goal: to boost students' technological literacy 2. T&E in Science: to improve students' ability to better understand nature and to solve problems by integrating knowledge and methodologies. 3.LT/IT in IPA: problem-solving and innovative making 4.IT in senior high school: Information awareness,	1. Developing students' technological literacy through the cultivation of technological capability, technological understanding and technological awareness. 2. Primery Level: Awareness & Exploration; Junior Secondary Level: Experiencing & Application; Senior Secondary Level: Orientation for Lifelong	To learn basic knowledge and technologies through practical and hands-on learning such as manufacturing assigned to all students	To help students cultivate technological competence, including abilities of technological problem solving, technological system designing, & utilizing technology	1. To develop technological literacy: assisting learners' preparation for life,both in the current and future technological world 2.Major goals: to teach students the capability to operate effectively and creatively in the made-world; to prepare students to participate in rapidly changing technologies, and to	1. Acquire basic technological knowledge and skills, and develop appropriate concepts, attitudes, and work habitsattitudes, and work habits 2.Become proficient in the use of technological knowledge and skills to carry out creative, design, critical, logical, and computation thinking 3.Integrate theory and practice to solve problems and meet	1. Nature and Characteristics of Technology & Engineering 2. Core Concepts of Technology & Engineering 3.ntegration of Knowledge, Technologies, and Practices 4.Impacts of Technology 5.Influence of Society on Technological Development 6.History of Technology 7.Design in Technology & Engineering Education 8.Applying, Maintaining & Assessing Technological Products and Systems

	Australia (AU)	China (CN)	Hong Kong (HK)	Japan (JP)	Korea (KR)	New Zealand (NZ)	Taiwan (TW)	United States (US)
		Computing thinking, Digital learning and innovation, and Sense of responsibility for information society 5. GT in senior high school: Technology awareness, Engineering mindset, Creative design, Engineering drawings, Competence of materialization	Learning and Specialization			intervene creatively to improve quality of life for themselves and others	needs 4. Understand the technology industry and its future development trends 5. Cultivate an interest in technological research and development 6. Understand the interactions between technology and individuals, society, the environment, and culture, and reflect on ethical issues related to its use	
Characteristics of the target group	From Kindergarten to Year 12	All students from Grade 1 to 12	All students from primary education to junior secondary level. TE subjets in senior secondary level are electives for students with specific interests and inclinations.	All students in lower secondary education	From Grade 5 to all students in middle schools	Students from Year 1 to 10	All junior and senior high school students	All middle and high school students

	Australia (AU)	China (CN)	Hong Kong (HK)	Japan (JP)	Korea (KR)	New Zealand (NZ)	Taiwan (TW)	United States (US)
Content organizers	Engineering principles and systems, Food and fiber production, Food specializations, Materials and technologies specialization, Computer Science, Design, Manufacturing, Engineering, Textile technology, Food technology, Woodwork, Metalwork, Cooking, practical work	1. T&E in elementary Science: three big ideas 2. IT and LT integrated into IPA: Design & Making (like manual production and digital processing, handicraft workshop, nutrition and cooking, etc.) 3. IT in senior high school: Module 1: Data & computation; Module 2: Information & society, etc.	1. Junior secondary level: Computer Literacy, Design and Technology (D&T), Home Economics / Technology and Living 2. Senior secondary level: 'Information and Communication Technology' (ICT) has Compulsory Part (Information Processing, Computer System Fundamentals, Internet and Its Applications, Basic	1. In 2012 curriculum: Technology & Manufacturing, Information & Computers 2. Curriculum in 2021consisting of Material and processing technology, Raising organisms technology, Energy conversion technology, and Information technology	1. Technological system including production, transportation, & communication technology 2. Utilization of technology including standardization, invention, and sustainability	1. Three strands of learning: Technological Practice, the Nature of Technology, & Technological Knowledge 2. Within five technological areas: designing and developing material outcomes, designing and developing processed outcomes, design and visual communication, the design and development	1. Six themes in IT: Algorithms, Programming, System platforms, Data representation, processing & analysis, Application of information technology, and Information technology, humans, & society 2. Four themes in LT: Nature of technology, Design & making, Application of technology, and Technology & society	Material Conversion & Processing, Transportation & Logistics, Energy & Power, Information & Communication, The Built Environment, Medical & Health-related technologies, and Computation, Automation, Artificial Intelligence and Robotics, Practices (Making by Doing, Systems Thinking, Creativity, Collaboration, Communication, Optimism, Critical Thinking, and Attention to Ethics)

