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Examining computer science education of Asia-Pacific countries successful in the PISA

Semra Fiş Erümit [a] *, Esra Keleş [b]

[a] Karadeniz Technical University, Trabzon, Türkiye.
[b] Trabzon University, Trabzon, Türkiye.

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Highlights

- Computer science courses both directly and indirectly affect student achievement in PISA, as they provide students with technology-producing knowledge and perspective.
- It has been observed that Computer Science education is compulsory in secondary and high schools in Asia-Pacific countries and Türkiye.
- Although the computer science education of countries are almost similar to each other, the development processes of the curriculums and their reflections on the educational processes have been different.

Article Info: Research Article

Keywords: *Asia-Pacific countries, PISA, Computer science education, K-12, Computer science curriculum*

Abstract

In this study, the Computer Science (CS) education in K-12 of the countries in the "Asia-Pacific region", which are among the top 10 in PISA, and CS education of Türkiye were investigated. PISA is conducted to assess science, mathematics, and reading skills. PISA, which is carried out every 3 years by the OECD, evaluates 15-year-old students. When the countries that have been successful in PISA are examined, it has been observed that the number of countries in the "Asia-Pacific region" in the top 10 has increased in recent years. In this study, data analysis was done with document analysis, which included PISA results and reports, OECD reports, computer science curriculum of countries, and academic studies on PISA and computer science education. As a result of the data obtained, the countries' CS education was compared to identify successful practices. Also, the countries' practices in computer science education were compared to Türkiye, and implications were made about the effects of such works on PISA results.

1. Introduction

Since the year 2000, with the rapid developments in technology, there has been a great change in "Information and Communication Technologies" (ICT), and this has caused the education systems of the countries to revise. The changes brought along by ICT have started to shape educational reforms in countries (Kuno et al., 2015; Ndibalema, 2020). For this reason, many countries are currently engaged in development and planning studies on the integration of ICT into education (Fiş Erümit & Keleş, 2021). In addition to supporting the educational processes of 21st-century students with ICT, individuals who use and produce ICT in the best way should be trained.

Due to the effects of the digital age on society and the requirements of Society 4.0 and 5.0, the existence of individuals who can produce and develop technology beyond just using it has become a necessity, not an obligation (Fukuda, 2020; Kay & Greenhill, 2011). For this reason, the need for individuals to learn digital literacy and information technologies under a discipline has increased. Although we use technology in many areas of our lives, the development of computer science curricula and programs in schools is of

* Corresponding author. Distance Education Application and Research Center, Karadeniz Technical University, Trabzon.
e-mail addresses: semrafiserumit@ktu.edu.tr

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importance to respond to the needs in use, production, and development in general (Webb et al., 2017). Today, the Computer Science (CS) curricula of countries significantly affect their social and cultural life and economies (Fluck et al., 2016; Tondeur et al., 2011). According to economic reasons, it is considered important for a country to maintain its competitive advantage in a world driven by technology and to train experts who will support innovation and development. From a social point of view, instead of technology creating passive consumers in society, it is desired to raise innovative and creative individuals who will lead society. From a cultural point of view, it is to create societies that can direct cultural change with technology, not keep up with the changes that technology imposes on society (Jayaprakash & Pillai, 2021; Leidner, 2010; Webb et al., 2015). For this reason, CS in school curricula has become important for politicians, educators, and researchers, especially in the last 20 years.

ICT did not receive sufficient importance in school curricula in many countries up to the 2000s. One of the main mistakes made at this point is that it could not be decided whether each individual should study CS or for what purpose the individual would use it. However, after the 2000s, CS education has become an important issue due to the effects of technology in all areas of life such as industry, education, and society. Over time, it has been clearly seen that the purpose of CS education at school is not to find a job in the industry but to show the basics of the discipline, provide a perspective for other disciplines, and raise productive individuals. Thus, studies on both the integration of ICT into education and updating CS curricula and incorporating them into school curricula have increased (Armoni & Gal-Ezer, 2014). In addition, it is stated that the regular presence of CS lessons in the school environment will help students' general learning processes and develop creativity, problem-solving, and analytical thinking, which are 21st-century skills (Webb et al., 2017; Wong & Cheung, 2020). Additionally, it is reported that the regular presence of CS lessons in the school will help the general learning processes of the students (Chauhan, 2017; Lei et al., 2020; Merino-Armero, González-Calero, & Cozar-Gutierrez, 2022). It can help develop basic skills such as “problem-solving”, “analytical thinking”, and “creativity” which are considered 21st-century skills (Florez et al., 2017; Grover & Pea, 2013; Li et al., 2022). It is stated that CS and programming education can support students in many ways in a learning environment. This perspective does not mean that all students will necessarily become professional programmers, but it does mean that they must acquire the useful practices and skills of the digital age (Garneli et al., 2015).

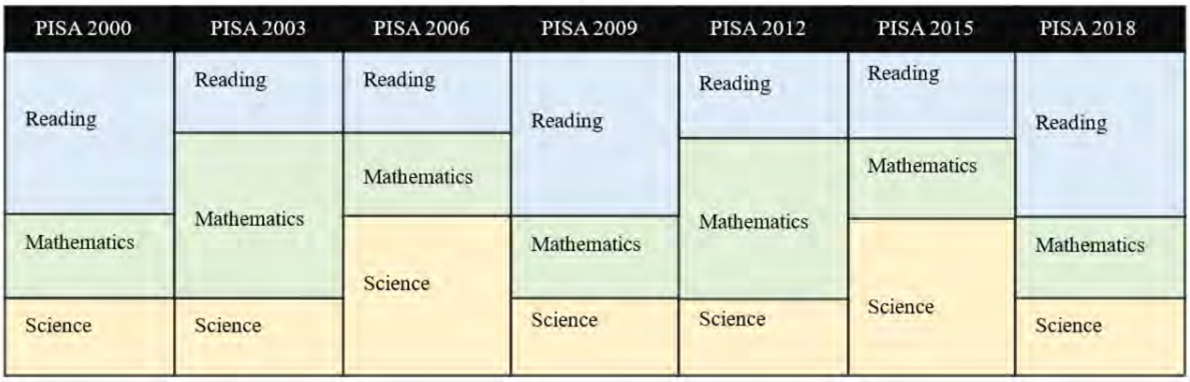
Although many countries have made adjustments to CS curricula at the K-12 level, this is a new phenomenon in many countries. In addition, in the curricula arrangements, it is seen that the education starts at different age levels, different subjects are handled according to the age level, and there are different practices and problems such as giving the education within the scope of compulsory or elective courses, and teacher qualifications. In the countries, different terms are used for CS education. Information technology, computer science, computing, digital literacy, informatics, computational thinking, and programming are the main terms that can be used for CS education at the K-12 level (Webb et al., 2017). Studies of CS curricula are still ongoing in many countries, there has not been much work on the development of curricula (Falkner et al., 2019). In this study, the CS education curricula of the “Asia-Pacific region” countries’, which were among the top 10 in PISA evaluations from 2000 to 2018, and CS education curricula in Türkiye were examined. When the countries that have been in the top 10 in PISA between 2000 and 2018 are examined, it is seen that the countries of the “Asia-Pacific region” come to the fore. These countries are Japan, Singapore, Hong Kong (China), South Korea, China (“B-S-J-G”, “B-S-J-Z”, Shanghai), Taiwan, Macau (China), and Vietnam (Fiş Erümit & Keleş, 2021). Considering that CS curricula have an impact on different fields such as mathematics and science, examining the CS curricula of the countries that are at the top of the PISA assessment, which includes questions in mathematics, science, and reading skills, is considered beneficial for the improvement of both CS education and curricula. In addition, important findings can be obtained in terms of the effects of CS on other branches, the plans that can be made, and the lessons that can be learned.

