Developing computational thinking best practices for early childhood education in Kuwait and United States

by

Safia A O E A Malallah

BS, Kuwait University, 2010
MS, Montana State University, 2017

AN ABSTRACT OF A DISSERTATION

submitted in partial fulfillment of the requirements for the degree

DOCTOR OF PHILOSOPHY

Department of Computer Science
Carl R. Ice College of Engineering

KANSAS STATE UNIVERSITY
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Abstract

There are many concerns from early childhood educators regarding allowing children to use technology, pointing to the adverse effects of screen time and barriers such as lack of resources. To support advocating CT in early childhood settings using technology, this dissertation proposes solutions and resources for early childhood educators by highlighting the best practices in using technology as a medium for children to grow and learn while working through the adverse effects. The contribution of this work developed a "bes-T-ech" framework that has been used to develop two programs created based on the gaps in literature reviews. The first one relates to integrating CT into non-CS disciplines, namely drama. The lesson learning objective was delivered using robotic activities with the aim to create a template that can be used as a sample for other educators to align their lessons with CT standards. The second program teaches CT using our suggested Computational Thinking Pedagogical + Framework. The chosen environment is a virtual world (VW) due to the few studies or resources linking early childhood education and VW. Accordingly created a CT VW blueprint. By the same token, three reinforcement experiments were executed to advocate CT into Kuwaiti society. The reinforcements were complemented with a developed STEM model designed to meet the needs of Arabic/Persian Gulf region learners. The first reinforcement investigates the educators' CT awareness and proposes a plan for implementing CT into the Kuwaiti education system. The second reinforcement transferred a successful CT outreach program from a Western country into Kuwait, which brought insight into the CT ability of the young Kuwaiti educators. Compared to U.S. students, they carry a similar trend and gains in CT concepts and program knowledge. The third reinforcement investigates the ability and preferences between males and females, showing

that society and maturity factors are the leading two influencers over Kuwait students' STEM choices, reversing the gender stereotype in Kuwait.

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There are many concerns from early childhood educators regarding allowing children to use technology, pointing to the adverse effects of screen time and barriers such as lack of resources. To support advocating CT in early childhood settings using technology, this dissertation proposes solutions and resources for early childhood educators by highlighting the best practices in using technology as a medium for children to grow and learn while working through the adverse effects. The contribution of this work developed a "bes-T-ech" framework that has been used to develop two programs created based on the gaps in literature reviews. The first one relates to integrating CT into non-CS disciplines, namely drama. The lesson learning objective was delivered using robotic activities with the aim to create a template that can be used as a sample for other educators to align their lessons with CT standards. The second program teaches CT using our suggested Computational Thinking Pedagogical + Framework. The chosen environment is a virtual world (VW) due to the few studies or resources linking early childhood education and VW. Accordingly created a CT VW blueprint. By the same token, three reinforcement experiments were executed to advocate CT into Kuwaiti society. The reinforcements were complemented with a developed STEM model designed to meet the needs of Arabic/Persian Gulf region learners. The first reinforcement investigates the educators' CT awareness and proposes a plan for implementing CT into the Kuwaiti education system. The second reinforcement transferred a successful CT outreach program from a Western country into Kuwait, which brought insight into the CT ability of the young Kuwaiti educators. Compared to U.S. students, they carry a similar trend and gains in CT concepts and program knowledge. The third reinforcement investigates the ability and preferences between males and females, showing

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Table of Contents

List of Figures

List of Tables

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Dedication

This work is dedicated to my beloved mother. I owe it all to you. Without your endless love, encouragement, and support I would never have been able to reach this milestone. You sacrificed your dream of a graduate degree to raise us. Here I am continuing your dream. I hope I made you proud.

Chapter 1 - Introduction

The rapid growth of technology requires children to be equipped with high computational capabilities because today's workforce is strongly shaped by computing [6]. Typically, thinking abilities can emerge from brain maturity or teaching new thinking experiences [1]. Waiting for them to emerge simply through maturity wastes an individual's lifetime; the fast growth of technology requires a quicker acquisition of skills. One type of tool kit that can guide the thinking process to reach better solutions using computer science (CS) concepts is called Computational Thinking (CT). Mastery of CT requires acquiring a set of CS concepts such as Abstraction and Algorithmic thinking.

Policymakers around the world recognize the importance of CT and have started advocating the terms across the education system [8]. Yet, kindergarteners and preschoolers were overlooked even though it has been shown that children as young as 4 can use technology [9, 10] and develop CT abilities [11-14]. In fact, the current generation possesses a greater ability to handle and use technology than older generations [3]. Statistics have shown that they use technology regularly and become familiar with digital devices before being exposed to books [4]. This generation, labeled generation Alpha, has become tech-savvy in today's technology-heavy world [5]. Yet, early childhood educators have a long history of being very cautious about using technology for young ages, creating a technology-usage debate heavily weighted toward prevention and the view that too much technology can impact growth [15-17]. Many educators base their judgments on early research that highlights the negative impacts screens have on childhood development. New early childhood educators are not fully equipped with the knowledge needed to select, evaluate, and integrate technology in the classroom. Not all college programs have mandatory technology classes related to integrating technology and early childhood. For example, Kansas State University offers an optional one-credit course for technology in education for the early childhood degree, and that class is not adequate for early childhood [18, 19].

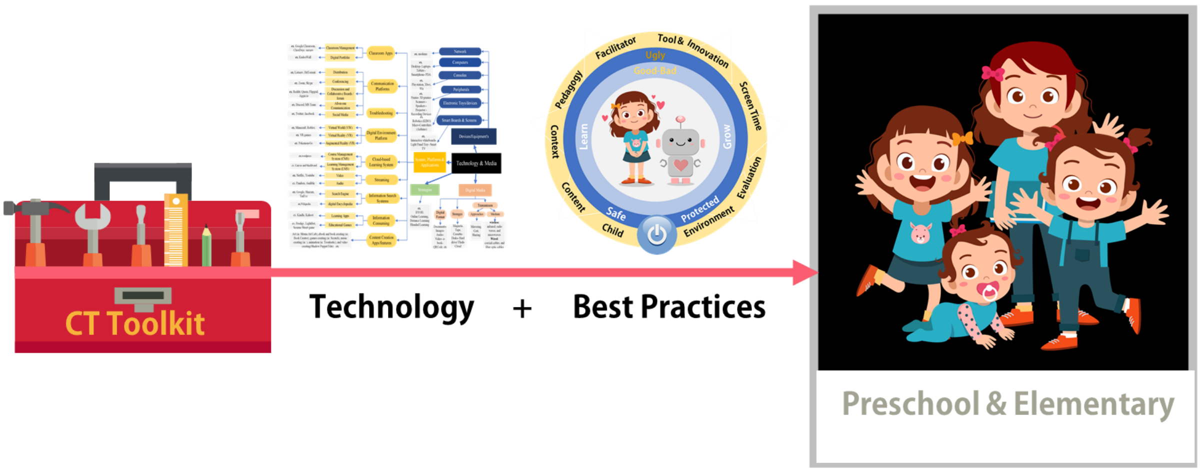
Melinda Plumb and Karlheinz Kautz summarize the concerns and the barriers to integrating technology into early childhood.

> Educator beliefs and attitudes, lack of knowledge and skills, educator lack of confidence … lack of equipment/resources, lack of support, lack of training, lack of time, physical environment constraints, classroom condition constraints, IT technical problems, lack of appropriate educational software, lack of funding, nature of early childhood education sector, early childhood curriculum and guidelines.

This integration barrier slowed down CT integration in early childhood classrooms. Early childhood educators need to understand technology's unique characteristics such as interactivities. And because of the fast growth of the tech industry, suitability for young children must constantly be examined. Current resources are insufficient; further cooperation from technology experts and early childhood educators is needed to investigate modern interactive technologies, especially tools children already use and enjoy, tools such as virtual worlds. More research can help create adequate resources to aid the integration of technology to make it intentional and appropriate while educators confidently handle the flawed side. The same trend is seen in Kuwait, where there are no formal standards for CT in the education system or technology involvement; instead, the education system focuses on computer literacy [20, 21].

Early childhood technology use requires special handling because of its nature. Children's growth rapidly changes in short periods of time and stages. Every stage of development requires different needs and handling. Young children cannot be treated the same as older children. To deliver CT to young children, it has to go through their educators because they are the ones specialized in understanding early education needs.

Figure 1.1 Bringing CT to Early Childhood Using Technology and Best Practices



This dissertation advocates CT in preschool and elementary classrooms using technology and technology best practices (see Figure 1.1). It aims to develop tools and resources to help early childhood educators adapt and create best technology practices inside classrooms.

Chapter 2 answers early childhood educators' concerns about the good, the bad, and the ugly sides of using technology as a medium for learning by referring to the latest facts, statements, and contributions by early childhood professional communities. While technology can have negative impacts on children, at the same time it is an essential, inevitable, irreplaceable, and inescapable part of a child's life. Children now are born and raised around technology. Parents and other adults intentionally or unintentionally promote it. The rational solution for dealing with the bad side of technology is to use the best practices and enforce them when children interact with technology. Thus, technology's bad and ugly side can be contained and minimized to an extent where children can learn in a safer environment and benefit from technology when using the best practices.

Chapter 3 proposed and identified the elements that educators should use to create good practices. The literature review identified nine key elements: child; content; context; pedagogy; tools and innovations; facilitators; environments; evaluation; and screen time. Together, I called them the *bes-T-ech* framework. During the development stages, several frameworks and models were created to fill the gaps in needed resources. For example, technology options were not clear for early childhood educators. Thus, this chapter proposed a holistic illustration describing the technology options early childhood educators have at their disposal.

Chapter 4 revisits the *bes-T-ech* framework and condenses it on CT, using literature reviews for computational thinking. Several submodels were built to support using technology as a medium to teach CT. For example, the element context was replaced by using CT as context to deliver or teach any material. Also built was a computational thinking pedagogy framework, considering previous research pedagogy activities from engineering, coding, and data analysis.

Chapter 5 describes programs that teach CT for early childhood using the CT *bes-T-ech* practices. Two programs were developed to implement the practices and were created based on the gaps in literature reviews. The first one relates to integrating CT into non-CS disciplines, namely drama. With limited lessons available as a guide, the aim was to create a template that can be used as a sample for other educators to align their lessons with CT standards. The second program teaches CT using the Computational Thinking Pedagogical Framework+. The chosen environment is a virtual world (VW). With few studies or resources linking early childhood education and VW, this framework can create a pedagogical environment to build a blueprint of the CT-VW. Thus, chapter 6 developed essential frameworks to create VW for early childhood, then used the framework to create CT-VW.

The COVID-19 global pandemic forced school closures and young children had to stay home. Not all countries delivered online learning, such as Kuwait, where I was. This shifted my course of research to try to bring CT to Kuwait. Kuwait needs methods to improve the CS curriculum in K–12 public schools, a curriculum that fails to prepare students for the 21st-century workforce because it primarily focuses on computer literacy, not CS concepts [3]. Instead of using project-based learning, the CS curriculum relies on written exams, in which 70% of the grades are based on theoretical content [4]. So, chapter 7 investigated Kuwaiti students' ability to learn CT and educators teach it. The first experiments investigated Kuwaiti students' ability to learn CT through a replicate study that took place in the United States first. The results were compared between American students and Kuwaiti students. One of the findings shows that Kuwaiti female students have higher capabilities than Kuwaiti male students in programming. This led to other experiments that investigated the gender difference and found out that around 60%–80% of science, technology, engineering, and mathematics (STEM) colleagues' seats were enrolled by women. This led to further investigation of the reasons behind the reverse gender stereotype in Kuwait. The results show that motivation and cultural factors are the two strongest motivators to STEM preferences and performance. A third experiment investigates educators' abilities to teach CT by creating an assessment tool built from the TPACK model to measure CT and technology abilities. The results were used to propose and outline solutions to implement CT in K–12 education. A summary, limitations, and thoughts on future work round things out. This dissertation does not include information regarding CT and older students, as that has already been published.

The main contributions of this work are:

1) Coining the good, bad, and ugly sides of technology using recent contributions. **(Chapter 2)**.
2) Constructing the *bes-T-ech* framework that identifies nine elements as a pathway toward developing appropriate settings and interactions **(Chapter 3)**.
3) Representing a CT + *bes-T-ech* framework, which is a revision of the *bes-T-ech* framework that focuses on CT **(Chapter 4)**.
4) Included is an application form that supports aiding the implementation of the CT + *bes-T-ech* framework **(Chapter 5)**.
5) Preparing lessons to teach drama acting using CT as a medium **(Section 5.2)**.
6) Outlining VW pedagogy framework in relation to early childhood education, and creating a blueprint of the VW environment using the CT pedagogy framework **(Section 5.3)**.
7) Designing CT VW **(Chapter 6)**
8) Developing a STEM GCC Model to support adopting foreign STEM programs into Gulf Cooperation Council (GCC) countries **(Section 7.2)**.
9) Reporting a replicate study of adopting a STEM outreach program from the United States to Kuwait **(Section 7.3)**.
10) Reporting a study investigating the reversing gender stereotypes in STEM education in Kuwait **(Section 7.4)**
11) Developing a CT TPACK questionnaire to measure educators' technological and computational skills **(Section 7.5)**.

12) Reporting a suggested CT implementation plan for the Kuwaiti educational system **(Section 7.5.4)**.

Chapter 2 - The Good the Bad and The Ugly of Technology in Early Childhood

Technology became widely accepted and used as an educational tool for children around 1970 [16]. It continued to evolve with the creation of Logo, the first child-friendly programming language by Seymour Papert where children used the Logo language to command a robotic turtle to create simple graphics [34]. The creating process empowered children to think creatively, leading them to make sense of their experience and seek to improve their world through technology [34]. However, schools maintained computers in labs that could only be used during specified times primarily to play games that passively trained children's discrete skills [16]. Educators did not know best practices for technology integration for young children because technology college courses were optional—most educators never learned how to effectively integrate and evaluate technology [35]. Meanwhile, commercial companies also began developing technologies and applications that drove technology usage far from Papert's goal and led to imbalanced use of technology [36] and a debate regarding technology's suitability for young children.

Most educators initially supported a ban on technology in schools because it was believed that children had enough technology exposure at home [37]. Recently, however, professional communities such as the National Association for the Education of Young Children (NAEYC)—a nonprofit association representing early childhood educators, students, and families [39]—and The Fred Rogers Center for Early Learning and Children's Media—a nonprofit organization committed to perpetuating Fred Rogers' legacy of "helping the helpers as they care for, educate, and raise children to thrive in this digital age" [40]—have worked to advance the use of technology in early childhood education by providing guidance and best practices [38]. Other early childhood professional communities include the Office of Educational Technology (OET) in the U.S. Department of Education, which "develops national educational technology policy, advocates for the transition from print-based to digital learning, and supports the president's and secretary's educational priorities" [41], and the American Academy of Pediatrics (AAP), "an organization of 67,000 pediatricians committed to the optimal physical, mental, and social health and well-being for all infants, children, adolescents, and young adults" [42]. In addition, Common Sense Media "provides education and advocacy to families to promote safe technology and media for children" [43], while the DevTech Research Group at the Eliot-Pearson Department of Child Study and Human Development at Tufts University "aims to understand how new technologies that engage in coding, robotics, and making, can play a positive role in children's development and learning" [44]. Purdue University research's groups (INSPIRE Research Institute and FACE Lab research group) aim to support engineering and technology in informal and formal learning settings for K-2) learners [3, 4].The Education Development Center (EDC) is a global nonprofit that "advances lasting solutions to improve education, promote health, and expand economic opportunity" [28]. And finally, HighScope, a nonprofit educational research foundation, strives to "empower early educators and ensure young children receive a high-quality education" by defining and proposing best practices for early childhood education [45].

At the United Nations Commission on Science and Technology for Development, Julia Sieger, a tech journalist, described technology as "a double-edged sword;" and Shamika Sirimanne, head of technology and logistics for the United Nations Conference on Trade and Development (UNCTAD) encouraged discussion of "the good, the bad and the ugly" aspects of technology [22]. For example, studies have shown that children who use text messaging may be stronger readers and writers than those who do not text [23]. However, the overuse of texting apps has been shown to prevent a child from learning to read facial expressions or understand the impact of texted words, two essential skills for the development of social-emotional intelligence [24]. The ugly aspect of technology is apparent in the increased potential of threats and risks when children communicate with strangers, even across a variety of platforms, such as video calls and texting [25].

Technology is here to stay. Young children are born where technology is deeply integrated, and parents unintentionally promote it to children. Children are linked with technology and socialize online before they are born. It has become common for parents to post ultrasound pictures and get favorites, likes, or retweets on social media [5]. Parents model technology usage to their children daily. They use phone alarms to wake them up, check the weather apps to decide what to wear, google recipes to cook, monitor their homes with security systems apps, and navigate their car using electronic maps [6]. They also use technology as a part of family daily interaction. Families video call distant relatives; watch a movie together; play multiplayer video games such as Mario Party; or reward good behavior by providing the Wi-Fi password or allowing extra screentime. Even potty-training tools became linked with technology; some models have iPad holders so children can watch screens while they use the potty [5]. We need to understand the three aspects of technology use to propose appropriate solutions within the good practices.

This chapter outlines recommendations and concerns of early childhood advocates and educators. It discusses the good, bad, and ugly aspects of technology usage to answer the educators' concerns. It addresses how bad aspects can be converted into good through good practices and ugly aspects can be eliminated with the implementation of technology best practices.

2.1 The Bad of Technology

Recent studies have investigated the bad side of technology, specifically the consequences of increased screen time [7-11]. NAEYC summed up the primary adverse effects of screen-focused technology as "irregular sleep patterns, behavioral issues, focus, attention problems, decreased academic performance, negative impact on socialization and language development, and increased time young children spend in front of screens" [12].

Some studies have suggested that the negative effects of technology have been overestimated, and much previous research has focused on the negative impacts of screen technology on development [13]. However, even similar technologies are not equal, and one conclusion does not fit all technology tools [12, 14]. For example, TVs and iPads both have screens, but they have different functionalities. Equal comparison of screens creates a fundamental misconception that the screen itself is more important than a technology's functionality [15].

One core technological concern is how children interact with screens and the type of content consumed [16]. Based on studies before the widespread implementation of iPads and other educational interactive devices, well-known organizations recommended eliminating screen time for children; they later revisited those recommendations [17]. Dr. Christakis, a coauthor of the 2011 APP Guidelines on Infants and Media, argues that

> Screens had evolved from the days of TV when most viewings were passive and lacked interaction. Today, tablets can be used for language learning, playing games, watching Khan Academy videos, or chatting with family. The possibilities are endless, and while

it's all done on the same screen, each activity is different, tapping into different emotions, skills, and parts of the brain." [14, 18]

An NAEYC joint statement asserts that digital technology evaluation should expand linear judgment and consider unique screen criteria to maximize learning opportunities while managing time and reducing the potential risk of misuse and overuse [12].

Technology is here to stay, and it is rapidly changing [12] [19]. Rapid advancements in technology lead to rapid changes in the good, the bad, and the ugly aspects of technology. What once was bad can become good as new generations of technology improve and remedy previous disadvantages. For example, navigation and mapping tool technology (i.e., Google Maps) provides a quicker and more accurate travel resource than paper maps [20]. However, using an electronic map while driving has been shown to distract drivers and lead to driving accidents, so policymakers have created regulations that prohibit phone use while driving [21]. Until the voice command and loudspeaker features became standard on mobile phones, the law allowed "hands-free devices while driving" [21]. Although device-use regulations vary by state, the enabling of voice commands for electronic mapping usage helped reduce driving risks and increase technological benefits.

Some studies, however, have suggested that technology does not cause adverse effects on its own; instead, it is often misused to passively remedy other problems [22]. For example, parents are often likely to calm children down with their favorite show or a video game, and most parents admit to providing a screen as a distractor or babysitter while doing household chores.

Removing technology in total is not a reasonable choice. People desire to use technology and have perpetuating dependency on technology [23]. According to Statista, the number of internet users has grown exponentially to approximately 3.9 billion active users [24], or 50% of the world's population [25]. Technology consumption is also expected to increase, as well as the technology budget, which is expected to surpass $5 trillion, evidence of a 4.2% growth rate in the USA [26].

Increasing technological dependency requires the establishment of best practices that can minimize risks associated with bad practices instead of prohibiting individual technologies [10]. Therefore, adults should follow recommended good principles and practices to ensure that technology is used appropriately to expand a young child's learning.

2.2 The Ugly of Technology

Although the bad and the ugly aspects of technology may initially seem similar, they are distinct. Adverse (bad) effects occur when technology misuse leads to short-term or long-term harm, such as health problems from excessive TV or video game consumption. In comparison, ugly effects occur when predators intentionally abuse technology to harm or take advantage of innocent users. Access to the internet and new technology has increased the number of predators [27, 28]. Studies have estimated that 500,000 predators are active online daily, with approximately more than half of those predators exhibiting sexual thirst toward children [27, 28]. [27, 28]Predatory online behavior often starts with a simple text message or a friend request, with predators exploiting children's profiles by examining their interests and pretending the same. Children's innocence and natural curiosity predisposes them to trust predators and reveal even more personal information. Internet frauds and scammers target children via identity theft, invasion of privacy, phishing, fraudulent advertising, and in-app purchases, all of which often stem from social media access. Cyberbullies also use online influence to target their victims. According to a Pew Research study, nearly 59% of teenagers have experienced online bullying

[29]. Technology comprises a substantial portion of children's everyday lives, and repetitious use makes them feel that technology is safe as they establish predictability [28]. Because experience has not yet taught children to develop a sense of caution, adults must monitor technology usage carefully to protect children from the ugly aspects of technology.

Increasing technology worldwide has escalated technology misuse and online safety concerns. This requires that adults increase awareness in children about the dangers that technology poses and provide them with needed skills to handle challenges that emerge from living in an online society [30]. They also need to be equipped with the skills to be respectful technology users [31].

2.3 The Good of Technology

2.3.1 Complement Learning

Technology has been shown to positively affect the education and development of students [7, 32] because technology can complement and even extend learning experiences. Similar to blocks, art materials, or books, technology has proven to be a valuable educational tool for young children [33]. Technology provides extra options for learning. For example, children now have the option to read a traditional print book or an e-book. Additionally, it can increase children's development skills such as cognition; language and speech; visual; fine motor; gross motor; and social and emotional skills.

Regarding cognitive skills, previous research has shown that playing video games can significantly enhance selective attention and the ability to learn and perform new tasks [34]. Evidence also suggests that playing video games can enhance memories and spatial skills [35]. Various early childhood studies have investigated the development of cognitive ability in correlation with interactive technologies such as video games, coding, and educational apps [36-

38]. One study found that exposure to appropriate technology at an early stage could impact a child's ability to think, concentrate, use memory, and search for information [39].

Language and speech skills have seen promising results through the use of essential app features. Voice and face calling have boosted language learning for this age range. The AAP focuses on technology use and language development, including technology that can positively impact language use and speech, especially via interactive educational applications geared toward toddlers [40]. In addition, multiple studies have shown that video-call technology encourages regular language practice, thereby promoting a better oral language [12, 41, 42]. Similarly, e-books offer pronunciation, music, and animation features to engage and motivate young readers while promoting language development [43]. Many technologies have built-in features to support differentiated instruction for a variety of learners. These features are often used to enhance and nurture gifted and bilingual children [44, 45]. For example, the Read&Write text-to-speech app assists bilingual students and students with other literacy needs [46].

Visual skills are another area influenced by technology use. Since the early 1980s, research consistently has demonstrated that playing computer games challenges a player's visual skills, including hand-eye coordination, memory, ability to notice changes and identify patterns, and problem-solving skills [47, 48]. In fact, video games have been shown to be an effective tool for rehabilitating hand-eye coordination for children with autism [49].

Concerning fine motor skills, several studies have also shown a positive correlation between fine motor skills and technology, with results suggesting that interactive technology can motivate young children to experiment with finger and hand motions and later transfer this to real-world objects [50-52]. Additionally, touch screens are valuable learning tools for children with physical disabilities because screen interactions can occur via their finger, a stylus, buttons, or voiceovers [53].

Previous research has found that virtual reality technology can enhance children's gross motor skills [54]. Virtual reality-based rehabilitation therapy has also been shown to improve gross motor functions of children with cerebral palsy [55]. Social and emotional development skills can be enhanced through technology [53, 56, 57]. In addition to current use to promote collaboration and learning in small groups [20], tablets have been shown to effectively introduce children to STEM concepts in a collaborative environment [58, 59]. Children and adults can express their thoughts and feelings using emojis [60]. Technology is a powerful tool to address a child's emotions.

2.3.2 Extended Learning

As an educational tool, technology offers unique features that can complement and extend learning opportunities [12]. Tech devices can now convert children's limitless creativity into tangible art, such as 2D or 3D animations that can be printed on a 3D printer [61]. Children can also experience extended learning beyond traditional classroom instruction, such as web-based space simulations like the National Aeronautics and Space Administration (NASA) Space Place website for children [62]. Virtual trips, commonly offered by museums and libraries, allow children to visit remarkable places without leaving the classroom, thereby eliminating transportation costs and saving time spent on travel [63]. Distance learning is another valuable technological advantage for extended learning that is heavily used by the education sector [64]. Distance learning became essential for all students during the Covid-19 pandemic; without technology, students worldwide would have missed up to a full year of schooling.

In addition to beneficial extended learning tools, technology also can enhance learning for all students. For example, English learners can connect and share with their classmates and teachers across language barriers [45]. Linguistically diverse technology solutions make it possible to add new languages for English learners, which supports dual-language learners and helps develop appropriate learning experiences with enhancements in their home languages [44]. Technology can also support gifted and special need individuals [12], potentially closing the gap between high- and low-performing students [65]. Unfortunately, the educational needs of gifted students are often ignored because they are already "good enough" [66]. Technology resources for extended learning allow classroom teachers to fulfill the needs of gifted students without interfering with their ability to help other students [65]. Also, accessibility to innovative resources such as Khan Academy can offer more advanced content and accelerate learning for high-achieving students [67]. For children with special needs, technology provides many potential benefits [68]. Augmentative communication—devices to help people with speech or language disorders—have been successfully used as adaptation tools in classrooms to increase participation of students with special needs [69].

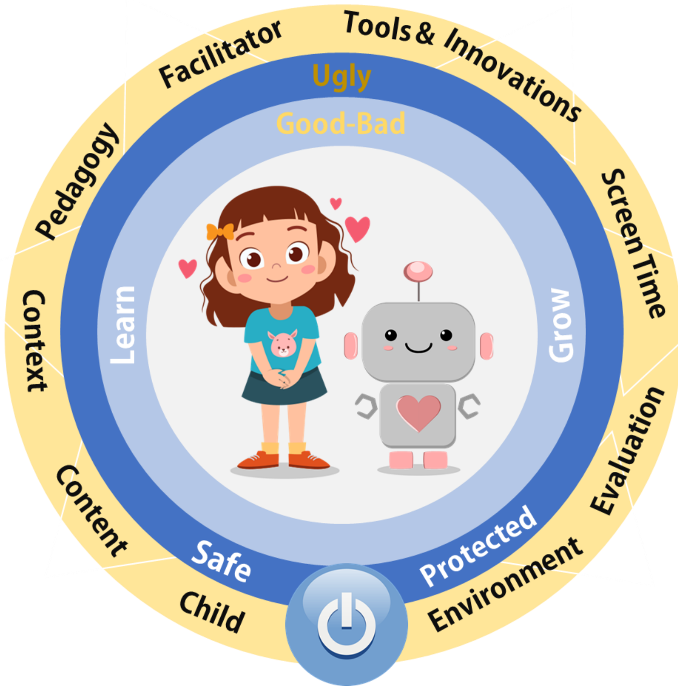
Chapter 3 - Technology Best Practice for Early Childhood

3.1 The "bes-T-ech" Framework

Continuous developments in technology have created a myriad opportunities for young children to interact with tech innovations [10, 70]. As a result, best practices for technology has become a topic of concern within the early childhood sector, leading to an emphasis on appropriateness and intentionality to ensure children develop essential technology literacy skills to succeed in a computational era [7].

This chapter describes a framework to aid educators as they promote positive learning around technology, especially for young children. The model is labeled as "bes-T-ech" framework. The uppercase "T" is the Technology in STEM, and the two words together make best-technology. Additionally, the word bes "بس" in Arabic means "only." In Arabic, the name means "only technology," which speaks to the goal of this framework design. In the *bes-T-ech* framework presented in Figure 3.1, the light blue circle of the model merges the good and bad categories of technology usage, indicating that portions of bad aspects can convert into good through good practices. Various best practices through researchers recommend technology integration as play for kids to explore, learn, and grow [15, 26–29]. The dark blue circle of the figure indicates the ugly side of technology usage, including practices that can help increase risk awareness. The light beige circle are the nine key elements that educators need to consider when creating the best practice for technology: child, content, context, pedagogy, facilitator, tools and innovations, screen time, environment, and evaluation.

Figure 3.1 The bes-T-ech Framework to Integrate Technology into Early Childhood Using the Best Practices



The first of the three C's of the bes-T-ech framework, **child**, is an important avenue to explore. Although children each develop at their own pace, specific skills or developmental milestones should be reached by certain ages. Similarly with technology. Understanding the child's individual abilities and needs can support technology as a playground for kids to explore and play to learn and grow. We suggested age intervals that can align with the recommended technology practice of early childhood stages (see section 3.2.1.2) together with describing the needed development milestones to use technology. After all, psychologists have developed many theories that suggest different periods and milestones for human life [32]. Additionally, they highlight what educators need to know about the unique characteristic that the current early childhood generation carries as each generation can have different preferences and abilities [5].

The second of the three C's of the bes-T-ech framework, **content,** typically encompasses what viewer retain from using technology. Careful consideration of appropriate technology for a child is essential to minimize risks that might harm a children [116]. The third C, **context**, describes the way content is delivered through technology and how adults interacted while children consumed the content (social factors). The engagements of parents and educators' before, during, and after technology is essential to create opportunities for learning.

Pedagogy is 4th main element in the best-T-ech framework. Pedagogy refers to the theory and practice of educating, and its objective is to aid learners in developing new skills and mindsets built from prior knowledge [120]. To support integrating technology into early childhood pedagogy, educators need to be aware of technology literacies, as there are many different types such as digital literacies and computer literacies (summarized in section 3.2.4.1). Input devices should also not be ignored. Common input devices that enable young children to control technology using their development skills, considering that input devices are the way to communicate with technology, are described in 3.2.1.

There are numerous numbers of **technologies** in education. Young children can learn from a technology like any other materials, such as blocks or books. Educators should be aware of the options to know which options and tools are more appropriate for a lesson. We illustrated a holistic picture of the various technology and the term, specifically as it applies to education to helpful educators see the options in section 3.2.5.

Facilitators include early childhood educators, parents, and families who play a critical role in guiding and facilitating learning experiences with technology. Because facilitators have many options for children's technology access, their choices must be intentional and they must know how and when to appropriately select, use, integrate, and evaluate technology for young children [12].

Environment is a place where a child and technology are located, whether it be physical, digital, or hybrid. The environment element can easily be overlooked with the number of tasks educators need to do every day [234]. Yet, the environment can change the way children interact with technology [25]. A well-designed environment can make a big difference in children's success.

Screen time is "the amount of time someone spends looking at an electronic device with a screen" [246]. Implementation of this factor should be lean and flexible. Child learning concentration should not be broken because of reaching the time; instead, wait until the child stops on its own. Screen time should be used as a second threshold.

Evaluating technology appropriateness is an essential element of the best practice. The fact that the market is flooded with different gadgets and technology is rapidly changing poses a need to regulate its effectiveness in education. Evaluation help integrate the appropriate technology.

3.2 Literature Review

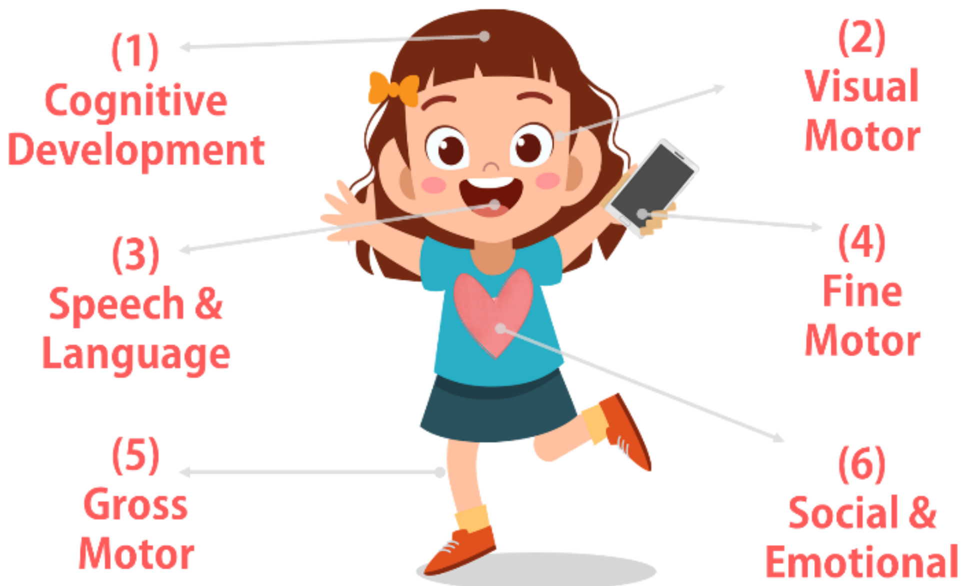
3.2.1 Child

We analyzed more than 70 papers from early childhood proficient and scientific experiments. Previous research has identified the three C's (child, content, and context) as the three factors that substantially influence children's learning from media and technologies [41]. Educators should understand *children's* developments and abilities when it comes to technology. Thus, we describe the development skills needed to use technology, recommending age stages and the current generation ability as each generation carry different features.

3.2.1.1 Child Development Skills and Technology

Although children each develop at their own pace, specific skills or developmental milestones should be reached by certain ages [71]. Therefore, technology usage and CT related to early childhood should consider the following child development areas (Figure 3.2): cognitive development; visual motor skills; speech and language skills; fine motor skills; gross motor skills; and social and emotional skills.

Figure 3.2 Child Development Skills



Cognitive Development: Cognitive development is the change of thinking and reasoning and natural implementation of acquired logic while interacting with physical and social environments [71]. Primary components of cognitive development include

> Intelligence; arousal, orientation, attention, and executive function; memory (short and long term); information processing functions (such as pattern recognition, facial-emotional content, imitation, cause-and-effect associations, processing multiple sources of information simultaneously); representational thought; and

reasoning and concept formation (problem-solving, language, perspective-taking, social context, and rules). [72]

Cognitive ability and technology use are codependent, meaning each technology requires unique cognitive skills because technologies are not created equally [12, 14, 16]. For example, video games require children to apply analogies, processing speed, and deductive reasoning [73]. Online subject searching requires recall memory, spelling or speaking, and Boolean logic [74]. Overall, successful technology usage is highly dependent on a child's cognitive ability.

Visual Motor Skills: In general, visual motor skills are "a complex perceptual processing system of visual information, proprioceptive feedback of our hands and arms and the cognitive controller that manages these sensory inputs and executive motion" [75]. Connections between hand-eye coordination and visual processing skills are essential to "perceive and process visual information and use that information with motor skills to manipulate and move objects in tasks and activities" [75]. Visual motor skills that are naturally learned throughout early childhood are often taken for granted in everyday tasks throughout adulthood [71]. Consider technology; almost all screens require players to use cognitive and visual motor skills [76, 77]. For example, typing on a keyboard requires a user to tap the desired letters (motor skills), look at the screen (visual skills), and apply logic to validate the written text (cognitive ability) [78]. Overall, successful hand-eye coordination enhances the quality of controlling the technology.

Speech and Language Skills: Speech and language development, which involves comprehending and producing messages to interact with the social world, typically progresses from prelinguistic social communication such as crying, facial expressions, gestures, motor movements, and eye contact to sound recognition and word production to form language [79]. In addition to tech communication via texting, voice, or video, users can type commands, such as online queries in Google, or use spoken words for virtual assistance [39]. Language is an essential communication feature of technology.

Fine Motor Skills: Fine motor skills include small movements of muscles in the hands and fingers to accomplish a task, such as pinching to button a shirt or grasp a pencil [79]. Technology use requires users to have developed fine motor skills for tasks such as moving a mouse or touching a screen [20]. Research has shown that children as young as 2 years old have sufficient fine motor skills to control a touch screen and understand what is being manipulated [80].

Gross Motor Skills: Gross motor skills, or physical skills that utilize movements involving the entire body, are often required in the form of jumping or dancing when interacting with certain modern technologies [71]. Tools equipped with motion-sensing capabilities can enable players to have a more prominent presence [81]. This is evident with specialist applications that have sensing hardware. For example, virtual reality games require whole-body interaction with the motion-sensing camera, including facial expressions (e.g., smiling and laughing) or body movements (e.g., jumping, hitting, and dancing) [82]. Whole-body interaction enables a heightened somatosensory experience, where factors such as duration, intensity, and repetition may improve the gross motor functions of children [55]. In fact, research has found that virtual reality technology can enhance children's gross motor skills, especially when virtual reality-based rehabilitation therapy is used to improve gross motor functions for children with cerebral palsy [55].

Social and Emotional Skills: Social and emotional development, also referred to as early childhood mental health, is the ability to create and sustain meaningful relationships with other children and adults [71]. This development is influenced by biology and experiences; genes provide instructions for development, while experiences affect how and whether those instructions are conducted. Children develop, regulate, and express a range of emotions while actively exploring and communicating with the environment, including their interactions with technology [79]. Technology requires certain emotional skills. For example, some video games and robotics that necessitate repeated trial-and-error activities that can cause frustration and failure until a user gains confidence and the skills necessary to succeed [83]. Other technologies require group work and depend on reliable communication collaboration, such as online video games. All of this means children must use social skills to work together to solve a problem [84].

3.2.1.2 Age Stages and Technology Usage

Before the 20th century, children in the first stage of the human life cycle—early childhood—were considered miniature versions of adults. That changed when Jean Piaget, a child-development psychologist, suggested that children see the world differently [85]. Subsequent researchers developed theories that helped future generations understand how children learn [86]. Although resulting age ranges of child development varied, the current research used the following age intervals that align with recommended technology practices of early childhood stages (Figure 3.3): baby (0–17 months), toddler (18–35 months), preschooler (3–5 years), and school age (6–11 years).

Figure 3.3 Child Development Age Intervals

Baby (0–17 months): Research has shown that babies need extensive interaction with their physical environment (touching, smelling, tasting, listening, and observing) and interaction with a caring human being (singing, talking, and playing) [87]. Because a baby's vision does not fully develop until 6 months of age and they are unable to sit up on their own until around 8 months of age, babies need to be able to sit and stare at the screen to enjoy themselves [88]. In addition, a baby's cognitive ability is still developing, meaning they are only attracted to the light, movement, and activity on screens; they do not have the necessary attention span to understand the plots on a screen [89]. They can recognize some repetitive characters, voices, or actions and begin reacting with actions like clapping or stomping their feet [90].

Various academic researchers have investigated the benefits and drawbacks of screens on babies' learning. Garrison and Christakis claim that evidence of cognitive ability for this age is unsupported over a range of TV programs because of "the video-deficit or transfer-deficit phenomenon whereby very young children find it more difficult to learn information from a video compared to the same information being taught in a live presentation by a human" [91]. Furthermore, results have shown that young children can only comprehend elements of programs grounded in their understanding of their everyday experiences [92]. Those studies, however, only investigated passive screen tools; very little research has been done on the effects of interactive educational apps on cognition and learning in babies [93, 94].

Toddler (18–35 months): Around 18 months of age, children begin to develop fundamental cognitive skills that increase their curiosity about their world [95]. They also begin to distinguish what they see on a screen from what they experience in real life [96]. Toddlers exhibit increased understanding and enjoyment of technology when they focus on the visual aspects, because they cannot always follow the nonvisual components, such as language features, and they demonstrate increased focus and comprehension of shows in which characters face the camera and speak directly to viewers [90]. Although toddlers are unable to fully distinguish differences between fantasy and reality, they progressively develop the ability to apply what they see on a screen to real-life situations [97].