	Australia (AU)	China (CN)	Hong Kong (HK)	Japan (JP)	Korea (KR)	New Zealand (NZ)	Taiwan (TW)	United States (US)
		4. GT in senior high school: Technology & Design, Engineering, ntegrated application of technology, etc.	Programming Concepts and Social Implications) and Elective Part (Databases, etc.); 'Design and Applied Technology' (elective subject)			of digital technologies, & computational thinking.		
General characteristics	1. Australian Technologies Curriculum is divided into two strands - Knowledge and understanding and Process and production skills	1. Relative emphasis on design and making in Grades 1-9 2. Relative emphasis on the integration of theory and practice in senior secondary education	1. Learning in TE centers on the processes that take place in a range of Knowledge Contexts, & the development of the awareness of the impact of technology	1. Focus on deepening the understanding of the relationship among technology, society and environment, and on developing abilities and attitudes to evaluate	1. TE curriculum includes two areas: technological system and utilization of technology in real world	1. Adopt a sociocultural approach which posits that learning is to understand the relationships between human action and mental functioning, as well as the cultural,	1. Stressing the integration among disciplines 2. Curriculum planned according to a systematic and complete approach, with detailed curriculum goals and learning content	The use of hands-on learning as a primary means of instruction, and the creation of some form of product as an outcome

	Australia (AU)	China (CN)	Hong Kong (HK)	Japan (JP)	Korea (KR)	New Zealand (NZ)	Taiwan (TW)	United States (US)
	2. They give students the opportunity to develop their problem-solving and creative skills to address issues in society.	3. Including both compulsory and elective programs	2. Overstressing of the content of Knowledge Contexts inthe latest TEKLA Curriculum Guide undermines the importance of the role of practical problem-solving activities	and use technologies properly for establishing a better society		institutional, and historical context in which this action occurs		
TE achievement recognition	Varied types of assessments could be used to collect learning evidence for either individual or group projects, such as portfolios, tests, examinations, research	1. Formative and summative assessment during and after students take a program 2. Unified tests: The Academic Test for the Junior	1. Pen-and-paper examination, School-based Assessment (Case studies, Technology exploration task, Projects, Portfolios, etc.)	1. 3 perspectives of evaluation: “knowledge and skill” “ability to think, ability to judge, ability to express” and “attitude to take initiative in learning	Employ diverse assessments (portfolio, checklist, scoring rubric, students’ work, paper and pencil test, etc.) to recognize students’ achievement	1. National Certificate in Educational Achievement for secondary school qualification that students progress from Level 1 in Year 11 to Level 3 in Year 13	Assess technology knowledge, attitudes, practice skills, & integration ability via diverse approaches (interview, student self-assessment, peer review, portfolio, etc.)	Teacher Excellence Award program and Program Excellence Awards program sponsored by the International Technology & Engineering Educators Association (ITEEA)

	Australia (AU)	China (CN)	Hong Kong (HK)	Japan (JP)	Korea (KR)	New Zealand (NZ)	Taiwan (TW)	United States (US)
	tasks, posters, videos, website creations, use of contracts, et al.	Secondary School Students (IPA and IT); The Academic Test for the Senior Secondary School Students (IT and GT) 3. Competitions: Olympics of the Mind, National Computer Production Activities, etc.	in the Hong Kong Diploma of Secondary Education examination 2. for learning in schools, TLAs are both continuous and summative assessments that constitute the yearly overall results in the report cards. TLAs include tangible products made and the folios composed to reflect the students' capabilities 3. The Chief Executive's Award for Teaching Excellence is organized by the Education Bureau to recognize accomplished teachers who demonstrate exemplary teaching practices	2. Consider aspects like descriptions in notebook and report, remark, behavior observation by teachers and self-evaluation and interactive evaluation by students		2. Assessed against either Achievement Merit, Excellent in Achievement Standards and /or pass /fail in Unit Standards		