2. Literature

2.1. A Glance at PISA from the Educational Content and CS Education Perspective

"Programme for International Student Assessment" (PISA) is a research conducted by "The Organisation for Economic Co-operation and Development" (OECD) for three-year terms and evaluating 15-year-old students. With PISA, students' knowledge in the fields of mathematics, science, and reading skills and their ability to use this information is evaluated (OECD, 2022). Since 2003, questions based on problem-solving have also been asked, and questions on computational thinking skills, which are considered the basis of programming, are also asked. The purpose of these questions is the assessment of individual problem-solving skills. There are different types of questions in PISA such as "multiple choice", "open-ended" and "closed-ended" questions. In addition, comprehensive research is conducted in which the reasons for the success and failure of students are investigated by applying questionnaires to students, parents, and school administrations (Turkish Ministry of National Education [MoNE], 2011).

In PISA, examinees are not evaluated for their mathematics, reading, and science knowledge alone. The focus is also on making the right decisions in various situations by relying on the learned knowledge. In this way, students are assessed regarding not only their knowledge and experience in these disciplines but also applying such gaining to the solution of problems and everyday life and the way they put the knowledge into practice (MoNE, 2009). PISA sessions give weight to different areas every 3 years (Figure 1), and the participating country rankings vary depending on the weighted areas.



**Larger boxes symbolize weighted areas.*

Fig 1. Focused areas by years in PISA

Figure 1 shows that in 2000 when the first PISA exam was held, reading skills became the main domain with the majority of questions in the test. Then, the main areas were rotated yearly. This pattern allows a more extensive assessment of each of the three fields every 3 years (OECD, 2022).

In addition to making assessments by asking questions in the determining fields in PISA, questions are also asked about the ability to interpret daily life events by using the knowledge of these fields. For this reason, it is stated that students who are successful in their lessons at school do not mean that they will be successful in their problem-solving and interpretation skills in PISA (Döş & Atalmış, 2016). In PISA, questions that reveal thinking skills such as "critical thinking" and "problem-solving", which are also considered 21st-century skills, are asked. When we look at the questions in the field of mathematics in general, it is seen that there are questions about the mathematical formulation of real-life problems and the skills of using and interpreting mathematics. The ability to use mathematics in daily life is considered within the scope of problem-solving skills. Questions in the field of mathematics are mostly related to the subjects of space and shape, relations, numbers, and patterns. In the field of science, questions are asked about physical systems, earth and space systems, living things, and scientific inquiries. In the reading area, questions arise from areas such as text interpretation, discussion, prose, text types, graphics, forms, and lists (Batur et al., 2019). In PISA, it is seen that questions that require cognitive processes such as exploring, interpreting, and formulating for mathematics, science, and reading skills are asked. It is seen that these processes may be related to computer science issues, although not directly, and an interdisciplinary approach is possible in PISA. Just as reading comprehension is considered a grammar-specific skill, it is also a skill associated with other lessons. According to studies, it is stated that people with unsuccessful reading skills will not be successful in other subjects. For this reason, it is clear those different skills such as understanding and interpretation are used in solving mathematics and science problems, and the training given for computer science can contribute to the fields in PISA. The best proof of this is asking questions about "computational thinking", "critical thinking", and "problem-solving skills", which are considered the basis of programming in PISA (MoNE, 2011). In addition, it is stated that there is a connection between CS courses and PISA success of countries. Spiezia (2010) stated in his study that there is a connection between high science scores in PISA and students' computer use. Similarly, in another study, it was stated that students' access to a computer was one of the most important factors affecting their science achievement in PISA (Anıl & Özer, 2012). In another study, it was stated that the quality and quantity of computer use had an impact on the success of PISA in the USA (Cheema & Zhang, 2013). On the other hand, Zhang and Liu (2016) could not find a relationship between ICT usage and science and mathematics achievements according to the PISA results between 2000 and 2012 in their study. They stated that high achievement scores were not related to computer use and knowledge. However, it is stated that the increase in self-confidence towards computer use positively affects the scores. Many studies show that there is a positive relationship between computer use and PISA success. Having all these in mind, it is thought that the K-12 level CS education and curricula of the Asian-Pacific countries that were successful in PISA will shed light on their success in PISA.

2.2. Purpose of the Study

In the digital age, the integration of ICT into schools and CS education is of great importance. The achievements of the countries in the "Asia-Pacific region", which have been in the top 10 in PISA, especially in the last 10 years, draw attention. In the first study carried out in this context, how the countries in the "Asia-Pacific region", that were successful in PISA, integrated ICT into their educational environments and the effects of these integration efforts on the success of the countries in PISA were examined (Fiş Erümit & Keleş, 2021). In this study, which is a continuation of the previous study, the CS education and curricula of the countries were investigated. Accordingly, the study aims to investigate how the countries in the "Asia-Pacific region" (Singapore, South Korea, Japan, China, Hong-Kong, Tapei, Macau, and Vietnam), which are among the top 10 in the PISA evaluation, perform CS education. The research questions in this study are stated below:

- How is CS education performed in K-12 schools in "Asia-Pacific region" countries?
- How is CS education performed in K-12 schools in Türkiye?

In search of an answer to research questions, it was tried to find out the description of the content of the CS education and the topics taught at different grade levels.

3. Methodology

3.1. Research Design

The study was carried out with the qualitative research method. In the study, the CS education and curricula of the countries in the "Asia-Pacific region" and Türkiye were investigated. Document analysis was used to investigate the CS education of countries. In document analysis, data are collected from various sources such as printed and online documents, reports, and theses (Bowen, 2009). Document analysis is a qualitative research method used to examine and evaluate printed and electronic materials. As other methods used in qualitative researches, document analysis requires the examination and interpretation of data in order to make sense of it, to form an understanding about the subject, and to develop empirical knowledge (Corbin & Strauss, 2008). In this study, the CS curriculum of the countries were investigated by referencing different sources in order to reflect the studies on CS education of the countries that were successful in PISA. In our study, detailed research was realized on a blend of documents and resources including PISA reports, the national education curriculum, and academic studies in the field of CS. The findings were summarized and the CS curriculum of the countries at all levels were compared to each other. For this reason, document analysis method was preferred in the study.