Research has shown that 75% of toddlers use smart devices daily [98, 99]. In fact, one study that investigated the ability of toddlers (age 24 months) to interact with touchscreen tablets found that the children were able to open videos, even the Netflix streaming service app, without assistance. Early research suggested that screens may negatively impact child development, especially when used passively [59], but recent studies have shown that children as young as 18 months learn new words even when the entire task takes place on a screen [100]. Dr. Tim Smith, a cognitive psychologist, investigated differences in cognitive, fine motor, and gross motor skills of high-tech and non-tech toddlers. Results showed that toddlers who used technology regularly demonstrated more fine motor coordination with their hands and similar gross motor skills than toddlers who had no experience with technology, proving that tapping and swiping encourage precision and dexterity [101]. However, experts have emphasized the need for continued research on the relationship of technology and child development, asserting that

> We know very little because devices entered into the home environment recently. We're all figuring out how we use them, and the children are early attracted to them, so the science is actually really quite far behind, but we're trying to address that as much as we can, looking specifically in the first few years of life. [101]

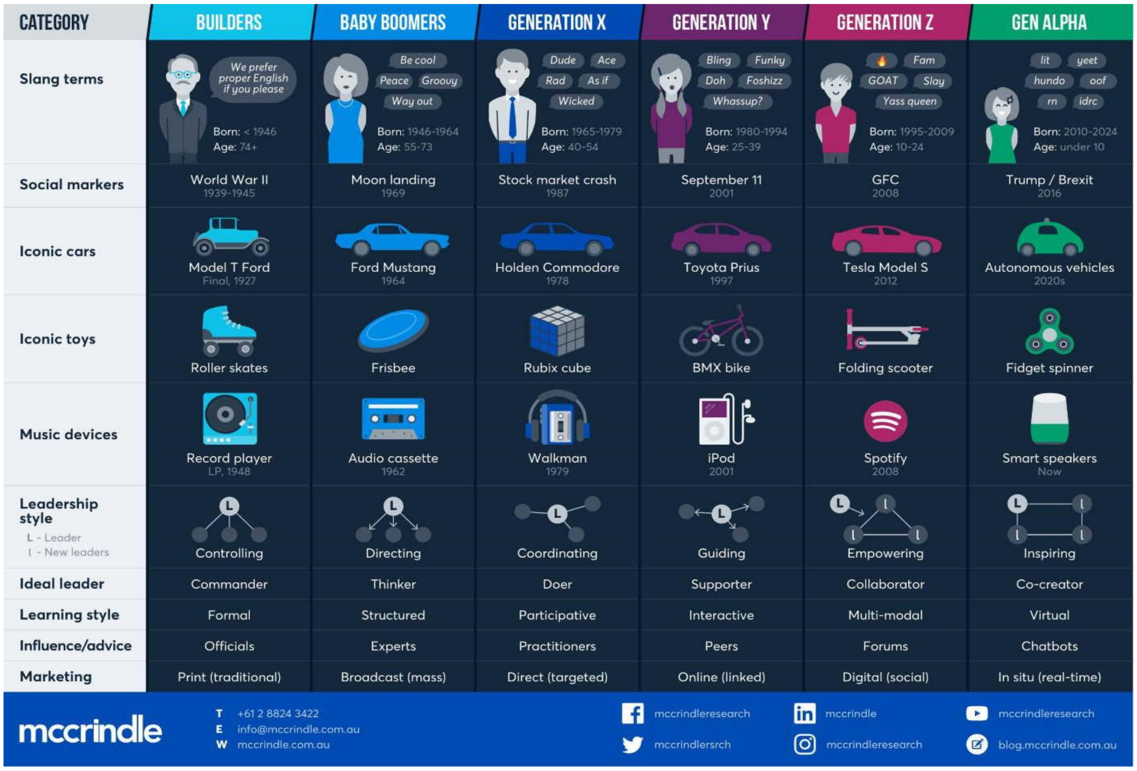
Preschooler (3–5 years): Starting at 3 years of age, a child's problem-solving skills begin to develop, thereby increasing their curiosity and open-mindedness about learning [102]. As children age, they become increasingly able to comprehend screen content [10]. Previous research has shown that, in their initial interactions with technology, 3- and 4-year-old children are able to replicate technology usage based only on observations of parents or siblings [103]. Other studies have proven that preschoolers gain mastery of simple digital devices with adult mediation [104, 105]. Educational tools have also been shown to effectively teach knowledge and cognitive skills, depending on the type of content consumed and positive interaction [12]. Overall, results have shown that preschoolers benefit most from technology instruction and intentional selection of content to increase learning [12, 41].

School Age (6–11 years): Evidence has shown that as school age children develop, they become increasingly proficient with and benefitted by technology [106-108]. Technology can harness their interaction performance, allowing them to communicate their ideas and feelings, investigate their surroundings, and locate information [109]. For example, "older children can learn the alphabet, counting, or how to discriminate between similar and different objects by interacting with a computer programmed to present information, receive responses, and offer new information based on the children's responses" [110]. Results have shown that school-age children are more likely to spend more time learning on technology they enjoy than if the material were presented in another format [111]. This age has building blocks that provide a foundation on which more complex skills grow.

3.2.1.3 Generational Distinctions

Just as each individual has unique learning preferences (e.g., visual learning versus auditory learning), each generation has distinct features [112]. Figure 3.4 illustrates the unique characteristics of various generations [113].

Figure 3.4 Generation Infographic Update [113]



CATEGORY	BUILDERS	BABY BOOMERS	GENERATION X	GENERATION Y	GENERATION Z	GEN ALPHA
Slang terms	We prefer proper English if you please	Be cool, Peace, Groovy, Way out	Dude, Ace, Rad, As if, Wicked	Bling, Funky, Doh, Foshizz, Whassup?	🔥, Fam, GOAT, Slay, Yass queen	lit, yeet, hundo, oof, rn, idrc
	Born: < 1946 Age: 74+	Born: 1946-1964 Age: 55-73	Born: 1965-1979 Age: 40-54	Born: 1980-1994 Age: 25-39	Born: 1995-2009 Age: 10-24	Born: 2010-2024 Age: under 10
Social markers	World War II 1939-1945	Moon landing 1969	Stock market crash 1987	September 11 2001	GFC 2008	Trump / Brexit 2016
Iconic cars	Model T Ford Final, 1927	Ford Mustang 1964	Holden Commodore 1978	Toyota Prius 1997	Tesla Model S 2012	Autonomous vehicles 2020s
Iconic toys	Roller skates	Frisbee	Rubix cube	BMX bike	Folding scooter	Fidget spinner
Music devices	Record player LP, 1948	Audio cassette 1962	Walkman 1979	iPod 2001	Spotify 2008	Smart speakers Now
Leadership style (L - Leader, l - New leaders)	Controlling	Directing	Coordinating	Guiding	Empowering	Inspiring
Ideal leader	Commander	Thinker	Doer	Supporter	Collaborator	Co-creator
Learning style	Formal	Structured	Participative	Interactive	Multi-modal	Virtual
Influence/advice	Officials	Experts	Practitioners	Peers	Forums	Chatbots
Marketing	Print (traditional)	Broadcast (mass)	Direct (targeted)	Online (linked)	Digital (social)	In situ (real-time)

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Child development of the current generation, Generation Alpha (Gen Alpha, birth years 2010–present), is significantly impacted by technology [114]. Members of this generation spend their early childhood and elementary stages of development surrounded by the technological innovations of the 21st century, including devices such as the iPad, Chromecast, Amazon Echo, and Alexa. In addition, social media platforms and communication apps such as Instagram, iMessage, Snapchat, and TikTok are prevalent in their lives. All knowledge is just a click away, which affects their experiences and defines how they interact with others. As an example of generational differences in problem solving, a previous viral video of a young girl needing help with her math homework shows her using modern technology—her phone—to call the police for homework help. Updated versions of that video show Gen Alpha students using virtual assistants to help with homework while parents proudly record and post their children's interactions.

The five distinguishing features of Gen Alpha have been identified as digital, social, global, mobile, and visual. Digital is a prominent characteristic of the current generation because they are considered "digital natives," meaning they were born with access to technology and they readily use it to solve problems. They are young consumers of intelligent technology (e.g., virtual assistants), whereas the previous generation typically was not exposed to personal digital devices until elementary school. Gen Alpha members are also very social. Social media trends strongly influence these children, and they willingly participate by creating and posting personal videos. In fact, some children are bullied if they do not have personal social media accounts. This generation also is considered the first global generation. They are increasingly aware of what happens worldwide, and any viral phenomenon can highly influence them. For example, Pokémon GO, released in 2016, became a global trend, growing to 50 million users in 19 days. Mobile, the fourth defining characteristic Gen Alpha, means that as adults, this generation will have ample opportunities to work or study virtually, allowing them to live anywhere, regardless of job or school location. Finally, visual is a defining characteristic of this generation because of their familiarity with online video platforms such as YouTube, the most popular internet search engine for this generation. One of the most famous child YouTubers is Ryan, a 9-year-old boy with his own YouTube channel called Ryan's World where he reviews toys to more than 24 million subscribers with more than 35 billion views. In summary, the current generation carries more ability to handle and use technology than the older generations.

3.2.2 Content

Previous research has identified content as a main factor that substantially influence children's learning from media and technologies [41]. High-quality television programs such as Sesame Street and Curious George satisfy all three factors because they are designed around a specific educational curriculum and include formative and evaluative research testing to ensure that children comprehend the content and engage with context [115]. The three C's also can be used as indicators for educators and parents to determine the appropriateness of technology for a child's development [41]. Researchers developed a quiz to help parents estimate and reflect on their children's experiences to increase accuracy in technology selection [116].

Correct implementation of these three influential factors requires a thorough understanding of them. Content typically encompasses what educators want learners to retain or the outcomes of the lesson [117]. Careful consideration of appropriate technology and subsequent content is essential to avoid elements that could harm children, such as exposure to violence or sexualized videos and images [116]. The Education Development Center (EDC) developed a checklist to help educators determine appropriate content resources for early childhood programs [118].

3.2.3 Context

Context can influence student motivation to learn [119]. For example, content delivered via game X may motivate children interested in game X, thereby increasing their understanding of the content. Although accurate selection of the appropriate context can support and enhance the learning process, the context should not replace essential activities for child development, such as creative play, real-life exploration, and social interactions [12]. However, social factors such as co-viewing and working together should be encouraged before, during, and after use of technology [41]. Technology contexts should create opportunities for learning and development by complementing or extending learning [12].

Interaction with parents and educators also should be considered part of the context as described by the technology department, because parents often are the first influencers on the child. They can influence the learning through co-viewing, questioning the children about the content, and joining them.

3.2.4 Pedagogy

The Queensland Government in Australia is committed to evidence-based approaches for teaching and learning in the early years of school. They viewed and analyzed more than 100 recent teaching and learning early childhood studies and identified seven age-appropriate pedagogies: inquiry learning, event-based approach, project approach, explicit instruction, play-based learning, direct teaching/instruction, and blended approach. They also identified 10 views to consider when selecting pedagogies to ensure that teaching responds to learners and achieves curriculum outcomes [121].

Pennsylvania Digital Media Literacy Project designed a yes-or-no checklist consisting of four sections (selecting, using, integrating, and evaluating technology) to gauge educators' thinking about technology integration into a curricula [122].

3.2.4.1 Technology Literacies

Although professional communities invest in developing appropriate technology for children, which technology literacies should be included is vague and confusing. The definition of literacy has expanded from the ability to read and write to the possession of needed skills to achieve common goals [123]. The professional community has labeled several areas of technological literacy: digital literacy, computer literacy, information literacy, technology literacy, and media literacy [124]. Each literacy can contain multiple definitions, although school districts, states, and professional organizations have developed certain media standards.

According to the Center for Teaching at the University of Iowa, digital literacy

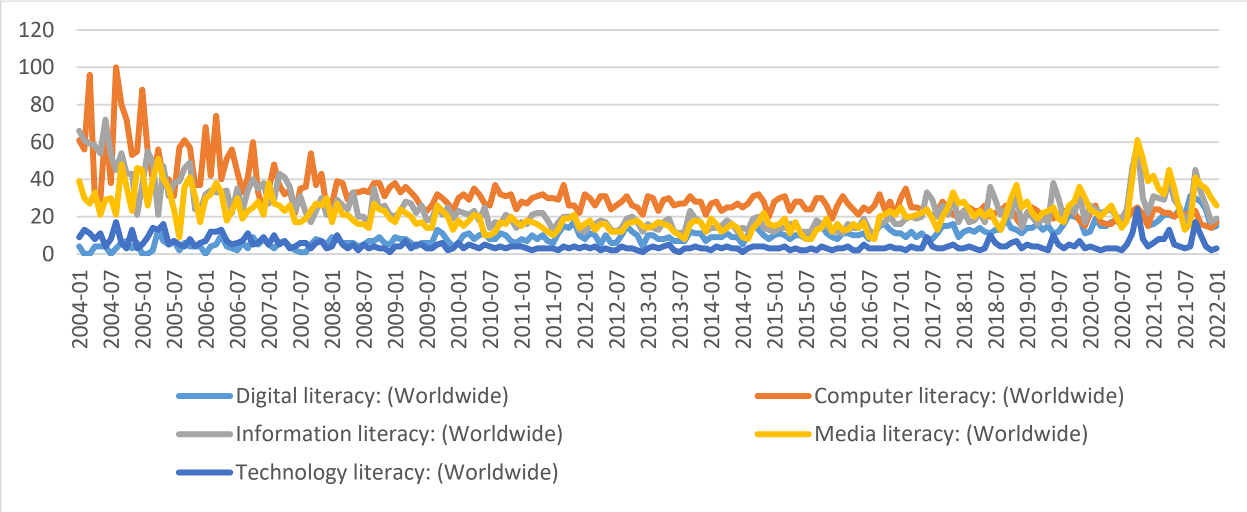
> Is more than just the technical ability to operate digital devices properly; it comprises a variety of cognitive skills that are utilized in executing tasks in digital environments, such as browsing the Internet, deciphering user interfaces, working with databases, and chatting in chat rooms. [125]

The center defines computer literacy as "the ability to use a computer and its software to accomplish practical tasks." Information literacy is "the ability to know when there is a need for information, to be able to identify, locate, evaluate, and effectively use that information for the issue or problem at hand." Technology literacy is "the ability to responsibly use appropriate technology to communicate, solve problems, and access, manage, integrate, evaluate, and create information to improve learning in all subject areas and to acquire lifelong knowledge and skills in the 21st century." And lastly, the center defines media literacy as "the ability to access, analyze, evaluate, and produce communication in a variety of forms" [125].

Analyzation and comparison of the definitions and objectives reveals that computer literacies and cognitive skills were essential elements for all five literacies. It also showed that, although digital and technology literacies both require tools or devices that accomplish tasks digitally, media literacy requires tools that access, search, and create media—tools such as graphic design or video editing. Information literacy was shown to require tools to process existing data, such as database management tools that locate information. Information literacy is often a subcategory of media literacy because information literacy processes existing data, while media literacy often creates new information.

To have a better view over the current literacy in education (i.e., pre-kindergarten–grade 12), this study used Google Trends to investigate worldwide popularity of the terms. The graph in Figure 3.5 shows that the popularity of media and information literacies increased from 2004 to 2022, with significant increase during the Covid-19 pandemic in 2020–2021. At the same time, computer literacy declined, potentially because all technology literacies depend on computer skills, meaning this essential literacy showed less individual growth in popularity.

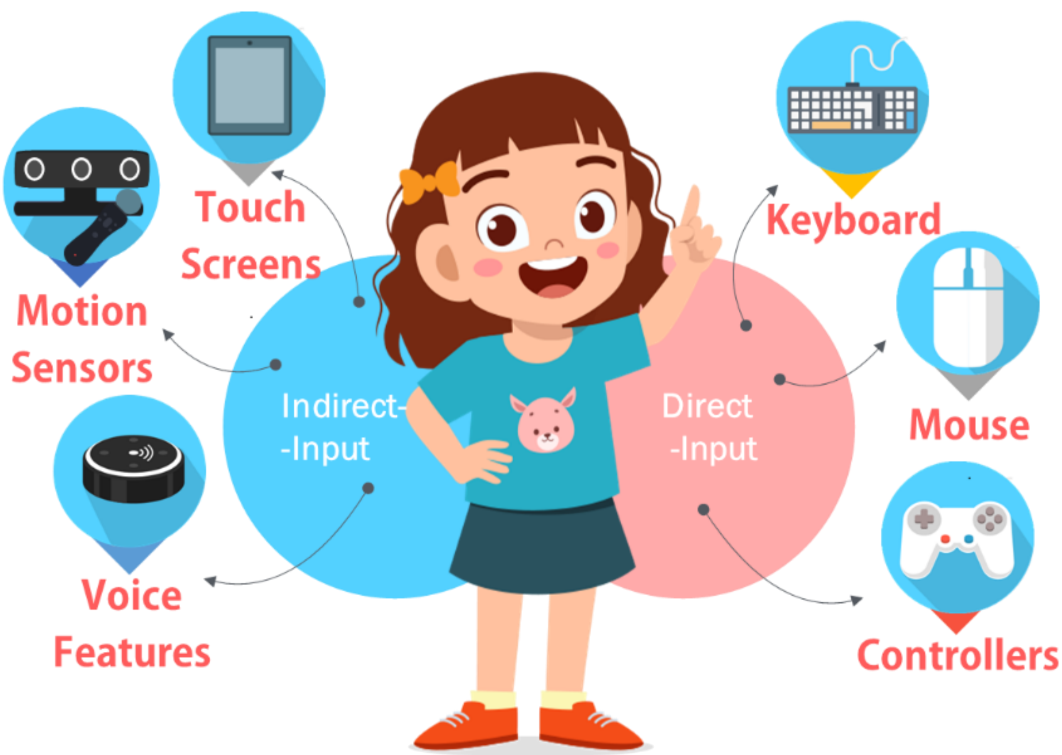
Figure 3.5 Popularity of Technological Literacies Terms According to Google Trends



3.2.4.2 Child Interactions with Input Devices

To design a curriculum that integrates technology with learning outcome, we need to understand how to control technology. Children can control technology in several ways depending on the input devices. Input devices, which allow individuals to communicate with technology, typically require device-specific skills that vary based on a device's sensing capabilities, its ability to readily incorporate state transitions such as button-presses into the device's design, and the user's physical abilities and hand comfort when using the device [126]. Input devices are often highly dependent on a user's fine motor skills for operating a mouse, keyboard, controller, or touch screen [20, 126-128]. Other devices use motion sensors, which require refined gross motor skills, or virtual assistance and developed language skills for voice command [127]. A previous study categorized devices as direct-input or indirect-input appliances [129]. Figure 3.6 categorizes common input devices. Direct-input devices include keyboards, mice, and controllers. Indirect-input devices are motion sensors, touch screens, and voice features. Although they are not comprehensive, the suggested classifications offer fundamentally progressive categorizations to manage technology and develop technological literacy. Research has shown that children build and polish skills through repetition, beginning with exploration, then mastery, and finally functional subordination. Anecdotal evidence suggests this same learning progression occurs with technology [12]. Therefore, sufficient time to explore a device's functionality can increase children's technological proficiency [130].

Figure 3.6 Technology Input Devices for Early Childhood



Keyboarding: By definition, keyboarding is a way to pass letters, numbers, or symbols into a device through a screen [131]. Classic and virtual keyboards typically consist of alphanumeric, numeric, and special keys [131]. As humanity has become more reliant on technology, however, keyboarding skills have become necessary for younger users, meaning the recommended time to start learning foundational keyboarding skills is from preschool to fourth grade [132]. Foundational keyboarding skills are important to lay the groundwork for finishing a task successfully [128]. For example, Keyboarding Without Tears (KWT) develops comprehensive developmentally appropriate typing skills for students in kindergarten through fifth grade [133]. The first stage of KWT establishes correct keyboarding habits by asking users to identify keys and then use correct fingering to hit the desired letters. The second stage develops finger dexterity and finger-key association as familiarity with keyboard functionality increases. The third stage builds muscle memory by requiring users to practice looking at the screen instead of the keyboard. The fourth KWT stage sharpens keyboarding accuracy and fluency and builds muscle memory, accuracy, and speed to reinforce formatting and keyboard skills.

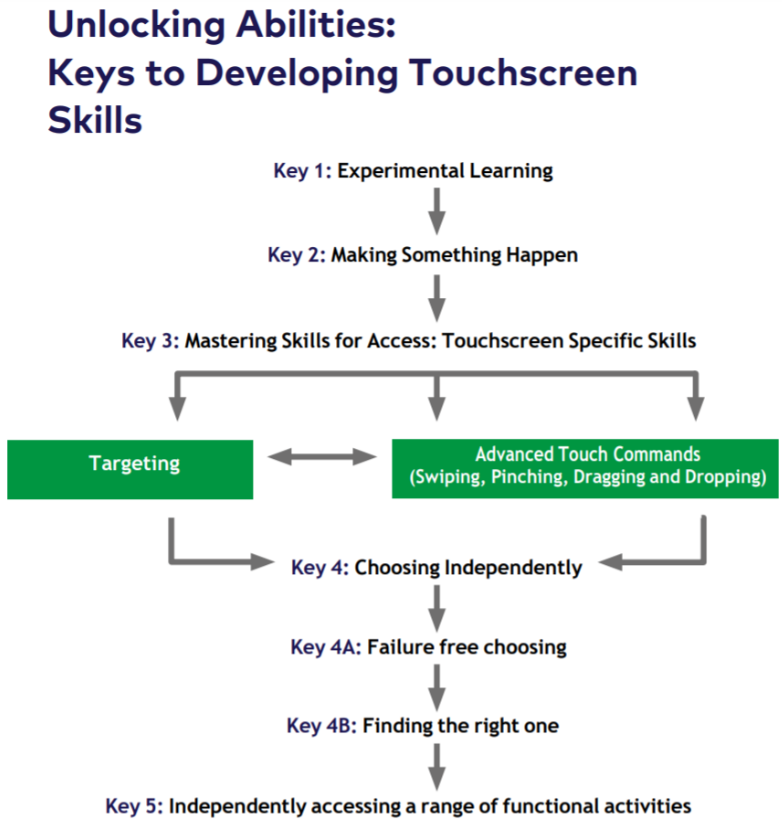
Mousing: A computer mouse is a handheld input device that lets a user control a cursor on a computer screen [134]. Although they come in different shapes and sizes, a standard mouse has a palm rest, two buttons, and a scroll wheel [135]. Using a mouse is necessary for playing games, navigating documents, and creating digital art [136]. Using a mouse requires coordinated muscle use of the hand, wrist, arm, and shoulder, as well as hand-eye coordination [126]. As mentioned, babies do not have the needed motor skills or visual abilities to move a mouse, and even toddlers demonstrate limited ability to use a mouse accurately. Although previous research showed that preschoolers and school-age children are generally capable of using a mouse to operate educational software, new research suggests that practice frequency is more important than age for determining how well a child can control a mouse [137]. Common foundational skills for using a mouse include identifying mouse parts, holding the mouse correctly, moving the mouse, pointing, hovering, clicking features (double-clicking, right-clicking, left-clicking), and scrolling. Combining concepts, such as dragging, dropping, resizing, opening a window, closing a window, drawing, and highlighting have been shown to develop accurate cursor control. Mousing skills are often paired with keyboarding because children need to develop synchronization between typing and mouse movement to operate educational software [138, 139].

Touch Screens: The touchscreen is an efficient replacement for the mouse and the keyboard because it replaces the functionality of the mouse pointer with finger movements and the classic keyboard with a digital board, plus it offers extra features such as emojis and the ability to send pictures and files [140]. Touchscreens are typically glass-screened devices that instantly respond to the pressure of a fingertip touch over an icon-based interface that enables users to manipulate the device independently [141]. Computer accessibility had been limited for children because controlling the traditional computer-user interface required a high ability level not yet developed in young children, and the high cost of computers made them risky for children to explore by unsupervised [142]. With the advent of touchscreens, however, financial and developmental barriers have been reduced meaning infants, toddlers, and preschoolers can intuitively engage with the digital world [80]. Touchscreens are also lightweight, mobile, and sized appropriately for children, with a user-friendly interface based on simple motor skills. In addition, the screen mechanism provides interactive multimedia displays that stimulate visual, auditory, tactile, and kinesthetic sensory systems that instantly respond to a child's input [77]. Research has shown that children typically can control the screen by their first birthday and progress efficiently with practice [91].

Touchscreen researchers recommend nine basic touchscreen gestures: tapping, scrolling, swiping, flickering, selecting, dragging, pinching, resizing, and rotating [143, 144]. Tapping occurs when one finger quickly touches the screen once or multiple times. Tapping with several fingers or long-press taps can activate more features. Sliding involves firmly touching the screen without lifting a finger while moving from position A to position B. The interface can detect different gesture speeds of the finger, causing an inertial response to the system differentiating sliding as average, fast, and very fast, compared to scrolling, swiping, and flickering. For example, with a series of 20 photos, swiping moves from one photo to the next photo, while scrolling may move to further photos depending on the aggressiveness of the finger gesture. Comparatively, selecting is a touch-and-hold gesture like tapping except only certain objects may be available for selection. The selecting feature combined with additional actions allows the user to move/drag and drop, pinch, resize, or rotate an object. Dragging moves an image, such as to organize app icons or play games. Resizing and rotating primarily change the position of an image. Pinching, which increases or decreases the size percent of a page, can be pinching-in (zoom in) by placing two fingers on an object or screen and spreading them apart to increase the size or pinching-out (zoom out) by placing two fingers on an object or screen and bringing them together to decrease the size.

Indigo Australasia Incorporated [78] has proposed a touchscreen skills framework that focuses on training cognitive and motor skills. The framework consists of five stages, as shown in Figure 3.7. This framework is not a fixed progression; students may simultaneously work on multiple keys and may need to regress to consolidate skills.

Figure 3.7 Literacies to Develop Touchscreen Skills [78]



Key 1: Experimental Learning—This exploratory stage is meant to build comfort and reaction toward touchscreens where children can explore apps that develop touchscreen skills, especially sensory experiences (sight, sound, movement, patterns).

Key 2: Making Something Happen—This stage is the cause-and-effect stage because it reinforces to a child that they are in control, and they can do many things intentionally using the screen. This stage requires repetition until a child is ready to move from swatting at the screen to achieving the desired effect.

Key 3: Mastering Skills for Access: Touchscreen Specific Skills—The goal here is for students to master use of gesture skills to achieve their ultimate objective, such as drawing or designing a digital picture.

Key 4: Choosing Independently—This stage supports option selection. The first part of this stage offers multiple choices on the touchscreen to allow students to thoughtfully choose one they think is appropriate without the parameters of a right or a wrong answer. The second portion of the stage teaches students to make correct choices suitable to a specific problem to increase a child's communication skills and demonstrate their learning.

Key 5: Independently Accessing a Range of Functional Activities—By this stage, the student should master the touchscreen skills and functionality to achieve a goal independently, whether this is communicating, reading books, writing, taking photos, making phone calls, or playing music.

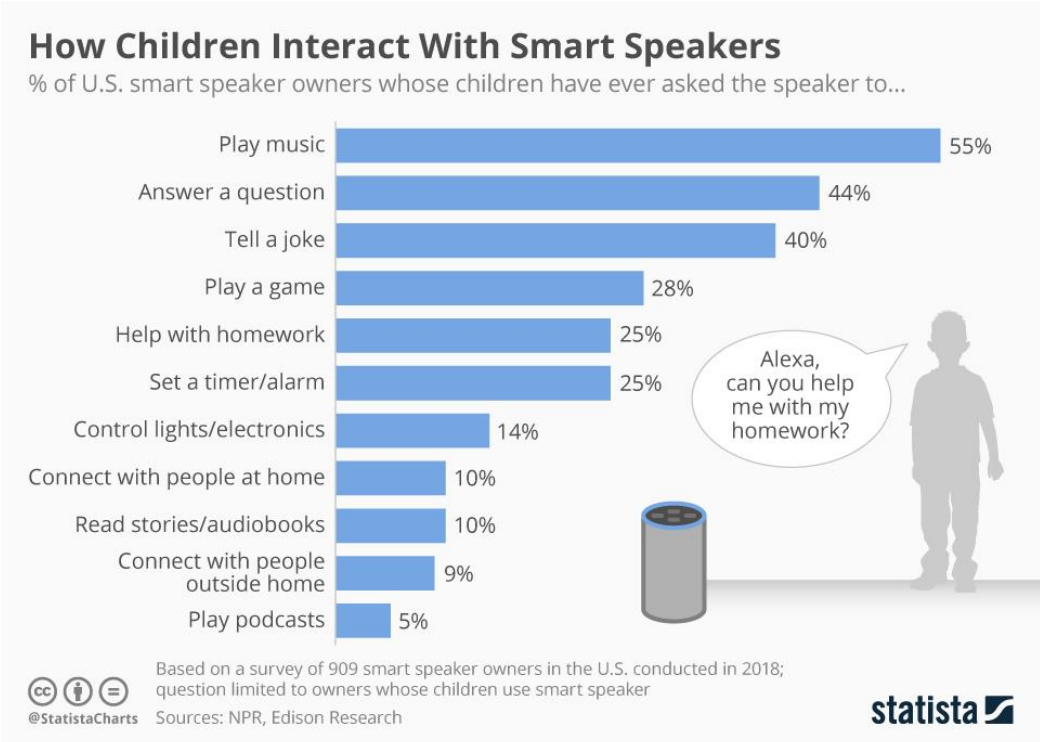
Controllers: Controllers are external devices that provide input (i.e., control or move an object or character) to an entertainment system, such as video games consoles [145]. Controllers, which include gamepads, joysticks, light guns, drum controllers, and sports controllers, are either wired (i.e., plugged into console ports) or wireless [146]. The average number of buttons on a classic controller is 10–20 [147]. Gamers typically use the traditional grip or the claw grip [148]. In the traditional grip, the controller rests on the user's palms between the two hands while the index and middle fingers rest behind and atop the controller for the trigger buttons with one thumb on the joystick's button for moving. The other thumb controls the buttons on the front of the controller. The claw grip is a unique grip that gamers use to maximize button input on console games. Although they rest the controller on the palms as in a traditional grip, they use their index fingers for the buttons on the front of the controller instead of their thumbs. Their middle fingers are used to control the top buttons. Studies have shown that those as young as preschool can grip controllers to play children's games.

Motion Sensors: Motion sensors, also called motion detectors, are input devices that detect and capture real-time physical movement within a certain range. They are typically embedded systems with three major components: a sensor unit, hardware, and an embedded computer. Motion sensors, such as motion-detected floodlights and alarms, were originally used to protect homes, businesses, and government buildings [149]. Recently, however, motion sensors have been utilized for in-game consoles and virtual reality systems [150]. Sensor functionality can be active or passive. Active sensors use transmission and receiving techniques to detect an emotion by measuring the change of the amount of sound or radiation reflecting back to the receiver. Passive sensors measure only the reflection based on a perceived radiation increase [149].

Motion sensors are commonly used for interactive learning and video games because they can identify individuals based on face, hand, gesture, voice, or whole-body recognition [81]. Three main consoles incorporate motion sensor technology: Sony PlayStation (at least PS3), XBOX 360 Kinect, and Nintendo WiiU with the Sony PS VR headset and the XBOX 360 Kinect and Wii motion controllers, respectively. Wii requires a player to hold a sensor controller that is scanned by the console, while the Kinect technology makes the human body the actual controller [151].

Voice Features: Voice features are built into smart devices such as phones and tablets to allow users to perform hands-free actions using voice commands instead of keyboards, mice, and touchscreens. Voice interfaces such as Apple's Siri, Amazon's Alexa, or Google are accessible to children as young as 18 months [127]. Statistics show that children most commonly use virtual speakers for "playing music, answering questions and telling jokes" [70], as shown in Figure 3.8

Figure 3.8 Children's Interactions with Smart Speakers [70]



3.2.4.3 Frameworks Integrating Technology into Early Childhood Pedagogy

Educators have historically struggled to integrate technology because they have not adequately addressed the pedagogical principles that can guide teaching and learning with technology [152]. Mike Sharples, Emeritus Professor of Educational Technology at The Open University, asserts that "To improve education focus on pedagogy, not technology," meaning educators must plan for technology use as part of the pedagogical process [153]. Similarly, another researcher has pointed out that

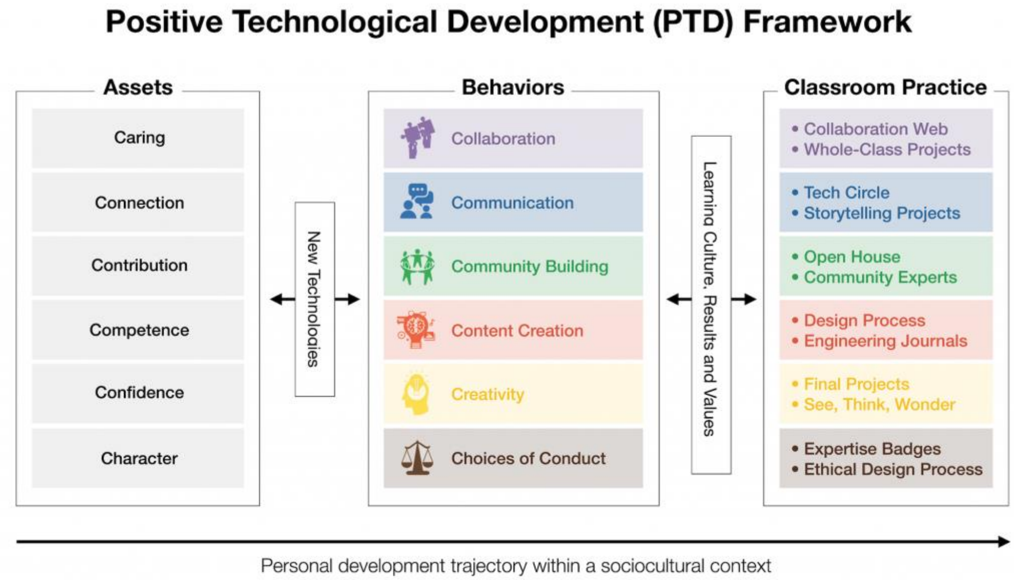
> The decision on the selection and use of technology for instruction should be made at the onset—when the instruction is being prepared, not in the middle or after the instruction. The objective and method of instruction including technology and outcomes of instruction should be specified at the planning stage [153].

Previous research proposed a theory-based framework that is considered one of the best frameworks to promote positive behaviors around technology. It is called Positive Technological Development (PTD) and it helps integrate technology using children's existing pedagogy. In addition, the Digital Citizenship frameworks help technology users handle opportunities and challenges that emerge from being part of an online society. The two frameworks together provide standards for educators to align lessons with.

3.2.4.3.1 Positive Technological Development Framework

PTD is a framework that promotes children's growth in a technology-rich environment [154, 155]. Elements of the framework were drawn from theoretical results from two areas: the field of Positive Youth Development (PYD), which fosters young people's cognitive, personal, social, emotional, and civic characteristics; and Seymour Papert's constructionism theory that carries ideas to make them a reality while considering how educational technology can be used. Adding to Papert's theory Timothy Koschman suggests computer-assisted instruction (CAI), intelligent tutoring systems (ITS), and constructionist authoring environments and tools for computer-supported collaborative learning (CSCL). Consideration of both elements can influence the construction of tech projects to achieve project outcomes and promote positive behaviors. It defines how children should use technology to accomplish tasks to the best of their abilities while fostering wonder and creativity that can satisfy developmental needs and positively contribute to society. Educators can use the framework to design and evaluate curriculum and makerspaces in various early childhood settings. The framework is comprised of three levels, as shown in Figure 3.9: assets (standards for positive outcomes), behaviors (positive interactions with technology), and classroom practice (for early childhood classrooms).

Figure 3.9 PTD Framework [154, 155]



The assets level includes the six assets identified by PYD (caring, connection, competence, confidence, character, and contribution). These interdependent characteristics provide the foundation for personal development in children. Competence is the ability and motivation to thrive in different environments while developing moral identity and confidence. Practicing ethical views and participating in a range of connections such as school, families, and friends can put children on a journey to develop and polish their characteristics. In addition, connections with individuals who carry different characteristics can increase exposure to working with different types of people. Caring and compassionate consideration of others builds empathy. The first five assets help prepare a child to contribute meaningfully to a community, while the sixth asset—character—relates to an individual's growing more skills to achieve a better life and others feel more comfortable working alongside them, as detailed in Figure 3.10.

Figure 3.10 Assets Column Definitions of PTD Framework [154, 155]

- **Competence.** An ability to use technology, to create or design projects to accomplish a goal, and to debug projects and problem-solve.
- **Confidence.** A sense of oneself as someone who can act and learn to act successfully in a technology-rich environment, find help when necessary, and have perseverance over technical difficulty.
- **Character.** A moral compass that guides the use of technology in responsible and safe ways and the ability to express one's values using technology.
- **Caring.** A sense of compassion and willingness to respond to the needs and concerns of other individuals, to assist others with technical difficulties, and to use technology as a means to help others.
- **Connection.** Positive bonds and relationships established and maintained by the use of technology.
- **Contribution.** An orientation to contribute to society by using and proposing technologies to solve community/social problems.

The behaviors level includes collaboration, communication, community building, content creation, creativity, and choice of conduct. Collaboration is the "willingness to respond to the needs of others. To assist others, and to use technology as a means to help others". Communication includes sharing ideas and maintaining social relationships. Community is opportunities to present and explain technological projects are essential for communication in a learning environment. Content creation allows children to be producers of content and activities instead of just consumers. This is also one of the primary 21st century skills. Because children typically consume technology instead of creating content, creativity requires a deeper level of thinking to expand perspectives and metacognition opportunities. And Choice of Conduct refers to opportunities to allow children to practice autonomy, meaning children become responsible for their decisions, including positive opportunities to learn from their mistakes.

The classroom practice level encompasses various educational practices in diverse learning environments—schools, libraries, or museums—to provide opportunities for exposure to new routines, values, and cultures. Even similar environments can vary their practices; for example, schools that follow the Montessori [156] approach use different methods than schools using Reggio Emilia by implementing self-directed experiences, classroom design, and learning tools [157]. Also, Montessori schools in Islamic countries can include extra factors like religion [158]. That is why Bers recommends keeping it blank to be filled by facilitators' needed practice [155].

3.2.4.3.2 Digital Citizenship Plus

The increased use of technology worldwide has increased online safety concerns. In response to these concerns, digital citizenship was coined to teach technology users skills to handle opportunities and challenges that emerge from being part of an online society [30]. Digital citizenship focuses on technology access, digital literacy, and rules to help individuals practice positive behaviors toward others online [159]. Common concepts covered include positive/respectful behavior (kindness, empathy, and responsibility); safety and well-being (preventing victimization); privacy and reputation (digital footprints); and security (passwords, personal information, etc.) [31].

Although many educational institutions worldwide have adopted the term into their curriculums for all ages, no agreement has been reached as to which skills and areas digital citizenship should encompass [160]. Therefore, students from Harvard conceptualized 17 primary concepts mapped from 35 frameworks that pertain to digital citizenship or related concepts (Table 3.1), and they called it Digital Citizenship+ (Plus). This platform offers "the skills needed for youth to fully participate academically, socially, ethically, politically, and economically in our rapidly evolving digital world" [161].

Table 3.1 Digital Citizenship+ Concepts [161]

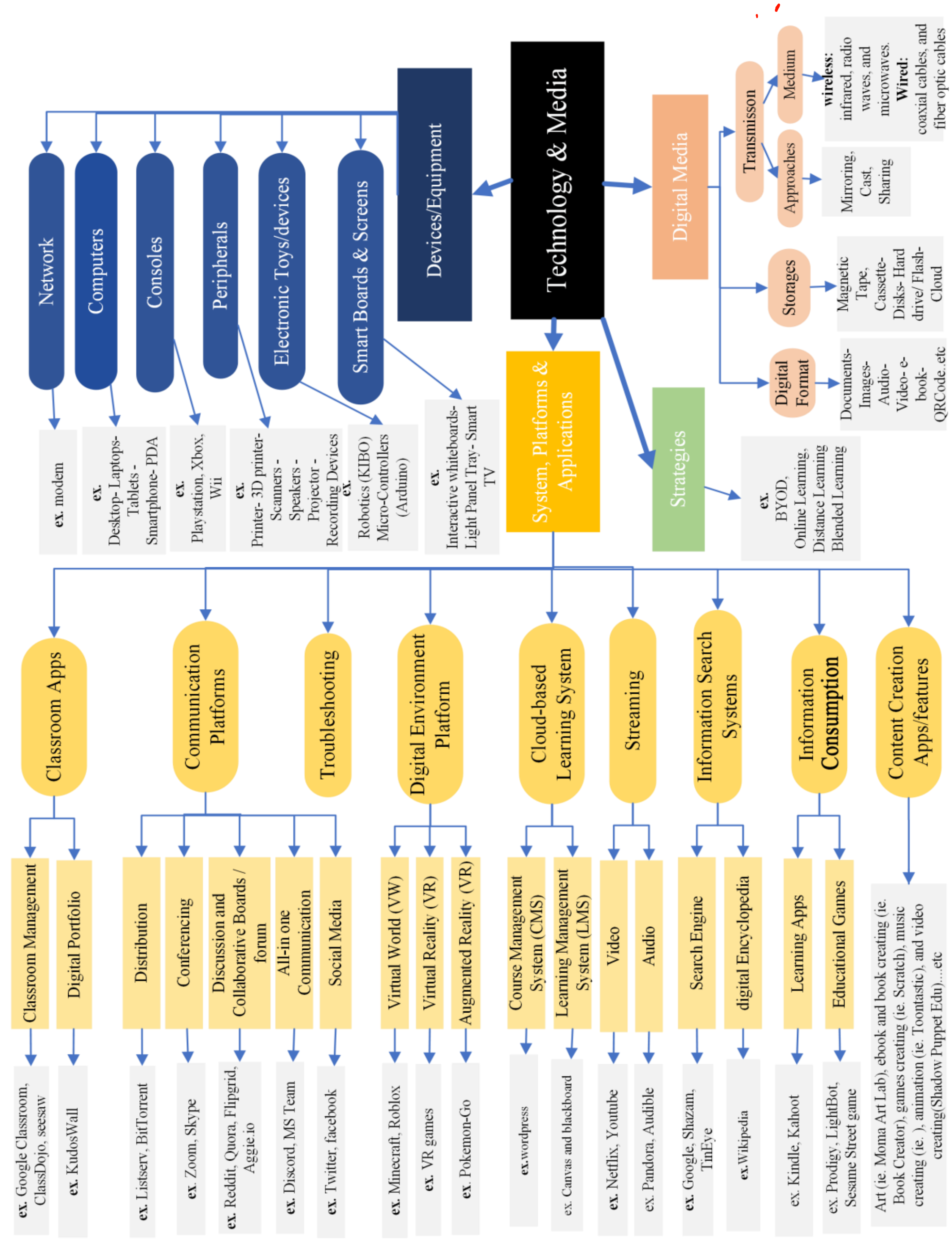
	Concept	Description
1	Artificial Intelligence	The ability to understand the algorithms involved in the AI-based platforms one interacts with, and the ethical conversations happening around the development of these technologies.
2	Civic & Political Engagement	The ability to participate in public matters (e.g., LGBTQ rights, peace-building, addressing hate speech) and advocate for issues one cares about — using digital and non-digital tools — ideally to improve the quality of life in one's community, from micro to macro levels (Levine, 2007)
3	Computational Thinking	The ability to understand and apply computational concepts, practices, and perspectives.
4	Content Production	The ability to produce (digital) content using (digital) tools.
5	Context	The ability to be aware of, understand, and interpret the contextual factors of relevance (e.g., cultural, social, local/regional/global) in a given situation — with a particular emphasis on the experiences and perspectives of underrepresented groups, whether in terms of age, ethnicity, race, gender and sexual identity, religion, national origin, location, skill and educational level, and/or socioeconomic status — and effectively engage in the situation
6	Data	The ability to be aware of, create, collect, represent, evaluate, interpret, and analyze data from digital and non-digital sources.
7	Digital Access	The ability to connect to and access the Internet, individually or collectively (e.g., mesh technologies).
8	Digital Economy	The ability to navigate economic activities online and offline to earn different forms of economic, social, and/or cultural capital (e.g., earning money, increasing social connections, building personal brands).
9	Digital (Literacy)	The ability to use the Internet and other digital tools and platforms effectively to find, interact with, evaluate, create, and reuse information (Palfrey & Gasser, 2016). The ability to comprehend and work through conceptual problems in digital spaces (Carretero et al., 2017).
10	Identity Exploration & Formation	The ability to use (digital) tools to explore elements of one's identity and understand how the communities one is part of shape one's identity.
11	Information Quality	The ability to find, interact with, evaluate, create, and reuse information (broadly speaking, e.g., news, health information, personal information) effectively (Palfrey & Gasser, 2016).
12	Law	The ability to engage with legal frameworks, concepts, and theories surrounding the Internet and other digital tools (e.g., copyright, fair use), and the ability to apply these frameworks to one's activities.
13	Media (literacy)	The ability to analyze, evaluate, circulate, and create content in any media form (e.g., print, visual, interactive, audio), and to participate in communities and networks. "Media literacies," in the plural, include "media literacy" (Hobbs, 2010), what some researchers have conceptualized as "new literacies" (Lankshear & Knobel, 2007), and "new media literacies" (Jenkins et al., 2006). That is, they encompass literacy approaches that not only focus on individual engagement with media (media literacy) but also that address community involvement and participatory cultures. "Media literacies" also include literacies such as reading and writing.
14	Positive/Respectful Behavior	The ability to interact with others (both individuals and the larger collective (James, 2014)) online in a respectful, ethical, socially responsible, and empathic manner.
15	Privacy & Reputation	The ability to protect one's personal information online, and that of others. An understanding of the digital "trail" left behind as a result of the activities one engages in online, the short- and long-term consequences of this trail, the appropriate management of one's virtual footprint, as well as an understanding of inferred data (i.e., new data derived from capturing and analyzing other data points, which may result in new knowledge about a person (van der Hof, 2016)).
16	Safety & Well-being	The ability to counteract the risks that the digital world may come with to protect one's physical and mental well-being (e.g., guarding against Internet addiction and repetitive stress syndrome). Online risks can be classified along three main dimensions: conduct (e.g., cyberbullying, sexual harassment/ unwelcome "sexting"); contact (e.g., face-to-face meeting after online contact, communication with individuals pretending to be another person); and content (e.g., exposure to pornographic content, violent or aggressive content, harmful speech, content about drugs, racist content) (Livingstone, Kirwall, Ponte, & Staksrud, 2014).