	Australia (AU)	China (CN)	Hong Kong (HK)	Japan (JP)	Korea (KR)	New Zealand (NZ)	Taiwan (TW)	United States (US)
Instruction	1. A broad range of pedagogies are used 2. Traditionally, the prevailing strategy was the process of dem	1. Integrative-activity-based approaches such as the investigation & exploration approach,	1. Realizing the distinguishable subject status under the introduction of STEM education (inconsistence and instability in definition, scope, position in curriculum) 2. Challenges for PGDE D&T: Introduction of a loose and ill-defined STEM education led to "anything goes" that downplays the significance of practical learning experiences in problem solving; & Teacher training for D&T will cease	1. Project-typed learning focusing on manufacturing subjects 2. By using many teaching materi	1. Project (or problem) based learning and cooperative learning in middle school and general high school	1. A future-focused approach to education within learning (flexible to accommodate students'	1. Offer students opportunities to gain hands-on experience and increase designing and making capabilities	1. Learning by doing 2. Technological problem-solving method (addressing a challenge, researching solutions, proposing multiple solutions, prototyping a solution, and refining a

	Australia (AU)	China (CN)	Hong Kong (HK)	Japan (JP)	Korea (KR)	New Zealand (NZ)	Taiwan (TW)	United States (US)
	onstration; more recent and sophisticated philosophical underpinnings, problem-based and design-based approaches	the design & making approach 2. Multi-discipline-based approaches: project-based approach and the problem-based approach, the STEM approach 3. Whole-task-based teaching and learning approach	founding aims of the latest TEKLA Curriculum through "authentic hands-on problem-solving learning activities", i. e. technology learning activities, though this is undermined by the plethora of contents in the knowledge context that is introduced in the 2017 Curriculum Guide	als, effective and efficient education is provided in order to learn the knowledge and skills of technology	learning needs) 2. Experiential Learning 3. Inquiry learning and guided inquiry 4. Talking for learning		by providing technology tools, materials, and resources 2. Assessment covers different aspects such as technological knowledge, attitudes, practical skills, comprehensive capabilities	prototype into a working product) 3. Using rubrics for projects, portfolios, and other form of authentic assessment

THE STATE-OF-THE-ART OF TECHNOLOGY TEACHER EDUCATION

In this section, we conduct a comparison of the state-of-the-art of technology teacher education (TTE) among the eight cases in APAC. Table 3 presents the summarized information. Three points are raised for the following comparison: certification requirements for technology teachers, TTE programs, and features of the TTE.

Point 1: Certification Requirements for Technology Teachers

The requirements for initial technology teachers (such as education level, coursework, certification examination) have similar components among the target countries/areas. For most cases, the minimum education level for initial technology teachers is a Bachelor degree. An exception is CN where secondary normal school graduates meet the educational requirement for being an elementary school teacher.

Usually, the student teachers are required to complete a certain number of hours/credits in an education program (teaching profession/pedagogical courses) and technology/relevant subject coursework. In the US, due to the lack of qualified teachers, some states/local governments open access to those who have not completed an approved collegiate level teacher-preparation program. People who have working/practical experience or interest in teaching could serve as teachers and take the teacher-preparation program at the same time.

After finishing the teacher education program and technology/relevant subject credits, students have to pass the teacher qualification/ licensing examination. In some countries like KR, due to the oversupply of teachers, licensing examinations for secondary school teachers are very difficult, making licensing a key selection point rather than admission to initial training. In AU, the Teacher Performance Assessment will be conducted to assess pre-service teachers' quality against the Australian Institute for Teaching and School Leadership (AITSL) Standards. Students need to evidence certain requirements of the Standards in order to become a registered teacher or achieve Highly Accomplished and Lead certification.

Point 2: Technology Teacher Education (TEE) Programs

Most cases have a pre-service/initial TEE program as well as an in-service/ professional development TEE program (an exception is HK where there is no professional development requirement for in-service technology teachers). For the pre-service TEE program, the coursework usually includes three categories: general/ common/ basic courses (like Introduction to technology, Mathematics, Physics, etc.), subject-specific/ technical/ content courses (like Energy & Power, Manufacturing, Mechanical design, Structural design, Woodworking, etc.), and professional education courses (like Pedagogy of Technology Education, Teaching Methods, Educational Psychology, etc.). The training program also includes practical/ field experience/ practicum units. The TEE programs need to be accredited by an independent or national agency to ensure their quality.