3.2. Data Collection

For literature review on CS curriculum and education of the selected countries, search engines of "ERIC", "ISI Web of Science", and "Google Scholar" were used, and content analysis was carried out on the relevant scientific articles. The article screening process was completed using English and Turkish keywords. The following keywords guided the search: "computer science education", "CS curriculum", "computer education", "information technologies and software curriculum", "information technology education", and "computing education". Once the screening was completed, data collection was done by using the following data collection tools:

- PISA results and reports (21 reports)
- Articles about CS curriculum of the countries (73 articles)
- Reports on CS curriculum of the countries (9 reports)
- National Education websites of the countries (11 websites)

3.3. Sample

The sample of this study is Asia-Pacific countries, which were among the top 10 in PISA between 2000 and 2018. The top 10 countries in PISA are Japan, South Korea, Hong Kong (China), Macao (China), Chinese Taipei (Taiwan), Shanghai (China), Singapore, "B-S-J-Z" (China), "B-S-J-G" (China), and Vietnam. Along with these countries, Turkey's CS education was also investigated. Turkey participated in PISA in 2003 (MoNE, 2022). Looking at the top 10 countries participating in PISA, it is seen that China participated in PISA with certain provinces (Shanghai, "B-S-J-G [Beijing, Shanghai, Jiangsu, Guangdong]", "B-S-J-Z [Beijing, Shanghai, Jiangsu, Zhejiang]". Since these provinces are under Chinese administration, China's CS education studies have been examined. Although some provinces are dependent on China in foreign relations, they have their own education curricula (Hong-Kong, Macao) because they have self-government in internal relations. Taiwan is recognized independently by a few countries in the world. Since China doesn't recognize Taiwan's independence, so Taiwan participates in the PISA using the name Taipei, which is its capital. Taiwan has a separate administration; thus it has its own education curriculum (Fiş Erümit & Keleş, 2021). The sample of the study consists of Japan, Singapore, Hong Kong (China), South Korea, China (Shanghai, "B-S-J-G", "B-S-J-Z"), Taiwan, and Türkiye (Table 1).

Table 1.

Sample

	Country	Region	State
Japan	✓		
Singapore	✓		
Hong Kong (Autonomous region under the reign of China)		✓	
South Korea	✓		
Shanghai (China)			✓
B-S-J-G [Beijing, Shanghai, Jiangsu, Guangdong] (China)			✓
B-S-J-Z [Beijing, Shanghai, Jiangsu, Zhejiang] (China)			✓
Taiwan-Taipei (China)			✓
Türkiye	✓		

Although Macau and Vietnam rank high in the PISA, they were not included in the study. Few academic studies on the subject have been reached in these countries, and some sources could not be translated because they were in the countries' own languages.

3.4. Data Analysis

In this research, collected data were analysed with descriptive analysis. In descriptive analysis, data are summarized and interpreted according to predetermined themes. The purpose of this analysis is to organize and interpret the findings and present them to the reader (Yıldırım & Şimşek). Researched documents were screened in relation to the research questions. In the documents examined, CS curricula were analyzed. As a result of the CS curriculum screening, analyses were made on how CS education is performed in primary, secondary, and high schools. The findings obtained from the examined documents were carried out with descriptive analysis, since the study was presented in a summarized way depending on the research problems in order to make it easier for the reader to understand without changing and theming. For this purpose, the resources examined for curriculum studies were analyzed by paying attention to the following headings:

- Computer science education content offered by grade level (primary, secondary, and high school)
- Compulsory or elective status of ICT courses
- The years in which the curriculum was revised
- The facts forcing the revisions and challenges faced
- The contents of the curriculum in question.

4. Findings

Computer science education is named differently in the countries concerned here. It is called “Informatics Education” in Japan, formerly “Computer Education” and then “Informatics Education” in South Korea, “Technology Education” in Hong Kong, “Computer Applications” in Singapore, “Computing” in Taiwan, “Information Technology Education” in China, and formerly “Computer” and “Information Technologies” replaced by “Information Technologies and Software” in Turkey. Collectively, education provided by all the sample countries in this field is referred to as Computer Science (CS) in this paper. Besides, CS education is offered at different educational grades and age levels in each country; therefore, the section about CS education in the countries is given only after the compulsory education age, and education levels in those countries are introduced.

4.1. Japan

Japan offers 6 years of “primary school” education, 3 years of “secondary school”, and 3 years of “high school” education. The compulsory education lasts 9 years covering both primary and secondary education. The purpose of CS education in K12 schools in Japan is defined as "acquiring the ability to make use of information" in general terms. In parallel with the CS works and activities conducted in the 2000s, the “Ministry of Education, Culture, Sports, Science, and Technology” (MEXT) of Japan determined three objectives for K12 informatics education (MEXT, 1997): to gain practical skills to draw on knowledge, to gain an understanding of scientific knowledge, and to develop scientific approaches to access information. In Japan, there is not a specific curriculum on information education prepared for primary school education between the ages of 6-12. Most primary school teachers do not have the knowledge and equipment to teach these topics. It is left to school administrators’ disposal whether to offer informatics education, and informatics education is not given in many primary schools (Kanemune, Shirai & Tanı, 2017; Kuno et al., 2015). Informatics education is provided in the scope of the "Technology and Home Economics" course in secondary school (for three years starting from the age of 13). In this course, all students learn computer literacy, basic robotics, and programming (Kanemune, Shirai & Tanı, 2017).

The Japanese government launched some works in the late 90s to restructure informatics education. As such, an elective "Informatics" course was added to the high school curriculum in 2003 (Hagiya, 2015). By building a bridge between high schools and universities in Japan, it was aimed to implement a more integrative curriculum, and CS education was rearranged to be more systematic by inserting "Information Study" topics into this course (Kuno et al., 2015). This curriculum was revised in 2013 and finalized in 2015 to be implemented as a compulsory course. The course was also renamed and taught in two elective courses, which are "Society and Information" and "Information Science". Students learned programming-related topics in the "Information Science" course. However, only 20% of the schools chose to teach this elective course (Kanemune, Shirai & Tanı, 2017). This course, with the coverage of programming subjects, did not opt for much in high schools, and, expectedly, the course objectives could not be attained. The main reasons for this situation are stated as follows:

- 15-day training courses given by the "Ministry of National Education" for teachers for the teaching of the newly introduced "Information Study" course are not long or qualifying enough for teachers.
- Generally, the use of application software is not taught as a part of education, and given training is not adequate for bringing up competent IT teachers in high schools.
- School administrators and teachers underestimate this course, thinking that it is a subject about how to use computers.
- Books that do not serve the main purpose of the course are selected for the teaching of the course, such as guidebooks on how to use computers.
- Teachers consider this course unimportant and teach irrelevant subjects in the course.