3.2.5 Tools and Innovations

Throughout history, experts have referred to technology differently, depending on their positions and goals [162, 163]. For example, scientists, engineers, technicians, and computer experts often conceptualize technology as devices, processes, and systems. Take the American Apollo moon project, which as a whole was considered modern technology, as were the series of small, advanced tasks that comprised the project (e.g., building rockets, sending astronauts into orbit, designing and testing lunar vehicles) [163, 164]. In comparison, educators often contextualize technology within the social organization it resides, meaning human activity is a vital aspect of the technology [165]. Usage of the term has continued to evolve and expand to include many innovations. Subsequent judgments of those innovations also grow. Technology in education encompasses a broad range of digital devices, applications, media, and strategies.

Figure 3.11 illustrates the technology classification as derived from educational reports [98, 166-169] and a computer science framework [170]. As shown, the classification contains four main categories (devices/equipment; system, platforms, and applications; strategies; and digital media) that highlight the range of digital devices and acronyms in educational reports. The categories are clustered according to the core concepts of the K–12 Computer Science Framework: computing systems, networking, data, algorithms, and programming. The categories kept broadening and narrowing until they held all the variances logically. Educators' familiarity with terms and term usage was considered in the process.

Figure 3.11 Sofia's Technology Classification



Devices/Equipment: The devices/equipment category broadly refers to all mechanical or electronic equipment used for educational purposes, specifically the hardware of the computing systems and networking. This category includes the network (i.e., modem, switch, and hub) that enables computing devices to communicate [170] and the computers themselves, including desktop computers, laptops, tablets, smartphones, and PDAs, which consist of hardware and software that collaborate in sequences of mathematical or logical operations to carry out user tasks. Computers may have an interface that allows humans to install software made available through app stores [171]. This technology classification category also includes consoles, which are electronic devices that output video signals or images to display a video game (e.g., PlayStation and Xbox) [172], and peripherals, which are accessory devices that can be plugged into computers to perform an input or output function and include printers, 3D printers, scanners, cameras, speakers, projectors, and recording devices [173]. The devices/equipment category also includes electronic devices that use programming to control the hardware. Examples of electronic devices include robots (e.g., Kibo, Cubito, Bee-Bot, Robot Mouse, Ozbo, Matatalab, and Wonder Workshop), that can be programmed to perform human tasks [174], and microcontrollers (e.g., Arduino and Makey Makey), pocket-sized computers that can be programmed for functions such as controlling LED lights [175]. Electronic devices also include interactive smart boards and screens (e.g., interactive whiteboards, light panel trays, and smart TVs).

System, Platforms, and Applications: The system, platforms, and applications category of the technology classification is comprised of the applications and platforms used for educational support. The software is derived from computer system elements combined with programming logic. A user always interacts with content, resulting in two usage classifications: content-creating applications and content-consuming applications. Further categorization classifies applications according to their purposes. Elements of this section can overlap as some application functionalities exist in multiple categories, as shown in the clusters according to primary functionalities in Figure 3.11.

The system, platforms, and applications category contains nine subcategories: classroom applications, communication platforms, troubleshooting, digital environment platforms, cloud-based learning systems, streaming, information search systems, information consumption, and content creation. Classroom applications are further classified as classroom management and digital portfolio. Classroom management applications (e.g., Google Classroom, ClassDojo, Seesaw) help teachers manage grades, student attendance, student behavior, seating charts, assessments, and parent communication [176]. The digital portfolio classification refers to an app-created collection of a student's achievements, interests, and abilities, including audio recordings, video, text, and pictures [177]. Examples of digital portfolio applications include Seesaw's digital portfolio, ClassDojo Portfolios, and KudosWall.

The second subcategory, communication platforms, includes a variety of functions and applications. Distribution, via programs such as LISTSERV and BitTorrent, allows a user to send a file to a group of receivers [178]. Conferencing enables live online communication for audio, video meetings, or seminars with built-in features such as chat, screen sharing, and recording [179]. Zoom and Skype are examples of conferencing applications. Similarly, discussion and collaborative boards/forums (e.g., Google Classroom discussion board, Reddit, Quora, Flipgrid and Aggie.io) are "online discussion site[s] where people can hold conversations in the form of posted messages" [180]. Compared to chat rooms, messages in these boards/forums are often longer than one line of text and are at least temporarily archived. All-in-one communication includes voice calls, video calls, text messaging, media, and files in private chats or as part of communities (i.e., servers) [181]. Platform examples include Discord, Microsoft Teams, and Slack. Finally, social media platforms "allow the creation or sharing/exchange of information using different media formats such as text, photos, videos, audio, Emojis" [182]. Popular social media platforms include Instagram, Facebook, Twitter, TikTok, Snapchat, and WhatsApp.

The third subcategory, troubleshooting, refers to a form of problem-solving often applied to repair failed products or processes on a machine or a system [183].

Digital environment platforms, the fourth subcategory of the systems, platforms, and applications category, is comprised of multiple virtual applications. Virtual worlds (digital worlds, digital space, and virtual space) refer to "a computer-simulated representation of a world with specific spatial and physical characteristics. Users of virtual worlds interact with each other via representations of themselves called avatars" [184]. Virtual world applications include Minecraft, Second Life, massively multiplayer online games, and Roblox. Comparatively, virtual reality refers to "a simulated environment where the player, instead of viewing a screen in front of them, users are immersed and able to interact with 3D worlds" [150]. Virtual reality (VR on PlayStation) attempts to simulate as many senses as possible, including sight, sound, touch, and even smell. Similarly, augmented reality simulates artificial objects in the real environment, such as the Pokémon GO app [185].

The cloud-based learning systems subcategory includes two primary systems. A course management system (CMS) provides a centralized, cloud-based repository to manage online content. CMSs such as WordPress, Joomla, and Drupal allow users to control document access, enable coauthoring, and track file changes; users typically have to download files to a desktop or laptop computer to change file contents [186]. Comparatively, a learning management system (LMS) such as Canvas or Blackboard delivers online learning content (e.g., academic courses);

manages learning activities (including classroom and hands-on training); and tracks learner information (e.g., academic history and progress). Content can be modified on the platform [187].

The sixth and seventh subcategories, streaming and information search systems, respectively, both relate to databases and information accessibility. Streaming services such as Netflix, HBO, and YouTube for video options and Pandora and Audible for audio selections provide “a wide variety of Media (Audio or Video) where users watch from the list” [188]. Similarly, information search systems are designed to search databases systematically for particular information in a search query [189], including text, images [190], or voice [191]. Digital encyclopedias such as Wikipedia and search engines such as Google, Shazam, and TinEye are examples of these systems.

The final two subcategories focus on information consumption and creation, respectively. Information consumption, or computer-assisted instruction, includes software developed for teaching and learning. This subcategory covers a wide range of subjects for various levels and learning styles, including educational apps for reading (e.g., Kindle) and assessment (e.g., Kahoot), as well as educational math games (e.g., Prodigy), coding games (e.g., LightBot), and literacy games (e.g., Sesame Street) [192]. The ninth and final subcategory, content creation, is comprised of applications and features that allow users to create and produce digital content, including art (e.g., MoMA Art Lab), books (e.g., Book Creator), games (e.g., Scratch), music (e.g., MuseScore), animation (e.g., Toontastic), and videos (e.g., Shadow Puppet Edu).

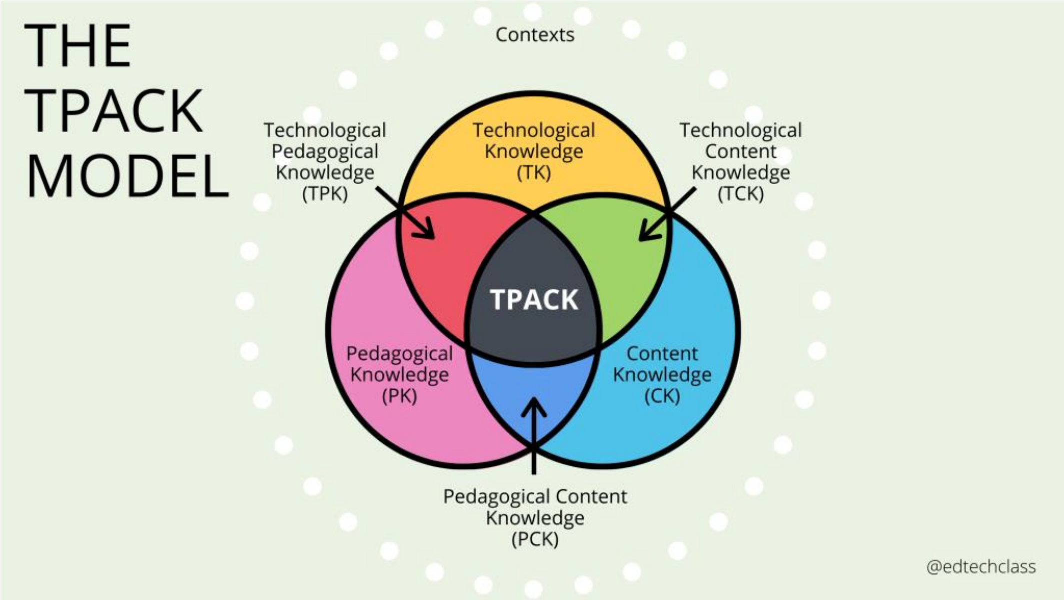
Strategies: The strategies category of the technology classification (Figure 3.11) includes strategies and methods to support technology use in educational systems. Online learning refers to learning that occurs in a fully virtual environment via recorded lessons depending on the student’s base [193]. Distance learning occurs synchronously or asynchronously when “Students and teachers do not meet in a classroom but use the Internet, email, mail, etc., to have classes” [193, 194]. Hybrid or blended learning is a combination of online and distance learning [193]. The Bring Your Own Device (BYOD) policy allows students to bring their own devices to school for classwork [195].

Digital Media: The digital media category encompasses all digital data types that can be stored and transferred through communication outlets. This category specifically pertains to data, element storage, and visualization and transformation as outlined in the K–12 framework. This category contains three subcategories. First, digital format refers to “the organization of information according to specifications for computer processing,” including documents (pdf, Word), images (png, jpg), audio files (mp3, Wave), videos (mp4), electronic books (e-books), and codes (exe) [196]. The second subcategory, storage, includes magnetic tapes and cassettes (e.g., video home system [VHS] and digital audio and tape [DAT]), digital compact cassettes (e.g., digital video discs [DVDs] and compact discs [CDs], hard drives/flash memory), and cloud-based storage (e.g., Google Drive). The final subcategory, transmission, is comprised of technology that manages transmitter media entities. Transmissions can be wireless via infrared, radio waves, or microwaves, or they can be wired via coaxial cables or fiber optic cables. In addition, various approaches can be used to allow the screen of a computer device to be transmitted to the screens. For example, the mirroring approach shows the “exact desktop, laptop, phone or tablet screen and all of the movements on another screen display that is in the same room” [197]. Casting, such as via Chromecast, casts media from a device to a TV and only be able to watch on the TV [197], while sharing (e.g., Zoom) “displays content from one device to another in a separate or remote location” [197].

3.2.6 Facilitators

Early childhood educators must be trained with quality early childhood-tech programs that include in-depth, hands-on technology exercises and ongoing support for the latest technology tools, as well as examples of successful practice to meet expectation outcomes [198]. First, however, educators' abilities and knowledge must be assessed to appropriately allocate needed resources [199]. TPACK is a theoretical integration framework that can measure educators' required knowledge for successful ed-tech integration "while addressing the complex, multifaceted, and situated nature of teacher knowledge" [200]. Koehler and Mishra introduced the TPACK framework in 2006, which includes CK, PK, and TK. CK refers to issues related to content taught by teachers to students; PK is associated with pedagogical activities, practices, and processes used in the educational situation; and TK is related to technologies and technological integration to enhance teaching [201]. Dimensional intersections include pedagogical content knowledge (PCK), or the didactic knowledge related to a content area; technological content knowledge (TCK), which refers to the knowledge of how to employ technology to represent specific concepts; and technological pedagogical knowledge (TPK), or strategies that use technology and TPACK [200]. This research applied the three primary dimensions (CK, PK, and TK) to measure CT awareness among educational institutions, presented in Figure 3.12.

Figure 3.12 TPACK Model [202]



3.2.7 Environment

The environment can change the way children interact with technology, meaning a well-designed environment significantly increases a child's success by encouraging exploration and discovery for children and decreasing management issues and wasted time for educators [203]. Children will not explore or discover unless they feel secure and comfortable in the classroom, while insecurity and discomfort lead to problematic behaviors, such as being destructive to materials [204]. Early childhood environment theories should be applicable over technology. For example, Montessori's view of the environment considered the impact of the prepared atmosphere in which "the environment can be designed to facilitate maximum independent learning and exploration" [156]. Reggio Emilia considered the environment to be a "third teacher" that potentially inspires learners [157]. And Lisa Kuh defines the environment as "Formal, informal and virtual areas where children have the opportunity to express themselves and make choices as they encounter what the environment has to offer" [205]. There are three types of environments: physical, digital, and hybrid.

Physical Environment: The physical environment can be anywhere: schools, homes, libraries, hospitals, waiting areas, airports, science museums, and more. DevTech researchers developed a checklist that contained six sections that each represented a behavior from a PTD framework. In addition, another checklist focused on children's engagement in the tech environment [206].

Hybrid Environment: The hybrid environment is a blend of physical and digital worlds through which the user lives in a mix of interactions between the human, the physical environment, and the digital environment. Users need to be aware of the interactions that happen in the two environments simultaneously. It is based on advancements in computer vision, graphical processing, display technologies, input systems, and cloud computing. To use them, users need to build an understanding of spatial mapping, anchors between locations, and positioning elements in physical and virtual spaces. Those tools have focused on assembling physical objects, and often shaping them or sorting them can trigger action in the digital environment, which is controlled on screen.

Digital Environment: The digital environment is an environment that carries the potential for scaffolding learning, supporting iterative refinement, and enabling children to use visualizations to learn. There are two ways a child can use a digital environment, either as a producer or consumer. A producer is when a user interacts with the environment and creates digital objects—like creating a digital product like animation, game, app, etc. Usually, it requires using coding skills to deliver the output. A consumer is when a child learns from digital environments, like playing a game or watching educational media. Digital environments can include various tools such as VW and video games.

Laura Beals developed a framework to design Virtual Worlds for Children constructed from integrating developmental psychology literature and virtual communities research. She proposed six aspects: purpose, communication, participation, play, artifacts, and policies [207, 208].

3.2.8 Evaluation

The fact that technology is rapidly changing poses new challenges for policymakers and educators as they strive to develop a deep enough understanding to regulate it effectively. Top talented engineers and developers recruit employees to speed up the improvement and the evolution of technology. As a result, the technology market is flooded with different gadgets [26]. High-quality devices became affordable for middle- and low-income families and became an essential part of every house [26]. Additionally, the good, bad, and ugly sides of technology are also rapidly changing [12, 19]. What once was bad can be good as is evidenced by new versions and generations of technology that carry improvements and fixes. And all of this together highlights the importance of technology evaluation to protect children.

Pennsylvania Digital Media Literacy Project designed a yes-or-no checklist consisting of four sections (selecting, using, integrating, and evaluating technology) to gauge educators' thinking about technology usage [122].

3.2.9 Screen Time

As described previously in section 2.1, all screens are not created equally. Still, that doesn't make this element less important or must be ignored. Many countries throughout the world consider screen time—"the amount of time someone spends looking at an electronic device with a screen"—as an influential factor in technological best practices [209]. Table 3.2 summarizes recommended screen times for age ranges. As shown, an average of 1 hour of screen time per day can be beneficial for children in early childhood and older stages, but the time increases as a child grows to the next stage. Overall, infants and toddlers are limited to no usage or only high-quality content and video chat [209].

Table 3.2 Screen Time Limit Around the World [210]

Country/institution	Infants/toddlers	Early childhood	School-age - adolescence	Other recommendations
AAP (United States) (AAP, 2016[8])	None, except video chatting (under 18 months); Only high quality programming (18-24 months)	1 hour of high quality programming, co-view	Consistent limits on time and type	Turn off screens when not in use; ensure screen time doesn't displace other behaviours essential for health
Canada Canadian Society for Exercise Physiology (CSEP, 2017[9]) Canadian Paediatric Society (Canadian Paediatric Society, 2017[10])	None	<1 hour	<2 hours (CSEP only)	Limited sitting for extended periods (CSEP); Adults model healthy screen use (CPS)
Australian Government Department of Health (Australian Government Department of Health, 2017[11])	None (under 12 months); <1 hour (12-24 months)	<1 hour	<2 hours (entertainment)	
New Zealand Ministry of Health (Ministry of Health, 2017[12])	None	<1 hour	<2 hours (recreational)	Adapted from CSEP guidelines
German Federal Ministry of Health (Rütten and Pfeifer, 2016[13])	None	30 minutes	1 hour (primary school) – 2 hours (adolescents)	Avoid as much as possible; avoid screen time completely for children under 2 including background television

Chapter 4 - Computational Thinking Best Practices for Early Childhood

Future work is strongly shaped by computing. Some manual job roles will be replaced by automated machines and systems [211]. Organizations exert efforts to move from only focusing on field knowledge to including critical thinking skills across digital, businesses, and people [212]. It is expected that job roles will be redefined, and people will work alongside advanced technology such as AI and machine learning, software, tools, and gadgets. Fewer candidates will be hired for their manual skills, and more employees will be retained for their creative and strategic thinking skills [213]. Currently, skills are in demand in the business world, and organizations are trying to train their employees to maximize the human-machine effect [212]. In a 2019 report, an HR leader described that quantifying the skills gap given business objectives has traditionally been seen as a challenge [214]. New graduate candidates lack the needed skills to adapt to the rapid growth of technology [214]. According to the 2021 global talent trend, "24% of employees said short courses or training don't help them learn a new skill." In fact, 23% of Gen Y and 21% of Gen X employees say they don't know where to go for learning or what they should learn [214]. Given this, it is realistic to expect that current students need to be equipped with high computational capabilities. But that is not the case. Schools are only preparing them with the required knowledge of their field—hard skills. Students must improve thinking, cognitive, and intellectual skills—soft skills—to be successful in enhancing future work quality [212].

Typically, a thinking ability can emerge from brain maturity or teaching new thinking experiences [1]. Waiting for maturity wastes an individual's lifetime; and the fast growth of technology requires a quicker acquisition of skills. One type of thinking tool kit that can guide the thinking process to reach a better solution using computer science concepts is called Computational Thinking (CT) [215]. Mastery of CT requires acquiring a set of CS concepts that includes—but is not limited to

> **Decomposition** skill: the ability to break down a problem into sub-problems to reduce its complexity; **Abstraction** skill: concentrates on significant information instead of consuming time analyzing worthless details; **Pattern recognition** skill: uses patterns to refer to data sequence for prediction purposes; **Algorithmic thinking** skill: uses ordered rules and logical instructions to solve problems; **Logical thinking** skill: uses a tested premise to reach a conclusion using certain logical steps; and **Evaluation** skill: judges proposed solutions to enhance creative problem solving and measure student empowerment to formulate problems within the computational context. [2]

CT can not only improve the quality of the workplace but also the individual's decision-making choices [215]. Students unintentionally use CT. They use it to devise more functional solutions for current real-life problems, such as finding the best biking path from their house to school. Students unintentionally select the best route using the CT that was built from their previous experience. They view/remember the needed block on a map then identify all the possible roads (decomposition) while ignoring the unnecessary details of each road like the number of turns and street names (abstraction). They then compare which is the best path (pattern recognition) by thinking of distance, curves, hills, and other obstacles (logical thinking). Like solving a big math problem, they portion the related description (pattern recognition, abstraction, and decomposition) and logically apply needed rules to solve each portion. Later, they can use the portion technique to solve similar problems. The thinking process can be enhanced if the thinker intentionally uses CT to determine a more efficient, suitable thinking process [215]. CT concepts can offer supplementary steps that can lead to the solution using different, shorter, or even more efficient paths. At a higher level of education, CT concepts can empower all fields [216]. When CT concepts were combined with the health care industry, the biotechnology field arose. CT helped to develop more efficient systems to make better decisions for the benefit of the patients. Using pattern recognition on patients' records can help predict and estimate better diagnoses. Other disciplines created through CT include computational neuroscience, computational physics, and computational linguistics.

If CT is to be truly grasped by the future professionals and to avoid skills gaps, children need to be familiarized with these concepts early and often [217]. Studies have shown that children as young as 4 can successfully learn and use basic CT concepts [9, 10]. Learning CT can be "an engaging and rewarding experience" because CT carries a cross-disciplinary nature [218] so it makes sense to blend them together as early as preschool. In fact, using CT to teach English, math, science, and other subjects is a great way to support problem-solving across all disciplines [219] [218]. Hunsaker described how using CT in several subjects at the same time at the same school can help students to extend the connection by seeing the link and draw to real-life problems [219].

Policymakers worldwide recognize the importance of CT and have started advocating the terms across the educational systems [220]. Yet, kindergarteners and preschoolers were overlooked even though it has been shown that children this young can use technology [9, 10] and develop CT abilities. New early childhood educators are not fully equipped with the knowledge needed to integrate CT into their lessons. Not all college programs have mandatory classes related to integrating technology and CT [221, 222]. At the same time, early childhood educators are the bridge to deliver CT.

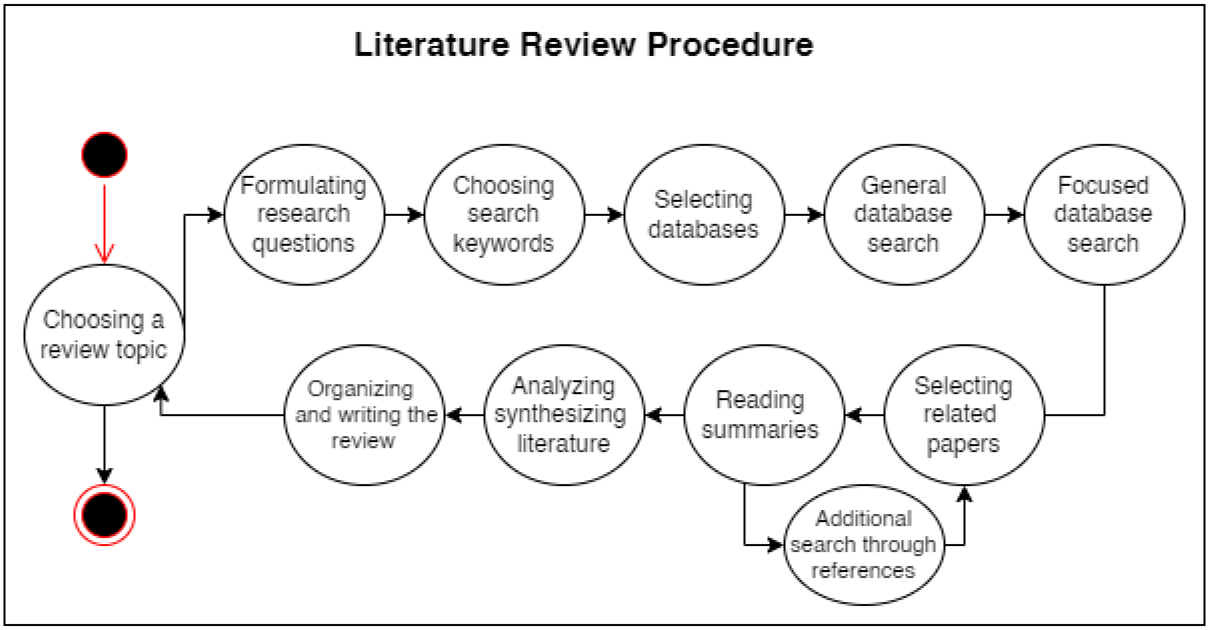
This chapter describes a CT bes-T-ech framework to aid educators in teaching CT while promoting positive learning around technology. It customizes elements of the bes-T-ech frameworks outlined in Chapter 3 to support teaching CT. The contributions of our work are seen within context, pedagogy, and facilitators, which are building theoretical models within the CT context (described "CT as a medium" for CS and Non-CS Disciplines). The pedagogy element consists of Computational Thinking Pedagogical + Framework and Operational Developmental Coding Stages to aid in integrating CT. Lastly, a developed CT survey for educators is described.

4.1 Literature Review of Computational Thinking for Early Childhood

"Few studies have examined whether and how CT can be promoted in preschool in ways that resonate with young children's experiences and are consequential for early learning" [223]. To propose the best practices for employing CT we need to investigate the elements of the best practice through CT by exploring the current works.

The literature review research method of Youngkyun Baek [224] and Juho Hamari [225] was used to create a procedure that searches for each element of the best practice. Accordingly, we expanded the search method loop and updated the process as presented in Figure 4.1.

Figure 4.1 Our Primary Research Topic Procedure



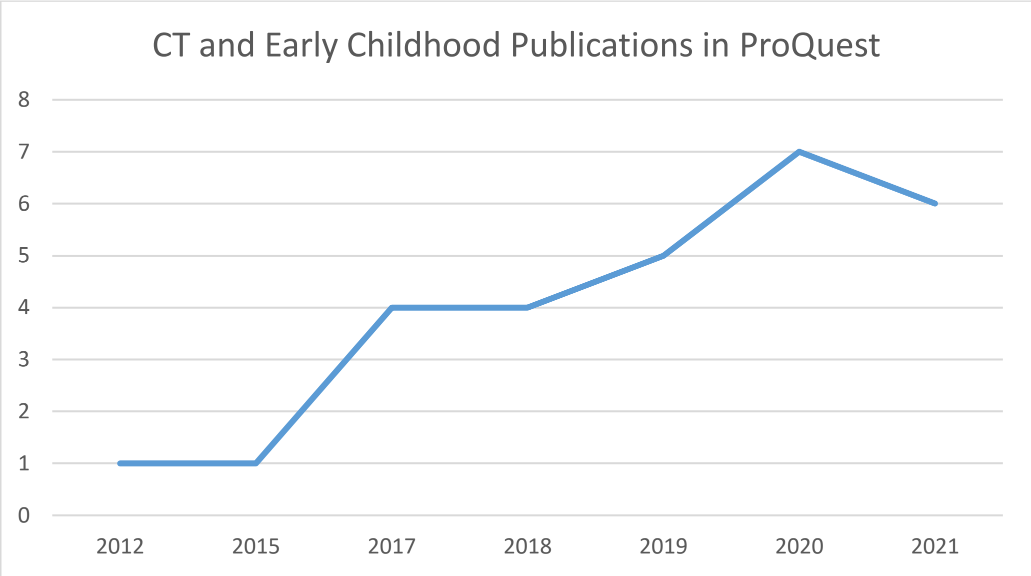
Our research procedure:

- **Topic**: "Computational Thinking and Early Childhood"
- **Database**: ProQuest
- **General search keywords**: computational thinking AND (preschool or early childhood or kindergarten)

Query: (ab(Computational Thinking) AND ab(Preschool)) OR (ab(Computational Thinking) AND ab(Early childhood)) OR (ab(Computational Thinking) AND ab(kindergarten))

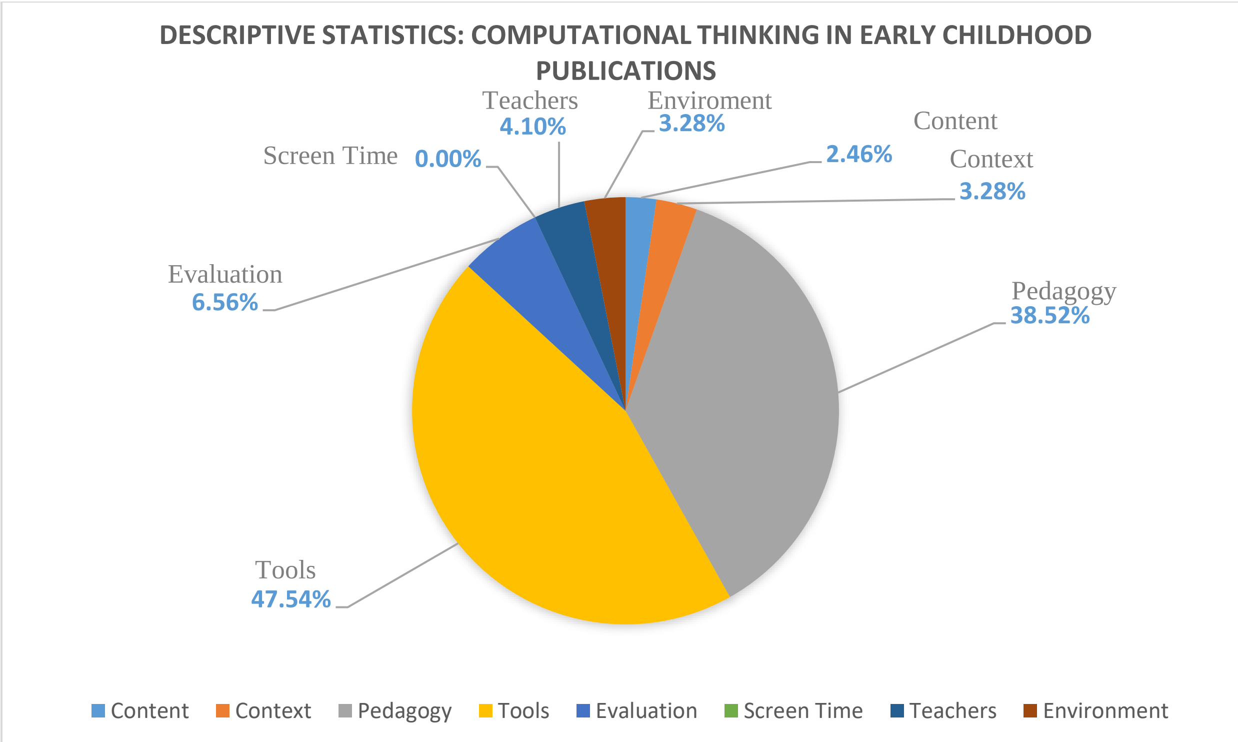
- **Filter:** keyword over abstract and title and in English
- **Source type:** books, conference papers and proceedings, dissertations and theses, government and official publications, scholarly journals

Figure 4.2 CT in Early Childhood Publications in ProQuest in the Past 10 Years



The results found were 40 documents ranging from conference papers, to dissertations, and books. After excluding the results that are not intended for early childhood, we end up with 28 papers that match our search criteria, sorted chronologically in Figure 4.2 and summarized in Appendix D. There were no time periods chosen, but no results were found prior to 2012. We identified the biggest communities that contribute to creating research and resources: DevTech research group (Tufts University) and Purdue University research groups (INSPIRE Research Institute [3] and FACE Lab research group [4]). DevTech contributions started in 1996 and include 186 STEM publications; 25 of those directly investigate CT. Purdue's research groups have 35 publications related to engineering and education and 12 papers related to early engineering and CT in early childhood. We went back to the research procedure, revisiting the paper references, and ended up with 129 papers.

Figure 4.3 Descriptive Statistic over the Publications of the CT in Early Childhood



Figures 4.3 illustrates the percentages of the number of papers categorized into the nine elements of bes-T-ech framework using the MAXQDA tool. With the purpose of giving insights over research efforts and where suggested future research can be. For example, Screen time has 0% of research; in contrast, tools took a big portion of the investigation. Similarly, content needs more investigation as only three research studies explored suitable CT content for early childhood. Deriving from literature reviews and found gaps, we developed the Computational Thinking Pedagogical + Framework and the Operational Developmental Coding Stages for early childhood. More details of each element described in the below sections.

4.2 Child

Previous research investigates which cognitive abilities underlie CT [189]. They suggest that CT acquisition depends on three cognitive abilities: fluid reasoning (Gf), visual processing (Gv), and short-term memory (Gsm) [226]. These three abilities need to be at a certain maturity threshold for computational thinking to start. Development skills influence the ability to understand; the more maturate the skills are, the more complex a task the child can complete. Marcos Alez described the three cognitive abilities as:

> **Fluid reasoning** which is defined as: "the use of deliberate and controlled mental operations to solve novel problems that cannot be performed automatically. Mental operations often include drawing inferences, concept formation, classification, generating and testing a hypothesis, identifying relations, comprehending implications, problem-solving, extrapolating, and transforming information. Inductive and deductive reasoning are generally considered the hallmark indicators of Gf." **Visual processing** (Gv) is defined as "the ability to generate, store, retrieve, and transform visual images and sensations. Gv abilities are typically measured by tasks (figural or geometric stimuli) that require the perception and transformation of visual shapes, forms, or images and/or tasks that require maintaining spatial orientation with regard to objects that may change or move through space." **Short-term memory** (Gsm) is defined as "the ability to apprehend and maintain awareness of a limited number of elements of information in the immediate situation (events that occurred in the last minute or so). A limited-capacity system loses information quickly through the decay of memory traces unless an individual

activates other cognitive resources to maintain the information in immediate awareness" [226].

That raises the questions of what is the best age to start and which CT concepts (content) are suitable for their cognitive development ability? Piaget's Theory of Cognitive Development states people pass through four primary stages of development: sensorimotor, preoperational, concrete operational, and formal operations [85, 95]. Children 0–3 years old are in sensorimotor and preoperational stages, which makes them think their logical ability is very limited [95]. Accordingly, it is recommended to start incorporating CT around age 4, the preschooler age (3–5 years old) [79]. In this stage, children exhibit an increase in language and symbolic thinking ability [79]. As Sigelman and Rider described, they "can use words as symbols to talk about a problem and can mentally imagine doing something before actually doing it" [227]. Despite their capacity for symbolic thought, they lack logical thinking tools. As a result, they must rely on their perceptions, which can be easily deceived by appearances. In theory, after appropriate training, they can recognize patterns that involve symbols and use symbols or simple words to present sequences and algorithm designs. Previous research has shown that children as young as 3 can do unplugged CT activities, and those 4–6 years old can build and program simple robotics projects (Section 3.2.1).

4.3 CT Content

For CT learning to be successful, educators must first understand and identify the concepts that are developmentally appropriate for young children. In the past decade, it is less common (or even rare) to see research investigate which content is suitable. The literature review shows three main areas of research investigating the CT content for young children.

4.3.1 Seven Powerful Ideas of Computational Thinking

Marina Bers proposed seven computational thinking concepts based on theoretical and scientific research frameworks and resources using coding, unplugged, and robotics experiences. Her work was inspired by Papert's philosophy book, *The Mindstorms: Children, Computer, and Powerful Ideas* [228]. She called the CT concepts the "seven Powerful Ideas." Her studies have shown that those seven concepts are suitable for children as young as 4 years old, and they can be used in simple programming to create robotics projects and animation projects [155], described in Table 4.1.

Table 4.1 CT Concepts—Seven Powerful Ideas of Computational Thinking [155]

Powerful Idea	Definition	Example
Algorithms	Sequencing/order, logical organization	Child understands that KIBO blocks must be scanned in a specific order
Modularity	Breaking up larger task into smaller parts, instructions	Child use repeat blocks in order to accomplish a goal rather than scanning a large number of blocks
Control Structures	Recognizing patterns and repetition, cause and effect	Child recognizes that they must use a begin and an end when making a program and are able to use if blocks and repeat blocks
Representation	symbolic representation, models	Child sees the difference between the blue motion blocks and the Orange sound blocks
Hardware/Software	Smart objects are not magical, objects are human engineered	Child describes what the function of KIBOs electronics do. Child understands that you must give the robot a program in order for it to work
Design Process	Problem solving, perseverance, editing/ revision	Child has the capability to plan and test an idea in order to improve a project
Debugging	Identifying problems, problem solving, perseverance	Child identifies a bug in either hardware or software and is able to fix the problem

4.3.2 CT Skills with AHA Island [229]

Fundamental CT concepts that can be delivered through media and engineering targeting low-income 4- to 5-year-old children and their parents at home have been developed through the

AHA! Island project. The AHA! Island project is funded by the National Science Foundation (NSF) and aims to teach CT concepts and skills through spared joint engagement between media and tasks. They distribute a collection of cartoons, videos, and hands-on activities around suggested fundamental CT concepts. The proposed CT concepts support the development of CT-based problem-solving strategies relevant to any number of real-world problems [229]. See Table 4.2.

Table 4.2 CT Concepts by AHA! Island Project [229]

CT	Activities
Design	Create, Test, Improve
Sequencing and algorithmic thinking	Sequencing: Step It Out
Debugging	Make It Work

4.3.3 STEM Plus Computation (STEM + C)

STEM+ Computation (STEM + C) focuses on CT concepts that can be integrated with engineering thinking for kindergarten through 2nd grade (K−2) learners to support STEM education in informal and formal learning settings. It proposes a suitable foundation for children to develop persistent beliefs about their abilities that can either support or hinder later STEM learning. Purdue University research’s groups developed the concepts from identifying the relation between CT and STEM. They described that CT already exists in the Picture STEM curriculum, as the previous CT definition highlights the problem-solving strategies and skills. They used suitable CSTA; ISTE; Google education; BBC; and the Australian Curriculum, Assessment and Reporting Authority [18]. See Table 4.3 for which CT concepts are suitable for early childhood [230].