Point 3: Features of the TTE

Each country/area has its unique features of TTE. In AU, technologies move toward the national curriculum, with a focus on design and computational thinking in an active learning environment and manipulative skill development. The structure of the technologies curriculum is sound and is based on contemporary principles of pedagogy and learning. In CN, TTE actively takes the dual perspectives of both globalization and localization. International talent is coming to CN and boosting the overall professionalism of technology teacher education. In HK, the recent curriculum revision overstresses the content of Knowledge Contexts leading to insufficiency in practical components in the D&T program. In addition, instantaneous introduction of STEM into the curriculum without reaching consensus on the purpose, pedagogies, and learning activities has posed challenges to teacher training programs. In Japan, training for 10 (or more) years' experience teachers has been offered, aiming to improve their guidance ability and to develop their specialties. Active teachers participate in a regional, national or international research institute or professional organization to improve professional competencies by themselves. In KR, there is well-organized pre-service TTE in the undergraduate programs which are closely related to the National Curriculum. Also, there is a well-designed in-service technology teacher education program. There is an engineering-based nature to the body of knowledge in TTE, and a need for technology from a holistic point of view. In NZ, initial teacher education programs prepare student teachers to teach technology through experientially-based inquiry learning approaches to design and develop technological outcomes, systems or products, and to meet identified needs within social, cultural and sustainable parameters. In TW, well-designed pre-service and in-service technology teacher programs equip technology teachers with sufficient professional knowledge and skills to effectively guide students' learning activities. In the US, there is a broad-based nature to the body of knowledge in TTE which looks at technology from a holistic point of view. The program emphasizes learning by doing and provides great variety and flexibility that allows the educators to customize the learning to the needs of students and the local economy.

Table 3. A summary of the state-of-the-art of technology teacher education in the Asia-Pacific Region

	Australia (AU)	China (CN)	Hong Kong (HK)	Japan (JP)	Korea (KR)	New Zealand (NZ)	Taiwan (TW)	United States (US)
Certification requirements for technology teachers	1. Teaching requires a minimum 4-year undergraduate degree or 2-year postgraduate degree. 2. Teaching Performance Assessment will assess pre-service teachers to collect evidence during the final professional experience against the AITSL standards.	1. Education level: elementary school teacher - graduated from a secondary normal school or above; junior secondary school teacher- a diploma or above from a higher normal college or university; senior secondary school teacher qualification-bachelor degree or above 2. Passing the technology teachers' certification tests	1. Hold a teacher qualification (e.g., a local Teacher's Certificate or Post-Graduate Diploma of Education, PGDE) and be a Hong Kong permanent resident 2. PGDE in D&T program: pass all credit requirements, the practicums, and the Information Technology Competency in Education (ITCE) before graduation	1. Graduate from university with a Bachelor's degree and credits in subjects relating to a prescribed course and the teaching profession (including teaching practice) 2. Possess a teacher certificate (3 levels with different required credits)	1. Bachelor's degree from 4- year undergraduate program or Master's degree from 2-year post-graduate program & complete a pre-service technology teacher educational program 2. Get a teacher's license of technology when graduating from the above institutions 3. Pass the National teacher recruitment examination to be employed	1. Bachelor's degree and graduate diploma 2. undertake a number of small tasks that are applicable to future school settings, and are reflective of a range of technological areas	1. Graduating from a college or university 2. Completing a pre-service TE teacher education program 3. Passing the teacher qualification examination 4. Finishing educational practicum 5.Meeting the teacher selection requirements	1. Each state follows a broadly similar process: certification paths for individuals who have completed an approved collegiate level program and those who did not. 2. Unique points: requirements for permanent licensure varied (each state may have a mentoring, assessment, and a continuing education components but they are all different in the details.)

	Australia (AU)	China (CN)	Hong Kong (HK)	Japan (JP)	Korea (KR)	New Zealand (NZ)	Taiwan (TW)	United States (US)
Technology teacher education programs	1. All Initial Teacher Education programs need to be accredited by the jurisdiction in which they exist based on the requirements of AITSL. 2. Each needs to have units that address various aspects of teaching education including curriculum, content and pedagogical units. 3.Students studying secondary education are required to have both a	1. Programs with academic degrees: science and technology education programs (for Science, IPA & GT teachers, covering courses of theoretical foundation of teaching and education & professional development) and educational technology programs (for IT teachers, covering courses in Pedagogy,	1. Both pre-service training programs: PGDE ICT & D&T; Entrance requirement: a relevant honorary Bachelor's degree 2. Program structure for PGDE ICT: Required Courses (8 Units), Core Electives (4.5), Electives (4.5), & Teaching Practice (3) 3. Programme structure for PGDE D&T: 30-33 ,	1. Technology teachers are trained in the engineering and agricultural departments of national and private universities 2. 128 credits including Common subjects, Professional education subjects (like Course major subjects: Woodworking, Metalworking, Machines, etc.; Teaching profession subjects: Technology	1. Pre-service teacher education: provided by 4-year undergraduate programs, or postgraduate schools of education 2. Includes two major parts: (1) General teaching profession including educational theory, practicums and others; and (2) subject-specific profession including pedagogy of TE such as foundation	1. Entry requirements are restricted to those with University Entrance AND all students must be interviewed and pass a police screening 2. Teacher education occurs at two levels: in pre-service or Initial Teacher Education (ITE) programs & in-service or professional learning and develop	1. Admission criteria: depend on each university 2. Pre-service education including general courses (Introduction to technology education, Electronic circuits, etc.), subject-specific courses (Mechanical design, Structural design, etc.), and professional education courses	1. Varies from program to program 2. Typical program includes: General Education (45 credits, like Mathematics, Physics, etc.), Professional Studies, (33 credits, like teaching methods, Educational Psychology, etc.), & Technical Studies (44 credits, like Energy & Power, Manufacturing, etc.)