In the curriculum to be applied in Japan between 2018 and 2022, "Information of Science" in secondary schools and "Information Study" in high schools were accepted as compulsory courses. Also, MEXT decided to ask questions about the content of this course in the examinations for entrance to public and private high schools (Kuno et al., 2015). The curriculum of informatics education to be given from primary to high school was planned as a whole, and the topics and objectives are given in Table 2 (Kuno et al., 2015).

Table 2.

Informatics Education Topics and Objectives in Japan

Contents	Objectives
Principles of Information and Computers	Teaching the basic working principle of computers, information technology, and computer networks
Organizing and Creating Information	With the help of suitable tools, arranging information, understanding the properties of textual documents, creating reports and presentations, creating websites or research groups
Modelling and Analysis	Collecting and analyzing quantitative and qualitative data for problem-solving
Planning and Procedural Thinking	Teaching programming topics covering "computational thinking" and "problem-solving" attempts
Communication and Cooperation	Teaching "information ethics" and "network society" issues and topics for leadership in the global community
Logicality and Objectiveness	Teaching subjective/objective knowledge distinction, knowledge ethics, and report writing
Problem Solving	Teaching discovering the problem, exploring the solution of the problem, and find the sub-problems of the problem

The headings in Table 3 cover all teaching topics of informatics to be given throughout the K-12, and the difficulty levels vary according to the grade levels (Kanemune, Shirai & Tanı, 2017).

The new informatics curriculum has entered into force in Japan after 2020. The Japanese government stated that it did not attach enough importance to informatics education in the past and added that students had been taught programming starting from primary school upon adoption of the new curriculum. They are planning to teach programming education as a compulsory course in primary and secondary schools. However, since primary school teachers are not trained to teach the course content, it is planned to employ teachers in primary schools who specialize in CS. It is also thought to renew the secondary CS curriculum as of 2021 to continue teaching within the scope of the "Technology" course (Kanemune, Shirai & Tanı, 2017). The contents of the secondary curriculum are as follows:

- Materials and Processing Technology
- Cultivation Technology
- Energy Conversion Technology
- Information Technology

The topics of the technology course include subheadings such as "Craft", "Agriculture", "Energy", and "Knowledge". It is understood that with technology, it is aimed to apply technology to all spheres of life, from agriculture to social life and engineering. CS education is thus carried out within the scope of information technologies. Under the subheading of "Information Technologies", the emphasis is on "information society", "problem-solving", "using computer networks", "automation technology", "social development", and "information technologies".

Likewise, the new curriculum will be put into implementation in high schools after 2022. With this curriculum, informatics education subjects will be taught in high schools for 2 years. It is planned to offer an "Information-I (compulsory)" course in the first year and "Information-II (elective)" in the second year. "Information I" curriculum topics are as follows (Kanemune, Shirai & Tanı, 2017):

- "Problem-Solving in Information Society (*Utilizing computers in society, Information Society*)
- Communication and Information Design (*Information and media, Information Design*)
- Computer and Programming (*Data representation inside the computer, Basics of programming, Modelling and simulation*)
- Information Network and Data processing (*How Networks Work, Server, Database*)

The compulsory high school course curriculum suggests that the main goal is to raise good digital citizens in the "information society" and to teach "the use of information and communication tools", "basic programming", and "basic information about networks". As for the elective course "Information-II", the curriculum covers "the use of different information and communication tools", "the use of ICT tools in solving different problems", "the basics of statistics", "data processing", and "project management".

4.2. South Korea

In South Korea, 6 years of "primary school", 3 years of "secondary school", and 3 years of "high school" education are provided. Primary and secondary schools are compulsory. CS education has a long history in Korea. It started for vocational purposes in schools in the 1970s and began to be given at all school levels in the 1980s. After the 1990s, intensive CS education was given in schools to achieve "ICT literacy". In 2000, "CS Education Guidelines" for primary and secondary schools were published. Computer-related content has become compulsory in primary schools at all levels. In 2004, nearly 80% of secondary schools opened "computer classrooms" and 40% of secondary school students received computer training. Strong computer training has played a major role in the strength of Korea's Information Technology sector. Educators thought that this could not happen only with information about CS. It was understood that by using computers, various real-world problems could be solved, and students' cognitive thinking skills could be improved. This perspective also affected other learning areas (Choi, An, & Lee, 2015).

Since 2000, elective computer courses have been given in secondary and high schools under the name of "Computer Course". "Computer" and "Information Society and Computer" subjects are determined as elective courses in secondary and high school curricula, and schools can decide to train their students with computers. The title of the course was changed to "Informatics" in 2007 (Heintz, Mannila, & Färnqvist, 2016). At the time, the aim of the course was to embody individuals with 21st-century skills instead of letting them leave school as conventional passive learners (Grzybowski, 2013). Between 2004 and 2012, there was a significant decrease in the rate of selection of informatics courses in secondary and high schools. The main reason for this was the inefficient guidebooks about the course and enforcing inexact policies regarding the course.

Before the revised curriculum in 2007, basic information such as computer systems and using the software was given to students in computer classes. The curriculum was revised again in 2009. Since 2009, in addition to the basic principles of computer science, it has focused on applications such as algorithms, problem-solving, and programming, that will improve students' computational thinking skills. For this purpose, the focus on training on the use of software such as word processing and spreadsheet usage has been reduced, and content related to problem-solving, algorithms, and programming has been strengthened. In addition, as the negative effects of computers in society became widespread, content related to information ethics was added. The contents of each level in the revised curriculum are given in Table 3.

Table 3.

Informatics Education Contents in South Korea

Contents	Primary School "Grade 5-6"	Secondary School "Grade 7-9"	High School "Grade 10-12"
Information devices and cyberspace	• Use of digital tools • Features of cyberspace • Information ethics		
Multimedia materials	• Producing multimedia materials • Using multimedia materials		
Information science and informatics ethics		• Information science and information society (G 7) • Ethical utilization of Information (G 8) • Accurate information and measures to be taken in the information society (G 9)	• Media and information ethics (G 10) • Laws and institutions related to information ethics (G 11) • "Cyber-crimes" and measures to be taken against them (G 12)
Composition and operation of information instruments		• Computer hardware and working areas (G 7) • The structure and functions of the operating system (G 8) • Network structures (G 9)	• The structure and operation of computers, the working mechanism of the central processing unit (G 10) • Resource management in the operating system (G 11) • Network structures, data transmission and network services (G 12)
Expression and management of information		• Data and information concept (G 7) • Binary expression of information (G 8) • Structuring of Information (G 9)	• Obtaining correct information (G 10) • The structure of data • and information (G 11) • Management of Information (G 12)
Problem-solving		• Problem-solving methods (G 7) • Algorithm (G 8) • Fundamentals of programming (G 9)	• Problem structures and problem-solving methods (G10) • Fundamentals of programming (G11) • Implementation of algorithms, sorting and search algorithms, binary tree and graph (G 12)

(Source: Choi et al., 2015).