Table 4.3 STEM Plus Computation (STEM + C) [230]

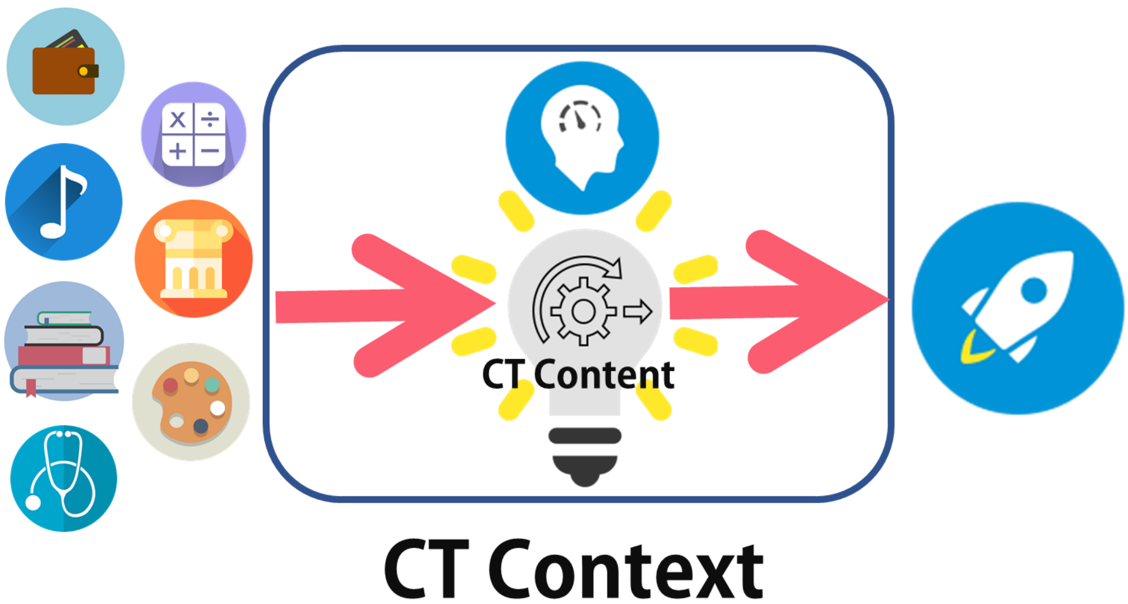
CT Competency	Definitions
Abstraction	Identifying and utilizing the structure of concepts/main ideas
Algorithms and Procedures	Following, identifying, using, and creating an ordered set of instructions (i.e., through selection, iteration and recursion)
Automation	Assigning appropriate set of tasks to be done repetitively by computers
Data Collection	Gathering information pertinent to solve a problem
Data Analysis	Making sense of data by identifying trends
Data Representation	Organizing and depicting data in appropriate ways to demonstrate relationships among data points via representations such as graphs, charts, words or images
Debugging/Troubleshooting*	Identifying and addressing problems that inhibit progress toward task completion
Pattern Recognition*	Observing patterns, trends and regularities in data
Problem Decomposition	Breaking down data, processes or problems into smaller and more manageable components to solve a problem
Parallelization	Simultaneously processing smaller tasks to more efficiently reach a goal
Simulations	Developing a model or a representation to imitate natural and artificial processes

4.4 CT Context as a Medium

4.4.1 Integrating with Non-CS Disciplines

The literature review shows that CT can be delivered using two methods: integrated with other non-CS disciplines or directly taught using CS activities [219]. Integrating with non-CS disciplines uses CT as a medium to deliver a discipline objective such as language, math, music, art, and others [219, 231, 232]. Successful integration can be achieved when CT context contributes to understanding new material while learning CT. The ultimate goal is to let individuals master CT skills and employ them efficiently to create more efficient solutions for non-CS fields. Someday, devising computational solutions and transferring the solutions into real results using machines. See Figure 4.4.

Figure 4.4 CT as a Context to Deliver Non-CS Disciplines



4.4.2 Teaching CT as Stand-alone Lessons

The literature review shows that teaching CT as a standalone lesson in early childhood happens through implementing the CT as a pedagogy [219, 233], describe in the next section.

4.5 Computational Thinking Pedagogical + Framework

The literature review shows that the "CT pedagogy element" has the second largest number of studies. Analyzing those results identifies that "Robotic" and board tools were the number one method to teach CT [234, 235], especially since it does not require a screen as it is delivered through tangible coding. Then the "Unplugged," "Making" [219, 230, 231, 236, 237], "Coding", and "Engineering" [219, 232, 238] activities came into the second places. Similarly, Donna Kotsopoulos suggested that unplugged, tinkering, making, and remixing are effective pedagogical experiences to train CT for young children in her Framework (CTPF), [239] presented in Figure 4.5. Her four experiences are designed from constructionism and social-constructivism theories. While NAEYC proposed making, tinkering, and engineering as three important overlapping concepts to teach STEM [240], see Figure 4.6. Lastly, data can be another medium to deliver CT. STEM+C identifies CT concepts that require data handling, such as "data collection," "data analysis," and "data representation" [238, 241-243].

Figure 4.5 Computational Thinking Pedagogical Framework [239]

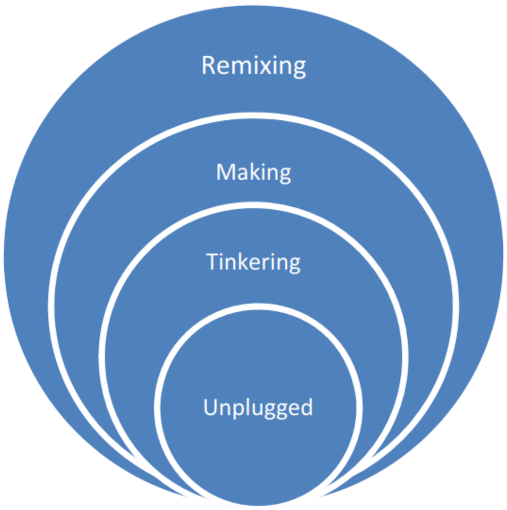
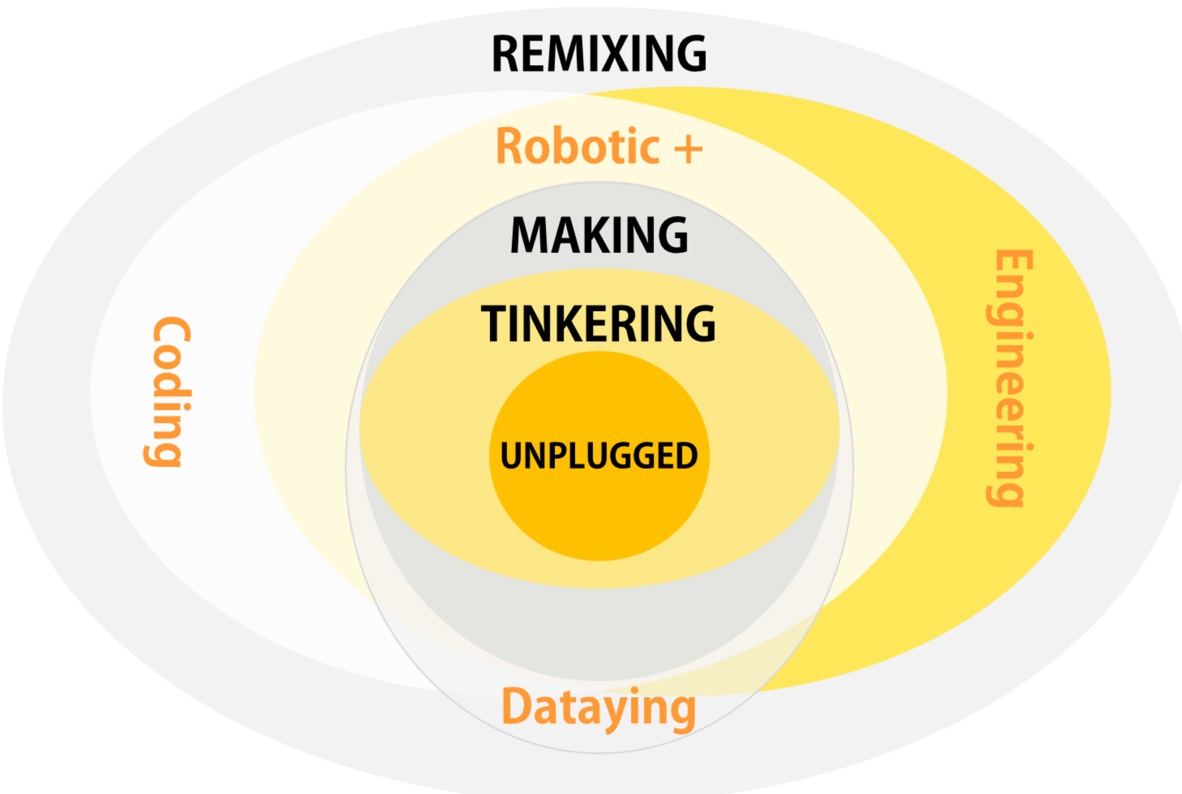


Figure 4.6. CT Pedagogical Experiences [240]

By analyzing the literature of the "CT pedagogy element" as a lens, we developed the Computational Thinking Pedagogical + Framework that consists of 8 pedagogical experiences: Unplugged, Tinkering, Making, Remixing, Robotics +, Engineering, Coding, and Data analytic (Dataying), presented in Figure 4.7.

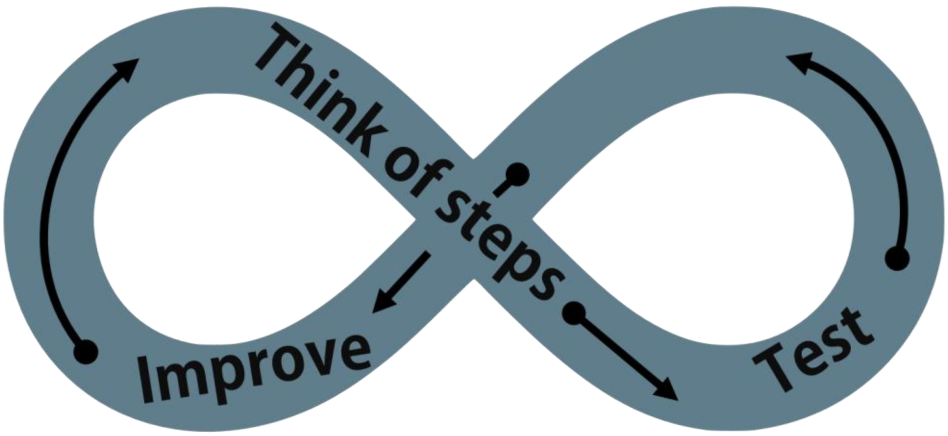
Figure 4.7 Computational Thinking Pedagogical + Framework



4.5.1 Unplugged

Unplugged experiences are activities implemented without the use of computers. Like doing CT exercises on coloring sheets. Or even not using any materials at all, like thinking of steps and reflecting. Both mainly focus on training thinking ability. Implementation of thinking can be defined in this stage as the ability to think of exact instructions needed to complete a task, where following the exact instructions should lead to the desired outcome. We propose a foundational thinking process that can train thinking for unplugged activities through a thinking loop: think of steps, testing the thinking, self-reflect on steps, fix the steps and go back to the testing. (See Figure 4.8).

Figure 4.8 The Coding Foundation Process (Coding-Thinking Process)



For example, describe the exact instruction [232] on how to make a peanut butter sandwich. If the instruction did not specify how to hold the knife, it may be held upside down. A child needs to fix the instruction by adding more details before trying again. Maybe the next time, the child did not mention the amount of peanut butter to use. The child should fix every detail and try again until they give the instruction to make the perfect peanut butter sandwiches.

4.5.2 Tinkering, Making, and Remixing

Tinkering experiences primarily involve activities that take things apart and changing or modifying existing objects. Constructing new objects is the primary focus of making. And remixing refers to experiences that involve the appropriation of objects or components of objects for use in other objects or for other purposes. Objects can be digital, tangible, or even conceptual. While NAEYC defines tinkering experiences as “using stuff” [240]. Therefore, tinkerers disassemble one object and change or modify it. Making is "using stuff to make stuff (that sometimes does stuff, but sometimes is just cool)." Makers follow instructions to create something [240].

4.5.3 Engineering

Engineering is using things to build a physical item to solve a problem. It is driven by a need or a desire [240]. Engineering activities often involve defining a problem in terms of multiple criteria—such as available materials and time—and then going through a process to solve them [155]. Bers said the engineering cycle for early childhood learners involves six steps: suggesting possible solutions, selecting the most convenient one, creating a prototype, testing, and enhancing the product, (see Figure 4.9) [155].

Figure 4.9 Engineering Design Process Cycle for Early Childhood [155]

4.5.4 Coding

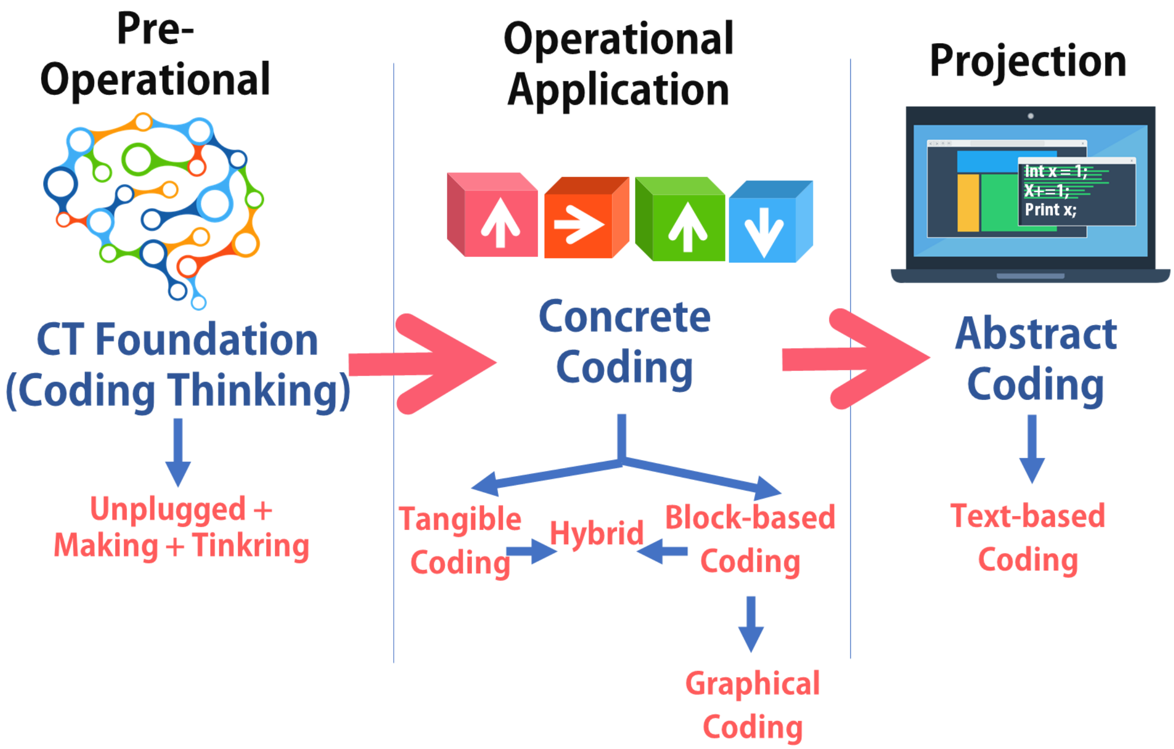
The engineering description also can align with coding. Both require a process to "make stuff that does stuff" [240]. However, coding and engineering are different in their product because engineering is mainly working with a physical object where coding with a digital process. Coding can be described as a process of creating step-by-step instructions a computer understands and needs [219]. The same engineering cycle can be used together with appropriate coding context that was described in Section 4.4 [155].

4.5.4.1 Operational Developmental Coding Stages

In general, children become better at coding as their cognitive ability advances. Children in the preoperational stage rely on their perceptions to solve problems [72]. Therefore, teaching anything new to a child in this stage requires starting with a concrete method and then moving to the abstract [72]. Also, children of this group are not familiar with computer-related language [244] and should be introduced to the necessary thinking activities before they are introduced to computer language. It recommended using CT contexts in sequential steps to help better train the CT abilities of children.

We propose three progressive stages to train thinking for those who teach coding for early childhood, illustrated in Figure 4.10. It starts with the Pre-Operational stage (coding thinking stage), moves to the concrete implementation stage (operational), and ends with the abstract stage (Projection). Each stage requires a different context. Take the example of moving a robot from point A to point B using code. Children need first to visualize the path that the robot should follow with accurate steps and direction, then transfer the thinking into visual objects (code), and finally extend their CT ability to include advance implementation. The first step highly depends on the algorithm's thinking ability; the second involves more engineering and coding ability to construct a project. The last step needs high abstract thinking and implementation abilities to replace the concrete.

Figure 4.10 Operational Developmental Coding Stages (CT Coding Development Stages)



4.5.4.1.1 Pre-Operational Stage (CT Foundation)

Machines will not think on behalf of humans, and they definitely will not try to understand what humans mean. Therefore, a child needs to be trained on how the machine takes orders. Machine language follows the *exact* instruction [232]. The coding-thinking stage prepares children to be able to use algorithmic steps [236]. It is recommended to start this stage after doing the Coding Foundation Process in Figure 4.6.

By the end of this stage, children are expected to understand algorithmic steps and to describe the steps verbally using commands (e.g., go straight ahead, go right, go left, go straight ahead). They will realize that the object needs a starting position and an ending position. They will be able to see different solutions such as having different routes for a robot to go from A to B, which differ in length or the sequence of commands. Children will be able to write down the steps correctly, try the commands independently, and explain why the steps were arranged in this order.

4.5.4.1.2 Operational application Stage (Concrete-Coding Stage)

In this stage, children need to apply different contexts. If stage 1 is preparing the recipes, then stage 2 is cooking them. Children need to translate their thinking into real computer language using a pedagogical coding environment. It provides a way for children to see all the coding options, select the desired command, and sort them accordingly. At the end of this stage, children should be able to formulate activities; practice plane and spatial orientation; deliver basic commands and movements; control the correctness of direction; learn how to quickly evaluate the situation; and recognize chronological order.

There are three types of concreate coding: block-based, tangible-based, and hybrid. All allow children to visually see or touch the build solutions in a convenient way.

Block-Based Coding

> “Block-based coding is a pedagogical coding environment that takes the form of dragging blocks into a scripting area and snapping them together to form scripts. The block has text and an icon to describe its usage. Along with using block shape to denote usage, there are other visual cues to help programmers, including color-coding by conceptual use and nesting blocks to denote scope. If two blocks cannot be joined to form a valid syntactic statement, the environment prevents them from

snapping together, thus preventing syntax errors but retaining the practice of assembling programs instruction by instruction" [231, 233, 245].

A growing number of environments have adopted the block-based programming approach to lower the barrier to programming across a variety of domains. The block-based method has become widespread in recent years with the emergence and popularity of Scratch.

Graphical-Coding Based

Block-based coding suits older children as its functionality requires the ability to read and write [234, 235]. However, young children have not developed this ability yet. For this reason, graphical-based coding was developed [226]. It carries all the fundamental features of block-based but is presented in a more child-friendly interface with simpler functionality where the blocks fully depend on graphical representation. Even children who cannot read can create a game or animation using it. ScratchJr—with some 88,000,000 users worldwide—is one such tool [246].

Tangible-Based Coding

Tangible programming tools are often similar to block-based but they incorporate physical objects to represent the code instead of digital blocks. Tangible-based coding is often developed to resemble stacking blocks or building with a tangible object. Each block represents an action, such as moving forward, rotating, or clapping. This method also has blocks that represent the coding functionality like start, end, if, and loop. Children need to align them logically to make the tools. Usually, robots follow instructions. If there is something wrong with the code—such as no end statement, the tool will alert the programmer with a sound or light to inform them that something is wrong with the code and they need to debug like Kibo [231, 245].

Hybrid Coding

Research suggests that some younger students find tangible programming both engaging and easy to use; other children see it challenging, especially older children as they prefer a graphical interface, Accordingly, researchers tried to find a hybrid method that melds tangible and graphical approaches [244]. Some research proposes that hybrid programming tools are more attractive and enjoyable among girls when they include artistic creation with sensors such as sound, light, and motion [247].

4.5.4.1.3 Textual-Coding Stage

Textual programming can be described as the advanced textual features that can produce complicated software for professional use. With textual programming tools, text editors write and modify the code and a compiler debugs the code then coverts it into a program. Although older students are the primary users of textual coding, opportunities do exist for younger students [231].

4.5.4.2 Progression Learning between Coding Stages

In the abstract and concrete, a child moves through other stages to build coding skills. Bers developed the coding stages framework, describing a progression-learning path in coding for young children that starts with simple skills and progresses to more complex ones. She proposed five stages capturing this developmental trajectory: emergent; coding and decoding; fluency; new knowledge; and purposefulness as described in Table 4.4 [248].

Table 4.4 Bers Coding Stages Framework [248]

Coding Stage	Description
1. Emergent	• The child recognizes that technologies are human-engineered and are designed with a variety of purposes. • The child understands the concept of symbolization and representation (i.e. a command is not the behavior, but represents the behavior). • The child understands what a programming language and the purpose of its use is (knows that a basic sequence and control structure exists). • The child is familiar with the basics of the interface (turn the tool on and off and correctly interact). This is a beginner's stage.
2. Coding and Decoding	• The child understands that sequencing matters and that the order in which commands are put together generates different behaviors. • The child has learned a limited set of symbols and grammar rules to create a simple project. • The child can correctly create simple programs with simple cause and effect commands. • The child can identify and fix grammatical errors in the code. • The child performs simple debugging through trial and error. • The child engages in goal-oriented command exploration. The most growth can be seen at this stage. Children learn the basics of the programming language and understand it can serve to create projects of their choice.
3. Fluency	• The child has mastered the syntax of the programming language and can correctly create programs. • The child is personally motivated to create complex programs. • The child understands how to distinguish and fix logical errors in the code. • The child is beginning to be strategic in debugging. This stage is characterized by the child moving from a "learning to code" to a "coding to learn" creative stance.
4. New Knowledge	• The child understands how to combine multiple control structures and create nested programs that achieve complex sequencing. • The child engages in more goal oriented logical exploration with their programs. • The child is personally motivated to create complex programs. • The child is strategic in debugging and has developed strategies. • The child learns how to learn new commands or novel uses of the interface. This stage is characterized by the child's ability to use their knowledge to create a personally meaningful project and if needed, acquire new knowledge on her own to meet the demands of the project.
5. Purposefulness	• The child can skillfully create complex programs for their needs and purposes. • The child understands how to analyze, synthesize, and translate abstract concepts into code and vice versa. • The child is able to identify multiple ways to translate abstract concepts into code. • The child understands how to create programs that involve user's input. • The child can create multiple programs that interact with one another. • The child can debug multiple control structures. This stage is characterized by the child being able to code in a rapid and efficient manner at high levels of abstraction requiring skill and flexibility and applying those skills to create a personally meaningful project. A child who reaches this stage has mastered all of the commands, grammar and syntax, of the programming language and has the ability to express herself through the project they create.

4.5.5 Robotics +

Robotics was born as a combination of the coding processes and create digital projects; and engineering processes and create a physical object. It requires physically building the parts and digitally controlling the movements and actions. Robotic and electronic tools become one of the popular subject to teach STEM in early childhood [244]. especially that it doesn't require screen. Now, Robots as a discipline can deliver many concepts, such as electronics, mechanics, artificial intelligence [249]. There are different types of Robotic and electronic tools used in for early childhood describe in section 4.6.

4.5.6 Dataying

Dataying is the basic handling of data from collection, analysis, and representation, which are the suggested data concepts for early childhood. The name "dataying" was selected intentionally for its similarity to coding and its catchiness for early childhood learners. The concept itself is not new to the early childhood curriculum. Through play, toddlers learn that rotating shapes can help those shapes better fit into the sorter [250], similar to data analysis. When preschoolers sort blocks by colors [251], this is similar to collecting and representation. And young learners also use data to make additional data, evidence when they mix the colors yellow and red to make orange. The literacies describe activities related to dataying.

4.6 CT Tools and Innovations

The literature review shows that the tools and innovations element has the greatest number of studies. We used the technology classification described in Section 3.2.5 to categorize the literature reviews results and proposed three main categories: media, applications, and devices. The applications category, and its subcategories, works to train the CT. The information creation subcategory has applications where children use coding to produce digital projects like games and animation. Some "information consumption" applications provide computational thinking training, such as Kodable where children apply algorithmic thinking to progress in the game. In addition, digital environments like Club Penguin [252] can provide environments for problem-solving and coding Summarizing some of results of this category identify the following applications and platforms: Scratch [233], Kodable [241], Cargo-bot [241], Codeable Crafts

[241], Daisy the Dinosaur [241], Kodable [241], Lightbot Jr [241], PBS KIDS ScratchJr [241], Robozzle [241], Run Marco! [241], Scratch Jr [253, 254] [241], Sushi Monsters [241], Draw2Code [253], The Foos [241] and Tynker [241]. Panwapa VW [208], Neopet VW [208], Habbo VW [208], Club Penguin VW [252], Webkinz VW [252], Barbie Girl VW [252], Moshi Monsters VW [252], Lego Universe VW [252],

Likewise with the devices/equipment category, we can use several methods. With electronic tools that don't require application, like KIBO, children use coding skills by sorting tangible wooden blocks to control the robot movements. For electronic tools that require applications and where children can control their electronic boards, such as Makey key, children use the electronic circle concepts and real-life objects together in micro-boards. Then they use a block-based coding app to control what the action is and when it will be triggered, like making a sound if paper is touched. Children cannot control electronic boards, however, they use the tools to do activities in the application; for example in Osmo. The Osmo application connects the tool object wirelessly to the micro-boards, where it is hidden inside the tools. It requires a clip-on camera to detect movement in the physical world. These types of applications have activities that can be solved by moving the object in the physical world. Some devices and equipment that were mentioned by the Raspberry Pi foundation that can teach coding to different ages KIBO [255], Snap Circuits [256] littleBits [256], Code Bit's [253], Circuit Stickers [256], Sphero [256], Ozobot [255, 256], Dash and Dot [256], Bee-Bot [255, 256], Cubetto [255],Thymio [255], Torino [255], Tanpro-Kit [255], Lego WeDo [244, 256] [234], Lego Mindstorms [256], Kubo [255], Pico Cricket [256], Vex Robotics [256], Makey Makey [256], PicoBoard [256], BlinkM [256], Sens Board [256], Phidgets [256], micro:bit [256], TinkerKit [256], Hummingbird [256], .Net Gadgeteer [256], StoryBlocks [245], Tactcode [255], AlgoBloc [255], Strawbies [255], PictoBlox [257], Osmo [258], CHERP [255], Blue-Bot [255], E-Block [255], Mouse Robo [258], AR-Maze[255], Tern [255], MOSS [255], and Quetzal [255, 259], PROTEAS [255], Flow Blocks [260], Topobo [260], Robot Park [260], I/O Brush [260], Dinosaur Pleo [255]..etc.

The media and animation tool also require supportive technology to teach CT. For example, in the AHA! Island project, children created animated stories, music videos, and live-action videos to foster CT [261].

4.7 Facilitators

Teaching computational thinking requires at least two types of knowledge and abilities: knowledge of the CT and knowledge of disciplines [254]. Effective educators need to be able to determine the types of understandings that students must have to be successful and design new ideas. Educators also must provide computational activities to provoke students to engage in CT [218]. In addition, educators need the skills to aid students in solving complex discipline problems using CT [232]. If educators themselves are not adequately skilled, they might lose control of the learning process and become uncomfortable [232]. Teachers' technological, pedagogy, and CT abilities must be diagnosed to provide appropriate training correctly [232]. Thus, we proposed an instrument to serve this purpose proposed in Section 7.5.2.3.

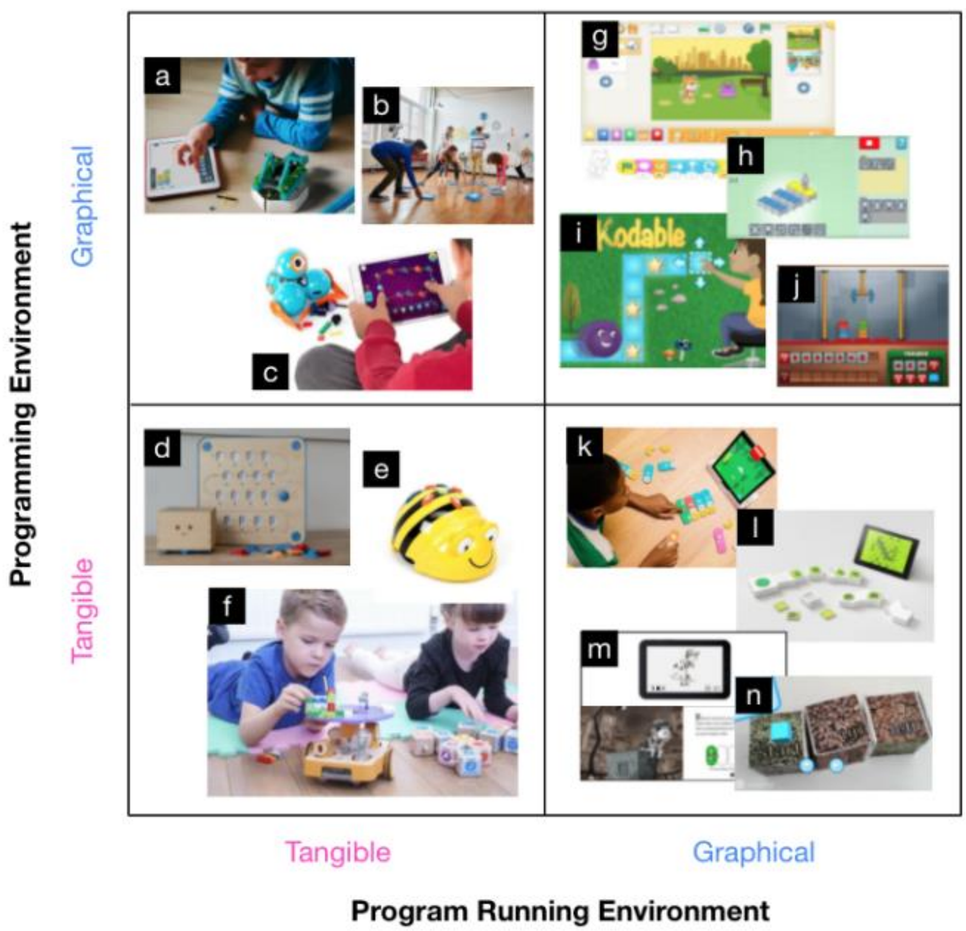
4.8 CT Environments

The environment to teach CT is not a new concept; Papert introduced it in his book *Mindstorm* [228]. Using different settings for CT may inspire learners' interest, and some environments appear to be more motivational than others [242]. The three proposed environments for learning are applicable to teaching CT. The physical environment arrangement is key for tinkering, making, engineering, or coding. Some coding solutions require no more space than a desk or table. Others—such as engineering moving a robot—require a larger space.

Additional research has recommended using technology tools in a specialized environment, such as a makerspace, to allow young children to explore [154, 262]. Makerspaces differ from traditional early childhood environments because they provide access to tools that would enable children to build experiences from tinkering and to observe their peers [263].

Hyejin Im proposed four experiences over the three environments: only tangible (in the physical world); only virtual (the digital world); or tangible-graphical and graphical-tangible (a hybrid environment) [253]. Figure 4.11 shows Hyejin categorization. First categorize based on "the programming environment and programming running environment; second, whether the interfaces are tangible or graphical."

Figure 4.11 Kits Categorized Based on the Coding Environments [253]



4.9 CT Evaluation and Instruments

Educators focus on gathering relevant information about student performance related to the curriculum objective in the classroom. And naturally, the objective is not related to CT learning. Part of best practice in CT is to be able to measure the CT acquisition. Thus, evaluation/instrument should be added as an extra layer to the pedagogy.

There have been relatively few studies in which computational thinking skills were assessed for young children. It is either not suitable for the classroom settings, or educators are not comfortable and feel confused overusing it [264].

DevTech tries to solve this problem by building instruments suitable for children from ages 4 to 9 in classroom settings. In addition to supporting educators by offering training and certification to the use of the instruments in the school [265]. They developed five instruments that assist coding and computational skills. Two address graphical-block-based coding, 2 cover tangible-based coding, and one targets unplugged assessments: CSA-ScratchJr, CSA-KIBO, ScratchJr -Rubric, KIBO-Rubric, and TechCheck. The instruments assess coding progress using Coding Stages frameworks (CSA); a child’s ability to transform their coding knowledge into creating purposeful and creative projects inspired by previous studies (Brennan & Resnick); or measure the CT abilities using cognitive multiple-choice questionnaires.

4.10 CT Screen time

As previously described, CT can be taught with or without the use of a screen. Thus, screen time in CT concerns can only be considered with the technology activities. So, in theory the description of screen time in Section 3.2.9 can be implemented here. In the literature review, no studies investigate or describe screen time limits to learn CT. Instead, related searches investigated no screen coding and screen time coding for young children. Strawhacker and Bers investigate tangible KIBO (no screen) and graphical interface ScratchJr (screen) in a kindergarten setting [244]. Their finding showed little association between user interface and programming comprehension, although there may be an order effect when introducing user interfaces. Another study did the same, and those findings claim that all CT scores in robotics are higher than coding in their experiments. It argued that children are more familiar with the nature of the tangible coding blocks in addition to using their hands to arrange the blocks and support the learning [247].

Chapter 5 - Applications of CT "bes-T-ech" Framework

As described in Chapter 4, CT can be introduced into education curricula either by directly teaching the CT concepts as a stand-alone lesson using the Computational Thinking Pedagogical + Framework or by delivering non-CS disciplines through CT as a medium. The latter option helps educators to employ CT through their curricula by providing the steps that guide the integration.

This chapter describes the necessary steps to implement the *bes-T-ech* framework for the two types of projects then creating two programs that can teach CT for Early childhood. The projects were not pilot tested on large samples. Because of the Covid-19 pandemic, we couldn't reach early childhood students. However, experts from DevTech research group reviewed parts of the projects and provided feedback. In addition, the lessons were tested with my daughters Hooreyah, 6 years old, and Laila, 7 years old.

We examined the literature trying to identify gaps in the field. The literature reviews articulate that there is a need to have a resource related to CT in virtual worlds. The searching results shows several studies investigate Augmented reality and early childhood and more research of virtual world for older students. For integrating CT into non-CS disciplines, we considered teaching drama and acting using robotic because experts agree that dramatic play is an integral part of early childhood development. Dramatic play can teach self-regulation of emotions and actions.

5.1 "bes-T-ech" Application Form

We developed a form that shows the nine elements as a selection list with all the options that the educator needs to consider for the integration. This allows educators to see all available paths and select what suits their curricula objective.

After implementing the form, the results consider evaluation of the facilitators elements. The results can be used as an indicator to evaluate where educators require further support, and it is found to be more beneficial than general training. See the form in Appendix A. Completion of the form takes four steps: filling out the form; deciding the training; aligning the lessons with standards; and designing lesson activities using identified standards

5.2 Teach CT Using Drama/Acting for Early Childhood

The literature review articulates that there are no previous studies related to teaching CT using Drama and Robotic for Early childhood. At the same token, experts agree that dramatic play is an integral part for early childhood development as it carries a lot of advantages such as it can teach children to self-regulate emotions and actions [266]. Thus, our lessons were inspired by Jessica McCuiston's book *Teaching Drama for Little Ones* [267].

5.2.1 Filling the Form

Goal: Teach CT as: (select one)

(a) ◯Integrated lessons ◯ (b) Standalone CT lessons

If (a) answer:

Disciplines lessons: ……Teaching Drama and Acting………………………

(1) CT-Pedagogy- the theme of the form lessons: (multiple option can be selected)

☐ **Unplugged** ☐ Tinkering, ☐ Making,

☐ Engineering, ☐ Coding and ☐ **Robotic** ☐ Datayíng

(2) Tools: ………**KIBO**……………………………………………………………

(3) CT-Context

For Beginners children's: ◯ **Coding Thinking**

For intermediate: ◯ Block based Coding, ◯**Tangible Coding,**

◯ Hybrid Coding

For Advance: ◯Textual Coding

Not Coding: ◯ video Gaming/educational application,

◯ Animation ◯ Media ◯Other platform

(4) Environment:

◯ **Physical, at…School and Club**…… ◯Digital, type……

◯ Hybrid type…………and………..

(5) Assessment:

Graphical Coding: ◯ CSA-ScratchJr, ◯ ScratchJr-Rubric,
Tangible Coding: ◯ CSA-KIBO**, ◯ KIBO-Rubric**
Unplugged: ◯ TechCheck

(6) Screen Time: (for a lesson)
…..**0**…. minutes of screen Time and, **…60**…. minutes of No screen Time

(7) Child:
Children **Age..7..**
Age appropriate for tool? **☐ Yes** ☐ No
Age appropriate for environment? **☐ Yes** ☐ No

(8) CT- Content:
◯**7 Powerful ideas:** Algorithm, Modularity, Control structures, Representation, Hardware/Software, Design Process, Debugging
◯Aha Island Concepts: Design, Sequencing and algorithm, Debugging
◯STEM+C: Algorithm and procedures, Automaton, Pattern Recognition, Data collection, Data Analysis, Data representation, Debugging/Troubleshooting, Problem Decomposition, Parallelization, simulation

5.2.2 Determining the Training

After writing the summary: "Teaching Drama lessons using tangible language through unplugged, making, and robotic activities using the Kibo tool," educators need to assess their knowledge by looking at the "Drama lessons for young students", "tangible language", "unplugged methods", "Making method", and "Kibo".

5.2.3 Aligning Lessons with Standards

We aligned lesson learning outcomes with standards from PTD and CT frameworks for the drama lessons. The three used frameworks: technology (positive technological development); drama (Next Generation Sunshine State—The Arts); and CT (seven powerful ideas). See Table 5.1.

Table 5.1 Standards Aligned with Drama Lessons

	PTD	**Drama Standard** DRAMA Next Generation Sunshine State - The Arts	CT
Lesson 2	**Communication** sharing ideas and maintaining social relationships **Creativity** deeper level of thinking to expand perspectives and metacognition opportunities	**TH.3.S.3.3** **Emotions** Describe elements of dramatic performance that produce an emotional response in oneself or an audience.	**Algorithm** Construct a simple program using. block-based programming through step-by-step instruction

Then, educators should decide the lessons' objectives from the drama book lessons and use the proposed time (screen + no screen) to decide the lessons, as described in Table 5.2.

Table 5.2 Decide on the Learning Objectives

	PTD	**Drama Standard** DRAMA Next Generation Sunshine State - The Arts	CT
Lesson 2	Communication Creativity	If You're Happy and You Know It **(5 min)** I have Emotions **(15 min)** KIBO Decoration **(20 min)** KIBO Emotions and Motions **(20 min)**	Algorithm

5.2.4 Create Lessons Using Standards

The result is a curriculum that introduces seven powerful ideas from coding with KIBO robotics in a structured, developmentally appropriate way for children ages 7 and older. The starting assumption of the "KIBO The ACTOR" curriculum is that both CT and acting can enhance one another. Instruction in both can be leveraged in service of the other. Both can support learners in developing new ways of thinking about themselves and the world. Children can learn how to act by acting out a scene from a story book with several characters. They will talk about emotions but work individually. Developmental skills targeted with this lesson type are assisting students in their ability to work with others, problem-solving, and working on fine motor skills for building. Various check-ins will be scheduled through the unit and mini lessons will be given as needed. Figure 5.1 describes a lesson plan and developed activities. The remainder of the lesson can be found in Appendix B.

Figure 5.1 Kibo Lessons Activities

If You're Happy and You Know it (5 min)

The teacher will sing "If You're Happy and You Know It" song, and the children will do the action that follows the "If You Are" part in the music. The teacher will repeat the song with different emotions (sleepy, sad, surprised, scared...etc.); most children are familiar with it or will catch on quickly.

I Have Emotions (15 min) Communication

Give the students papers and markers; ask them to draw the teacher's facial expression, for example, a happy face. Select a student and ask him to reflect on his painting by pointing out which areas of the face makes us think a person happy. Let other students show thumbs up if you draw this expression. If some students have an unmentioned expression for the same emotion, let him/her describe it. Repeat with different emotions and let other students do the description. You can do this activity differently, such as handing the children sheets in A.2 and let them color it and let them guess when to use these expressions.

KIBO Decoration (20 min) Creativity

We will get our KIBO robot out and decide on an emotion from the emotion sheets. We will be talking about emotions and about ways we can decorate our robot to express emotions. Let the kids explore different ways of decorating the robots using recycled materials, such as Legos, scraps of construction paper, egg cartons, toilet paper tubes, etc. Recommend folding a piece of paper in half and have a facial expression on each side (two faces emotion sheet) to be used in the "KIBO Emotions and Motions" activity.

KIBO Emotions and Motions (20 min)

Ask the students to code the KIBO robot to move in a way he expresses the emotions on the two-face-emotions sheet. The code should have the KIBO robot show one side of the emotions sheet, then half-spin and stop, showing us the other side of the two-face emotions sheet. Remind students that they need to have a begin, middle, and end for any code. Give each student a turn creating a program.

5.2.5 Laila's Experience

This project was tested over my little two girls Laila and Hooreyah. Laila managed to do 5 lessons and Horreyah only joined parts that include making activities. I couldn't record her as she moves a lot from the camera and left to play with her relatives. Laila chose the lessons that she wanted to try. We covered, what is theater and puppet show in lessons one, some pictures and the dialogues for lesson one can be found in Appendix C.

Laila's Tech Background

She is a big fan of technology such animation apps and video games especially Minecraft and ROBLOX. I noticed her ability when she was 6 after she asked me while playing Minecraft whether I prefer flat or tall ice-cream. Out of curiosity, I asked her to do both. She created 3D and 2D ice-cream figures using blocks. I was impressed as I never taught her anything about dimensions. I started observing her while she was playing competitions in Minecraft. The game asked players to build a figure satisfying some rules and requirements. My son (13y) explained the requirements to her, then they build on their own. After all the players complete the task, they must rate (1=OK, 2=good, 3=awesome) each other figures. Despite her young age, Lili always got the highest medal (almost all the players give her 3=awesome). To observe her coding logic, I brought her a Code & Go Robot Mouse where she needed to provide a sequence or direction, so the mouse can go through the maze and eat the cheese. I placed the mouse facing the other side of the path, expecting her to give direction to rotate his face, then start moving to the cheese. Purposely, she gave directions making the mouse go backward and then rotate his face after reaching the cheese. Saying it's more fun, and mousey can smell the cheese.