	Australia (AU)	China (CN)	Hong Kong (HK)	Japan (JP)	Korea (KR)	New Zealand (NZ)	Taiwan (TW)	United States (US)
	major and a minor teaching area.	Computer science & Media) 2. Programs without academic degrees: The National- or Provincial-level Teachers Training Program	credit points, including: Major Subject Studies (6/9), Education Studies (12) Electives Studies (6/9), Field Experience (6) 4. No professional development requirements for in-service technology teachers	Education), & Independent subjects 3. Workshops of certificate renewal are intended for in-service teachers	of TE, TE curriculum, Researching & developing teaching & learning materials of TE; and content of TE such as production, transportation, communication, invention/ standardization, and sustainable technology.	ment(PLD) 3. Most undergraduate and graduate courses have 15 points (1 point equivalent of 10 hours of study), undertaking 8-9 courses per year	3. The program mainly covers Content Knowledge, Pedagogical Knowledge, and Pedagogical Content Knowledge 4. In-service teacher training program provided by individual institutions, 6 credit (18 hours/ per credit)	
Features of technology teacher education	1. Technologies move toward national curriculum, with a focus on design and computational	1. It actively takes the dual perspectives of both globalization and localization	1. Overstressing of the content of Knowledge Contexts leads to insufficient	1. Training for teachers who have 10 years' experience has been offered,	1. Well-organized pre-service technology teacher education at the undergradu	1. ITE programs prepare student teachers to teach technology through	1. A well-designed pre-service & in-service technology teacher program	1. Broad-based nature of the body of knowledge 2. Looking at technology from a

	Australia (AU)	China (CN)	Hong Kong (HK)	Japan (JP)	Korea (KR)	New Zealand (NZ)	Taiwan (TW)	United States (US)
	thinking, in an active learning environment 2. Focus on manipulative skills development 3. The structure of the Technologies curriculum is sound and is based on contemporary principles of pedagogy and learning	2. International talent is coming to China and boosting the overall professionalismof technology teacher education	and even missing practical components in the PGDE D&T program 2. Instantaneous introduction of STEM yet without consensus on the purpose, pedagogies, learning activities, etc. has posed challenges to teacher training programs	aiming to improve their guidance ability and to develop their specialties. 2. Active teachers belong to a regional, national or international research institute or professional organization in order to improve themselves.	ate programs which are closely related to the National Curriculum through 'basic areas (or courses) of study to be completed' 2. A well designed in-service technology teacher education program 3. Engineering-based nature of the body of knowledge and technology needs from a holistic point of view	experientially-based inquiry learning approaches to design and develop technologicaloutcomes, systems or products, to meet identified needs within social, cultural and sustainable parameters	to equip technology teachers with sufficient professional knowledge and skills to effectively guide students' learning activities	holistic point of view 3. Emphasis on learning by doing4. Great variety and flexibility that allows educators to customize the learning to the needs of students and the local economy

CHALLENGES AND INNOVATION OF TECHNOLOGY TEACHER EDUCATION

In this section, a comparison of major problems/challenges for technology teacher education is conducted. In addition, the process of innovation and strategies undertaken in order to obtain solutions to the major problems identified are discussed. Table 4 shows a summary of challenges and innovation of technology teacher education in the Asia-Pacific Region.