CS education for “primary school” students begins in the fifth and sixth grades and provides basic information on how to use computers. In the "Informatics" course, which is an “elective course” in the “secondary school” curriculum, the basic concepts of CS, developing students' numerical thinking skills, and teaching ethical gains are aimed. High school CS education is an “elective course” and has the same subjects and achievements as secondary school computer science education. In high school, the subjects are given in more detail. CS education with a more detailed curriculum is available for science high school students and science students in general high schools. These curricula are focused on problem-solving ability and programming.

New studies were initiated in 2013 to regulate computer science education. The Korean government announced a new curriculum in 2018, which dictated teaching “Informatics” course with consolidated contents about programming and software from primary school to high school. It was decided to offer informatics as a compulsory course in middle and high schools after upgrading the contents of the Introduction to Computer with basic programming topics for primary school 5th and 6th grades. The curriculum is based on digital literacy, computational thinking, and programming (Choi et al., 2015; Heintz, Mannila & Färnqvist, 2016).

4.3. Hong Kong (China)

In Hong Kong, “primary school” education lasts 6 years, “junior secondary school” education 3 years, and “senior secondary school” education lasts 3 years. Compulsory education is 9 years in total. CS education in Hong Kong is given from primary school within the scope of the compulsory "Technology Education" curriculum. “Technology Education” has a pedagogical content that combines various teaching areas such as “Materials & Structures, Operations & Manufacturing”, “Technology & Living” and associates these areas with each other. It mainly relates to “the application of technology to daily life”, “production”, and “management” areas. The main topics covered in CS education are as follows (Education Bureau, 2017):

- Computer systems (*Hardwar-software, functions, and features of basic components*)
- Information Processing and Presentation (*Information Technology (IT), IT tools, use of IT*)
- Programming Concepts (Problem-solving processes and techniques, data types, data recording)
- Computer networks (Use of computer networks, Internet applications)

Education is given under these basic subjects at every school level. The content and difficulty levels of the topics given at each level vary (Table 4).

Table 4.

Technology Education Contents in Hong Kong

Contents	Primary School “Grade 1-3”	Primary School “Grade 4-6”	Junior Secondary School “Grade 7-9”
Computer systems	• Components of computers and their functions	• Differences between software and hardware concepts • Operations on different computer systems	• Customizing software and hardware for specific tasks in computer systems
Programming		• Meaning of the concepts of program and data • Ways of solving problem • Distinguishing abstraction and forming a pattern	• Trying different ways to solve the problem • Systematic solving of the problem • Finding solutions to problems with simple programs
Information Processing and Presentation	• How computers work, how devices connected to the computer work • Use of ICT in daily life	• Developing information access skills, processing, and presenting information • Accessing information on the Internet, sending, and receiving e-mails • Using IT tools or software to support learning	• Understanding the basic concepts of information technology and computers • Gaining the skills to process and present information, working in collaboration with peers • Making sure the information is correct and valid • Data security and privacy, ethics

	• Situations where ICT usage is needed	• Improving communication and presentation skills
Networks	• Defining the concept of computer networks • Function of computer networks • The impact of computer networks	• Developing different skills in Internet and network applications

In primary schools in Hong Kong, CS-related teaching activities are held after information technology topics are incorporated into different branches. When it comes to junior secondary school, CS is blended with the curriculum of "Computer Literacy", "Design and Technology", "Home Economics/Technology and Living" courses. In this model, computer systems are taught regarding input-output units, storage units, and features and functions of hardware units. The subject of programming covers finding solutions to problems, devising solutions by dividing the problem into sub-problems, designing algorithms, using arithmetic and logical operators, coding, and designing programs. Under the topic of information processing and presentation, teaching covers using office software, electronic forms, social tools, multimedia tools, arranging multimedia products, and preparing presentations with the aid of presentation tools. Lastly, different devices and equipment used in computer networks and Internet standards are taught. At the upper level, senior secondary school, the curriculum comprises the following contents (Education Bureau, 2017):

- Information Processing (*Introduction to Information Processing, Data Organisation and Data Control, Data Representation, The Use of Office Automation Software, Presentation of Information*)
- Computer System (*Basic Machine Organisation, System Software, Computer Systems*)
- Internet and Its Applications (*The Networking and Internet Basics, Internet Services and Applications, Elementary Web Authoring*)
- Social Implications (*Equity of Access, Work and Health Issues, Intellectual Property, Threats and Security on the Internet*)
- Programming (*Problem-Solving Procedures, Algorithm Design, Algorithm Testing*)

Within the scope of the topics listed above, students learn about information systems and information processing, and data representation in the computer. Alternative software used for processing different data types is also introduced. Other related items include Internet basics, networking, security on the Internet, and protection of personal data. Overall, the curriculum at this education level is targeted at increasing learners' productivity so that they can practice problem-solving, data analysis, and information presentation effectively.

4.4. Singapore

In Singapore, primary school education is 6 years, secondary education is 4, and high school education is 3 to 5 years depending on school type. Compulsory computer applications started in secondary school in 1994 for technical courses. Computer applications, referred to as the "Programming" course, is an integral part of the Science curriculum and is a compulsory course for students attending technical secondary schools after primary school. The course essentially gives basic CS skills that will support students' learning of other courses. However, for the realization of this curriculum, students are supposed to acquire basic CS skills by the time they finish primary school. Basic CS skills include creating and editing a text in a word processing program, entering data into a spreadsheet, formatting cells, and saving an image. CS education at the secondary level is module-based. It means that the essence and the applicable grade level of each module vary. The modules of the computing course and the corresponding grade levels can be seen in Table 5 below (Singapore Ministry of Education, 2019).

Table 5.

Computer Applications Contents in Singapore

Contents	Grade 1	Grade 2	Grade 3	Grade 4
Computer Fundamentals	✓	✓	✓	✓
Media Elements	✓	✓	✓	
Word Processing	✓	✓	✓	✓
Spreadsheets	✓	✓	✓	✓
Interactive Multimedia Communication	✓	✓		
Animation and Game Making		✓	✓	✓
▪ Visual programming language ▪ Planning	✓			
▪ Programming and debugging		✓		
▪ Documentation			✓	

The first module, computer fundamentals, comprises computer systems, hardware units, and their properties, computer networks and communication, system security, input and output units, operating systems and software, internet security, internet applications, viruses, protection of personal data, cyber-crimes, and impact of ICT. Second, Media Elements include vector graphics, raster graphics, audio and video. Another module, Word Processing, deals with text editing, page properties, inserting figures and images into the text, and inserting tables and graphics. The Spreadsheet module covers editing data and cells, inserting graphics, using formulas and functions, data validation and analysis. The fifth module, Interactive Multimedia Communication, comprises media elements, storyboarding, and preparing interactive presentations. Finally, the Animation and Game Making module encompasses four dimensions ("visual programming language", "planning", "programming and debugging", "documentation") (Singapore Ministry of Education, 2019).