5.3 Teaching CT Using Virtual Worlds for Early Childhood

Literature reviews shows a need to take advantage of young children's passion for playing VW. Thus, we developed a VW described in chapter 6 and use it as a pedagogical environment to train CT skills.

5.3.1 Filling the Form

Goal: Teach CT as: (select one)

(a) ◯Integrated lessons ◯ **(b) Standalone CT lessons**

If (a) answer:

Disciplines lessons: ……………………………………………………

(1) CT-Pedagogy- the theme of the lessons: (multiple option can be selected)

☐ Unplugged ☐**Tinkering,** ☐Making,

☐ **Engineering,** ☐ **Coding** and ☐ Robotic ☐ **Dataing**

(2) Tools: ………Roblox……………………………………………………………………

(3) CT-Context – which programing language?

For Beginners children's: ◯ Coding Thinking

For intermediate: ◯ Block based Coding, ◯Tangible Coding, ◯ Hybrid Coding

For Advance: ◯Textual Coding

Not Coding: ◯ video **Gaming** /educational application,

◯ Animation ◯ Media ◯ Other platform

(4) Environment:

◯ Physical, ◯Digital,…VW… ◯ Hybrid

(5) Assessment:

Graphical Coding: ◯ CSA-ScratchJr, ◯ ScratchJr-Rubric,

Tangible Coding: ◯ CSA-KIBO, ◯ KIBO-Rubric

Unplugged: ◯ TechCheck

(6) Screen Time: (for a lesson)

…60…. minutes of screen Time and, ……. minutes of screen Time

(7) Child:

Children Age……7..

Age appropriate for tool? ☐ Yes ☐ No

Age appropriate for environment? ☐ Yes ☐ No

(8) CT- Content:

◯**7** Powerful ideas: Algorithm, Modularity, Control structures, Representation, Hardware/Software, Design Process, Debugging

◯Aha Island Concepts: Design, Sequencing and algorithm, Debugging
◯**STEM+C:** Algorithm and procedures, Automaton, PatternRecognition, Data collection, Data Analysis, Data representation, Debugging/Troubleshooting, Problem Decomposition, Parallelization, simulation

5.3.2 Determining the Training

The form summary: Teaching CT lessons using VW through activities within the VW that use unplugged, making, and tinkering, Coding, Dataying, Engineering. For this summary the needed knowledge besides the CT content is how to start; playing; controling the VW; creating lessons; and troubleshooting, which can be gained from playing the game as a player and as an administrator.

5.3.3 Aligning Lessons with Standards and Pedagogy

CT Activities	PTD	CT Content
Tinkering Engineering Coding Datatying	Choice of Conduct, Communication, Creativity, Collaboration, Community building	Patten recognition Decomposition, Algorithm, Debugging, Data Collection, Data Analysis, Data representation,

5.3.4 Create Lessons Using Standards

Figure 5.2 describes a lesson plan and developed activities.

CT Activities	Description
Activity 1: Tinkering	Adopt a Pet **(10 min)** Treasure Hunting (**10 min) (Optional)**
Activity 2: Engineering	Build a House for Mr. Elephant **(10 min)**
Activity 3: Coding	Help the Flamingo's Family **(10 min)**
Activity 4: Datatying	Escape Rooms **(10 min)**
Activity 5: Making	Treasure Hunting (**10 min) (Optional)**

Figure 5.2 CT VW Activities

Tinkering: Adopt A Pet (10)

The player needs to go around the VW trying to explore to find the appropriate pet they want to adopt they need to think carefully which pets they want as they can't change it later. The player needs to feed the pet the right food and the right color; the red cat can eat red fish or dry red food. They can either hunt/farm/fishing or work to get coins then buy the food from the grocery. The child needs to be able to identify the right colors (pattern reignition) and choose what food to give first, as the pet will decide if they accept the food or not. The child will try to feed the pet until the right food is selected (choice of conduct).

Tinkering: Treasure Hunting (10) (Optional)

Children can hang out with their friends searching around and clicking as the island has some hidden gems (data collection). In addition, they can play with their pets and peers in the playground, waiting to take turns for items like the seesaw.

Engineering: Build a House for Mr. Elephant (10)

The task is to help the Island community by solving their problems. One community that needs help is the circus. Children need build a house for a stuffed elephant; it is raining heavily on his head and he is not happy. There are a limited number of blocks with different sizes, shapes, and colors. The children need to be able to use the blocks correctly to build the right size house; if the house is too small, the elephant won't fit, and if the house large, there will not be enough blocks (decomposition of the problem). This activity is inspired by the Aha Island lesson.

Coding: Help the Flamingo's Family (10)

The task is to help the island community by solving their problems. The flamingo's family is searching for a babysitter who can watch their kids for 10 minutes (community building). One of the baby-sitting tasks is to feed the baby. Every time the baby is fed, the player gets more points. But the baby can't reach the milk on its own, he needs help. Children must control the baby by moving it through an algorithm to reach the milk. The algorithm has five levels. The first two are controlling the movements with colors and the next three stages through arrows. This activity is adopted from obstacles in Box Island solution guide where players have a game involving moving a character using an algorithm.

Dataying: Escape Rooms (10)

The child will help Granny Squirrely to unlock her house. She has three rooms and each has a different passcode to unlock it. Children need to identify the colors and their patterns to answer color and shape riddles that will lead them to a letter putting the letter together should let open the doors (data collection, data analysis, data representation).

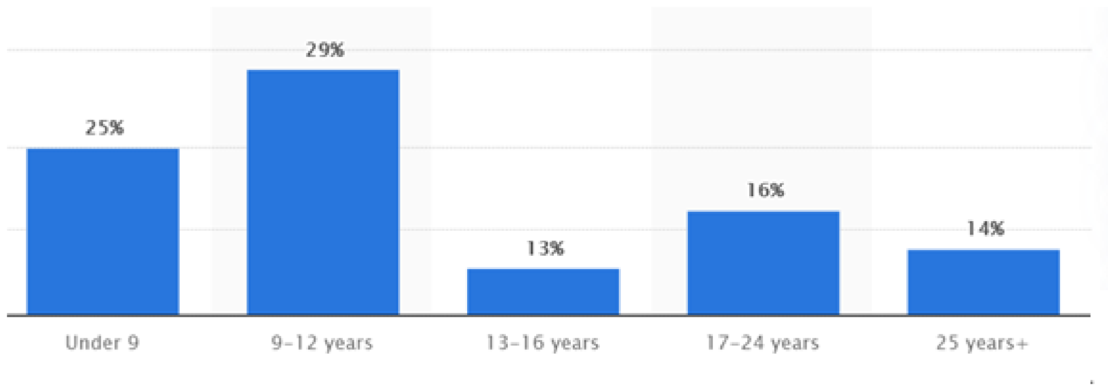
Making: Treasure Hunting (10 min) (Optional)

The player needs to go around the VW click on the object try to find treasure. Sometimes they need to build a ladder or bridge to reach it.

Chapter 6 - CT Virtual World for Early Childhood

Virtual worlds (VW) are considered a tool that opens new horizons toward more effective learning, as they can increase motivation in children to learn by making learning in different dimensions [252]. One such VW is Roblox—one of the most popular VW among young children. The data state that there are more than 33.4 million active players daily [268]; 25% of the players are younger than 9 years old; see Figure 6.1 [269]. That means at least 8 million young children play this game a day. Thus, Roblox was chosen as a be the pedagogy environment.

Figure 6.1 Age Distribution of Roblox User worldwide as of September 2020 [268]



At the time of this research, there were no VW designed to teach CT for early childhood ages in the literature. The purpose of this chapter is to begin filling the gap by developing resources to support creating VW for this age range and to create a blueprint for a VW that use the CT *bes-T-ech* framework.

6.1 Background of Game Studies and VW

6.1.1 Gaming Theories

Using VW as an educational tool in the classroom can be a challenging task for non-gamer educators. A lesson about VW as a medium must follow gaming theories related to learning. Game studies suggest that a lesson can be delivered as a game under two philosophies: storytelling or artistic sequencing in general. This is an old debate in game studies between narratology (game as storytelling) versus Ludology (games as rules in actions and events) [270]. Narratology is the school of thinking of a game as a text; it analyzes what happens as a whole package— like a whole book and not just the words and sentences. Analyzing would happen in the game through looking at the playing experience as a whole, not looking into the rules of playing and how the game is built [270]. On the other hand, Ludology looks at it as ludo (which means game or play) with emphasis on the player—what is the player doing, how is the game making them do it—and focuses on the rules of the game and its system [270].

To properly deliver lessons to early childhood critics of VW, the narratology perspective should be used because it can create experiences that draws attention to plot or story [271] While this may not be valid for all kinds of narratives, it certainly is suitable to deliver a CT lesson for this age range to keep them engaged.

6.1.2 Characteristics of the Gaming Generations

The characteristics of games get developed indirectly following different theories. According to Uusi-Mäkeläa, game goals can be categorized into three generations [272]. Games started simple, using stimuli and responses. They relied on repetitions to reach the end of the game, for example original Sega games. The CT lesson in this generation is considered here as direct learning and control input. The second generation is characterized by ognitivism/constructivism, where the learning focuses on the learner. Still, the levels were not specifically built as open-ended tasks; the players go into sequences of challenges, and the player can choose what to do first. The third generation supports the theories of constructionism and social-cultural aspects. It has open-ended tasks where teams/players can pair from anywhere and work together using the environment's setting to complete a task, like building a town. They can choose any materials, location, or design. This type of game requires higher thinking and mechanical skills to solve problems. Regardless, the three generations can overlap, and all are still present in contemporary learning games.

Most likely, Roblox education lessons would fall under the second and third generations. Further detail about the second and third generations can help to support building our model structure and highlight elements that educators should be aware of and use to transform lessons into a game mission.

6.1.3 Game Studies

According to Salen et al.'s book *Rules of Play*, the main game elements are objective, attributes, procedure, environment, and interactions. Understanding these elements aids in transforming lessons into interactive games [273].

Objective: VW lessons have two sides: gaming and education. Education objectives are achieved through completion of the game objective. Lessons can be related to achieving subject standards that suit students' education levels. Completing game tasks through quests or missions can be the game objective, which can be used to embed lesson objectives [273]. For example, a player is doing the lesson task by making game-rule decisions. While building a farm with certain animals to learn about them, the player must decide whether to finish the farm's tasks and then collect coins and resources for the next task or to first collect coins and resources and later go back to the farm to complete its quests. The player could focus on the game rules and pay less attention to learning English.

Attributes: These are a set of characteristics in the game that control how the game works, such as game rules and procedures. Game rules in VW control boundaries and limit players’ actions [273]. one example would be if touching the fire can kill a player. Game rules can support or hamper learning. Proper usage of the rules can develop cognitive process while learning, especially when players need to have a fast reaction to the rules to avoid losing.

Procedure: This is the sequence of events in a game; there are predetermined rules and a set of actions to make while playing. Students need to adapt to the steps to proceed and complete tasks [273]. For example, Draw-Two-Cards in the UNO card game forces the other player to draw two cards. Sometimes directions are labeled throughout the game for the player to progress or make the experience smoother.

Procedure should be considered while designing the lesson. For example, where should the player start the game and how. In game studies, researchers divided the procedure into four parts [273]. The theme/setting plays a significant role in deciding the lesson procedure. The ludology and narrative studies critique that was described above also factors in here. It is believed that a proper theme can help students get immersed in the game and satisfy the lesson’s objective [274]. Also, a proper theme can help “players feel more at home” with the game rules [273]. The CT lessons will be delivered as a story design.

Environment: This is a simulated space that holds its own properties. It can have a fictional environment, such as being a knight that is able to kill zombies. Lessons are built using VW features through existing or new obstacles in the game. Lessons can be physical or mental [273]. Physical obstacles require real-life actions—like clicking or pressing a button —to overcome or interact with other obstacles —like jumping or moving objects around. Another physical obstacle can be facing opponents such as computer-controlled enemies or other student players. Other obstacles are dealt with mentally. For example, players must solve riddles that require understanding words and ideas or complete puzzles using deductive skills. Other forms of mental obstacles need decisive decisions. Sometimes wrong decisions can lead to different outcomes, which can make students experience dilemmas [273].

Another feature concerning the environment is the game views. Sometime students can choose the camera's angle to view the world, and sometimes there is a fixed view in the world. When students roam in a VW, they encounter many objects and structures, and they view many sceneries. A basic mastery of using game views might be needed to complete tasks or have proper interaction with the surroundings, objects, or other players.

Interactions: Internal relationships and interactions are more about the players' gaming and social interaction abilities [273]. Roblox can be played individually (private server) or in groups (public server). However, Roblox was built around the idea of players interacting with other individuals. Thus, social interaction is core to the game. The amount of interaction in the world can be controlled by placing constraints on the number of players who can join a server. The number of participating players in a server might affect how players learn. In an open world, players can interact by choosing their roles or by influencing other players to play the way they play [273].

6.1.4 Game Development Life Cycle

Game Development Life Cycle (GDLC) is a model that "focuses on the standard streamlined engineering principles to build a robust software architecture" for games on all platforms [275]. Sumit Jain stated that any universal GDLC process should include six steps: idea, game design, technical requirements, developments, testing, and deployment [275]. The idea is the purpose and the reasons behind building the game. Game design is the skeleton of work including the four main elements of the *Rules of Play* in addition to game story; user interface; environment theme; avatars and characters; missions and tasks;, and audio. The technical requirements are where all the frameworks and *Rules of Play* convert into a requirement document for use in the developments stage. The final steps are testing the game deployment in a real environment.

6.2 VW Framework for Early Childhood

No previous research investigated or designed CT VW for early childhood. However, information exists about VW engagements for older students. Having a suitable framework is essential to design appropriate VW environments and missions that suit the abilities and needs of early childhood learners. Thus, we developed a CT VW framework for early childhood while focusing on the best practice elements [252]. The format of the framework describes the elements as a requirement that can be implemented within the GDLC model. The CT VW was designed to be amended, so the model can be generalized to any early childhood VW and not restricted to CT activities.

The model was created from Laura's frameworks, Guiding Principles of OET (Chapter 2), and the PTD frameworks in Sections 3.4.3.1 and 3.2.7.1. Those descriptions can support deciding the needed requirements. Laura's frameworks identified all the needed elements in VW that meet the development need for the early childhood age group and those that can develop CT skills of young players. OET described healthy interactions between young children and technology and the social aspects of what that interaction should look like. Lastly PTD models describe the elements and the layouts needed in a physical environment to support learning as well as the children's positive engagement foundations. We identify what can be employed in the VW and then group them by similarity.

Engagement:

1) The VW should allow players to find initiatives to explore their world. (young children)
2) The VW should allow players to develop their social skills with peers. (older children)

3) VW can strengthen relationships between players and their parents, families, and educators.
4) Players can observe and/or engage with each other's playing.

Communication:

5) Players can communicate using at least texts and symbols.
6) Players can communicate with only with users in the VW.
7) Communication is only public.
8) Communication is safe and protected.
9) Players are warm and friendly with each other.
10) The VW arrangement allows players to see one another's work.
11) The VW supports the effective interaction between facilitators, students, and peers

Collaboration

12) Players can play solo.
13) Players can work together on the same mission.
14) The VW materials arrangement can allow and promote sharing.
15) The VW arrangement allows multiple players to work on one mission.
16) Players can see each other's progress.

Participation:

17) The VW need can have various users access at the same time.
18) Players can see each other online in the VW.
19) Players need to have a legitimate account to access the VW.
20) Players need to be authenticated and authorized to access the VW.

Policy and Privacy

21) Parents and educators should be familiar with the common internet safety guidelines for children.

22) Game rules are rigid and clearly defined.

23) The VW rules can keep a real-life community safe and functioning.

24) The VW has different mechanisms to enforce the rules and policies.

25) The players and parents should be aware of the Children's Online Privacy Protection Act and other safeguards.

26) Entering and doing the VW activities is free (no real money), however, the system should support collecting points from doing missions in the VW games.

27) No ads in the VW.

28) Early childhood educators and administrators should be aware to ensure that the proper filters and firewalls are in place so children cannot access materials that are not approved for a school setting.

Environment

29) The VW should help children imagine and explore.

30) The VW has a time limit for players.

31) Players can allow controlling environment elements in the VW to explore.

32) Environmental elements support understanding the real-life world, such as having different kind of animals.

33) Some environmental elements can be customized; others can be locked.

Content Creation

34) The facilitators can collect students' artifacts, like taking pictures.

35) Players can save their artifacts using any means, such as print screen.

36) The activity appropriately matches with the child’s needs, abilities, interests, and development stage.

37) The activities have time limits.

38) The activities complement—and do not interrupt or harm—a child in any way.

39) The VW environment can expose players to CT concepts through games and missions.

40) The player can do missions and play games.

Facilitators

41) A facilitator player (teacher) can do all that a normal player can.

42) Educators (admins) have extra privileges, such as banning players and teleporting.

43) Educators can co-view/play with players.

44) Educators approve who can access the game.

45) The admin can control the player objects, lessons, or VW environment.

46) Educators can use environmental objects to build lessons.

Culturally Responsive

47) VW should support dual-language learners; for example, digital resources can support language development in the native language and in English.

48) The VW should be culturally responsive.

Community Building

49) Players can share their buildings or code with the community.

50) VW missions can be related to a community.

51) The VW has sections that present players’ artifacts.

52) VW designs are open and represent the community.

Creativity

53) Players can observe and manipulate objects in the VW.

54) Players can solve a task using a variety of approaches.

55) VW environments can encourage wonder and thinking.

Choices of Conduct

56) Players can clean up materials.

57) Players can respect other players by taking turns to use a space.

58) The VW has sections that present evidence in the space of the values of those who use it.

6.3 CT Pedagogy Appendments to VW Framework

The CT-Pedagogy framework was separated from the main framework and added as an appendix section to facilitate the model's use with any VW and not restrict it to CT activities. The appendix has the Computational Thinking Pedagogical + Framework converted into requirements.

Unplugged

1) Some game creation can be done in real life.

Tinkering

1) The VW materials that can be used by players are clear and reachable.

2) The VW materials can be limited or unlimited.

Making

3) The VW allows players to take part in creating content.

4) Players can gather and use materials in the VW.

Engineering

5) Players can solve a problem by creating and building objects in the VW.

6) Different building solutions can solve a problem in VW (CT concepts).

Coding

7) Players can solve a problem by coding in the VW.

8) Different solutions can solve a coding problem in the VW (CT concepts).

Dataying

9) Players can solve a problem by dataying in the VW.

10) Different solutions can solve a dataying problem in the VW (CT concepts).

Mixing

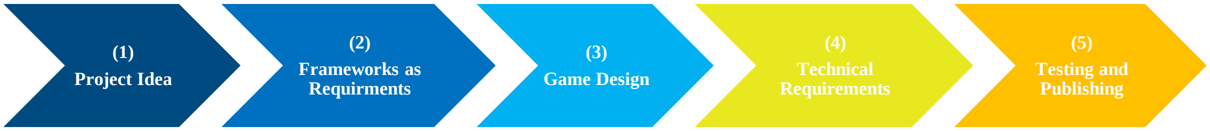
11) The VW materials can be used in multiple ways.

12) Different pedagogical experiences can be mixed to solve a problem.

6.4 VW Developments for Early Childhood

The GDLC and game studies theories guided the development stages of the VW, with modification by combining GDLC and game studies principles while considering Roblox as sandbox technology. Thus, the game design and technique requirements merge as one step in this cycle. (See in Figure 6.2).

Figure 6.2 CT VW Development Cycle



6.4.1 Project Idea

The purpose of the project is to create an hour of code CT VW for young children.

6.4.2 Framework and Requirements

The VW framework and CT appendices described in Sections 5.2 and 5.3 were used as a requirement templates for the development phase.

6.4.3 Game Design

6.4.3.1 Game Objective

The objective of the game is to create appropriate missions for age 6 and up that are engaging and fun while satisfying VW requirements. Mission objectives are derived from the Computational Thinking Pedagogical + Framework described in Section 4.5.

6.4.3.2 Story

This VW aims to be one hour of code for young children. Thus, the story carries this aim in one theme. The story:

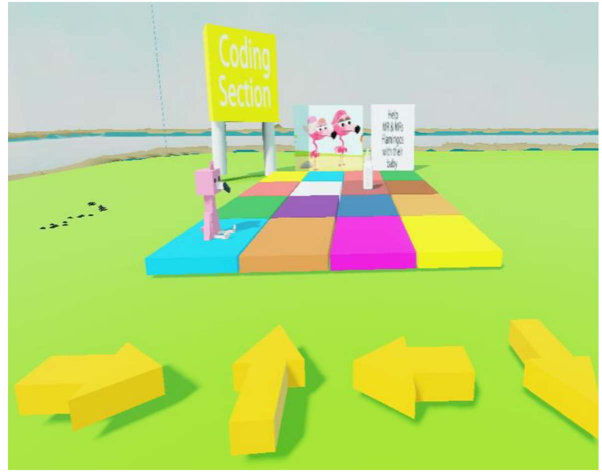
Once upon a time not long far away there was an island hidden in the deep ocean that only appeared once a year for only one hour. On the island, there are three families: Mr. Elephant, The Flamingo's family and Granny Squirrely. They have a lot of problems and no one to help them. So, in this one hour of the year, they cast a spell to bring the most gifted smart children in the world to help them solve their problems. If you receive an invitation, that means you are one of those smart children who might solve their problems. All three families desperately need your help. Can you make the pinky promise to try to help them?

6.4.3.3 Environment

The island has six main locations, presented in figure 6.3: the Tree House, the Elephant Ccircus Tent (engineering section), the Flamingo Yard (coding section), the Granny Squirrely Escape Rooms (datasying), the Grocery Shops, and the Playground.

Figure 6.3 CT VW Environment

(a) Tree House

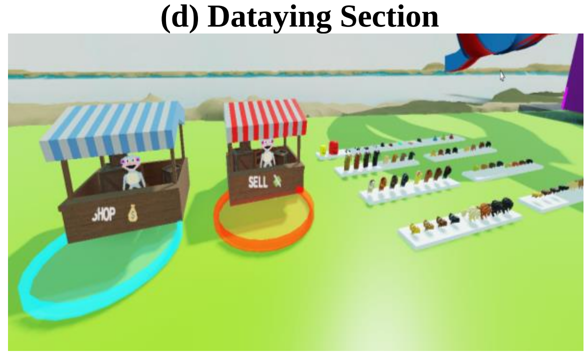


(b) Coding Section

(c) Engineering Section

(d) Datayang Section

(e) Playground Section



(f) Grocery Shops Section

6.4.3.4 NPC

The nonplayer character (NPC) is not a real player but exists to guide the players. The VW should have an NPC at every activity spot. NPCs can give missions to players or sell and buy items, including the pets and plants around the island. There are seven main NPCs in the game: Mr. Elephant, Mr. Flamingo, Mrs. Flamingo, Baby Flamingo, Granny Squirrely, and two twin monkey sellers. (See Figure 6.4).

Figure 6.4 CT VW NPC's

6.4.3.5 Audio

The VW should have general background music that carries a happy beat and has an island theme. In addition, each mission on the island should have its own music. The current demo doesn't include the music yet but the updated version should. The Roblox sandbox has built in sounds such as the beach, the jumping, footsteps, and more.

6.4.3.6 The Mission

The missions are mandatory tasks that children need to finish as part of the game and lesson objective. They relate to CT Pedagogical activities in that they engage students to implement CT concepts to solve problems of the families on the island. There are five types of missions: tinkering, making, engineering, coding and datayıng.

Engineering provides a limited number of tools for each team to let them build a project that solves a problem. This is usually done within the circus tent. Coding allows a player to control an object to move it to a destination using a step-by-step procedure. Datalaying requires finding a passcode by analyzing hints to create data patterns to unlock the door. This is presented in Figures 6.3 (b, c and d).

Missions should have progressive levels; that is, several levels of difficulty should exist for the mission to make children's abilities progress.

6.4.3.7 Activities

Activities are usually optional tasks that can support fulfilling the game objective. In this case they are tinkering, making, or socializing. Activities should be fun—Fletting children fish, plant, eat, shop, and hunt—or play in the playground alone or with a group. Children also can adopt a pet, feed the pet, and play with it. Children can tinker around by clicking on the island objects, some of which trigger sounds or show an item. Additionally, the objects can be used to make creative items.

6.4.3.8 Game Rules

There are two pointing systems, one for playing and another for digital citizens. Every time a child does something good—like helping a person or planting a tree—they can earn digital citizens points. Digital citizenship points are like golden points; they are worth double the regular points to encourage positive behaviors. Regular points can be achieved through finishing a mission or activities. Points can be used to buy from the shop. Children can buy hats, food, and gifts, which can be traded. The avatar can control which hat it wears. And certain wearing the correct hat for an activity—engineering, coding, or datalaying—can earn a child extra points.

The game has time rules. The total playing time of the VW does not exceed the 60 minutes; players will be logged out at that time unless the teacher decides to increase the limit.

6.4.3.9 Game Dilemma

Players can die in the game by eating poisonous food or by being attacked by a wild animal. If they die, players will respawn in the tree house; but the mission progress and points still be saved. This option can be turned on and off.

6.4.3.10 Game Procedures

The player will start in a tree house in the middle of the island. Animated stories would describe the story. The children have a choice to start with any mission (Elephant Circus Tent, Flamingo Yard, or Granny Squirrely Escape Rooms). After finishing all missions, players return to the tree house to finish the game.

6.4.3.11 Game Linguistics

The game world has written signs and audio that the players can trigger to describe the activities.

6.4.4 Technical Requirements and Developments

6.4.4.1 Coding Platforms

Roblox studio and Roblox templates were used to build the VW elements. The templates were customized to design some 2D elements using photoshop and illustrators (see Figure 6.5) and 3D elements using Cinema 4D application (see Figure 6.6). The interactions and the connection of the elements to the VW and players were programmed using Lua programming scripts and drag and drop tools within Roblox Studio. The coding environment is a sandbox that has its own rules, regulations, and features that this VW inherits by default, items like security policies.

Figure 6.5 The sky Template

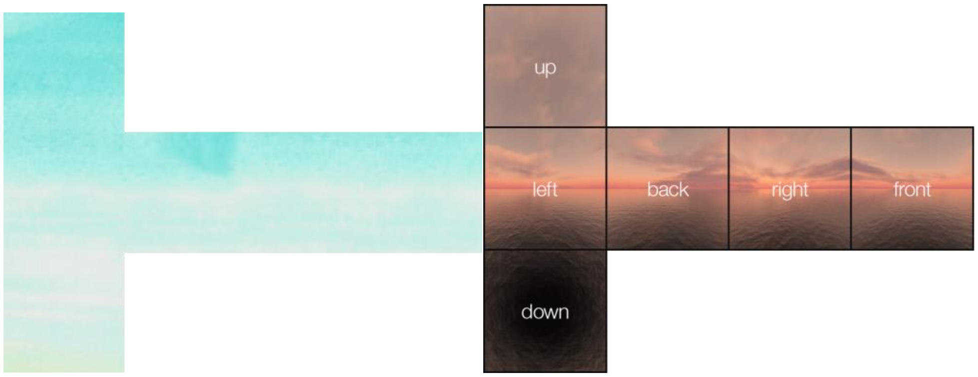


Figure 6.6 3D design

6.4.4.2 Avatar

The Roblox forces its own avatar shapes, see Figure 6.7. The shape of their avatar is inspired from Robotic + Blocks = Roblox. The developer can customize the body parts and can design their own clothing.

Figure 6.7 Roblox Avatar

6.4.4.3 Logo

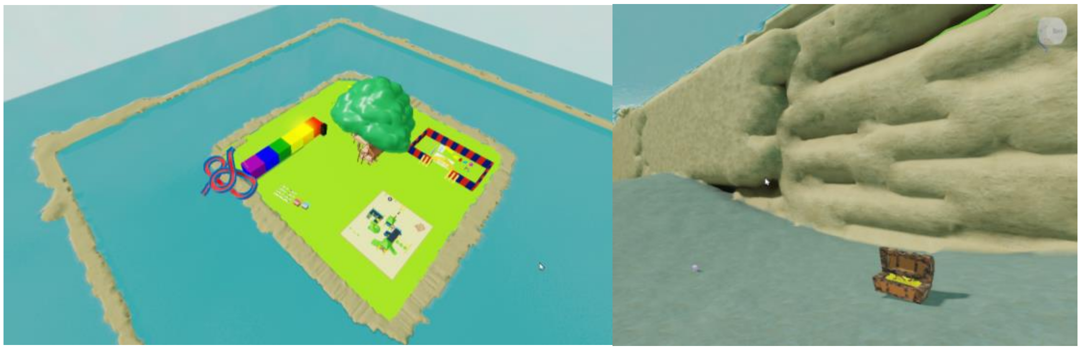
The logo was designed to be like an island where the land is shaped like a brain to represent computation thinking. The name published by VW is called "The CT Island", see Figure 6.8.

Figure 6.8 The VW logo

6.4.4.4 Environment

The environment is an island uses colors that appeal to children. It includes moving creatures and plants. The land should be solid—children do not fall into a hole and get stuck. The water around the island is considered part of the environment; players can use it to do missions or learn, even at the bottom of the sea, see Figure 6.9. The coast surrounding the island has glass barriers to prevent players from going under or very far from the island where they can get stuck. The architecture, sky and climate around the island should match the island's theme and color scheme.

Figure 6.9 The Island and the Under Water



6.4.5 Testing and Publishing

The developing, testing and publishing phases happen with Roblox VW using the built-in features. The testing phase seeks to find bugs. As this is a prototype, not every feature is fully implemented; still, the project is published into the Roblox world and can be played through different devices such as laptops, tablets, or phones. To access and play in the VW, players must have an account in Roblox and follow the appropriate game link.

Chapter 7 - Bringing Computational Thinking to Kuwait

The objective of (CT) is to increase (CS) knowledge so that students can take what they learn in the classroom and laboratory and apply that knowledge to the modern workplace. Early CT exposure is critical for future educational outcomes because it helps students understand the connection between current learning and future application. Introducing children to valuable STEM experiences, starting at a young age, has been shown to improve science literacy; promote critical thinking; develop problem solvers; and empower the next generation of innovators, creating new outcomes that strengthen the economy [1].

Not all countries, however, acknowledge the need for STEM education. Kuwait, a small country in western Asia, ranks 57th of 189 countries on the Human Development Index (HDI) with a score of 0.808 (or very high human development). However, the country ranks among the lowest in human development for Arabic/Persian Gulf countries [2]. The CS curriculum in Kuwaiti K–12 public schools fails to prepare students for the modern-day workforce because it primarily focuses on computer literacy, not CS concepts [3]. Instead of using project-based learning, the CS curriculum relies on written exams, in which 70% of the grades are based on theoretical content [4].

Educational reinforcements in Kuwait are necessary to prepare students to shape modern societies. Incorporating CT into the educational system is a shared responsibility between decision-makers and educators. Students and educators need to be aware that CT is more than just using technology or computer science. To efficiently allocate the resources, educational researchers suggest first estimating stakeholder awareness of the concept [3]. Because CT is a relatively new concept, many people are unaware of its nature [4]. Determining awareness is a prerequisite for adopting and improving CT [5]. We did an experiment to identify CT awareness in different educational roles and suggest a plan to promote CT in Kuwait education institutes. The results of this work were published in an ASEE conference 2021 paper titled "Measuring Awareness of Computational Thinking in Kuwaiti Educational Institutions" [276].

Another beneficial reinforcement approach is to increase CT abilities through after-school programs; STEM contests; design and building; and summer programs. Kuwaiti students must participate in out-of-school programs to grow their CT because the public-school curriculum contains limited programs to support CT education. Most STEM curriculum programs are developed in non-Arabic countries; therefore, a suitable curriculum must be designed for the Arabic region [7]. We investigated by transferring Western STEM programs to Kuwait's Arabic region to address and reduce barriers that might teaching CT skills to Kuwaiti students. The chosen STEM outreach program Mighty Micro Controllers (MMC) was designed for students in 6^{th} through 8^{th} grades with no previous CS skills. The results of this work were published in an ASEE conference 2020 paper titled "A Replicate Study: Adoption of a STEM Outreach Program in Kuwait" [277].

Women are the minority in STEM fields and degree programs in most countries throughout the world; however, in Kuwait, a country with gender segregation regulations, females have reversed the gender stereotype of the female minority in the fields. This study investigates another primary topic to identify factors that influence male and female performances and preferences in STEM education. The results of this work were published at the ASEE conference 2021 under a paper titled "Reversing Gender Stereotypes in STEM Education in a Gender-Segregated Region" [278].

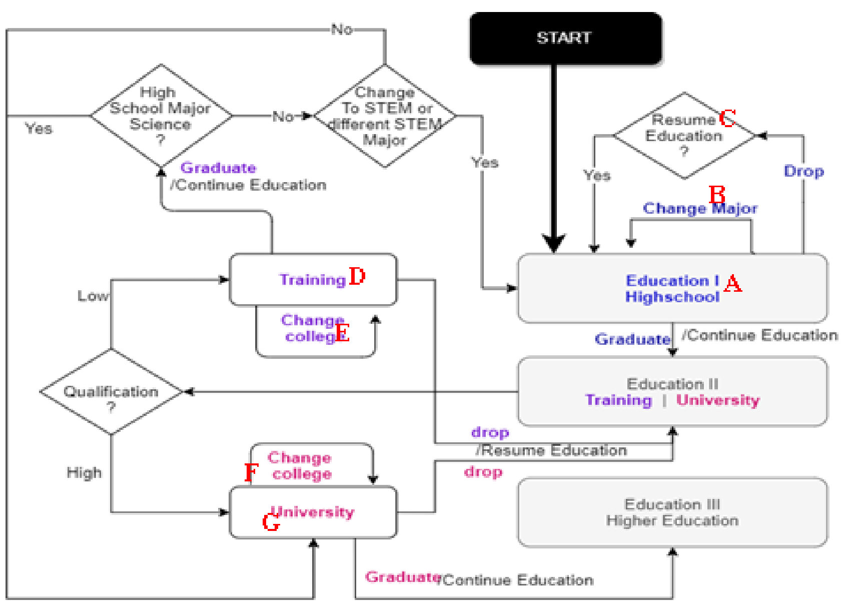
We developed a STEM educational model for Arabic/Persian Gulf regions to employ our reinforcement suggestions. The STEM model was built from a suggested educational model that meets the needs of current and future knowledge-intensive generations developed by Dr. Wim Veen [9]. It was expanded to include other STEM factors driven by the results of our experiments and literature review.

7.1 Background

7.1.1 Kuwait Education System and Regulations Related to STEM

Kuwait, a small country on the Arabian Gulf (also known as the Persian Gulf), located in the Middle East region between Iraq and Saudi Arabia, has an estimated population of 4.5 million composed of many ethnicities from South Asian countries and Iran [8]. The primary religion is Islam. Although Arabic is the official language for communication and education, English is widely used and regarded as the compulsory second language taught to students in schools. Kuwait is an economically stable society with abundant access to technological innovations because of the country's predominance of the oil and gas industry. Despite the unilateral access to technology, public schools are segregated by gender, even for young children. Schools in Kuwait are either public or private because the educational system does not allow home-schooling or online schooling [5]. Approximately 12% of the Kuwaiti population is 14 years of age or younger [6]. The Ministry of Education (MOE) implements a national curriculum and designs the books and distributes them across all public education systems [10]. The MOE provides annual in-house training for teachers [11, 12]. The ministry is the sole decision-maker for all issues related to national education, with the highest authority of decision-making being the Ministry's Undersecretary Council, chaired by the minister. The Civil Service Commission (CSC) is responsible for appointing employees and teachers to the MOE [13]. Kuwait's educational system begins with a 2 year kindergarten stage, followed by a 5 year elementary stage, a 4 year middle education stage, and a 3 year high school stage [9]. Students typically pursue either a 2-year diploma or a 4-year bachelor's degree. The 2-year diplomas are offered from the Public Authority for Applied Education and Training (PAAET). The only qualification to be enrolled in the PAAET is to earn the acceptance rate at high school [11]. In contrast to Kuwait University, approximately 10 private universities in Kuwait require an entry exam [12]. High school in Kuwait is the most critical stage in the educational system because high school students decide their college majors, which then determines available colleges. For example, a science major can attend almost any college for STEM or non-STEM majors. A literature major has limited options, just non-STEM majors. Students must retake high school to switch from literature to a STEM program. Figure 7.1 illustrates switching between majors according to Kuwaiti education regulations. The MOE grants full scholarships for diplomas and bachelor's degrees as well as monthly allowances.

Figure 7.1 Kuwait Education System



7.2 STEM Model for GCC Countries

7.2.1 The Original STEM Model

Recent rapid technological developments have provided modern information that has created challenging educational dilemmas. Young people are now growing up with smart gadgets that pervasively influence how they perceive the world. Dr. Veen derived factors for and suggested an educational system to meet the needs of this generation and future knowledge-intensive generations. The three interdependent, parallel factors are sociocultural, economic, and technological [9]. Sociocultural factors outline "how human beings communicate, collaborate and process information in a society." Economies factors describe when "production systems become global, and labor differentiation occurs at a continental level." He describes the technological factor as the influence of the continued growth of technology on education.

7.2.2 The Pre-STEM Model

The original model gets tested and expanded through two experiments to suit learners in Arabic/Persian Gulf regions. The first experiment examines the complications when a STEM outreach program from the United States was translated and adapted for use in Kuwait, including obstacle resolution. The model was expanded to include six sub-elements that can influence the Gulf Cooperation Council (GCC) regions: language, religion, institutions, geographical, gender, and quality. The model was used to adjust the transfer STEM program to ensure that the cultural differences did not alter the study significantly. The experiment results led to expanding the factors to include prestige and passion, where through the experiments, students were highly driven by these two factors.

7.2.2.1 Factors Influencing STEM Programs in GCC Countries

The six sub-elements were derived from the common features and characteristics of the GCC countries and they complemented the three factors of the original model. The Arabian Gulf is well known for its unique demographics and geographical and cultural backgrounds. Kuwait, Bahrain, Saudi Arabia, the United Arab Emirates, Oman, and Qatar share common habits, traditions, religions, and languages. These countries became even more united since the GCC was created in 1981 to promote and advance educational needs [18]. Although academic development has varied in each country, as a whole, the countries exhibit standard features [19]. Since GCC was created, CS and integrative technology have been the fastest growing educational trends[279-282].

Society

Because GCC countries share the same language and cultural practices, patterns of societal effects on technology are easily traceable. Individuals are influenced by their surrounding social life, beginning at home, where parents allow or prohibit the use of certain technologies in their households. For example, some parental authorities impose limits on interaction with the opposite sex until a certain age and subsequent segregation and prohibited interactions, even in school. Segregation of the sexes is more prevalent in these societies after kindergarten.

Gender: As mentioned, gender segregation is prevalent in GCC countries because of cultural traditions and customs. Some private schools, however, implement coeducation. According to UNESCO, despite educational segregation and strict views of female roles in society, female achievements in science and mathematics are higher than males throughout all GCC countries [283].

Language: Although Arabic is the official language of GCC countries, the entire region began considering adopting sciences in English because translations of modern sciences became difficult. English has become a global language for sciences, so learning English has become a priority in this region. However, the existence of Arabic at some point or compatibility is a must for non-English users.

Religion: Because 99% of the total population in GCC countries belongs to the Islamic faith, most legal systems in the region are based on the religion of Islam. This means that the implementation of any technological advancements must be regulated by Islamic rules or align with Islamic faith regulations.

Social Institutions: Social institutions can include any gathering of people to achieve a common goal. This includes families; organizations; mass media; and governmental and nongovernmental institutions, all of which can positively or negatively impact the implementation of STEM curricula.

Geographical: GCC has a desert climate while facing a body of water from at least one side. The general climate of this region includes high temperatures during the day and calmer nights, especially in the sandy areas. Because of the heat, some regions ban working in open areas in the afternoon.

Technology

Quality: Technology has become an essential component of modern teaching. However, the rate of technological advancement is faster than the rate of STEM program implementation in schools. By the time a technology is integrated into classrooms—including familiarizing teachers and students—it has already become outdated.

Economy

Populations of GCC countries are comprised of a variety of economic stratifications, including the very wealthy and a majority of middle- and low-socioeconomic classes. Despite the general wealth in the region, minimal financial resources are allocated for STEM implementation or training.

7.2.3 The STEM Model

The STEM model expanded to include more factors derived from literature review, educational regulations, and educational statistical data that investigate elements related to experiment reverse gender stereotypes in Kuwait. The final design included 18 subfactors, as presented in Figure 7.2 and defined in Table 7.1. For the technological category, the STEM model included availability (f1), quality (f2), and passion (f3). For the economic category, the model included workforce (f4), geography (f5), finances (f6), and prestige (f7). The sociocultural category was classified into social institutions, habits, and traditions. Social institutions included family (f8), friends (f9), schools (f10), and communities (f11). Habits included life routine (f12), study method (f13), maturity (f14), and ability (f15). Traditions included gender (f16), language (f17), and religion (f18). Subfactors such as passion (f3) and prestige (f7) overlapped between main factors.

The results of the second experiment suggested more modification on the elements. The geography (f5) factor should be combined with the workforce (f4) factor. Students with STEM preferences often change their preferences after facing sociocultural obstacles, even at young ages. The schools (f10) factor could be considered a theme instead of meaning where they significantly influence STEM performance, such as study method, school material, teacher connections with students, and teaching style. Thus, they should be included as a subgroup under the schools (f10) factor. Similarly, the language (f17) factor should be a shared factor between religion (f18) and schools (f10), where results identified a significant language gap between high school and college because the teaching language in high school is Arabic and English at college. The habits classification within the sociocultural category in the STEM model should be renamed to maturity and include life routine and ability as subfactors. In addition, the study-method (f13) factor should be shared between schools (f10) and habits to show that schools influence the method of study, such as when a student describes the differences between study techniques at high school and college.