Point 1: Major Problems/Challenges

Some prevalent challenges are observed among the target countries/areas in this region. First, there is a shortage of qualified technology teachers (in AU, CN, JP, TW, and the US). The enrollment in TTE programs in the US has even declined recently. Second, pre-service technology teacher education programs are insufficient. There are a small number of universities offering technology teacher courses in AU, CN, and JP. Such programs generally have a smaller number of students and instructors but need more facilities, equipment, and a bigger budget than other subjects. In KR, the lack of qualified technology teacher educators is a challenge. Third, technology has lower subject status compared to other school subjects, especially in CN and NZ.

Besides, each country/area has encountered its own set of challenges. For example, in AU, the university entry requirement relies more on sitting examinations than on vocational/skill tests, and primary teachers are unsure of how to teach technology. In HK, there is a resource limitation due to the minor subject branch in the universities; and STEM education has inconsistent and instable definition, scope, and position in the curriculum that lead to downplaying the significance of practical learning of problem solving. In JP, due to the integration of departments and universities, it is impossible to carefully foster technology teachers by individual prefecture. In KR, there is a discrepancy between current basic courses/ areas of study for technology teachers' license and technology education curriculum content. As for NZ, the challenges are the lack of understanding of the philosophy and key ideas that underpin technology; and teachers struggle with philosophical changes that need to shift technology from a technical, skills-based program to the needs-based student-centered program outlined in the current curriculum. In TW, TTE faces the problems of inconsistent levels of professionalism among technology teachers due to diversified educational channels; and TTE programs are impacted by emerging technology topics. In the US, inequity in terms of gender, race, and ethnicity among technology educators was raised.

Point 2: Innovation and Strategies

As mentioned above, technology teacher education in each country/area faces common problems as well as individual challenges. A number of innovations and strategies are raised in each country. For example, in AU, it has been suggested that more scholarships be offered by universities and potentially be funded by government departments to encourage both school leavers and tradespeople to consider teaching as a career. Professional learning opportunities from specific associations and universities directed to both preservice and in-service teachers would go a long way towards supporting content and pedagogical knowledge. In CN, the strategies include increasing provision for technology teacher education, refining TTE curricula, and building a network of teaching and researcher leadership with a disciplinary vision in provincial governments. In HK, teacher trainers are encouraged to arrange school visits for student teachers to ICT-outstanding schools in order to gain first-hand experience of excellence in ICT teaching pedagogy, and to understand what innovative learning activities look like. Besides, in search of the ideal D&T teacher training, it is encouraged to re-think what the teacher training courses should look like in order to develop potential D&T teachers' knowledge, capabilities and values in teaching the subjects. In JP, it is proposed to design "Examination certifying teaching ability of technology teachers" to evaluate the teachers' abilities in the Technology subject, and to promote and enlighten technology education via various committees, newspapers and projects. In KR, the current basic courses for the technology teachers' license should be stipulated in accordance with the 2015 revision of the national curriculum in order to narrow the gap between training programs and the licensing test. Additionally, more technology teacher preparation programs are needed at undergraduate school in terms of quantity. In NZ, practicing teachers need to move from a sole focus on specialist knowledge towards the interpretation of the curriculum and/or assessment standards, and move towards a student-centered approach. Student teachers need to reflect upon their own and others' perceptions of TE, and it is the responsibility of ITE programs to prepare them to critique the way that TE is taught in schools. In TW, strategies include boosting the maker movement to raise national awareness of teaching in technology, taking initiatives in developing hands-on capabilities, and promoting robot competitions, teaching and learning. In the US, in the case of declining enrollment, one may begin to solve the problem by bringing in students for workshops in fun and interesting subjects. Finding ways to certify more technology and engineering (T&E) teachers through alternative means (completing TE as a minor, etc.) are also proposed to deal with the problems of teacher shortage.

In sum, TE and TTE programs in the APAC have a long way to go. More time and attention in this field are warranted for improvement and a better future.