In high schools, CS education is considered a domain that promotes cognitive thinking skills. CS education at this educational level has 3 basic dimensions: "Computer as a Science", "Computer as a Tool", and "Computer as a Social Tool". The first dimension aims to improve students' algorithmic and robotic skills, system analysis, and design skills. In this scope, simple programs are designed by using programming languages. In addition, basic knowledge is taught on advanced skills such as software engineering and networks. The next dimension, Computer as a Tool, lists topics related to basic skills, applications, and hardware knowledge necessary for using a computer. The last dimension deals with computers from a social aspect by covering ethics, cyber-crimes, data privacy, and computer use to improve 21st-century skills.

The high school computer course curriculum consists of three dimensions and 4 modules in total and is given as a compulsory course for 2 years. These modules are categorized as follows (Singapore Ministry of Education, 2019):

- Data and Information (*Data Management, Data Representation, Ethical, Social, and Economic Issues*)
- Systems and Communications (*Computer Architecture, Data Communications*)
- Abstraction and Algorithms (*Problem Analysis, Algorithm Design*)
- Programming (*Program Development, Program Testing*)

The first module concerns processing data in computer systems and the use of ethical data. It also teaches different types of data and what data are for. The second module features systems that include computer technology and computers targeted at teaching relationships between parts of systems such as human-machine, machine-machine, and the functions of the system parts. The third module is related to solving problems by dividing them into sub-problems. It teaches the algorithm of a problem and establishes a flow chart. The last module covers writing a program code and testing the program. In summary, the module is centered on devising algorithms and using programming languages.

4.5. China ("B-S-J-G", "B-S-J-Z")

In China, "primary school" lasts 6 years, and "secondary and high school" last 3 years each. Compulsory education is 9 years. There are two different kinds of secondary schools general and technical secondary schools. With its renewed curriculum, the Chinese government has emphasized an education system based on inquiry rather than learning in major states such as Shanghai. Education is essentially provided to encourage students to think creatively and critically (Singmaster, 2019).

In Chinese schools, work on information technology education was first started in 2001, and the CS curriculum was introduced as a compulsory high school course. Then in 2003, CS began to be taught as a compulsory course in primary and secondary schools for one year (Kong et al., 2017). An applied training program named "Comprehensive Practical Activities" has been incepted across the country to give education on "information technology", "research-based learning", "community service", "social practice", "workforce skills", and "technology training" (Guan & Meng, 2007). The purpose of the CS curriculum in primary and secondary schools is to enable students to understand and master the basic knowledge of information technology. It is aimed to use CS both in daily life and for the development of science and technology. With this course, students learn about information literacy, obtaining information, transferring information, processing information, applying information, and cultural, ethical, and social issues (Yang & Zhang, 2020).

China has lately made significant progress in research and development in artificial intelligence technology. The Chinese government makes great efforts to nurture the next-generation artificial intelligence workforce and implements AI education programs on a model not only at the post-secondary level but also at the K-12 level. That is why the Chinese Education Bureau is now getting ready to place artificial intelligence courses in the primary, secondary, and high school curricula. The artificial intelligence textbook series consisting of 10 books was released in 2019 for primary and secondary schools. The artificial intelligence curriculum is being piloted in schools in Shanghai, and it is expected to appear in both the basic curriculum and elective courses across all state schools soon. Lastly, the first textbook on artificial intelligence for high schools was published in 2018 (Kabakçı, 2018).

4.6. Taiwan

In Taiwan, 6 years of "primary school", 3 years of "secondary school", and 3 years of "high school" education are provided. Compulsory education lasts 12 years. CS education was first given in high schools with the course titled "Introduction to Computer" in 1983. The major outcome of the course was teaching the programming language called BASIC as a result of the attempts for programming teaching. In 1997, the Ministry of Education of Taiwan declared computer classes compulsory for secondary schools (8th and 9th grade). The course covered computer literacy and application software instruction (Hu et al., 2014). During these years, the high school curriculum also changed, becoming compatible with the secondary school curriculum. The main targets determined for the ICT course in 1997 and the corresponding educational levels were as follows (Usa & Twu, 2002):

Primary school (Elective course for one hour a week)

- Computational thinking and its role in everyday life
- Gaining computational thinking skills
- Basic computer use

Secondary school (Compulsory course for one hour per week for 8^{th} and 9^{th} grades)

- Basic computer literacy
- Types of information and correct use of information

High school (Elective course for two hours a week)

- Basic computer concepts and theories
- Solving problems by using a computer

In those years, although high school subjects went hand in hand with secondary school subjects, the computer course covered science-based theoretical topics rather than application-based ones. The aim of the course was problem-solving and the fundamentals of computer science (Hu et al., 2014).

In 2001, the computer course was not an independent course in secondary schools yet. Instead, the topics were infused into different courses from grades 3 to 8. The topics were distributed from the 3rd grade to the 8th grade. But in that year, the system was revised, and the weekly class hours of the course were increased. As a result of this, the following topics were covered in CS education:

- ICT awareness
- ICT practices
- Data processing and analysis
- Using the Internet
- Computer and society

In 2006, another revision was done to the high school CS curriculum this time. One compulsory course (Introduction to Information Technology) and 3 elective courses were identified. The elective courses were "Basic Programming", "Advanced Programming," and "Computer Science". As for the compulsory Introduction to Information Technology course, the curriculum covered the following main headings:

- Software and Hardware
- Networks
- Problem-solving
- CS and society

The instruction was done to ensure the transfer of learned knowledge into real life rather than learning for the sake of learning (Usa & Twu, 2002).

In 2014, the transition to a 12-year compulsory education system brought along the renovation of the CS curriculum in Taiwan. CS topics were compulsory in secondary school but optional in high school depending on students' future career orientation. The contents were offered under two technology-related courses named Information Technology and Living Technology (Hu et al., 2014).

4.7. Türkiye

In Türkiye, compulsory education lasts 12 years and is distributed equally across three levels of basic education (4+4+4). In order to make widespread the use of computers and different ICT technologies in education, computers were put in vocational high schools in 1985 and 1986, and a 3-hour computer course was included in the curriculum. Computer education in regular schools was started as an elective course titled "Computer" in primary schools in the year 1998 (Keser, 2011). In those years, compulsory education consisted of 5 years of "primary school" and 3 years of "secondary school". It was decided to provide CS education 1-2 hours a week starting from the 4th grade for a period of one to five years. It was at individual schools' principals to teach the course in their schools (MoNE, 1998).

In 2006, the decision was made to teach the elective computer course in all primary and secondary schools (Grades 1-8). In 2007, the name of the course was changed to "Information Technologies", which was taught as an elective course for 2 hours in the "4th and 5th" grades and 1 hour in the "6th, 7th, and 8th" grades. In 2010, the IT course was removed from the curriculum for the first 5 grades, left to be offered as an elective course for 1 hour during the "6th, 7th, and 8th" grades. Not surprisingly, the importance of the course gradually decreased, and computer classes were not chosen by schools, and computer classes were not used. In 2012, the course content was amended, and the course was renamed as "Information Technologies and Software" (Demirer & Sak, 2015).