Figure 7.2 Factors Influencing Kuwait Educational System

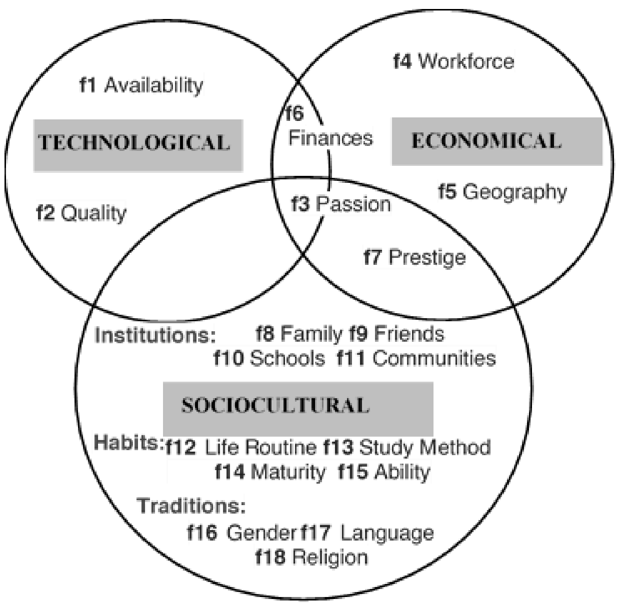


Table 7.1 Definitions of STEM Model Factors

F1	**TECHNOLOGICAL:** the ways new practices and equipment can affect education with respect to technological capabilities	
f1	Availability	"The opportunity, at a micro or a macro level, to materially access technology at reasonable prices, whether at home, at work, at school or in public places" (such as public institutions or commercial outlets) [284]
f2	Quality	How good and convenient technology is in terms of efficiency and durability with 72 technology qualities, including aesthetically pleasing, functional shape (form), accessible, culture fit [285]
f3	Passion	How much individuals are emotionally connected to technology to facilitate their learning processes for STEM subjects
F2	**ECONOMICAL**: the effect of a country's financial status on students' education and technology	

f4	Workforce	How available jobs influence individuals to pursue or reject STEM education
f5	Geography	How the environment and physical location affect individuals' perceptions of STEM
f6	Finances	How the economic status of a country and individuals affect STEM and individuals
f7	Prestige	Having the latest trend and showing off had affected STEM and individuals
F3	**SOCIOCULTURAL**: the ways habits, traditions, and beliefs consciously or unconsciously reflect a majority of society groups	
F3.1	**Institutions**	Group of people who come together for a common purpose
f8	Family	Certain life situations between common ancestors that help shape preferences
f9	Friends	Relationship of mutual affection between people that helps shape preferences
f10	Schools	Physical, human, materials, and resources used by schools to promote academic performance
f11	Communities	Social gatherings with mutual interests or goals, including institutional and official/no-official clubs or gatherings
F3.2	**Habits**	Recurring actions of individuals
f12	Life Routine	Lifestyles and daily routines that affect individuals' preferences
f13	Study Method	Learning and processing information styles that affect individuals' preferences
f14	Maturity	Quality or state of being fully mentally and physically developed, reflecting judgment and wisdom
f15	Ability	Current possession of a skill
F3.3	**Traditions**	"A belief or behavior (folk custom) passed down within a group or society with symbolic meaning or special significance with origins in the past" [286]
f16	Gender	Gender role, or the outward manifestations of personality that reflect gender identity [287]
f17	Language	System of communication used by a particular country or community [288]
f18	Religion	Belief in and worship of a supernatural power and its influence on individuals' preferences

7.2.3.1 STEM Factors – Reverse Gender Literature Reviews

The National Academies of Sciences recommends practices to increase female inclusion in STEM fields in Kuwait and the United States [1]. It published a book as a collaborative work between the Kuwait Foundation for the Advancement of Sciences and the National Academies of Science, Engineering, and Medicine. The book includes experiences of Arabic educators and chapters that discuss multiple gender-gap issues in STEM, including research summaries to reduce the gap between males and females and support women in the field. The book identifies males as the dominant gender in STEM fields. The present study relied on the influential factors noted by the book's six researchers.

Claudia Buchmann, a professor and chairwoman of the Department of Sociology at The Ohio State University, identified a connection between passion (f3), schools (f10), and study methods (f13). She found that lack of curriculum preparation (f3/f10) in science classes led to high rates of dropping out of college, even if a student had a high interest in the field (f3). In addition, standardized curriculum (f10) within a country was shown to affect gender performances (f13) and appeal (f3/f10) [289]. Similarly, El-Bahey and Zeid investigated female student motivations to study computer science and information systems in Kuwait [289].

While observing attitudes and perceptions of students, they surveyed male and female students in STEM colleges to determine their reasons for joining. Results showed that the motivation was a result of pragmatic factors such as interest (f3).

Hayfaa Almudhaf, the co-chair/senior advisor (ret.) of the Kuwait Institute for Scientific Research, studied workforce (f4) and prestige (f7) factors and found that, although women comprise 60%–80% of STEM fields, a majority of leadership and researcher positions are held by males (f4/f7/f11) [289]. Munirah AlAjlan, an English as a Second Language (ESL) instructor at the College of Engineering and Petroleum at Kuwait University, compared preferential career paths between males and females in Kuwait and found that males prefer military jobs or private business (f4) [289].

Hessa Amin, the deputy chief executive officer of FAWSEC Educational Company, a K–12 education company in Kuwait, investigated the finances (f6) and prestige (f7) subfactors as they relate to STEM education. Based on a survey of high school and college students she proposed 14 factors that influence male willingness to enroll in STEM colleges, including financial salary (f6) and prestige (f7). Similarly, she determined that factors such as the involvement of parents and other family members (f8) and friends (f9) significantly impacted the family (f8) and friends (f9) subfactors [289]. However, El-Bahey and Zeid found that parental advice (f8) and peer influence (f9) were not among the top influential factors [289].

For the communities (f11) and religion (f18) subfactors, most researchers agreed that the dominance of males in almost all STEM fields greatly influences the willingness or unwillingness of male and female students. Amin proposed 14 factors, including religious factors (f18). Zaha AlSuwailan found that female interest in STEM education is influenced by the adopted textbook at the K–12 education levels (f10), specifically if a book's images have many female role models (f11) and community pictures depicting women in real life or in various fields of the workforce (f4) [289].

For the life routine (f12) subfactor, AlAjlan found that men socialize with leaders informally outside working hours (f12) where women are not welcome to join, giving men the advantage of receiving support from leaders [289]. Amani, Al-Sanad, and Larkin surveyed female engineers in several fields in Kuwait to determine general attitudes toward gender bias among female engineers in the workplace. They found that women spend more time at home (f12), resulting in increased study time (f12/f13) [289].

For the ability (f15) subfactor, Abrar Al-Awadhi, assistant professor of special education at Kuwait University, found that the number of students at the STEM college at the university decreased since 2010–2011. However, the same trend was observed for other non-STEM majors at the university due to students transferring to other universities or dropping out of college completely, meaning students were unable or unwilling to complete their courses [289].

7.3 Experiment 1: A Replicate Study: Adoption of a STEM Outreach Program in Kuwait [277]

The K–12 CS curriculum in Kuwaiti public schools primarily focuses on computer literacy and secondarily on programming. However, students must understand CT before learning to code, meaning CT concepts must be incorporated into the Kuwaiti curricula to increase student learning. Utilization of a STEM outreach program would introduce CT concepts to Kuwaiti school children to prepare them for future academic and professional CS challenges. This paper investigates and examines students' abilities to learn CT concepts in Kuwait; addresses and reduces barriers to the successful transfer of western STEM programs to the Arabic region; and compares learner outcomes between the regions.

The experiments utilized the STEM outreach program Mighty Micro Controllers (MMC) for students in grades 6 to 8 with no previous CS skills. The program increases student learning by implementing fun, hands-on CS activities, such as building circuits by programming Arduino Uno microcontrollers using Scratch and offering brief exposure to text-based programming. MMC, which has been implemented since 2016, has effectively improved students' CT skills [8]. Also, it used the pre-STEM model that suit learners in Arabic/Persian Gulf regions. For example, the language and religion of the original MMC program was altered to minimize cultural barriers: the materials were translated into Arabic while maintaining the basic terminology, and the workshop was segregated into three gendered classes (i.e., boys, girls, and a mixed group). The results were promising for knowledge gained and increased CT abilities. Although overall scores from the United States were higher than scores from Kuwait, Kuwaiti females scored statistically higher on CT concepts than Kuwaiti male and U.S. participants. MMC learners in both countries showed confidence in project building, and their scores in Kahoot confirmed their gains, especially for U.S. students. That after controlling the barriers, the replication of the STEM program to Kuwait engaged the students and taught them CT and that served our goal.

7.3.1 Background

7.3.1.1 Computational Thinking

There are no unified agreements on the CT definitions and concepts. We used Weese and Feldhausen's suggested lists to incorporate CS principles into our work [290]. Table 7.2 contains the CT lists adopted for this paper.

Table 7.2 CT Concepts and Related Computer Science Principles [290]

Abbr.	Description
ALG	**Algorithmic thinking** – sequence of steps that complete a task, including operators and expressions
ABS	**Abstraction** – generalized representation of a complex problem, ignoring extraneous information
DEC	**Decomposition** – breaking a problem into small, manageable parts that can be solved independently of each other
DAT	**Data** – collection, representation, and analysis of data[6]
PAR	**Parallelization** – simultaneous processing of a task[6]
CON	**Control flow** – directs an algorithm's steps when to complete
IAI	**Incremental and iterative** – building small parts of the program at each step instead of the whole program at once
TAD	**Testing and debugging** – performing intermediate testing and fixing problems while developing
QUE	**Questioning** – working to understand each part of the code instead of using code that is not understood well
USE	**Reusing and remixing** – making use of other people's work and resources to solve a problem

7.3.1.2 STEM Outreach Program

The MMC program, designed by Weese and Feldhausen, focused on teaching students CT within the context of coding microcontrollers using Arduino Uno and block language. The program used hardware and software to successfully engage participants, using models to create and program simple circuits and then conduct problem-driven exploration to develop open-ended projects. Students were able to harness their prior knowledge while learning the fundamental principles of circuit building, electricity, and signals. In addition, pair-programming was used to improve student communication skills. To minimize the potential of overwhelming students with new concepts, the students observed illustrations and practiced unplugged activities to become familiar with the ideas. For example, students studied a figure that showed marbles rolling in a hoop to explain electricity and then had to sort the strongest and weakest resistors by plugging the resistors into a blinking LED circuit to determine the relationship between LED brightness and resistor strength. The weak resistor showed a bright LED, while the strongest resistor displayed no light.

Each lesson in the MMC program was designed to highlight the microcontroller's software for specific CT skills. Students trained to read circuit diagrams by plugging the expected pins on the Arduino board; most circuit activities in MMC are comprised of LED lights and buttons. Ultrasonic sensors were introduced within the Arduino IDE, and text-based programming language was used to teach students how to reflect the Scratch structure. As a result, students learned to correlate how the blocks programming corresponds to real-world coding. On the last day of the program, students utilized all previous lessons to draft and build a final project design [291].

7.3.2 Method

7.3.2.1 Instruments

This study used a self-efficacy survey to measure student learning of CT. The survey questions were categorized as problem-solving, computer programming skills, computer programming practices, and computer programming impact. All questions were measured using a five-value Likert scale: strongly disagree, somewhat disagree, not sure, somewhat agree, and strongly agree. as shown in Table 7.3. The survey also collected information about student participation in STEM and prior CS knowledge. An online presurvey was administered before any STEM teaching process, and the postsurvey was given on day four, after the projects were finished. Students played Kahoot daily to measure their understanding, and parents were able to review their children's feedback and ratings throughout the program.

Table 7.3 Self-Efficacy Survey Questions and Related CT Skills [290]

Five-value Likert scale: strongly agree, somewhat disagree, not sure, somewhat agree, and strongly disagree			
	عندما أحاول أن أحل مشكلة تواجهني When solving a problem		
1	create a list of steps to solve it	اقوم بعمل سلسلة من الخطوات للحل	Algorithms
2	use mathematics	اقوم بعمل عمليات حسابية	Algorithms
3	try to simplify the problem by ignoring details that are not needed	اقوم بتبسيط المشكلة عبر ازالة الاشياء الغير مهمة منها	Abstraction
4	look for patterns in the problem to create an efficient solution	ابحث عن الانماط فيها	Abstraction
5	break the problem into smaller parts	اقسم المشكلة الى اجزاء اصغر	Problem Dec
6	work with others to solve parts of the problem in parallel	اقسم المشكلة الى عدة اجزاء اصغر ، حتى يتمكن مجموعة من الاشخاص بحل تلك الاجزاء المتفرقة بوقت واحد	Parallelization
7	look how data can be collected, stored, and analyzed to help solve the problem	ابحث في كيفية تجميع البيانات و تخزينها ثم اقوم بتحليلها حتى يتسنى لي حلها	Data
8	create a solution where steps can be repeated	اخلق حلا يمكن من خلاله تكرار الخطوات	Control Flow
9	create a solution where some steps are done only in certain situations	اخلق حلا بحيث لا يتم عمل اي خطوة حتى تتم تلبية بعض الشروط	Control Flow
	I can write a computer program which...أستطيع كتابة برنامج يقوم ب		
10	runs a step-by-step sequence of commands	يعمل خطوة وراء خطوة	Algorithms
11	does math operations	يقوم بعمليات جمع وطرح	Algorithms
12	uses loops to repeat commands	يستخدم ال LOOP لتكرار العمليات	Control Flow
13	takes input from a user	يستجيب لضغطة زر .. على سبيل المثال	Control Flow
14	only runs commands when a specific condition is met	يقوم بتشغيل اوامر عندما تحصل بعض الشروط	Control Flow
15	runs commands in parallel	يقوم بعمل اكثر من شيئ في آن واحد	Parallelization
16	uses messages and other information to talk with different parts of the program	ارسل رسائل وبيانات بين أجزاء البرنامج	Abstraction
17	can store, update, and retrieve data	يقوم بحفظ و تحديث واسترجاع القيم	Data
18	uses custom functions	يستخدم custom functions	Abstraction
	When creating a computer program I...عندما أكتب برنامج فإني		
19	make improvements one step at a time and work new ideas in as I have them	اقوم بتطوير اجزاء بسيطة ابني عليها	Inc. and It.
20	run my program frequently to make sure it does what I want and fix any problems I find	اقوم بتشغيله مراراً لاتكد انه يقوم بما اريد واصلح اي خطأ ان وجد	Testing and Debugging
21	share my programs with others and look at others' programs for ideas	اشاركه مع زملائي لاخذ رأيهم فيه	Reu/Rem,
22	break my program into multiple parts to carry out different actions	اقوم بتجزئة البرنامج الى اقسام متعددة للقيام بمهام مختلفة	Problem Decomp.
	التأثير Impact		
23	I understand how computer programming can be used in my daily life.	اعلم انه يمكن استخدام البرمجة في حياتي اليومية	Questioning
24	I am confident I can use/apply computer programming to my field of study.	استطيع ان اكتب برامج يساعدني في مواد الدراسية اللأخرى	Questioning

7.3.2.2 Design

This replicate study compared student learning and engagement with CS and CT in the United States and Kuwait. The United States has offered the MMC program every summer since 2016, while Kuwait offered the program one time in 2019. Each country was a group (i.e., USA and KW), and the tasks were identical for both groups. The research was carried out over four 3-hour sessions for 3 weeks, excluding daily break time. On the first day, before any material was taught, students completed a survey about CT. Students played Kahoot after each session to test their knowledge about the material. Students retook the CT survey on the last day of the program. The workshops were identical to MMC lessons, with only minor changes and translations for the KW group. Parents were asked to share their children's impressions and feedback about the lessons. Additional information is included in the STEM outreach program section of this paper.

7.3.2.3 Replication Strategies

This research utilized a replication study to empirically reinforce results by clarifying issues and extending generalizability. The researchers determined generalizability for various subjects, races, locations, and cultures, embracing the factors that influence STEM programs in GCC countries. The initial research occurred at Kansas State University in the United States, and the replication occurred at Kuwait University in Kuwait. A total of 165 students participated, including (n = 100) students from the United States and (n = 65) students from Kuwaiti. U.S. participants were 67% male and 33% female subjects from the Summer STEM Institute in 2017 and 2018. Kuwaiti participants were 52% male and 48% female from the Little Engineer workshop in 2019. Although the United States requires no designation between gender in educational registering, Kuwait's program was divided into female, male, and mixed sections. The Kuwait workshops accepted students in grades 6–8, while workshops in the United States accepted students in grades 7 and 8 only.

Kuwait participants comprised 53% of private school students (84% used scratch before), and 47% of public-school students (66% did not use scratch before). Private school students are any learners who attend 2 years or more under the private education system starting from grade 1. The same investigator conducted both studies with different number of assistants (Kuwait had five and the United States had three). The difference between the two countries is because of transformation factors such as language, religion, institution, and gender. The programs occurred in the universities' laboratories with all necessary software and hardware. Study protocol was approved by both universities' research compliance authorities. Table 7.4 shows the differences and similarities between setting and sampling of the two countries.

Table 77.4 Setting and Sampling of the Replication Study

Country	***USA***	***KW***	**Country**	***USA***	***KW***
#Sample	100	65	**Timing**	Morning	Afternoon
Male - Female	M:67% F:33%	M:52% F:48%	**Grades**	7^{th}–8^{th}	6^{th}–8^{th}
Diversity	Yes	Only Kuwaiti	**Location**	University Laboratory	University Laboratory
Years	2017–2018	2019	**Language**	English	Arabic and English
Term	Starbase summer camp	Little Engineer summer workshop	**Instructor**	1 CS instructor 1 CS assistant 2 assistants	1 CS instructor 1 CS assistant 4 assistants
Period	Four 3-hour sessions	Four 3-hour sessions	**#student/ workshop**	18–20	23–25

7.3.3 Results

This study analyzed student interactions in the STEM program to understand barriers that arise from adopting the program in Kuwait. The following research questions were considered:

RQ1 What are the factors that influence transferring and teaching the STEM program in Kuwait?

RQ2 Does the STEM program improve students' CT abilities in Kuwait?

RQ3 What are the similarities and differences between Kuwaiti and U.S. student performances when they are taught STEM (MMC)?

T-tests and descriptive statistics were calculated from preprogram and post program self-efficacy surveys and Kahoot quizzing. If a student only participated in CT surveys, their answers were only used in those survey data sets. However, if a student completed all the surveys, all their responses were included in all data sets. This study created 10 groups: KW (all participants from Kuwait), USA (all participants from the United States), USA-Male, KW-Male, USA-Female, KW-Female, W-USA (Male and female participants from USA), W-KW (Male and female participants from Kuwait), W-F, and W-M, where W refers to the MMC knowledge score.

RQ1 What are the factors that influence transferring and teaching the STEM program in Kuwait?

The primary factors that impacted the replication study were language, religion, institution, geography, technology, and gender. Because the MMC program was designed in English, multiple obstacles arose when trying to teach it in the Arabic region. Parents were asked to indicate the preferred language for their children. Arabic (slang) was typically used to deliver the MMC while maintaining English words of the concepts. Likewise, translation sometimes made it harder to understand. For example, children are familiar with the word *loop*, but using the Arabic translation المكرر would be confusing to them. Public school students preferred the questions in Arabic, while private-school students favored English. Thus, all surveys were presented in both languages to satisfy all students (Table 7.3). In addition, some YouTube videos were replaced with Arabic videos with English subtitles or the facilitator described the video content.

Not only did the educational systems influence the teaching medium but they also influenced their technological background. The 6th graders' ability to complete the lessons tasks was similar between the public and private schools. However, 7th and 8th students' projects were distinct; the majority showed more basic projects and needed more help compared to the private school students. We suspect the causes behind the difference are the language barrier and the

STEM background. Sixth grader's knowledge of circuits and electricity were alike; both public and private were not familiar and showed similar reactions. Additionally, older private schoolers learned the concepts before, and some of them were even familiar with robotics.

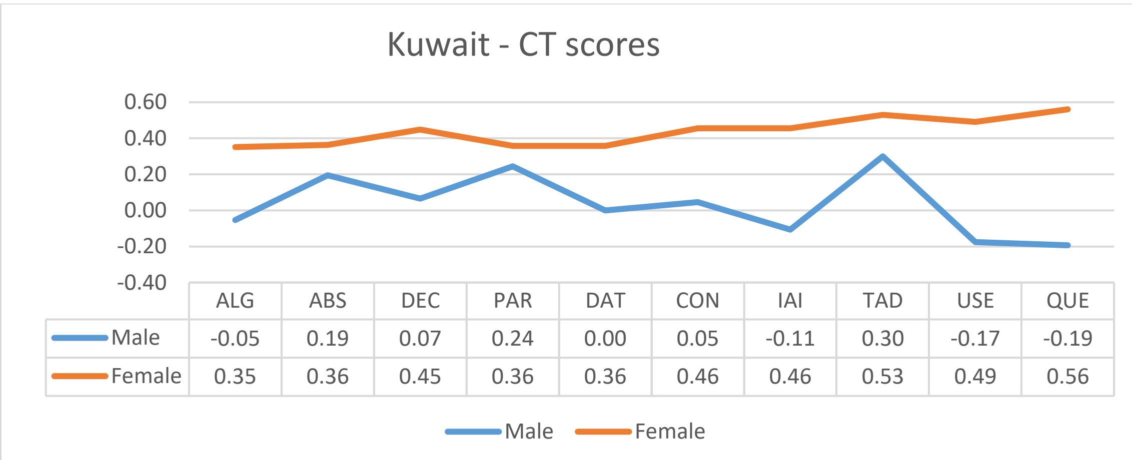
Religion and traditions comprised the second major factor that impacted this replication study. Because parents did not want their girls to be in a group with a mix of both genders, the class was divided into male and female sections. A nonessential change of class timing was also made in the MMC so that parents could drop off or pick up their children after finishing afternoon prayers. Besides the climate, after noon was more agreeable than the noon hour where the temperature reached 140 ˚F in summer 2019. In addition, this study promoted the MMC by preemptively describing the program and its success in the United States because Kuwaiti society respects prestigious universities. Parents of the participants were given a booklet describing the workshop to stoke excitement, and as an incentive, students who attended every day were refunded their registration fees.

Students also encountered obstacles while they were taking the self-efficacy survey. Because this was the first time Kuwaiti students had participated in this type of assessment, some students were confused about the structure and expectations of the survey questions. For example, one part of the survey asks students to rate six sentences that began, "When solving a problem, I...". Students were confused as to why they needed to provide different answers for one question, and they were unsure how to evaluate it as right or wrong. In general, Kuwaiti students do not freely answer questions nor are they specifically asked their opinions. Instead, they often respond to questions in unison at school, using words taken directly from textbooks issued by the MOE, where students have memorized the information for annual examinations. Rating is not part of the educational system in Kuwait. Furthermore, because they were beginning coders, many students struggled to see the connection between the questions and coding.

RQ-2 Does the STEM program improve students' CT abilities in Kuwait?

Figure 7.3 shows that students' CT abilities improved in almost all concepts. Notably, questioning (QUE) and testing and debugging (TAD) scores showed significant increases, potentially because of the social factor—competition between teams was very high and students wanted to prove their knowledge, especially in the gender-segregated sections.

Figure 7.3 KW Self-Efficiency Scores of CT Abilities



Female participants exhibited a similar trend between reusing and remixing (USE), control flow (CON), and incremental and iterative (IAI). Algorithm (ALG), abstraction (ABS), parallelization (PAR), data (DAT), and Decomposition (DEC), however, were not significant, which was potentially because the students needed to employ high levels of thinking.

The project results from the last day of the program showed a large section of code or identical to what was taught in the previous sessions, potentially indicating that students were not taught to divide their work. Obvious gains in student self-efficacy with CT skills were observed for females but not for males. According to UNESCO, females from this region always show higher engagement overall with education [283]. Male scores did not show any statistical significance, so the effect size could not be compared between genders.

Table 7.5 compares the knowledge scores of the two genders. Participant scores were statistically significant between the W-F group (m = 16.58, SD = 4.05) and the W-M group (m = 13.77, SD = 3.58), with p = .006, an effect size of -.02. Future research will provide additional data.

Table 7.5 Comparisons of the Knowledge Score Outcomes

Countries	*W-USA*	*W-KW*	*W-F*	*W-M*
Mean	17.03	15.20	16.58	13.77
Variance	15.68	16.39	16.38	12.81
SD	3.96	4.05	4.05	3.58
P-Value	0.046		0.006	
Effect Size	0.647		-1.022	

Table 7.6 Comparisons of CT Skills

Skill	**USA**	**KW**	**USA-Male**	**KW-Male**	**USA-Female**	**KW-Female**
ALG	0.33	0.14	**0.56**	-0.05	*0.34*	*0.35*
ABS	**0.73**	*0.28*	**0.61**	0.19	**0.62**	*0.36*
DEC	0.24	*0.25*	*0.34*	0.07	*0.42*	*0.45*
PAR	*0.44*	*0.30*	**0.54**	*0.24*	*0.39*	*0.36*
DAT	**0.56**	0.17	**0.66**	0.00	**0.63**	*0.36*
CON	*0.31*	*0.24*	*0.32*	0.05	*0.43*	*0.46*
IAI	*0.33*	0.16	*0.28*	-0.11	*0.23*	*0.46*
TAD	*0.25*	*0.41*	*0.21*	*0.30*	*0.21*	**0.53**
USE	0.20	0.15	*0.28*	-0.17	*0.05*	*0.49*
QUE	0.19	0.16	0.49	-0.19	*0.23*	**0.56**
# Students	100	65	67	34	33	31
Pre-Mean	3.61	3.46	3.71	3.55	*3.65*	3.35
Post-Mean	3.89	3.76	4.06	3.59	3.98	3.95
SD	1.06	0.79	1.05	0.82	*1.03*	0.67

The effect size $(\boldsymbol{post - pre / \ stdev})$ is noted as small, medium, and large; bold font indicates a medium effect (.5), and italicized font indicates small effect (.2). Statistically significant results are shaded based on associated p-values (<0.05).

RQ3 - What are the similarities and differences between Kuwaiti and U.S. student performances when they are taught STEM (MMC)?

Analysis of study results confirmed that the replication of the MMC program between the United States and Kuwait produced a similar trend and gains for CT concepts and program knowledge (Table 7.6). A comparison of scores showed that U.S. students demonstrated more significant effect sizes in ABS, PAR, and CON; KW showed higher gains in TAD skills.

Results of the remaining CT skills were ambiguous. As shown in the table, USA-Male exhibited higher scores in all CT concepts than KW-Male for the one with a significant p-value. Scores for the CT concepts of DEC, IAI, TAD, and USE scores were not statistically significant. In contrast, scores for KW-Female were slightly less in some concepts and higher in ALG, CON, and TAD than USA-Female. USA-Female scored higher in ABS, DAT, and PAR. Scores for the CT skills DEC, IAI, USE, and QUE were not significant.

For gained knowledge, Table 7.6 shows that students in both experiments grew more confident with programming and building LED circuits on their own. The T-test resulted in higher knowledge scores for the United States than Kuwait. Evaluation of the gained knowledge between the two regions showed that improved scores of participants were more statistically significant for the U.S. group ($m = 17,03.9$, $SD = 3.96$) than the Kuwait group ($m = 15.20$, $SD = 4.05$), where $t(56) = 2.04$, $p = .046$, and medium effect size $d = 0.647$. Thus, results showed that all participants learned fairly from the program.

7.3.4 Limitations

Although this study is limited to one region, it could have similar results for neighboring Arabic countries. However, knowledge backgrounds of residents in other countries may differ slightly. Another validity is participants' baseline and educational environment lead to different

CS and English background, and that is seen in their interaction through the program. In addition, Arabic speakers in the program required extra time to grasp the program's concepts because of the language barrier.

7.3.5 Conclusions

The replication of the pilot study in Kuwait was a unique experience that offered valuable insights. Positive insights included the high rate of acceptance and participation in both countries. Negative insights included unexpected obstacles that needed to be avoided or remedied. Language barriers and concepts need to be given ahead of time to save time because the concepts are new and require further explanations to make sense to the students. In addition, traditions and religious aspects should be accounted for, including minor adjustments to suit various people groups. Overall, the results revealed a promising start with many positive indicators. Further investigations should be undertaken in this field on a larger participant group in neighboring GCC countries.

7.4 Experiment 2: Reversing Gender Stereotypes in STEM Colleges in a Gender-Segregated Region [278]

Although women are the minority in STEM fields and degree programs in most countries throughout the world, reversed gender stereotyping is evident in countries such as Kuwait, United Arab Emirates, Sweden, and Iran. In these countries, women outnumber men in education and STEM fields. In fact, the 2020 report of the National Academies of Sciences, Engineering, and Medicine states that Kuwaiti females experience no gender-related academic barriers, with females comprising 60%–80% of college students in STEM programs and 81.7% of governmental STEM jobs [1]. Comparatively, 59% of male graduates majored in science fields, with only 20% of males graduating from STEM colleges [2].

To the best of our knowledge, no previous research has investigated factors that contribute to reversed gender stereotyping in Kuwait. Therefore, the primary goal of this study was to identify factors that influence male and female performances and preferences in STEM education. This study employed sequential exploratory methodology to identify contributing elements. Interview results of a small sample of participants were used to build measurement tools for a broader population. This paper is in the QUAL stage, the first step of the sequential exploratory methodology. A STEM model framework was created to detect the connection between STEM model factors and the participants' experiences. Interview results revealed 14 influential factors as well as an educational gap between high school and college stages. Skills and individual characteristics were shown to determine student success rate, meaning students with characteristics of high-ability learners, were projected to succeed, while students with characteristics of Peter Pan syndrome, a condition in which a person lives in such a way that prevents them from developing valuable psychological maturity, were expected to face more challenges.

Research Questions:

To identify the factors behind reversed gender stereotypes and build a quantitative tool, the following research questions were considered:

RQ1: What STEM Model Factors Influence Male Preferences and Performances in STEM Education?

RQ2: What STEM Model Factors Influence Female Preferences and Performances in STEM Education?

RQ3: How do Male and Female Preferences and Performances Compare based on STEM Model Factors

7.4.1 Method

7.4.1.1 Sample and Setting

The sample criteria were taken from education regulations in Kuwait. To maximize variation and account for unusual cases, this study included the following:

1. High school male science major who does not want to go to a STEM college
2. High school male science major who desires to go to a STEM college but is unable
3. High school male literature major
4. University male student who went to a STEM college and then switched to a non-STEM college
5. University male student who went to a STEM college and dropped out of college
6. University male student who went to a STEM college, dropped out, and then returned after some time
7. University male student who went to a non-STEM college
8. Male science major with a high GPA who enrolled in a training institute (first choice)
9. Male student who dropped out of a STEM college and enrolled in a training institute
10. High school female STEM major with a high GPA who wants to attend a STEM college
11. High school female student at a STEM college with a moderate GPA
12. Female graduate with a moderate GPA employed in a STEM job but no leadership position
13. Female employed in a STEM job but no leadership position

This study recruited 13 participants (nine males and four females) from organizations and educational institutes such as male high schools, female high schools, universities, and a training institute. Participation was incentivized with gift cards. Two interviewers conducted interviews via Zoom and Microsoft Teams, the same platforms used by schools during the Covid-19 pandemic. All the students had the necessary devices and familiarity with the applications. The study protocol was approved by university research compliance.

7.4.1.2 Instruments

Two instruments were developed for this study. Instrument 1, which consisted of 28 structured, open-ended interview questions, was used to investigate the existence of STEM model factors. The first column in Table 7.7 shows each interview question, and the second column shows the expected associative factor. Instrument 2 consisted of unstructured interview questions and spontaneous answers from the respondents to determine existing factors or identify new factors. Instrument 2 was only employed if the answers from the first interview were not clear or further investigation was needed.

7.4.1.3 Design

This research followed exploratory sequential research design, beginning with phase 1—QUAL phase—which involves collecting and analyzing qualitative data to build a tool to collect quantitative data. The QUAL stage is foundational for developing a measurement tool to assess a broad population by identifying items to be included and essential factors that shape students' STEM preferences.

This study was carried out over an 11-week period. Data were collected using interviews conducted in the Arabic language, with infrequent English use. The interviewers recorded participants' answers to primary interviews; follow-up interviews were conducted if data was unclear or further investigation was needed. The older participants carry multiple cases, where they have more stories about their high school, college, and workplace.

The interviewers memorized the questions and factors before the interviews to allow maximum eye contact and engagement throughout the interviews. Each interview lasted 30–55 minutes, and sessions were recorded with permission from the participants. The interviewer began with an open-ended question to encourage free discussion. The questions were then read clearly from G-file (described below), and participants were given ample time to respond. The researcher then asked if the interviewee wanted to share additional information after the questions were finished.

Table 7.7 Interview Questions to Identify STEM Model Factors

#	Questions	Factors
1	How is school/college?	Open-ended
2	Why did you choose your major? **What is your opinion of STEM majors?	Open-ended, f3
3	Describe your routine on school days and weekends.	**f12, f12**
4	Do you have any hobbies, interests? How do they fit into your daily routine?	**f12, f13**
5	What technology device do you use for studying? Would you like to replace it and why?	**f1, f2**
6	What is your responsibility at home?	**f12, f15**
7	How do you prepare for a math exam? How do you prepare for an English/Arabic exam?	**f13**
8	Do you think high school English class is enough to be fluent in English? Do you wish to study abroad to learn English?	**f13, f17**
9	How do you complete your STEM assignments? What do you do if you do not know the answers?	**f1, f2, f8-11, f13**
10	Describe your current study environment. (Alone? At home? Café?)	**f1, f2, f13**
11	What do you think of your science/math curriculum?	**f10**
12	What do you think of the way of teaching the STEM subject? (Instructors' method)	**f10**
13	Are there any science or math clubs or *after-school activities at your school/college? What do you think of them? Do you join them?	**f10-11**
14	What do you think of your school/college administration and their point of view on STEM subjects?	**f10**
15	Do you have any friends? Do they share the same major?	**f9**
16	What do you do when hanging out with friends? Do you have any study groups?	**f9, f13**
17	Have you and your friends decided where you want to go after graduation? Did you discuss it multiple times? Debates?	**f9, f4, f5, f6, f7**
18	In your opinion, what are the most desired jobs in Kuwait? And what do you want to be? Why?	**f4, f6, f7, f5**
19	How do your parents see you after graduation? Do you share the same expectations?	**f8**
20	In your opinion, does studying abroad differ from studying in Kuwait? Why?	**f14, f10, f6, f7**
21	Who is your role model? Does he/she inspire you in your life? How?	**f14, f8,f9,10,f11**
22	At the college level, do you prefer to study in Arabic or English and why?	**f10, f17**
23	How many times do you need to read an English book to fully understand it? How many pages? If you see unfamiliar words, what do you do?	**f7**
24	Which majors do you think Islam would recommend at STEM colleges? And why?	**f16, f18**
25	What is your opinion of Kuwaiti politics? Do the results meet your expectations? (Note: Kuwait just had an election and no women won)	**f16**
26	If you had the authority to change one assembly member, would you put a woman? Who and why?	**f16**
27	What do you think about the large number of females attending STEM colleges?	**f16**
28	If you could go back in time, would you change anything related to your education? Do you wish you had done things differently?	**f14**

7.4.1.4 G-file

G-file is a data management tool that reveals the links between model factors and participant answers by organizing the interview questions and factors into a matrix. The first column contains the list of questions, each in a separate row, followed by 18 labeled factor columns, as shown in Table 7.8. The intersection between a question and a factor is marked (x) if the interviewee's analyzed theme indicates a factor. In addition, each answer was added to the last column, the raw-answer column. A separate G-file was used for each participant.

Table 7.8 STEM Model Factors that Influence Male Preferences and Performances

	ID	Males	f1	f2	f3	f4	f5	f6	f7	f8	f9	f10	f11	f12	f13	f14	f15	f16	f17	f18
H*	1	SL			x	x		x	x			x		x	x	x	x			
	2	SN			x	x	x	x		x	x	x	x		x		x			
	3	L				x		x	x	x	x	x	x	x	x		x			
U*	4	S								x	x	x		x	x	x	x		x	
	5	AH			x	x		x				x	x		x	x	x		x	
	6	K			x	x			x			x		x	x	x	x			
	7	AZ						x	x	x		x				x				
T	8	MR				x	x	x	x	x		x			x					
	9	MSH			x	x		x	x			x			x	x	x			

*(H: high school, U: university, T: training institutes), ID is the participant sequence mentioned at the sample.

7.4.2 Results

Colaizzi's descriptive methodology was used to guide the data analysis and implement data interpretation techniques [292]. First, interview transcriptions were divided into paragraphs according to the questions, and then the paragraphs were divided to correspond to a question in the raw-answer column in the G-file according to the "cutting and sorting" of the Tactile approach. Second, significant statements were identified using keywords and keywords-in-context that highlighted a factor, as shown in Figure 7.4. Third, the meaning was formulated by examining all keywords and significant statements of a factor using comparison, contrasting, and social science queries. Fourth, common themes among STEM model factors were compared to confirm their existence and new themes were recorded. Fifth, participant experiences were described using the theme and quoted statements, and then the descriptions were validated by two older participants. Finally, the findings were updated, and figures were generated.

The comparison of themes found with STEM model factors (step 4) was the primary step in this research. As shown in Table 7.8 columns marked with an *x* indicate STEM factors over the themes, which could then be used for the QUAN tool. Results showed that the schools (f10) factor was prevalent, with themes such as teaching style, teacher-student connections, materials, commitment, and administration.

Figure 7.4 Keywords and Keywords-in-Context for School Factors and Habits Factors

3.a. Male School Factors **3.b. Male Habits Factors** **3.c. Female Habits Factors** **3.d. Female School Factors**

RQ.1 What STEM Model Factors Influence Male Preferences and Performances in STEM Education?

Table 7.9 shows that 14 factors influence male preferences and performances in STEM education: passion (f3), workforce (f4), geography (f5), finances (f5), prestige (f7), family (f8), friends (f9), schools (f10), communities (f11), life routine (f12), study method (f13), maturity (f14), ability (f15), and language (f17). Although the remaining four factors (availability [f1], quality [f2], gender [f16], and religion [f18]) did not significantly influence male STEM preference, the availability (f1) and quality (f2) factors of technology's current level meet the needs for self-fulfillment. To consider whether these two factors influence Kuwait's STEM performances and preferences, participants who lack technology or have inadequate equipment must be compared.

The schools factor (f10) was shown to significantly influence all educational stages, specifically challenges related to school materials (e.g., books, assignments, quizzes), teaching style; and teacher/student relationships that affect participants' academic performances. Students who overcome those obstacles in high school then encounter further challenges related to course materials, instructors' teaching styles, and unfamiliarity with course concepts in addition to the language barrier that occurs when the teaching language switches from Arabic to English when they enter STEM colleges.

Maturity (f14) and ability (f15) factors were shown to impact male students' abilities to face obstacles. Some participants' answers revealed limited skills that prevented adaptation to new study methods and materials. The schools (f10) and family (f8) factors directly affected participants' abilities and maturity. The school keywords were highly repeated over to private tutors, depending on the question banks, teacher's aperient, lack of guidance at school, and limited responsibilities at home, as shown in Figure 7.4.

The influence of specific factors varied throughout the educational stages, while student preferences and performances varied according to developmental growth. The factors that were shown to influence the preferences of young students, or students in the first years of high school, were passion (f3), workforce (f4), geographical (f5), financial (f6), prestige (f7), friends (f9), family (f8), and communities (f11). After experiencing higher-level academia, however, their preferences and performance factors changed to school (f10), study method (f13), life routine (f12), maturity (f14), and ability (f15), and students' goals aligned more realistically with their cumulative GPAs. The preferences of older students, or students who returned to academia after dropping out of college, pausing their education, or transferring to another STEM institute, were influenced by workforce, prestige, financial, and family factors. These students exhibited more maturity (f14) factors that helped them face obstacles and sustain academic advancement. Overall, the measurement tool considered 14 factors.

Table 7.9 STEM Model Factors that Influence Female Preferences and Performances

	Female	ID	f1	f2	f3	f4	f5	f6	f7	f8	f9	f10	f11	f12	f13	f14	f15	f16	f17	f18
H	AM	10			x			x		x	x	x	x	x	x	x	x			
U	LA	11				x	x	x	x	x	x	x		x	x	x	x		x	x
E	AS	12			x			x	x	x		x	x	x	x	x	x	x	x	x
	SH	13			x				x	x		x	x	x	x	x	x	x		x

(H: high school, U: university, E: employee)

RQ.2 What STEM Model Factors Influence Female Preferences and Performances in STEM Education?

Table 7.9 shows that 16 factors influence female preferences and performances in STEM education to varying degrees throughout development growth stages. Conversely, the results also show that the technology factors (f1 and f2) do not influence female preferences. In high school, the influences were shown to be passion, family, schools, communities, life routine, ability, financial, study method, and maturity. Workforce, geographical, financial, prestige, friends, schools, ability, family, life routine, study method, and maturity were the influential factors for college students. In the workplace, passion, prestige, family, schools, communities, ability, gender, and religion were influential.

Research results showed that factors' influences depended on participants' motivation. If a participant was determined to enter a certain profession, the workforce (f4), geographical (f5), prestige (f7), and financial (f6) factors were most influential. If a participant's motivation was passion (f3), however, they engaged more with sociocultural factors such as family (f8), friends (f9), and schools (f10). Overall, maturity (f14) was shown to be the most influential factor, indirectly affecting a person's ability to adapt to changes to life routine (f12) and study method (f13). Although language (f17) was shown to influence STEM education, female participants demonstrated readiness and ability to learn and adapt quickly. In fact, a female interviewee who admitted to struggling with English during her first year of college handled it quickly.