Table 4. A summary of challenges and innovation of technology teacher education in the Asia-Pacific Region

	Australia (AU)	China (CN)	Hong Kong (HK)	Japan (JP)	Korea (KR)	New Zealand (NZ)	Taiwan (TW)	United States (US)
Major problems/challenges	1. A small number of Universities offer Technology courses. 2. Technologies teacher shortages; 3. Issues with University entry requirements: rely most on sitting exams and less on vocational system 4. Primary teachers are unsure of how to teach technology 5. Concerns regarding 1- and 2-year teacher	1. Lower status of technology compared to other school subjects. 2. Insufficient provision of pre-service and in-service technology teacher education. 3. Lack of candidates to receive technology teacher education	1. Challenges for PGDE ICT: Resource limitation due to the minor subject branch in the university; & Distinguishable subject status under the introduction of STEM education (inconsistence and instability in definition, scope, position in curriculum) 2. Challenges for PGDE D&T: Introduction of a loose and	1. Due to the integration of departments & universities, it is impossible to carefully foster technology teachers by individual prefecture 2. Technology education course is generally smaller in terms of the number of instructors but needs more facilities, equipment and a bigger budget for research	1. There is a discrepancy between current basic courses or areas of study for technology teachers' license and technology education curriculum content 2. Lack of qualified technology teacher educator; those with an engineering background lack or misunderstand the technology education	1. Lack of understanding of the philosophy and key ideas that underpin technology, low subject status based on its predecessor technical education, and the lack of time and facilities available in teacher education programs 2. Teachers struggle with philosophical changes needed to move technology from a technical,	1. Insufficient number of technology teachers due to the reduced number of pre-service teachers 2. Inconsistent levels of professionalism among technology teachers due to diversified educational channels 3. The technology teacher education programs are impacted by emerging technology topics	1. Decline in enrollment in technology teacher education programs 2. A shortage of in-service teachers 3. An inequity in terms of gender, race, and ethnicity among technology educators

	Australia (AU)	China (CN)	Hong Kong (HK)	Japan (JP)	Korea (KR)	New Zealand (NZ)	Taiwan (TW)	United States (US)
	education programs 6. Focus on Vocational and General Technology education 7. The confusion of STEM		ill-defined STEM education led to "anything goes" that downplays the significance of practical learning experiences in problem solving; & Teacher training for D&T will cease	and education than other subjects 3. Insufficient qualified technology teachers	3. Insufficient enrollment quota in the pre-service technology teacher education program	skills-based program to the needs-based student-centered program outlined in the current curriculum		
Innovation and strategies	1. Scholarships offered by universities and funded by government departments are suggested to encourage both school leavers	1. Increasing provision for technology teacher education 2. Refining technology teacher education curricula	1. Teacher trainers arrange school visit for student teachers to ICT outstanding schools to gain first-hand experience of	1. Design "Examination certifying teaching ability of technology teachers" to evaluate the abilities of teachers in the Technol	1. Current basic courses or areas of study for technology teachers' license should be stipulated in accordance with the	1. Practicing teachers need to move from a sole focus on specialist knowledge, towards the interpretation of the curriculum and/or	1. Boost the maker movement to raise national awareness of teaching in technology and to take initiatives in developing	1. Bringing in students for workshops in fun and interesting subjects to boost enrollment 2. Finding ways to certify more technology & engineer

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	& tradespeople to consider teaching as a career. 2. Professional learning opportunities from specific associationsand universities directed to both pre-service and in-service teachers would go a long way towards supporting content and pedagogical knowledge. 3. Teachers would benefit from further	3. Building a network of teaching and researcher leadership with a disciplinary vision in provincial governments 4. Enhancing the technology culture atmosphere	excellence in ICT teaching pedagogy, and an understanding of what innovative learning activities look like 2. The endeavors initiated by theICT professional community and teacher trainers to promote learning experiences with ICT signatures 3. In search of the ideal D&T teacher training, to re-thinking what the teacher	ogy subject 2. Host “Contest on technology works with energy” that provides an environment where students work on manufacturing with technological views, and to foster national understanding of TE 3. Promote and enlighten technology education via various committees, newspapers and projects	2015 revision of the national curriculum 2. More technology teacher preparation programs are needed at undergraduate school in terms of quantity	assessment standards, and towards a student-centered approach 2. Student teachers need to reflect upon their own and others’ perceptions of TE, and it is the responsibility of ITE programs to prepare them to critique the way that TE is taught in schools 3. Recent curriculum revisions to increase the presence of digital tech	hands-on capabilities 3. Promote robot competitions, teaching and learning	ing teachers through alternative means (completing TE as a minor, etc.)

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	professional development includ-ing short courses and mentoring, creating an opportunity for both uni-versities and teacher as-sociations.		training course should look like in order to develop poten-tial D&T teachers' knowledge, capabilities and values in teaching the subjects 4. Professional requirement for teaching in Work-shops			nologies in the technolo-gy curriculum, and the move to teach-ing through inquiry		