It can be said that the curriculum of Information Technologies and Software was developed basically with a student-centered approach and teachers determine the teaching process according to student levels. There are no topics specifically appealing to grade levels in the teaching process. With the arrangement made in

2015, the curriculum is grouped into 3 levels Basic, Intermediate, and Advanced. This categorization allows teachers to teach by choosing from Basic, Intermediate, and Advanced level subjects depending on their students' academic levels. This classification was also valid for the curriculum before 2015, and subject selection was left to the teachers' discretion (Barut & Kuzu, 2017).

Pedagogical acquisitions related to programming skills were added to the curriculum in 2015 to be finalized following the reformatting in 2018. The “Information Technologies and Software” course curriculum has been prepared for primary schools (1-4th grades). This curriculum aims for students to use information technologies correctly, effectively, and safely, to use them for communication, research, and product development, and to gain skills such as “problem-solving”, “computational thinking”, and “algorithms”. This course has become an elective course for primary schools (MoNE, 2018a). As per that last update, “Information Technologies and Software” was taught 2 hours a week as a compulsory course for the secondary 5th and 6th grades. Looking at the overall objective of the curriculum, it seems that the focus is on raising digital individuals who can use information technologies effectively and inculcating students who possess computational thinking skills, can manage problem-solving and algorithm design, and use programming languages (MoNE, 2018b). In the curriculum of 2018, chapter-based instruction is adopted. In other words, the contents are taught in coherent units of knowledge in each subject. It is seen that there are the same gains at different levels in the curricula, but the content difficulties change. “Information Technologies and Software” subjects according to primary, secondary, and high school levels in Türkiye are given in Table 6.

Table 6. “Information Technologies and Software” Contents in Türkiye

Content	Primary School “Grade 1-4”	Secondary School “Grade 5-6”	Secondary School “Grade 7-8”	High School “Grade 9-10”
Information Technologies • The Importance of Information Technologies in Daily Life • Computer Systems, hardware-software • File Management	✓	✓	✓	
Ethics and Safety • Ethical issues • Digital citizenship • Privacy and Security	✓	✓	G7	✓
Communication, Research, and Collaboration • Computer Networks • Social Networks • Research on the internet • Communication Technologies and Collaboration	✓	✓	G 8	
Create a product • Creating products and toys with electronic waste (1-4 G) • Digital story-digital poster (1-4 G) • Image Processing Programs (G5) • Word Processing Programs (G5) • Presentation Programs (G5) • Spreadsheet Program (G6) • Audio-Video Processing Programs (G6) • 3D Design Programs (G8)	✓	✓	✓	
Problem Solving and Programming • Problem Solving Concepts and Approaches • Programming	✓	✓	✓	G9
Programming • Robotic • Web-Based Programming • Mobile Programming				G10

As an elective course for the “7th and 8th” grades, “Information Technologies and Software” is chapter-based, containing teaching units such as “information technologies”, “ethics and security”, “problem-solving and programming”, and “product generation” (MoNE, 2018c).

It is at each school’s choice at which grade level of high school the elective course "Computer Science" will be given. This course consists of two levels in total and is taught for 2 hours a week. Each of the levels encompasses pedagogical acquisitions spread across one academic year. Students at Level 1 are introduced to text-based programming. This level covers topics such as “Ethics”, “Security and Society”, “Problem Solving and Algorithms”, and “Programming”. At this level, any programming language can be selected among Phyton, C, Java, etc. At Level 2, there are three topics for teaching programming: “Robotic coding” “Programming”, “Web-Based Programming”, and “Mobile Programming” are included in Setup 2. Teachers are at liberty to teach any two of the topics for teaching (MoNE, 2018d).

5. Discussion and Conclusion

This study compared the computer science curriculum at K-12 level of Asia-Pacific countries that were successful in PISA. Similarly, there are many studies in the literature that compare countries' K-12 computer science curriculum (Falkner et al., 2019; Gal-Ezer & Stephenson, 2014; Hubwieser et al., 2011; Hubwieser, et al., 2014; Scime; 2008) or programming curriculum (Lindberg, Laine & Haaanen, 2019; Tian et al., 2017). However, this study differs in terms of both investigating the curriculum of Asia-Pacific countries that were successful in PISA and comparing these countries with Türkiye. Teaching CS contributes to the formation of societies that not only use technology in a beneficial way but also produce it. Therefore, it is no surprise that technology-producing countries have high student success in assessments such as PISA. In PISA 2018, Türkiye ranked 40th among 79 countries for reading skills and 31st among 37 OECD countries. Although it recorded an increase in reading scores after 2015, Türkiye could not go above the average of OECD countries. In 2018, the top five countries with the highest scores in reading skills were “B-S-J-Z” (China), Singapore, Macau (China), Hong Kong (China), and Estonia. When it comes to mathematics, Türkiye came the 42nd among all countries and 33rd among OECD countries. The top countries were “B-S-J-Z” (China), Singapore, Macau (China), Hong Kong (China), and Korea. In terms of science scores, Türkiye came to the 39th rank among all and 30th in OECD countries. The top 5 were listed as B-S-J-Z (China), Singapore, Macau (China), Estonia, and Japan (MoNE, 2018e; OECD, 2018). The results obtained in the most recent exam once again showed that “Asia-Pacific region” countries, which have improved greatly in economy and technology during the last two decades, became extraordinarily successful participants in this exam. Some of the reading comprehension questions in PISA overlap with CS fields such as computational thinking, algorithms, and logical thinking (Demirer & Sak, 2015). It can be suggested that the teaching topics of CS courses affect student success both directly and indirectly as they provide students with the knowledge and perspective that eventually produce technology.

In this study, the contents of CS education in the countries of the “Asia-Pacific region” and Türkiye were investigated, and their curricula at the K-12 level were determined (Table 7). The “Asia-Pacific region” countries examined here have imposed amendments and revisions on their CS education, formal curriculum, and grade levels for teaching the relevant contents over the years. Nevertheless, South Korea, Singapore, Taiwan, Hong Kong, and China could have had an established system of CS education before Türkiye could, and the topics are kept up to date as required by CS education. As an example, in South Korea, coding teaching was attached much importance, and CS education was modernized overall in 2011 to improve problem-solving skills (Choi et al., 2015). In another country of concern, Singapore, CS education formally starts at the secondary school level, yet acquisitions regarding basic ICT skills are given implicitly as a part of the primary school curriculum. The CS content in secondary schools is at such an advanced level that animation and game design is taught at that stage. In Hong Kong, students are trained in computer systems, programming, and computer networks until the end of secondary school, starting from primary school. In Taiwan, CS education started to be given as an elective course in primary and high schools and as a compulsory course in secondary schools in 1997. It is further noteworthy that the country placed computational thinking learning outcomes in its CS curriculum. In 2006, the software, hardware, networks, and problem-solving subjects in the CS curriculum were distributed from the 3rd to 8th grades (Usa & Twu, 2002). In China, CS education was made compulsory in primary and secondary schools in 2003. The government later included artificial intelligence courses in primary, secondary, and high school curricula with excitement about the change process it underwent. In Japan, CS teaching has progressed more slowly than in other countries, and CS education has not reached the desired level over the years. However, it has recently entered a promising renovation process by incorporating basic robotics and programming into CS education (Kanemune, Shirai & Tanı, 2017). Even though Japan delayed CS education works compared to other countries, it is one of the most brilliant countries in PISA and technology products worldwide. This can be accounted for by the overall characteristics of the Japanese education system. The education system is always almost built around acquiring mathematical skills and basic sciences to keep up with technological progress. The presence of a library, science lab, computer lab, gymnasium, house chores workshop, and music room in an ordinary Japanese primary school is a sign of their holistic approach to the planning of the educational process (Karsak, 2018). With the new CS curriculum introduced in 2018, Japan has tried to make up for the shortcomings in CS instruction.