RQ3: How do Male and Female Preferences and Performances Compare Based on STEM Model Factors?

Figure 7.5 Male Graduates 2018–2019

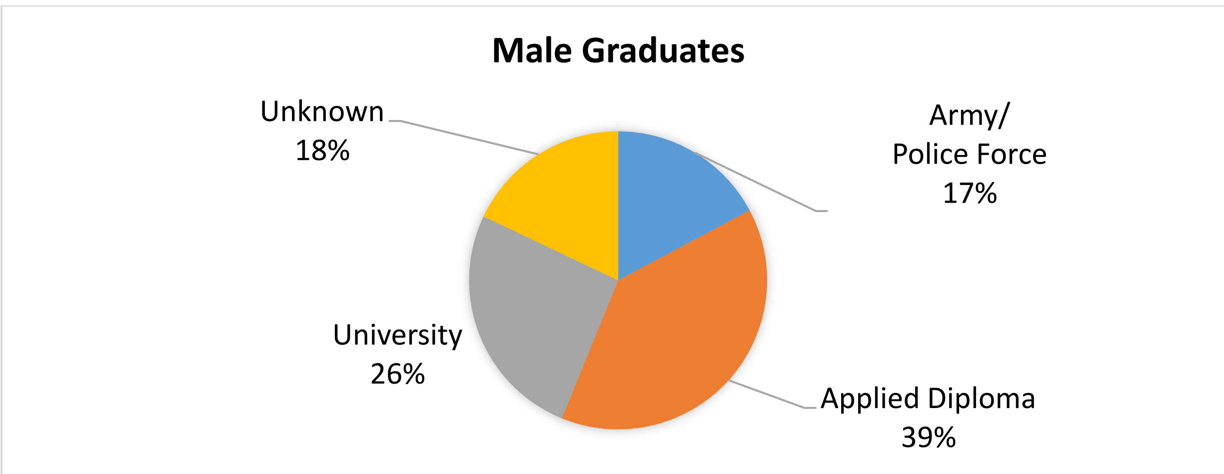
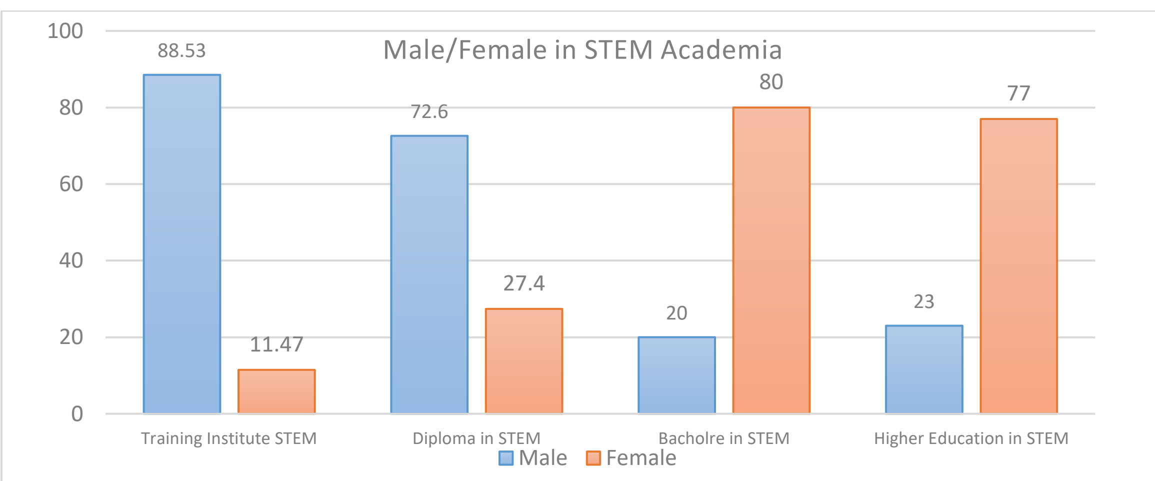


Figure 7.6 Male/Female Percentages in STEM Academia



Although males and females confront the same educational obstacles in Kuwait, certain factors uniquely shape their abilities and maturities. Social and economic factors often motivate both genders to choose science for a major at high school as students consider potential careers; salaries; prestige; parental guidance; the influence of friends and relatives; and science qualifications to enter college. However, maturity and ability factors were shown to play a greater role in motivating females to enroll in STEM colleges than males. A desire to gain independence as well as their commitment to studying, school activities, and finding solutions to obstacles identified the female participants in this study as high-ability learners [293, 294]. On the other hand, for the same factors, the teenage male participants demonstrated a lack of effort, including a dependence on tutoring and question banks as well as a tendency to skip classes when they felt bored or stressed [295], which indicated Peter Pan syndrome, or a lack of developed maturity.

The study results were correlated to statistical data from Kuwait University and Kuwait's Central Statistics Bureau (CSB) for academic year 2018–2019 [296, 297]. In that year, 8,839 males graduated from high school, 59% with a science major. Comparatively, 48% of female graduates were science majors. Of the 8,839 male graduates, 974 joined the police force; 128 joined the national guard; 334 joined the army; 3,248 enrolled in PAAET colleges for diploma degrees; 2,159 enrolled in other universities, and the remainder were unknown, as shown in Figure 7.5 [297]. Also, statistics showed that the number of male students who failed that academic year was double the number of females in the science major [298], as shown in Table 7.10 University STEM opportunities are very competitive, especially in engineering and medical fields. Kuwaiti males have abundant career options, which could influence their STEM preferences. Females have limited options, meaning they must demonstrate maximum academic performance to enter STEM colleges, resulting in increased motivation.

Figure 7.6 shows percentages of academic enrollment by gender in STEM majors. Although a higher percentage of males major in science in high school, a higher percentage of males pursue diplomas compared to females who apply for advanced STEM degrees. Females more readily attempt to earn higher degrees with the highest possible scores. Thus, as shown in Figure 7.6, females comprise a large majority (77%) of STEM higher education [296]. STEM colleges also have reported an increased number of female students, but women still must achieve a higher GPA than males to be accepted into the programs. In fact, lawsuits have challenged and cases won that have forced the public college in Kuwait to offer equal college acceptance opportunities, regardless of gender [299]. With a female population of less than 1 million, four Kuwaiti women are in the top 20 over the 100 strongest women in the Middle East [300].

Table 7.10 Comparison of Academic Failings by Gender in High School [298]

			Science				Literature			
Gender	Grade 10		Grade 11		Grade 12		Grade 11		Grade 12	
	m	f	m	f	m	f	m	f	m	f
Failing %	7.0	3.3	0.6	0.3	0.8	0.2	0.7	0.6	0.5	0.2

7.4.2.1 Recommended Improvements for the STEM Model and Suggested QUAN Factors

Results of this study show that the f3–f17 factors and three identified themes (school material, teacher connections with students, and teaching method) should be included in the QUAN instruments. A suggestion of changing the STEM model into the technological category (f1 and f2) demonstrated a neutral influence over STEM preferences in Kuwait society. However, the research occurred during the Covid-19 pandemic, which forced technological availability and access, meaning technological obstacles were previously resolved. However, we recommend considering one to two technological questions or reinvestigating the factor again in different situations to be able to measure their true influence.

The economical category (f4 and f5) was shown to influence STEM preferences, especially during the first year of high school, when students are building their STEM preferences. The influence of economic factors shapes student preferences throughout the educational stages. Students often choose science majors as a result of societal pressures of workforce (f4), finances (f6), and prestige (f7) factors. Because society highly values engineering and medical fields and only science majors can enroll in STEM colleges because of educational regulations, most students highly prefer STEM fields, which makes them more passionate (f3) to join science. Questions about economic factors should investigate preferences throughout all educational stages: before selecting a high school major, after finishing high school, at the beginning and middle of college/training, and at the end of college.

Study results suggest that the geography (f5) factor should be combined with the workforce (f4) factor to increase the influence on STEM preferences. Students with STEM preferences often change their preferences, even at young ages, after they face sociocultural obstacles. Young Kuwaiti students who grow up in wealthy environments (welfare and family) with minimal responsibility, have decreased chances to develop maturity (f14), life routine (f12), and strong ability (f15) factors to help them overcome obstacles. Results repeatedly showed that the schools (f10) factor could be considered a theme instead of meaning where they significantly influence STEM performance, such as study method, school material, teacher connections with students, and teaching style. Thus, they should be included as a subgroup under the schools (f10) factor with condensed questions for investigation. Similarly, the language (f17) factor should be a shared factor between religion (f18) and schools (f10), where results identified a significant language gap between high school and college because the teaching language in high school is Arabic and English at college. Overall, the sociocultural questions should be investigated throughout all the educational stages.

A measurement tool should investigate the diversity of a broader sample and consider the education regulations. Because Kuwaiti students often pause, drop, and return to school, the tool should include students who retake high school multiple times. And the questions should consider first-time students and students who retake high school or resume their education, with additional sections for a sample of those who resume school or change their major to identify the obstacle that caused students to change majors, drop out of college, or transfer to training institutes. The questions should apply to young students at high schools and universities as well as older students.

The habits classification within the sociocultural category in the STEM model should be renamed to maturity and include only life routine and ability as subfactors. In addition, the study method (f13) factor should be shared between schools (f10) and habits to show that schools influencing the method of study, such as when a student describes the differences between study techniques at high school and college.

7.4.3 Conclusions

STEM education in Kuwait has demonstrated reversed gender stereotyping, meaning females surpass males in STEM fields. The results of this research show the existence of the f3–f17 factors from the QUAN measurement tool. Economic factors were shown to shape STEM preferences, and sociocultural obstacles—such as school materials, unfamiliar teaching methods, and the use of English as the primary teaching language—most often cause students to change their preferences. The results show that students were unprepared for subsequent educational stages. However, ability (f15), maturity (f14), and passion (f3) factors equipped students to face obstacles, especially for females. Overall, this study introduced a measurement tool to capture the factors on a bigger scale. Future work could formulate a measurement tool to investigate the phenomenon in Kuwait in more depth.

7.4.4 Limitations

The main limitation of this study was that the researchers were part of the investigated society, meaning the data collection and analysis was susceptible to bias. Also, the accuracy of participant interpretation cannot be guaranteed because some participants are still high schoolers and may not have well-developed communication skills, which can lead to misperceptions of an experience. Another limitation of the study is that, because words can have multiple interpretations, dialogue with participants could have been misinterpreted.

7.4.5 Future Work

Future work could include studying the phenomena with a broader population to generalize the results by using the findings of this research. In other words, researchers could implement phase 2 (QUAL) of this exploratory sequential design, which involves collecting and analyzing qualitative data to build a quantitative tool to collect quantitative data, and which could help generalize the results to the Kuwait population.

7.5 Experiment 3: Measuring Awareness of Computational Thinking in Kuwaiti Educational Institutions [276]

CT is a mindset tool that uses computing ideas to improve reasoning through the processes of problem-solving. Continuous technological evolution needs more efficient ways to solve problems. In the same token, CT embraces reasoning skills to study a problem objectively (logic thinking) by concentrating on the essential features of a problem and ignoring low-level details (abstraction), recognizing similar characteristics (pattern recognition) to break down complex problem into subproblems (decomposition), using steps of instruction (algorithms) to solve the problem, and finally determining if a solution is efficient for the problem (evaluation). Educators must empower their students to become computational thinkers and encourage them to take ownership of their learning. Introducing CT concepts to students can help them become producers, not just technology consumers; they can use these abilities to impact the world. Policymakers have taken action to empower CT education worldwide [1]. However, not all countries—including Kuwait—have acknowledged the need for this knowledge. According to the Human Development Index (HDI) in 2020, Kuwait ranked 63 out of 189 countries, with the lowest HDI score among neighbor's countries. This paper aims to measure awareness of CT in educational institutions to propose a plan that can promote CT in the Kuwait education system. ISTE developed a CT Model to guide the way to implement CT in K–12 education [2]. To efficiently allocate the resources, educational researchers suggest first estimate stakeholder awareness of the concept [3]. Because CT is a relatively new concept, many people are unaware of its nature [4]. Determining awareness is a prerequisite for adopting and improving CT [5].

This study investigated CT awareness in Kuwait, with the primary objective of studying CT awareness of content knowledge (CK), or knowledge of CT concepts; pedagogical knowledge (PK), or knowledge of CT purposes, values, and aims; and technological knowledge (TK), or knowledge of the technologies and resources that support CT learning. Using the Technological Pedagogical Content Knowledge (TPACK) framework [6], the authors developed a questionnaire to measure CT awareness of survey participants using the six Computing at School (CAS) concepts of CT: logical thinking (LOG), algorithms (ALG), decomposition

(DEC), patterns recognition (REC), abstraction (ABS), and evaluation (EVA) [7]. The survey was distributed to students and educators in 18 educational institutions in Kuwait. Results showed a high level of awareness of CK, TK, and PK, with 65% of participants demonstrating a high level of familiarity with ALG, LOG, and EVA and less familiarity with DEC, ABS, and REC. Overall, 80% of survey participants were technology consumers. Study results revealed the need for more guides to increase the use of CT, especially for educators with administration roles who presented the lowest scores of CT awareness. Previous training and the job nature were shown to impact the awareness level for all ages, which guides the formation of a plan using the CT leadership toolkit model.

7.5.1 Background

7.5.1.1 Computational Thinking skills

Institutes define CT according to unique goals and standards, meaning no unified CT definitions exist among researchers. Computing at School (CAS) defines CT thinking as a cognitive process that involves thinking logically to solve problems using specific sequences in algorithms, decomposition, generalizations, patterns, and evaluation. A conceptual framework describes pedagogic plans for teachers and offers models for assessment [2]. This current study was adopted the CAS definition shown in **Error! Reference source not found.**.

Table 7.11 CT Concepts and CAS Definition [2]

Abbr.	Description
DEC Decomposition	Decomposition usually refers to the ability to break down a problem into subproblems to reduce its complexity.
ABS Abstraction	Abstraction concentrates on significant information instead of consuming time analyzing worthless details.
REC Pattern recognition	Pattern recognition uses patterns to refer to data sequence for prediction purposes.
ALG Algorithmic thinking	Algorithmic thinking uses ordered rules and logical instructions to solve problems.
LOG Logical thinking	Logical thinking uses a tested premise to reach a conclusion using certain logical steps.

EVA Evaluation	Evaluation judges proposed solutions to enhance creative problem solving and measure student empowerment to formulate problems within the computational context.

7.5.1.2 Technological Pedagogical Content Knowledge (TPACK)

We implemented the TPACK model described in section 3.7.

7.5.1.3 CT Model for Systemic Change

The Model for Systemic Change was designed to help incorporate CT into K–12 education [301] as part of the CT leadership toolkit plan developed by the ISTE and the Computer Science Teachers Association (CSTA) with generous support from the National Science Foundation (NSF). The model helps educators understand, value, and implement CT using four steps: lead, build, connect, and practice. It leads efforts to increase CT awareness among leaders and practitioners; builds traction by relating CT to local goals, educational initiatives, or reform efforts; connects teachers to help them explore grade-appropriate implementation; and creates opportunities to practice CT learning activities.

7.5.1.4 Related Work

Bower measured CT understanding of educators before and after CT workshops that identify the strategic issues that happen while using CT to solve problems. The authors applied the TPACK framework to survey teachers, resulting in observed CT skills of problem representation, abstraction, decomposition, simulation, verification, and prediction. The results highlighted teacher awareness, concept understanding, and confidence of CT. The current study also used TPACK, but different CT concepts were applied, and the survey style employed a questionnaire to measure CT instead of preworkshop and postworkshop surveys [20].

7.5.2 Method

7.5.2.1 Sample and Setting

This study conducted convenience sampling to select education institutions and willing participants. A total of 18 educational institutions were involved in the study, including three universities, one training institute, and 14 public K–12 schools. Overall, 55% of participants (n = 305) were females and 45% were males. Of the total sample, 118 participants were students, 136 were teachers, 19 were department heads, 12 were vice principals, 5 were principals, and 9 worked in noneducational fields. Participating students earned bonus points from their instructors. The percentages of age groups were: 32.9% aged less than 20 years, 31.9% ages 20–30, 27.5% ages 30–40, and 8.83% above 40 years old. Sample qualifications showed that 14.9% of participants had a postgraduate degree, 56.4% had a university degree, and the remaining participants were high schoolers. The survey was distributed online via social media and MS-Team's platforms, and study protocol was approved by university research compliance.

7.5.2.2 Design

This study applied survey research methodology to gain insight into educator awareness of CT in Kuwait. The research was carried out over a 3-week period in two stages. In the first stage, the pilot stage, the survey was emailed to experts (educators and linguistics) for review, and then it was modified according to their suggestions. The survey was initially applied to a pilot sample of 30 participants from the study community to ensure the questions' validity and reliability. In the second stage, the distribution stage, users were required to sign an online consent form to start the survey. The expected time range to finish the survey was between 30 minutes and 50 minutes, although the survey platform allowed the participants to save their current progress to finish later. After completing the questionnaire, the form was automatically saved onto the server while marking was completed.

7.5.2.3 Instruments

This study designed and used a CT awareness questionnaire derived from the TPACK framework. The questionnaire consisted of three parts. The first part, comprised of one section for students (current grades, major) and one section for teachers/employees (job, years of experience, department), collected demographic variables such as age, gender, and qualifications. The second part of the questionnaire was related to technological backgrounds of participants (daily technology usage, previous technology training, CT terms familiarity). The third part included the six main axes (ALG, DEC, ABS, REC, EVA, and LOG), with each CT categorized as CK, PK, or TK, as shown in Table 7.12. The questionnaire was answered according to a five-point Likert scale (strongly disagree, disagree, neutral, agree, and strongly agree).

Instrument Reliability and Validity

The pilot stage was validated by a calculated Cronbach's alpha test to determine the reliability of the questionnaire statements, and the Pearson correlation coefficient was used to measure the validity of the statements. The internal consistency validity tested using the Pearson correlation coefficient included the correlation of each item with its dimension in the axes of the survey, with a range of 0.0716–0.982 for the questionnaire statements. All correlation coefficients were statistically significant at the (0.01) level, which revealed the high level of internal consistency of questionnaire validity. General structural validity was calculated using the correlation of each axis with the total. Correlation coefficients ranged between 0.961** and 0.986**, and the statistically significant high correlation coefficients at the (0.01) level revealed the high level of general structural validity. Alpha Cronbach's reliability coefficient was calculated for the axes that ranged between 0.988 and 0.990, and the overall reliability coefficient was 0.999, which demonstrated high reliability as well as stability and suitability for an application.

Table 7.12 CT Awareness Questionnaire

	Content Knowledge (CK)	Pedagogical Knowledge (PK)	Technology Knowledge (TK)
Algorithms	• Individuals should use sequences as a way of solving problems. • Learners should follow rules in order to find solutions to challenging situations. • One must use a systematic approach in dealing with different tasks. • Mathematical processes should be employed in solving problems using finite steps. • Data driven approach is essential for problem solving.	• Teachers should develop students' algorithmic capabilities. • Effective teaching strategies should be provided to enhance algorithms. • Teachers should understand how to integrate algorithms into the curriculum. • Algorithms can be used for doing multiplication or division in classrooms. • Cooperative learning can be used to encourage students to adhere to rules in solving problems.	• Background knowledge of computer sciences can help understand algorithms. • Teachers should understand the mechanism of programming applications. • Teachers should have the ability to digitize a mathematical problem expressed verbally. • Computer based algorithm can be used in order to complete a task on time. • Machine learning can enhance the effectiveness of the learning processes.
Decomposition	• Solving problems will be easier when they are divided into parts. • Identifying the component parts of problems will help understand their different dimensions. • Large systems are usually consisted of smaller parts. • It will be harder to solve a problem that is not decomposed. • Students' cognitive resources can be managed effectively if the problem is broken into manageable parts.	• Knowledge schemas can be used to divide the task into sub-tasks. • Programming activities can be used to enhance decomposition tasks. • Teachers should provide students with strategies to enhance analysis and synthesis abilities. • Teachers present the complex problem and facilitate conversations to help students break it down. • Unplugged coding activities can be used to enhance decomposition abilities.	• Teachers can use Scratch programming activities to enhance students' synthesis and analysis sills. • Coding patterns can be used to divide a problem into manageable parts. • Digital learning environments can be used to enhance problem decomposition. • Structured programming can be used for problem factoring. • Teachers can break down the material on the computer program into parts to keep students' attention.
Abstraction	• One should focus on significant information while solving problems. • All unnecessary information should be deleted to focus attention on the main problem. • It is useful to design a model of proposed solutions after extracting the fundamental characteristics of the problem. • Abstraction helps students create a general framework of the problem and how it can be solved. • Simplifying a problem is regarded a critical step for solving it.	• Teachers should encourage students to simplify situations to facilitate studying its characteristics. • Teachers should explain multiple layers of abstraction and relations among them. • Abstraction can be involved in teaching different subjects such as Humanities and Social Sciences. • Mind mapping can be used in order to enable students to capture relevant information. • Teachers can use teamwork in order to encourage students to summarize the most important details within a lesson.	• Computer hardware can be used to manage the problem complexity. • Computing helps automate different abstractions by providing methods for scalability. • Electronic mind maps can be used to encourage students to focus on details. • Online extractive summarization can help determine the most relevant details in the topic to be studied. • Graph-based methods can help extract significant ideas during learning.
Pattern Recognition	• It is important to search for similarities among problems and within them. • The use of grouping and organizing processes can help reach efficient outcomes. • Students should recognize connections and differences among the different parts of a system. • Identifying patterns help make predictions during learning. • Students must identify the rules that govern adding a new pattern to existing ones.	• Class projects can be used in order to enhance pattern recognition skills. • Pattern recognition can be presented using slides. • Teachers should encourage students to find patterns to increase their awareness of the surrounding environment. • Teachers should encourage students to employ current patterns for solving future problems. • Teachers should encourage students to identify patterns across different disciplines.	• Teachers should help students identify how to use computers for pattern recognition. • Pattern manipulation using a digital slider can help students explore patterns visually. • Computers can be used to sort patterns through their shared characteristics. • Modules with codes can be used to organize related functions. • Artificial intelligence tools can be used for pattern recognition.

7.5.3 Results

This study analyzed student and educator responses to the following research questions:

RQ1 What is the level of CT awareness of educators in Kuwait?

RQ1.1 What is the level of CT Content Knowledge awareness?

RQ1.2 What is the level of CT Pedagogical Knowledge awareness?

RQ1.3 What is the level of CT Technical Knowledge awareness?

RQ2 How different is CT awareness between educators?

Responses were analyzed using repeated measures, ANOVA, and descriptive statistics. Of the total 305 participants, 11 did not complete the questionnaire and were excluded. Results were categorized into 27 datasets, as shown in Table 7.13. Datasets were formed as follows: Three from averaging the mean of the knowledge scores, six from averaging the means of the CT concepts, and 18 combinations between the knowledge scores and CT concepts, as presented in Table 7.14.

Table 7.13 Knowledge Concepts and CT Concepts Datasets

Acronyms	Description	Acronyms	Description
(1) CK	Content Knowledge scores	**(6) ABS**	Abstraction scores
(2) TK	Technical Knowledge scores	**(7) REC**	Pattern recognition scores
(3) PK	Pedagogical Knowledge scores	**(8) EVA**	Evaluation scores
(4) ALG	Algorithmic thinking scores	**(9) LOG**	Logical thinking scores
(5) DEC	Decomposition scores		

Table 7.14 Datasets Between Knowledge Concepts and CT Concepts

Acronyms	Description	Acronyms	Description
(10) ALG-CK	The scores of *Algorithmic thinking* and *Content Knowledge* questions.	**(19) REC-CK**	The scores of *Pattern recognition Content Knowledge* questions.
(11) ALG-TK	The scores of *Algorithmic thinking* and *Technical Knowledge* questions.	**(20) REC-TK**	The scores of *Pattern recognition* and *Technical Knowledge* questions.
(12) ALG-PK	The scores of *Algorithmic thinking* and *Pedagogical Knowledge* questions.	**(21) REC-PK**	The scores of *Pattern recognition* and *Pedagogical Knowledge* questions.
(13) DEC-CK	The scores of *Decomposition* and *Content Knowledge* questions.	**(22) EVA-CK**	The scores of *Evaluation* and *Content Knowledge* questions.
(14) DEC-TK	The scores of *Decomposition* and *Technical Knowledge* questions.	**(23) EVA-TK**	The scores of *Evaluation* and *Technical Knowledge* questions.
(15) DEC-PK	The scores of *Decomposition* and *Pedagogical Knowledge* questions.	**(24) EVA-PK**	The scores of *Evaluation* and *Pedagogical Knowledge* questions.
(16) ABS-CK	The scores of *Abstraction* and *Content Knowledge* questions.	**(25) LOG-CK**	The scores of *Logical thinking* and *Content Knowledge* questions.
(17) ABS-TK	The scores of *Abstraction* and *Technical Knowledge* questions.	**(26) LOG-TK**	The scores of *Logical thinking* and *Technical Knowledge* questions.
(18) ABS-PK	The scores of *Abstraction* and *Pedagogical Knowledge* questions.	**(27) LOG-PK**	The scores of *Logical thinking* and *Pedagogical Knowledge* questions.

The datasets were compared by gender (male, female); education roles (student, teacher, department head, vice principal, principal, and noneducational careers); concept familiarity (no, yes, not sure); technology usage (always, usually, rarely, never); previous technology training (MS office, programing, graphic design, database, search and browsing, others); ages (less than 20, less than 30, less than 40, more than 40); and qualifications (high school, college degree, postgraduate degree).

Tables 7.15 and 7.16 have significant results shaded based on associated p-values. The effect size following eta-squared η2 =($\boldsymbol{SSeffect}/\boldsymbol{SStotal}$) is noted as a small, moderate, and large reference; bold font indicates a large effect (.14), underlined results indicate a medium effect (.06), and no marks indicate a small effect (.01). The abbreviation M stands for the mean and SD for the standard deviation.

Table 7.15 Mean of CT Concepts for Gender and Roles

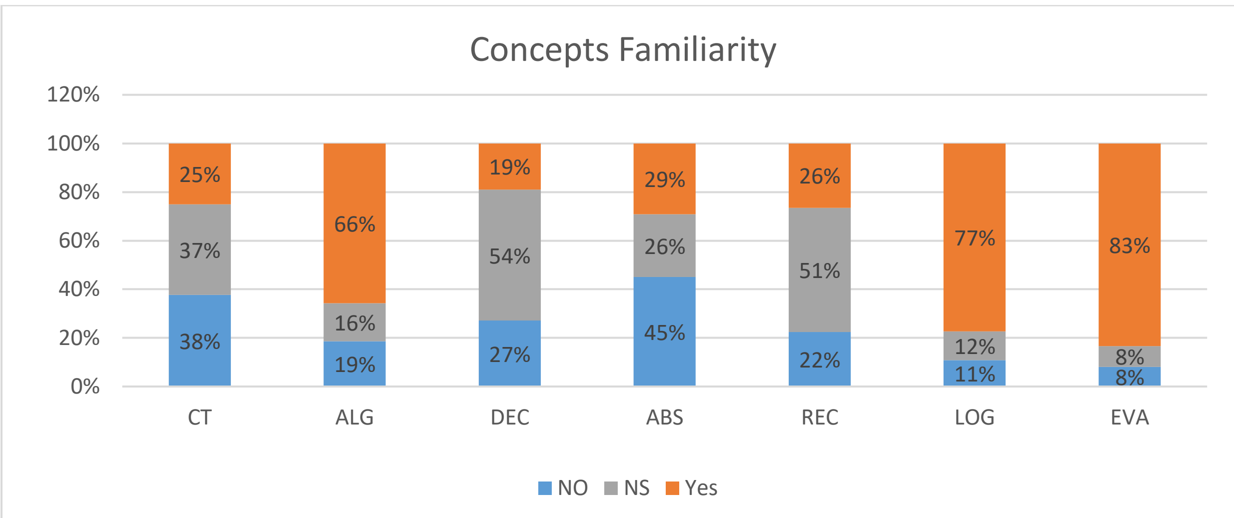
		ALG			DEC			ABS			REC			EVA			LOG		
		CK	PK	TK	CK	PK	TK	CK	PK	TK	CK	PK	TK	CK	PK	TK	CK	PK	TK
Female	M	4	4.1	3.8	3.8	3.9	3.8	3.8	4.2	3.7	3.8	3.9	3.8	3.8	3.9	3.8	3.9	4.2	3.7
	SD	0.7	0.8	0.8	0.8	0.8	0.9	0.8	0.9	0.9	1.0	0.9	0.9	0.9	0.9	0.9	0.9	0.9	1.0
Male	M	4	4.2	4.1	4.2	4.1	4.3	4.1	4.1	4.2	4.1	3.8	4.2	4.2	4.3	4.3	4.2	3.7	4.2
	SD	0.6	0.6	0.7	0.6	0.6	0.6	0.6	0.6	0.6	0.7	0.7	0.7	0.6	0.7	0.7	0.7	0.6	0.7
Student	M	4.1	4.4	4.4	4.2	4.2	4.4	4.2	4.4	4.2	4.2	4.3	4.2	4.3	4.3	4.4	4.3	4.2	4.2
	SD	0.5	0.6	0.6	0.6	0.5	0.6	0.5	0.5	0.6	0.7	0.7	0.7	0.6	0.7	0.7	0.6	0.7	0.7
Teacher	M	4.4	4.4	4.3	4.2	4.3	4.2	4.1	4.4	4.1	4.1	4.2	4.2	4.4	4.2	4.3	4.2	4.3	4.1
	SD	0.6	0.7	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9
Head-dep	M	4.8	4.7	4.7	4.6	4.8	4.7	4.6	4.5	4.6	4.7	4.6	4.6	4.4	4.3	4.6	4.5	4.6	4.5
	SD	0.3	0.3	0.6	0.6	0.4	0.4	0.2	0.1	0.2	0.0	0.2	0.3	0.1	0.2	0.2	0.1	0.2	0.1
Vic-principal	M	3.5	4	3.7	3.2	3.5	3.5	3.2	3.5	3.5	3.3	3.5	3.5	3.4	3.6	3.5	3.5	3.4	3.3
	SD	0.9	1.1	0.9	0.9	1.0	1.1	1.0	1.2	1.1	1.2	1.1	1.1	1.1	1.2	1.1	1.2	1.1	1.1
Principle	M	3.3	3.4	3.6	2.6	3.4	3.6	3.3	3.2	3.3	2.6	3.3	3.4	3	3.1	3.3	3.5	3.7	3.7
	SD	0.9	1.2	0.9	0.9	1.0	0.8	1.0	1.2	1.0	1.0	1.2	1.0	0.9	1.1	0.9	1.3	1.1	1.0
Other	M	4	4.3	4.5	3.9	4.2	3.7	3.5	3.8	3.7	3.9	4.1	4.3	4.5	4.1	4.5	4.6	3.9	4.6
	SD	0.7	0.2	0.2	0.3	0.9	0.8	1.1	0.4	1.4	0.2	0.5	0.5	0.8	0.2	0.5	0.9	0.5	0.5
Total	M	4.2	4.2	4.2	3.7	4	4	3.8	3.9	3.89	3.8	4	4	4	4.1	4.1	4.19	4	**3.99**
	SD	0.6	0.7	0.7	0.7	0.8	0.8	0.7	0.7	0.8	0.8	0.8	0.8	0.8	0.7	0.8	0.8	0.7	0.8
Overall	M		**4.13**			**3.9**			**3.87**			**3.93**			**4.06**			**4.0**	
	SD		.626			.766			.733			.800			.77			.76	

RQ1 What is the level of CT awareness of educators in Kuwait?

A repeated measure ANOVA between CK, PK, and TK scores indicated a significant difference for scores (F(1.88,551.7) = 27.4, p = .00, partial-eta-squared = .086). All main interactions were statistically significant at the .05 significance level except for the PK score. The effect size was small on PK and moderate on CK and TK. The comparison yielded a similar means to CK (M = 4.03, SD = .67) and TK (M = 4.03, SD = .73), followed by PK (M = 4.02, SD = .73).

Table 7.15 shows group interactions between the three knowledge and the six CT concepts. A significant difference of (F(17,4964) = 10.19, p = .00, partial-eta-squared = .034). The highest CK scores occurred near LOG (M = 4.2, SD = .8), with a similar mean between ALG (M = 4.0, SD = .6) and EVA (M = 4.0, SD = .8), followed by REC (M = 3.8, SD = .8), ABS (M = 3.8, SD = .7), and finally DEC (M = 3.7, SD = .7). The highest PK scores occurred near ALG (M = 4.2, SD = .8) and then EVA (M = 4.1, SD = .7), with a similar mean between DEC, REC, and LOG (M = 4.0, SD = .8), and finally ABS (M = 39, SD = .7). The highest TK scores were ALG (M = 4.2, SD = .7) and then EVA (M = 4.1, SD = .7), with a similar mean between DEC and REC (M = 4.0, SD = .79), followed by LOG (M = 3.9, SD = .8) and ABS (M = 3.8, SD = .8). Concept ALG always showed the highest score, followed by EVA.e ABS demonstrated the lowest knowledge scores.

Figure 7.7 CT Concept Familiarity



RQ1.1 What is the level of CT Content Knowledge awareness?

Pairwise comparisons between the CK scores and the CT groups showed the following statistical results: ALG-DEC (p = .02), ALG-REC (p = .003), ALG-EVA (p = .005), ALG-LOG (p = .00), ABC-DEC (p = .003), ABC-REC (p = .03), and ABC-LOG (p = .00). Figure 7.7 illustrates CT terminology familiarity to highlight the sequence of CT scores. Figure 7.7 and Table 7.15 show that the ALG concept had the highest scores in familiarity (Yes) and mean (M = 4), reinforcing the observation that high familiarity coincides with high means, which could be a result of CT learning at school because high school math lessons introduce the concept algorithm خوارزميات [22]. Also, the words originate from an Arabic scientist, thus, the information can be repeated in several subjects [23]. The term evaluate "تحليل" is used in almost all science courses [24, 25]. Logic thinking as terminology is popular among society. Many logic thinking trainings exist in Kuwait; for example, logical thinking is taught and used at the debate club of the Kuwait University Engineering Department [26]. However, at least 70% of the answers indicated that the concepts DEC, ABS, and REC were new or unfamiliar to the participants. Overall, the participants demonstrated a high level of familiarity with ALG, LOG, and EVA concepts and high unfamiliarity with DEC, ABS, and REC concepts, with a moderate effect size, meaning introduction to these concepts should be increased in the educational system.

RQ1.2 What is the level of CT Technical Knowledge awareness?

Pairwise comparisons between the TK scores and the CT groups showed no statistically significant effect between the groups. Previous training and technology were analyzed to understand the high TK scores.

Figure 7.8 Technology Usage

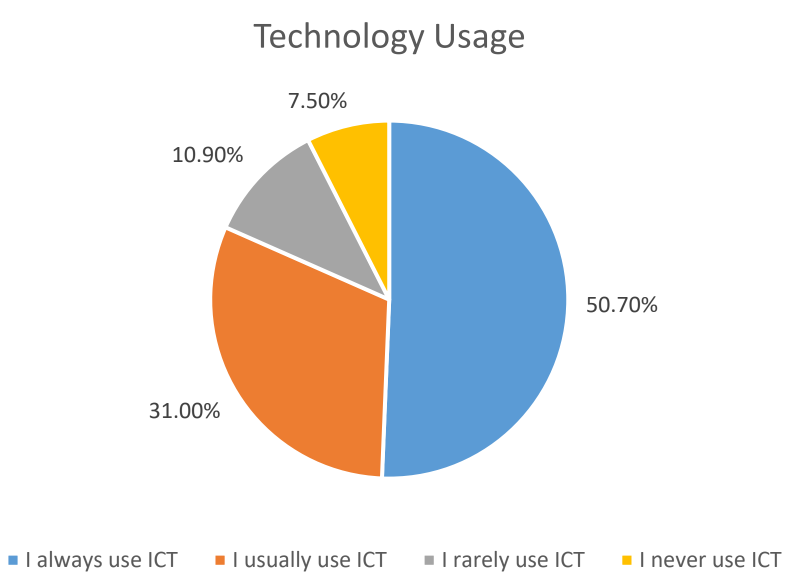


Figure 7.9 Previous Technology Training Courses

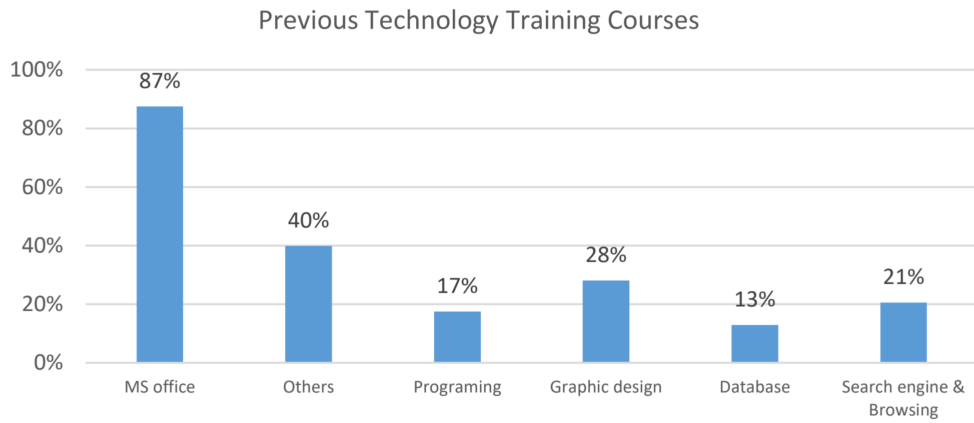


Figure 7.8 shows that approximately 80% of the study participants use technology in their daily life, with a majority of those respondents identifying as educators or college students. It could be inferred that the high score was due to the fact that the participants agreed to include technology in the classroom. The 20% of participants who responded that they rarely used technology were comprised of a mix of high school students and school principals, who are typically involved in decision making and administration [27].

Figure 7.9 illustrates participants' previous technological experience. Results showed that 87% of respondents had participated in MS Office training and 40% had taken diverse training courses, which could explain the high TK scores. Notably, less than 20% of study participants had database, programming, or data searching skills, which are directly related to CT skills, potentially implying that individuals are consumers of technology, not producers.

RQ1.3 What is the level of CT Pedagogical Knowledge awareness?

Pairwise comparisons between the PK scores and the CT groups showed the following statistical results: ALG-DEC ($p = .00$), ALG-REC ($p = .003$), ALG-EVA ($p = .005$), ALG-LOG ($p = .00$), DEC-ABS ($p = .003$), ABS-REC ($p = .03$), and ABS-LOG ($p = 0.00$). The highest score was for ALG ($M = 4.2$, $SD = .7$), followed by EVA ($M = 4.1$, $SD = .7$). A similar trend was observed for DEC, LOG, and REC with (M = 4.0, SD = .79), followed by ABS (M = 3.9, SD = .7).

Table 7.16 Mean of Age and Qualification for CK, PK and TK Scores

		CK		PK		TK		**P**	#
		M	SD	M	SD	M	SD		
Age	Less than 20	4.1	.45	3.93	.47	4.2	.4		97
	Less than 30	4.3	.6	4.1	.64	4.2	.6	**.00**	94
	Less than 40	3.93	.8	4.2	.85	3.9	.8		81
	40 and older	3.8	.63	3.82	.68	3.85	.6		22
Qualification	High school or below	3.8	.7	3.8	.77	3.9	.8		84
	University degree or diploma	4.1	.61	4.2	.63	4	.6	.09	166
	Post-graduate degree	4.1	.63	4.1	.69	4.2	.7		44
Total	M	4.03		4.02		4.03			294
	SD	.67		.7		.73			

Table 7.16 shows the knowledge scores for the age and qualification groups. The qualification group did not demonstrate a significant difference in PK scores (F(2,293) = 9.07, p = .09, partial-eta-squared = .03). The highest score was seen in college (M = 4.2, SD = .6), followed by the postgraduate degree category (M = 3.9, SD = 0.6), and then high school or below (M = 3.8, SD = .7). The age group showed statistically significant results (F(3,293) = 7.56, p = .00, partial-eta-squared = .074), with significant interaction between the groups (20-&40-)(p=.01), (20-&40+)(p=.002), and (30-&40+)(p=.00). The highest gain was observed for the younger ages; the PK scores gradually decreased with increase aging.

The study sample consisted of 62% of young educators with at least a bachelor's degree in teaching. Although it was not statistically supported, young educators had higher scores than older educators, presumably because younger generations are more tech-savvy and more open to learning via technology and logic [28]. This study concluded that, overall, students and younger educators are eager to obtain CT skills and logic within pedology, while older educators may require more CT training.

RQ2 How Different is CT Awareness Between Educators?

A repeated measure ANOVA indicated a significant difference in knowledge scores among the various education roles ($F(10.8, 3138.4) = 3.480$, $p = .00$, eta = .012). All effects were statistically significant at the .05 significance level except students and others (in noneducational fields). As shown in Table 7.16, the highest scores were obtained from department heads ($M = 4.6$, $SD = 0.3$), followed by students ($M = 4.29$, $SD = .6$), teachers ($M = 4.2$, $SD = .8$), vice principals ($M = 3.48$, $SD = 1.1$), and principals ($M = 3.3$, $SD = 1$). Although educators are trained in the same basic technological knowledge, recent graduates gain the latest technological skills and standards in education. In addition, the MOE offers in-house training for educators to remain abreast of advancements in education [29, 30]. The Development and Training Sector of the MOE prepares workshops and training to fit the needs of each educational role, including communication skills, critical thinking, classroom management, technology deployment, and school administration and planning. Consequently, age, training, and occupational role can be the reason behind the alternate of the awareness scores.