The CS curriculum in Türkiye has undergone changes several times. Since the first years of instruction in schools, changes and amendments have been made to the course title, the corresponding education levels, the grade levels of compulsory courses, and the content of the lesson. The elective status of the CS course without grading in primary school has gradually decreased the importance of the course over time (Öztürk & Yılmaz, 2011). In the course of time, the loss of popularity of the course in primary schools and secondary school students' lacking the basic knowledge in this area have forced teachers to choose the basic level subjects and topics for teaching to their students. Teachers who did not use their programming skills over the years did not choose from advanced topics finding themselves not knowledgeable enough to train their students (Gülcü, Aydın & Aydın, 2013). Since 2004, the weight of the pedagogical attainments of the CS course targeting ICT literacy among students and teachers' liberty to select the relevant courses depending on their students' academic level has hindered many students in reaching advanced-level learning outcomes and software skills. In addition, although many subject acquisitions were included in the curriculum before 2018, only generic explanations are provided, leaving guidance missing on what grade levels these acquisitions appeal to, how they will be taught, and how the instruction will be done on the ground (Barut & Kuzu, 2017). For this reason, CS education could not reach the targeted level in schools and did not see the desired value.

At first sight, the extent of CS education in different countries today looks closely; however, the development course of the curriculum and its consequences on the education processes have been different in each of them. In addition to being a good digital citizen today, it is seen that the basic programming education and robotics applications required by the age come to the fore in the curriculum. In a century surrounded by technologies and applications such as 5G technology, Web 5.0, artificial intelligence, augmented reality, and the Internet of things, it is getting more difficult to predict what kind of world order will be settled in the future. In these years, when technology dominates our lives, the CS education curriculum should be kept up to date and structured adequately to raise new generations.

Table 7.

CS curriculum at the K-12 level in "Asia-Pacific region" countries and Türkiye

	Japan	South Korea	Hong Kong (China)	Singapore	China (B-S-J-G, B-S-J-Z)	Taiwan	Türkiye
Primary School (Grade 1-4)	-	-	*Compulsory* • Computer systems • Information Processing and Presentation • Programming	-	*Compulsory* • Information literacy • Obtaining information • Transferring information • Processing information • Applying information, and cultural, ethical, and social issues *There is not enough information about the topics*	*Elective* • Computational thinking and its role in everyday life • Gaining computational thinking skills • Basic computer use	*Elective* • Information Technologies • Ethics and Safety • Communication, Research, and Collaboration • Create a product • Problem Solving and Programming
Middle school (Grade 5-8)	*Compulsory* • Information society • Computer networks • Problem-solving • automation technology • Social development, and information technologies.	*Compulsory* • Information devices and cyberspace • Multimedia materials • Information science and informatics ethics • Composition and operation of information instruments • Expression and management of information • Problem-solving methods and procedures	*Compulsory* • Computer systems • Programming • Information Processing and Presentation • Networks	*Compulsory* • Computer Fundamentals • Media Elements • Word Processing • Spreadsheets • Interactive Multimedia • Communication Animation and Game Making (Programming)	*Compulsory* • Information literacy • Obtaining information • Transferring information • Processing information • Applying information, and cultural, ethical, and social issues *There is not enough information about the topics*	*Compulsory* • ICT awareness • ICT practices • Data processing and analysis • Using the Internet • Computer and society • Fundamentals of computer science *(added later)* • Problem-solving *(added later)*	*Compulsory* • Information Technologies • Ethics and Safety • Communication, Research, and Collaboration • Create a product • Problem Solving and Programming *Compulsory for 5th and 6th grades, elective for 7th and 8th grade*
High School (Grade 9-12)	*Compulsory* • Problem-Solving in Information Society • Communication and Information Design • Computer and Programing • Information Network and Data processing	*Compulsory* • Information science and informatics ethics • Composition and operation of information instruments • Expression and management of information • Problem-solving methods and procedures	*Compulsory* • Information Processing • Computer System • Internet and its applications • Programming • Social Implications	*Compulsory* • Data and Information • Systems and Communications • Abstraction and Algorithms • Programming	*Compulsory* *There is not enough information*	*Compulsory* • Software and hardware • Networks • Problem-solving • CS and society	*Compulsory* • Information Technologies • Ethics and Safety • Communication, Research, and Collaboration • Create a product • Problem Solving and Programming • Programming (Robotic, Web-Based Programming, Mobile Programming)

6. Limitations and Future Research

The CS education of each country has not been adequately reached. For this reason, CS education contents or curricula of each country could not be given in a wide scope in the study. Adequate information could not be obtained from China's official websites and scanned resources; thus, little information could be provided about their CS education.

As a result of the research, our recommendations specifically for CS education in Türkiye are listed as follows:

- It is seen that the CS course is generally compulsory at the secondary school and high school level in countries that are successful in PISA. In addition, it is seen that there is a lot of practical planning in primary school. So, CS courses should be compulsory for at least 1 year at all levels, from primary school to high school. This would help the acquisition of the skills needed by 21st-century citizens, like computational thinking skills, in basic education institutions. Instruction of that type is also expected to greatly contribute to teaching students' knowledge, experience, and skills for achieving in assessments that require different thinking skills such as the PISA.
- Programming and robotics coding should be taught starting from primary school, and technology workshops should be set in secondary and high schools to practice new-generation applications such as coding, robotics, and augmented reality.
- In today's world, where intelligent tutoring systems, virtual assistants, and augmented reality applications are increasing in educational environments, it is clear that the use of environments adapted for students and the use of metaverse in educational environments will be intense in our lives in the near future. Considering that countries such as China have accelerated the implementation of artificial intelligence at the K-12 level, it is known that studies on this have also started in Turkey (Sargın & Göçen, 2020). However, applications have not yet become widespread. Today, when artificial intelligence is spoken at the K-12 level, it is necessary to provide programming, robotic programming, and artificial intelligence education within the scope of compulsory courses at primary, secondary, and high school levels, to organize education policies accordingly, and to follow up the practices.

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