Results also showed that roles were not significantly affected by the gender of the participant ($F(3, 293) = 3.3$, $p = 0.08$, partial-eta-squared = 0.34). The CT scores were slightly higher for males ($M = 4.13$, $SD = .64$) compared to females ($M = 3.8$, $SD = .87$). A comparison of gender in the role of department head shows females had the highest scores ($M = 4.6$) compared to males ($M = 4.5$), even though the results weren't statistically significant

7.5.4 Suggested CT Implementation Plan into the Kuwaiti Educational System

The proposed Model of Systemic Change would introduce CT into the Kuwaiti educational system. The first step in model implementation is the lead process, or influencing the decision-makers, in which Kuwait's stakeholders must understand the importance of implementing CT into the educational system. The results of this study revealed that leadership positions often have decreased CT awareness; therefore, a third party should provide training and emphasize the importance of CT in education via collaboration between the MOE training center and an international specialized organization. A third party is essential because, according to the HDI in 2020, Kuwait ranked 63 out of 189 countries [31]. A leading team can then be developed to plan for CT adoption. The team should include a principal, vice principal, educational superintendent, and a department head. Department heads would have a critical role in the change plan because they are the link between the teachers and the leaders. According to the survey results, department head educators had high scores and abilities, making them a valuable resource for the teachers. All departments should be part of the development plan, and the leadership team should receive additional training to learn about CT standards.

The second step of model implementation is the build step, in which the leadership team builds CT awareness among teachers. The department heads and curriculum development department should map and align common core standards as well as CT standards and concepts to the current curriculum. The leadership team should also develop or adapt instruments to measure CT and yearly progress.

The third step of implementation, the connect step, extends existing lessons in CT to build value and understanding. Teachers and department heads should work together to provide age-appropriate activities for their curriculum, emphasizing STEM content and 21st century skills in plugged and unplugged activities. In addition, the teachers should prepare the CT vocabulary appropriate for the development sequence. The practice step, the fourth and final step of model implementation, incorporates the plan into classroom instruction, including regular measures of development.

7.5.5 Limitations

A primary limitation of this study was the lengthy questionnaire, which occasionally overwhelmed the participants, causing them to provide inaccurate or dishonest answers. Additional limitations were the risk of different interpretations of question meanings and biased data because of to nonresponse questions.

7.5.6 Conclusion

CT has been gaining worldwide attention as a 21st century learning skill. Therefore, this study developed a survey to measure CT awareness from the cognitive, educational, and technological aspects. Survey results provided valuable insights, including the high rate of acceptance, CT awareness, and the eagerness of young-aged educators and students to adopt CT into the classroom with or without technology. Negative insights included less familiarity of DEC, ABS, and REC concepts and society's tendency to be technology consumers because of the nature of the education system. Also, older educators demonstrated a lower score of CT awareness although members of the older generation are the educational stakeholders in Kuwait. From these insights, a suggested plan was presented to begin the process of implementing CT into the Kuwaiti education system.

Chapter 8 - Summary and Future Work

8.1 Conclusion

Computational Thinking has become an essential skill in this computational world. Individuals need to be equipped with these skills to find more efficient solutions for real-life and industrial problems. Starting as young as 4 is the best way to create more computational experts, reduce workplace skill gaps, and support STEM learning. It has been proven that children at age 4 can start learning CT; however, early childhood educators express concerns about the pitfalls of excessive screen time and a lack of resources for educators. While CT can be delivered using an unplugged pathway, doing so limits opportunities for children to be producers of technology. The current generation is tech-savvy and is eager to use technology, so it is rational to take this chance to involve CT learning in their learning. Early childhood educators are the best preceptor to teach and support learning and development CT for this age group, which is why this dissertation attempts to aid those educators by providing and developing related resources that guide create best practices.

Chapter 2 address educators' concerns by gathering recent studies' statements that answer their worries on the good, bad, and ugly sides of technology. It discusses how best practices can convert the bad into good and protect children from the ugly side. Additionally, technology already has a good side—the ability complement and extend traditional learning.

The good practice elements were identified in Chapter 3 in the *bes-T-ech* framework. The framework was developed after analyzing recent statements and experiments of early child communities and it highlights nine main elements that educators can use to aid in integrating technology in the classroom: child, content, context, pedagogy, facilitators, environment, tools, screen time, and evaluation. Understanding a child's ability and need as well as the special characteristics of the current early childhood generation are one of the keys to creating experiments that are developmentally appropriate to their abilities and age stages. The content and the pedagogy of what children should learn and how children should learn varies by state, and each district has its own determinants. Educators should consider several factors when deciding which technology to implement, especially unappropriated advertisements and appropriate tools and innovations. With an increasing amount of technology flooding the market, educators periodically need to evaluate the tools in place to choose what is suitable to serve the pedagogy. The classroom environment is the third teacher, and classroom room layout will influence the learning process—technology tools should be positioned and used to motivate exploration, but space is a relevant constraint. Screen time is the last element that should be considered. Screens do not carry equal impact. TV interaction differs from iPad interaction. If a child is engaged and learning, this process should not be interrupted just because a screen-time limit has been reached.

Chapter 4 proposed the *bes-T-ech* framework as a medium to deliver CT into early childhood settings after revisiting the elements to suit CT. The child element research shows that the cognitive ability of a 4-year-old child can support learning CT skills—but only when using the appropriate CT content. Three research groups developed CT skills that proved to be suitable for early childhood abilities. We proposed CT pedagogy framework derived from STEM and CT frameworks. Blending and expanding the two models shows that engineering, coding, and data analysis are great paths to train CT and support STEM. The screen-time element of technology also is applied here; however, CT can be used with unplugged activities that do not include screen time. The CT environment was classified into physical, digital, and hybrid areas, all of which support building CT in a different context and with different tools. Whichever way the child is trained—tools, applications, or unplugged skills—their CT ability needs to be assessed. For facilitators, DevReach group develop training and certificates to aid educators to integrate and assets coding and robotic tools.

Chapter 5 presents an application of the CT *bes-T-ech* framework using a checklist. It was implemented through two projects: one that teaches coding directly through CT pedagogy, such as a virtual world using a Roblox sandbox; and one using CT as a medium where developed lessons teach drama concepts using CT as a medium. The second project taught CT directly through Computational Thinking Pedagogical + Framework, where a virtual world was created for this purpose, which is described in Chapter 6.

Chapter 7 outlines three reinforcement experiments that were executed to advocate CT into Kuwaiti society. The reinforcements were complemented with a developed STEM model designed to meet the needs of Arabic/Persian Gulf region learners. The first reinforcement investigates the educators' CT awareness and proposes a plan of implementing CT into the Kuwaiti education system. The second reinforcement transferred a successful CT outreach program from a Western country into Kuwait, which brought insight to the CT ability of the young Kuwaiti educators. Compared to U.S. students, they carry a similar trend and gains for CT concepts and program knowledge. The third reinforcement investigates the ability and preferences between males and females, showing that society and maturity factors are the leading two influencers over Kuwait students' STEM choices, reversing the gender stereotype in Kuwait.

8.2 Limitation

The main limitation of the study is the Covid-19 global pandemic, as school closed for a time and then moved online for about a year—and even longer for early childhood learners in

Kuwait. This affected the validation and experiments of the research. Thus, a portion of this research is related to theoretical models and frameworks.

8.3 Future Work

I am considering my future work validating theoretical models. Each model will need to be evaluated with the appropriate research type. Especially, the good-bad-ugly chapter, Sofia's Technology Classification model, the *bes-T-ech* framework, the CT *bes-T-ech* framework, the Operational Developmental Coding Stages, the CT pedagogy framework plus, VW framework for early childhood, CT VW prototype, and training CT through drama lessons using Robotics. Future goals include finishing the CT VW prototype and making it available for use so children can play and learn together as an "hour of code". Should time allow, other research was started during this process and its completion would benefit CT in early education. That includes the study between three learning methodologies: **asynchronous** online learning, in which teachers and students interact online in separate places at different times; **synchronous** online learning, in which teachers and students interact online in separate places at the same time; and **in-class** learning, in which teachers and students interact in the same place at the same time. The experiments took place over a 2-week camp using storytelling and animation that introduced young children to coding, including block programming, art, and literacy. It also proposed CT concepts as animals to teach children as a concreate object where they are aware of the skills they use. A proposed timeframe to finish the future works is presented in table 8.1.

Table 8.1 Future Works Timeframe

<table>
<tr><th></th><th>2022</th><th>2023</th><th>2024</th><th>2025</th><th>2026</th></tr>
<tr><td>Current Research</td><td>Validate
bes-T-ech Framework (Chapter 2)
Validate
CT pedagogy (Chapter 3)
Validate
CT as a medium (Chapter3)</td><td>Analyze
“Ability to learn CT over different environments” (experiment)</td><td>Validate
scientific experiment over Drama-Robotic
Analyze
Drama-Robotic</td><td>Validate
scientific experiment over CT-VW
Analyze
CT-VW</td><td>Validate
CT animal
Analyze
CT animal</td></tr>
<tr><td>New Research</td><td></td><td colspan="2">Developed all the functionality of CT VW for an hour of code</td><td colspan="2">Teach CT as a concreate method “The CT animal”</td></tr>
<tr><td rowspan="2">Publications</td><td>(1)
bes-T-ech Framework</td><td>(3)
CT as a medium</td><td>(5)
“Ability to learn CT over different environments”</td><td>(6)
Drama-Robotic</td><td>(7)
CT-VW</td></tr>
<tr><td>(2)
CT pedagogy</td><td>(4)
CT Bes-T-ech framework</td><td></td><td></td><td></td></tr>
</table>

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Appendix A - "bes-T-ech" Application Form

Goal: Teach CT as: (select one)

(a) ◯Integrated lessons ◯ (b) Standalone CT lessons

If (a) answer:

Disciplines lessons: ……………………………………………………………

(1) CT-Pedagogy- the theme of the lessons: (multiple option can be selected)

☐ Unplugged ☐Tinkering, ☐Making,

☐ Engineering, ☐ Coding and ☐ Robotic ☐ Dataing

(2) Tools: ………………………………………………………………………………

(3) CT-Context

For Beginners children's: ◯ Coding Thinking

For intermediate: ◯ Block based Coding, ◯Tangible Coding,
◯ Hybrid Coding

For Advance: ◯Textual Coding

Not Coding: ◯ video Gaming/educational application,
◯ Animation ◯ Media ◯ Other platform:

(4) Environment:

◯ Physical, at……… ◯Digital, type……

◯ Hybrid type…………and………..

(5) Assessment:

Graphical Coding: ◯ CSA-ScratchJr, ◯ ScratchJr-Rubric,

Tangible Coding: ◯ CSA-KIBO, ◯ KIBO-Rubric

Unplugged: ◯ TechCheck

(6) Screen Time: (for a lesson)

…..…. minutes of screen Time and, ……. minutes of No screen Time

(7) Child:

Children Age

Age appropriate for tool? ☐ Yes ☐ No

Age appropriate for environment? ☐ Yes ☐ No

(8) CT- Content:

◯7 Powerful ideas: Algorithm, Modularity, Control structures, Representation, Hardware/Software, Design Process, Debugging

◯Aha Island Concepts: Design, Sequencing and algorithm, Debugging

◯STEM+C: Algorithm and procedures, Automaton, Pattern Recognition, Data collection, Data Analysis, Data representation, Debugging/Troubleshooting, Problem Decomposition, Parallelization and Simulation

Appendix B - KIBO the Actor

CONTENTS

CURRICULUM OVERVIEW

The developed curriculum is based on teaching the children theater/drama. We will be using the KIBO robots from KIBO[1]. We currently have these robots for our Lower School Robotics Program. The project will be geared towards our Junior Kindergarten/Kindergarten 7-year-old students. Our curriculum unit will be the first exposure of theater for our children and also tie in engineering, computer science and art. The students will be learning different skills with their robot.

THE LEARNING GOALS

The learning goals for this curriculum unit revolve around computational thinking, the engineering design process and drama for young children.

Goal 1: Foster computational skills such as algorithms, debugging, and pattern repetition.

Goal 2: Find solutions to problems by being involved in the engineering design process.

Goal 3: Integrate drama activities, such as expressing different emotions, through movements when programming KIBO the robot.

Goal 4: Promote acting skills for a specific s during the process of programming KIBO

This curriculum unit entails six lessons that will be executed in two weeks; three lessons each week. Every lesson will be implemented for an hour. The curriculum combines two concepts from two curricula lessons: A KIBO Coding Curriculum for Emergent Readers[2] and Teaching Drama to little ones. [3].

CODING WITH ACTING

This curriculum introduces powerful ideas from programming with KIBO robotics in a structured developmentally appropriate way for young children ages 5-7. The Coding While Acting approach puts computer science ideas into direct conversation with powerful ideas from drama. The starting assumption of the KIBO The ACTOR curriculum is that both computer science and acting can enhance one another. Instruction in both can be leveraged in service of the other. Both can support learners in developing new ways of thinking about themselves and the world.

Children will learn how to act using acting a scene from a story book with several characters, they will talk about emotions, ways people show emotion on their faces and through body language, they will talk about one particular character and decorate their KIBO as that character showing the emotion of their choice, they will use the blocks to create a program where their character expresses the emotion through their movement, they will show classmates their robot and explain how they

[1] https://www.KIBO.com
[2] https://sites.tufts.edu/codingasliteracy/files/2019/06/CAL-KIBO-Emergent-Final-Curriculum.pdf
[3] https://www.bbbpress.com/wp-content/uploads/2015/10/TDLO-10-8-15-PREVIEW.pdf

decorated it and how it shows an emotion through its movements, and for the last lesson they will teach another child how to set up the program that they created for their robot.

Learning goals for the unit are to recall characters from the story and sequence them in the proper order. Students will be working individually at this time due to only having two KIBO robots available at our school.

Developmental skills targeted with this lesson are: assisting students in their ability to work with others, problem-solving, and working on their fine motor skills for building. Various check-ins will be scheduled through the unit and mini-lessons will be given as needed.

FRAMEWORKS

Each lesson is aligned with Standards from PTD, Drama and CS framework. **Technology**: Positive Technological Development. **Drama**: Next Generation Sunshine State - The Arts. **Computational thinking and Computer science**: K–12 Computer Science Framework

lessons	PTD	DRAMA Next Generation Sunshine State - The Arts	CS K-2nd Grade
1	Communication Choices of conduct	**TH.K.C.3.2** Share reactions to a live theatre performance. **TH.2.S.3.1** Create imagined characters, relationships, and environments using basic acting skills.	**Standard 1: Responsible use of technology and information** SC.K2.CS-PC.1.1 Demonstrate proper care for electronic devices (e.g., handling devices carefully, logging off or shutting down correctly, and keeping devices away from water/food). **Standard 2: Computer programming basic** SC.K2.CS-CP.2.1 Define a computer program as a set of commands created by people to do something.
2	Creativity	**TH.3.S.3.3** Describe elements of dramatic performance that produce an emotional response in oneself or an audience.	**Standard 2: Computer programming basics** SC.K2.CS-CP.2.4 Construct a simple program using tools that do not require a textual programming language (e.g. block-based programming language). **Standard 4: Hardware and software** SC.K2.CS-CS.4.3 Explain that a computer program is running when a program or command is executed.
3	Communication	**TH.K.S.2.1** Pretend to be a character from a given story.	**Standard 2: Problem solving and algorithms** SC.K2.CS-CS.2.4

	Collaboration		Define an algorithm as a sequence of defined steps.
4	Communication Collaboration	**MU.K.S.3.4** Imitate simple rhythm patterns played by the teacher or a peer.	**Standard 1: Communication and Collaboration** SC.K2.CS-CC.1.3 Collaborate and cooperate with peers, teachers, and others using technology to solve problems. **Standard 2: Problem solving and algorithm**s SC.35.CS-CS.2.7 Identify and correct logical errors in algorithms; written, mapped, live action, or digital.
5	Content Creation Collaboration	**TH.5.S.2.1** Collaborate with others to create productions and solve challenges. **TH.68.S.2.3** Analyze the relationships of plot, conflict, and theme in a play and transfer the knowledge to a play that contrasts in style, genre, and/or mood.	**Standard 2: Computer programming basics** SC.K2.CS-CP.2.4 Construct a simple program using tools that do not require a textual programming language (e.g. block-based programming language). **Standard 1: Communication and collaboration** **SC.35.CS-CC.1.3** Identify ways that technology can foster teamwork, and collaboration can support problem solving and innovation.
6	Community Building Choices of Conduct	**TH.912.S.3.3** Develop acting skills and techniques in the rehearsal process. **TH.2.O.1.2** Explain the difference between the stage, backstage, and audience areas.	**Standard 2: Problem solving and Algorithms** SC.35.CS-CS.2.6 Write an algorithm to solve a grade-level appropriate problem (e.g., move a character through a maze, instruct a character to draw a specific shape, have a character start, repeat or end activity as required or upon a specific event), individually or collaboratively.

LESSONS

Lesson 1: Care of the materials +Theatre	What is theater? **(10 min)** Wake Up As An Animal **(10 min)** Puppet Show **(20 min)** Kibo Happy to Meet You **(20 min)**
Lesson 2: Decorating Kibo using Emotions	If You're Happy and You Know It **(5 min)** I have Emotions **(15 min)** Storybook **(10 min)** KIBO Decoration **(10 min)** KIBO Emotions and Motions **(20 min)**
Lesson 3: Sequencing + Voice	I Can Make a Sequence **(20 min)** Good Afternoon, Your Majesty **(10 min)** Kibo Programming **(25 min)** Reflection **(5 min)**
Lesson 4: Debugging + Rhythm	Follow the Beat **(10 min)** KIBO Confused **(5 min)** Debugging the Dance **(10 min)** KIBO Can Dance the Beat **(30 min)** Reflection **(5 min)**
Lesson 5: Sensors + Imagination	KIBO Can Hear **(10 min)** Imagination Stretching **(5 min)** Acting Is Imagination **(15 min)** The Design Process **(15 min)** Behind the Scenes **(15 min)**
Lesson 6: Repetition + Acting	Repetition in Stories **(10 min)** KIBO Learn to ACT **(15 min)** Becoming the Character **(15 min)** Rehearsing Together **(10 min)** Showtime and Reflection **(10 min)**

LESSON 1: CARE OF THE MATERIALS & THEATER

Powerful Idea from Computer Science: Program, robot, barcode

Powerful Idea from Drama: Emotions, musical theatre.

OVERVIEW

Today's technology continues to change the way in which people interact and communicate with one another. In this lesson, students have the opportunity to connect communication and technology; how human beings and robots can communicate something in different ways. During the lesson, students will use their body and facial expressions when pretending to be animals, develop some acting skills during the performance of a musical show. Furthermore, students will learn how to take care of materials when taking them out and putting them away, and how to put blocks together and take them apart when they create their own code to make KIBO move.

PURPOSE

The purpose of this lesson is to help students understand that people can convey different ways of communication such as verbal and non-verbal expressions through their whole body and facial expressions. They will also realize that the process of communication entails expressive and receptive language. Students will notice how KIBO understands commands to perform specific movements.

ACTIVITIES

- Wake Up As an Animal (10 min)
- What Is Theatre (10 min)
- Puppet show (20 min)
- Kibo happy to meet you (20 min)

MATERIALS

FOR THE TEACHER:

- Animal pictures
- KIBO, blocks

FOR STUDENTS

- Emotions sheet
- Craft materials, crayons
- KIBO, coding blocks

VOCABULARY

- Musical theater: A type of drama that involves singing and dancing play
- Movie theater: A place where movies are shown for entertaining
- Stage: A floor on a theater where actors perform
- Program: A set of instructions for a robot
- Robot: A machine that can be programmed to move, perform certain behaviors.
- Barcode: A pattern of parallel lines

STUDENT WILL BE ABLE TO...

- Make a musical or acting show
- Create their own code to make KIBO move
- Put coding blocks together, take them apart and scan them
- Distinguish the meaning of movie theater and musical theater

ACTIVITIES

What Is Theatre? (10 min) Communication

Ask students if they went to shows before or the cinema. If they did, let them describe what they saw there? Where the people sit? Introduce the word "Theatre" and explain how musical theatre is different from a movie theater. Talk about how musical theatre actors do live singing, dancing, and acting. Explain to them that the audience will face the direction of the stage. Describe that a show can have different scenes and sets.

Wake Up As an Animal (10 min) Communication

Ask the children to spread around the room, find a spot to pretend to sleep. Tell them that you will pretend to turn the light off. Tell them that you will turn the light on and call an animal's name; everyone should walk up and pretend to be that animal; use your whole body and facial expression to become the animal. You will then close the light again, and they need to go back to sleep in their current spot. Repeat the game using different animals' names as reminding

Puppet Show (20 min) Collaboration

Ask the students to make a little show from the classroom materials. They need to have an audience and actors. It can be a musical show or movie acting. No restriction.

Kibo Happy to meet you (20 min) Communication & Choices of Conduct

Introduce the KIBO robot and explain to the students that the robot can move and sing. Have the children watch as you build a program with the blocks, scan the program, and watch the robot go through the movements. Explain that each of the children will be creating their own code and having the robot move according to the program they design. During the last class, they will make an acting show using KIBO. Have them take turns saying things they notice about the robot and the blocks, show the children how there are holes in the blocks, put the blocks together, and take them apart. Explain and show how to take out and put away the robot and blocks from the container. Have the children take turns picking up and setting down the robot gently.

LESSON 2: DECORATING KIBO & USING EMOTIONS

Powerful Idea from Computer Science: Algorithms

Powerful Idea from Drama: Emotions: Sad, Surprised, Scared

OVERVIEW

In the previous lesson, the students use their body and facial expressions to communicate something. In this lesson, they will display specific emotions such as sad, scared, surprised, etc. when singing a song and connect this experience when program KIBO to make some movements that represent certain emotions. In addition, they will use their creativity to decorate KIBO with recycled materials and two-emotion faces.

PURPOSE

The purpose of this lessons is to facilitate students to recognize and describe certain facial features when someone displays emotion and help them identify the beginning, middle, end during the process of programming with the blocks

ACTIVITIES

- If You're Happy and You Know It (5 min)
- I have Emotions (15 min)
- KIBO Decorations (20 min)
- KIBO Emotions and Motions (20 min)

MATERIALS

FOR THE TEACHER:

- If You're happy and You Know it lyrics

FOR STUDENTS

- Two-face emotions sheet
- Recycled materials: scrap paper, egg cartoons, toilet paper tube
- KIBO, motions blocks: beginning, middle, end blocks

VOCABULARY

- Algorithm - A set of instructions to perform a specific task.

STUDENT WILL BE ABLE TO...

- Identify the beginning, middle, end when programming KIBO to represent some emotions.
- Recognize emotions through facial expressions

ACTIVITIES

If You're Happy and You Know it (5 min)

The teacher will sing "If You're Happy and You Know It" song, and the children will do the action that follows the "If You Are" part in the music. The teacher will repeat the song with different emotions (sleepy, sad, surprised, scared...etc.); most children are familiar with it or will catch on quickly. The lyrics is included in the appendix A.1.

I Have Emotions (15 min) — Communication

Give the students papers and markers; ask them to draw the teacher's facial expression, for example, a happy face. Select a student and ask him to reflect on his painting by pointing out which areas of the face makes us think a person happy. Let other students show thumbs up if you draw this expression. If some students have an unmentioned expression for the same emotion, let him/her describe it. Repeat with different emotions and let other students do the description. You can do this activity differently, such as handing the children sheets in A.2 and let them color it and let them guess when to use these expressions.

KIBO Decoration (20 min) — Creativity

We will get our KIBO robot out and decide on an emotion from the emotion sheets. We will be talking about emotions and about ways we can decorate our robot to express emotions. Let the kids explore different ways of decorating the robots using recycled materials, such as legos, scraps of construction paper, egg cartons, toilet paper tubes, etc. Recommend folding a piece of paper in half, and have a facial expression on each side (two faces emotion sheet) to be used in the "KIBO Emotions and Motions" activity. See A.3 and A.4

KIBO Emotions and Motions (20 min)

Ask the students to code the KIBO robot to move in a way he expresses the emotions on the two-face-emotions sheet. The code should have the KIBO robot show one side of the emotions sheet, then half-spin and stop, showing us the other side of the two-face emotions sheet. Remind students that they need to have a begin, middle, and end for any code. Give each student a turn creating a program.

LESSON 3: SEQUENCING & VOICE

Powerful Idea from Computer Science: Algorithms, representation.

Powerful Idea from Drama: Play some characters: King/Queen

OVERVIEW

In this lesson, the students will understand the meaning of sequence in computer programs in a meaningful way by playing the game, Good Afternoon, Your Majesty with their peers. Then transfer this experience to make a sequence with the coding blocks so they can see the KIBO can follow a sequence as well.

PURPOSE

The purpose of this lesson is to understand what a sequence is and create a simple sequence with the coding block in order to make KIBO walk, make a sound, spin around when playing Good Afternoon, Your Majesty.

ACTIVITIES

- I Can Make a Sequence (20 min)
- Good Afternoon, Your Majesty (10 min)
- KIBO programming (25 min)
- Reflection (5 min)

MATERIALS

FOR THE TEACHER:

- Instructions of the game: Good Afternoon, Your Majesty

FOR STUDENTS

- KIBO, motion blocks, sound blocks

VOCABULARY

- Sequence - The order of instruction that a robot will follow.

STUDENT WILL BE ABLE TO...

- Understand and apply the concept of sequence when playing the game: Good Afternoon, Your Majesty and when programming KIBO to play that game.
- Scan the blocks properly

ACTIVITIES

I Can Make a Sequence (20 min) Communication- Choice of Conduct

Describe how KIBO understands by the following sequence. This is called an algorithm in the KIBO language. Show the children the function of each block. Play a guessing game taking turns guessing which block does by looking at the picture on it. Create a sequence with the blocks and show how to scan the blocks. Give each child a turn creating a program with the blocks, telling you what their robot will do as they point at each block in their program, scanning the blocks, and having the robot go through the steps. If the robot doesn't follow all of the steps, ask students what they think happened, and see if they want to try it again.

Good Afternoon, Your Majesty (10 min) Collaboration

Choose one student to be the King/Queen and sit on a "throne" facing away from the rest of the group. The rest of the students need to stand in a line to salute the king. Ask them to try to walk on their tiptoes behind the king, saying, "Good Afternoon, Your Majesty," in a silly, weird voice. The king gets three guesses to figure out who is speaking. If they are unsuccessful, the student with the silliest voice becomes the new king.

KIBO Programming (25 min)

The teacher pretends to be the king and asks the student to program the KIBO robot to come to perform the "Good Afternoon, Your Majesty." The teacher will explain to the children that the program should let the KIBO robot walk to the throne facing the king, make a sound, spin around to show two-faces, and leave. The students should figure out how many forward steps they need to reach the throne.

Reflection (5 min)

Let the kids reflect on the code and how we can improve it.

LESSON 4: DEBUGGING & RHYTHM

Powerful Idea from Computer Science: Debugging

Powerful Idea from Drama: Awareness of rhythms and tempos

OVERVIEW

In this lesson, students engage in rhythms and tempos to make steady beats by clapping and find the missing beat. This experience will be connected to the process of debugging. Students will learn what debugging is, identify the errors when programming KIBO to perform certain movements for a particular song.

PURPOSE

The purpose of this lesson is to make students aware that it is alright to make mistakes when programming a robot. Through the process of debugging, they can design a new algorithm to solve the problem.

ACTIVITIES

- Follow the Beat (10 min)
- KIBO confused (5 min)
- Debugging the Dance (15 min)
- KIBO can Dance the Beat (25 min)
- Reflection (5 min)

STUDENT WILL BE ABLE TO...

- Keep a steady beat by clapping
- Be able to find the mistake when following a rhythm
- Recognize the errors "bugs" and solve the problem when programming KIBO

MATERIALS

FOR THE TEACHER:

- Rhythm play video
- Rhythm cards: Ta-Ta, Ti-Ti
- Rhythm reading lesson: Stage One
- Extra AA batteries

FOR STUDENTS

- Rhythm cards
- KIBO, motion blocks, begin and end blocks
- A variety of craft and recycled materials

VOCABULARY

- Debug - Figure out what went wrong and fix the code.
- Steady beat - It's the repetitive pulse that occurs in songs.

ACTIVITIES

Follow the Beat (10 min)

The teacher plays a video that has various rhythms and tempos. The teacher will ask the students to follow the video rhythm by clapping. The rhythm will get harder and faster increasingly, causing students to miss a beat or clap out of sync with the beat. Repeat the video until the majority of the students perform it correctly.

KIBO Confused (5 min)

The teacher will explain to the students that it's ok to get confused and make a mistake in following the rhythm; we need to try again and again until we do it correctly. There are also times that repeating the same steps won't solve the problem and that we may need to make some changes after we figure out what needs to change.

Debugging the Dance (15 min)

Communication ,Collaboration

Play a piece of music and give the students a program that only goes forward. Ask the students to fix the code so the KIBO robot dances to the music. The children will need to change the forward blocks with other blocks that make the KIBO robots movements like dancing to the played music.

The teacher will introduce the word "debugging" to the students. The teacher will explain to students that debugging is a process to explain why a program does not work by finding out the problem, then trying different solutions to fix the code. The teacher will explain to the students the story behind the word "bug." In the 1940s, computers used to be very large and one time a moth got stuck inside, which caused an error in the computer. A smart admiral, Grace Hopper, found the moth and resolved the error by taking out the bug. Since then, the word for fixing a problem has been called "debugging"!

KIBO Can Dance the Beat (25 min)

Collaboration

The teacher will divide the students into small groups. Give each group a card (see A.5) that has rhythm. Ask the students to find the beat behind the code by replacing a rhythm with a coding block. As an example, all the "Ti-Ti" will be replaced with a forward block. Ask the students to share the dance. Optionally, let the students decorate the KIBO robot using materials inside the class.

Reflection (5 min)

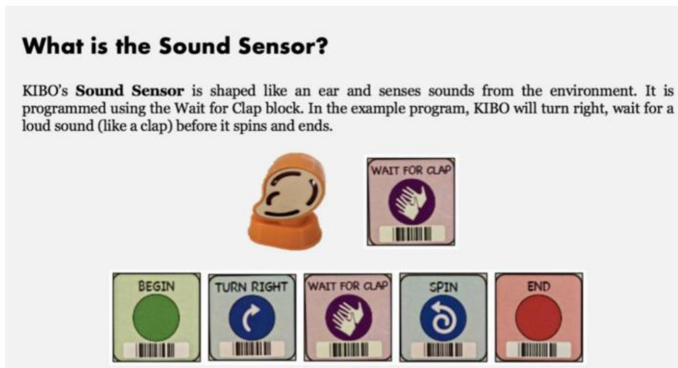
The teacher will ask the students to reflect on what they found hard while debugging. What was a common problem in coding KIBO, and how did they solve it?

ACTIVITIES

KIBO Can Hear (10 min)

Collaboration

The teacher will describe to the students that humans have five senses and use them to learn about the world around us. How our body parts are associated with the senses. Even robots can sense using "sensors," and we plug the sensors into the robot body. Divide the students into groups, hand each group "wait for clap" and "sound sensor". Ask them to make a code using two more blocks. An example is shown below.



Imagination Stretching (5 min)

The teacher will ask the students to spread around the room and relax. Explain to them they will hear a scenario; they will need to act it using their full-body, facial expression, and voice for a whole minute for each scene. Tell them to start on the count of three after the action word.

1) You are lost in the middle of the frozen forest and trying to find a house. Give them a hint like tell them you can pretend you are looking left and right while shoveling. 2) In the next scene, you start to give up, fall on the ground, and start crying. 3) you remember your family trying to stand, and finally, you did it.

Acting is Imagination (15 min)

Communication

The teacher will ask everyone to sit in a comfortable way to hear a story of the big bad wolf and the three little piggies. After reading, review with the students the plot, the storyline, and the characters. Talk about the characters' emotions and movements.

The Design Process (15 min)

Content Creation

The teacher will explain to students that they will create a show from the three little piggies story. The KIBO robot will act with them at the concert. KIBO will be the helper of the wolf, so our version of the story would be "the big bad, silly wolf, small KIBO wolf, and the three piggies." KIBO will need to be programmed to make the three little piggies house fall. Ask the students to plan the show using the planning sheet. The sheet needs to be filled from a scene of the story. The selected scene is when the wolf is trying to blow the three little houses. Students need to identify: the characters, scripts, background.

Behind the Scenes (15 min)

Imagine having a stage and putting the chairs facing the stage. Ask the students to prepare the background for the stage by drawing on paper and hanging it as a background or any classroom materials. The background design should match the planning sheet. Put x's on the ground where the actors should stand, even after moving around, including KIBO stop points.

LESSON 6: REPETITION & ACTING

Powerful Idea from Computer Science: Repeat loops, patterns

Powerful Idea from Drama: Rehearsal

OVERVIEW

In this lesson, students will perform a final show: The Big Bad Silly Wolf and The Three Piggies. Before, the students will rehearse together, learn about repetition that is found in children's stories, code repeated sequences to make KIBO (the bad wolf) know down the three little pigs' houses. Reflection about their own acting will be considered as a way to get better outcomes.

PURPOSE

The purpose of this lesson is to Emphasize that the repetition is crucial not only in stories to reinforce a concept, an idea, or call the reader's attention but also in computer programming to get outcomes. Students will notice repetition through repeat loops when they program KIBO to know down the three little houses three times.

ACTIVITIES

- Repetition in Stories (5 min)
- KIBO learn to Act (15 min)
- Becoming the Character (15 min)
- Rehearsing Together (10 min)
- Showtime and Reflection (10 min)

MATERIALS

FOR THE TEACHER:

- Script of the Three Little Pig story

FOR STUDENTS

- KIBO, motion blocks, repeat end block
- Pictures of characters

VOCABULARY

- Loop - Something that repeats over and over again
- Pattern - A sequence that repeats

STUDENT WILL BE ABLE TO...

- Identify patterns in sequences
- Program using repeat loops to crash houses down
- Compare how repetition is used in stores and in computer programming

ACTIVITIES

Repetition in Stories (5 min)

Read again the scene that will be played to refresh their mind. Make them notice that the wolf repeats the action three times with the same scripts. Ask students: Why might the author have done that? What purpose does that serve the reader? The purpose of this activity is to remind students that repetition is essential in stories; even in acting, we need to repeat to learn. What would we call a rehearsal?

KIBO Learn to ACT (15 min)

Draw on board the stage and where Kibo will stand and stop points and where the piggies house will be placed. Ask the student to code KIBO to crash to the houses and make them fall. After succeeding in moving. Ask the student to identify which parts can be looped.

Becoming the Character (15 min)

Collaboration - Communication

Divide the students' characters. Have students look at the pictures of their characters in the planning sheet. Let them imagine what their character is supposed to feel, as well as give them ownership of their role. Read the script to the students multiple times. Let them memorize one part at a time. For example, the wolf walking happily thinks he can eat the pig. He stops next to the pig house with challenging and confident looks. Wolf starts knocking and screaming, 'Little pig, little pig, let me come in! Or I'll huff, and I'll puff, and I'll blow your house down!'.
All the script are below:
1) WOLF Wolf goes to the piggies. "He knocked on the door. 'Little pig, little pig, let me come in! Or I'll huff, and I'll puff, and I'll blow your house down!' called the wolf.
2) PIG: The little pig felt safe in his house, so he shouted back, 'Not by the hair on my chinny chin chin!'
3) WOLF: So the wolf huffed, and he puffed, and he blew the house down.
4) PIG: The little pig escaped and ran to his brother's house of sticks.
5) WOLF: The wolf followed – excited that he might get to eat two little pigs.

Rehearsing Together (10 min)

Collaboration

Ask the students to stand on the X's taped on the theater ground; each pretends to be characters waiting for their turn to say the scripts. One of the students would be responsible for acting like he's the little wolf Kibo and control and take care of Kibo. Tell the students that the show will be video recorded, so they need to face the camera's direction while saying the script. The teacher acts as the director, and the kids will start rehearsing after hearing the word action!. Repeat rehearsing and until all of them are ready. Ask the student to bow to the audience when they are done.

Showtime and reflection (10 min)

Communication

The teacher prepared the camera and recorded the show. Play the show on the screen; let the child see them self-acting. Reflect on their acting. Each will mention something nice about their friend and what they learn.

APPENDIX

A.1 [4]
if you happy and you know it

If your happy and you know it, clap your hands
Clap, clap
If your happy and you know it clap your hands
Clap clap
If your happy and you know it, then your face will surely show it
If your happy and you know it, clap your hands
Clap clap

If your happy and you know it, stomp your feet
Stomp, stomp
If your happy and you know it stomp your feet
Stomp, stomp
If your happy and you know it, then your face will surely show it
If your happy and you know it, stomp your feet
Stomp, stomp

If your Sleepy and you know it, take a nap
ZZZ, ZZZ
If your Sleepy and you know it, take a nap
ZZZ, ZZZ
If your Sleepy and you know it, then your face will surely show it
If your Sleepy and you know it, take a nap
ZZZ, ZZZ

If your Sad and you know it, say
boo hoo!
If your Sad and you know it, say
boo hoo!
If your sad and you know it, then your face will surely show it
If your Sad and you know it, say
boo hoo!

If your Surprised and you know it, say!
Oh my!
If your Surprised and you know it, say!
Oh my!
If your Surprised and you know it, then your face will surely show it
If your Surprised and you know it, say!
Oh my!

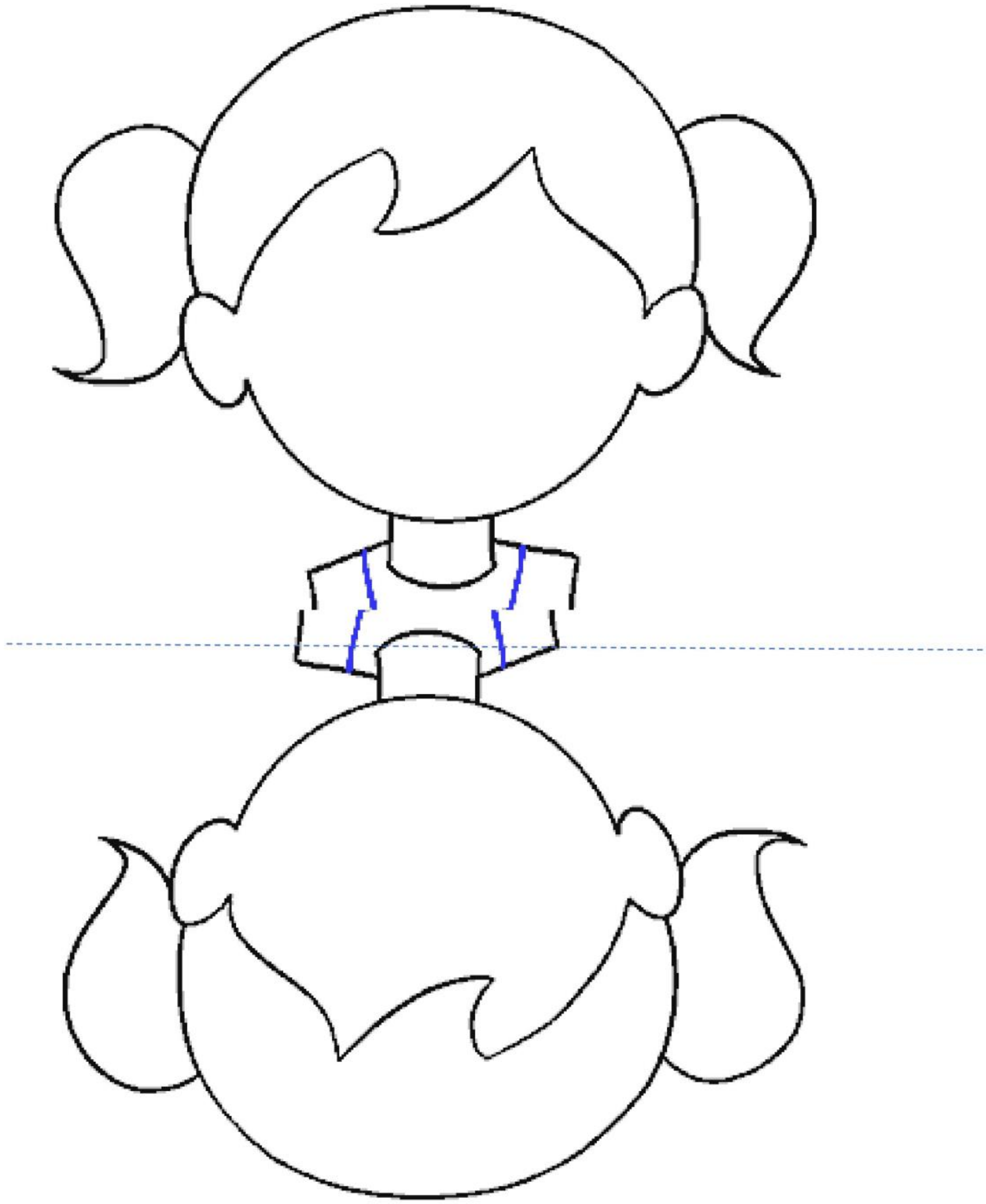
If your Scared and you know it, say!
Oh No!
If your Scared and you know it, say!
Oh No!
If your Scared and you know it, then your face will surely show it
If your Scared and you know it, say!
Oh NO!

[4] http://testyyettrying.blogspot.com/2011/11/if-youre-happy-emotions-version.html

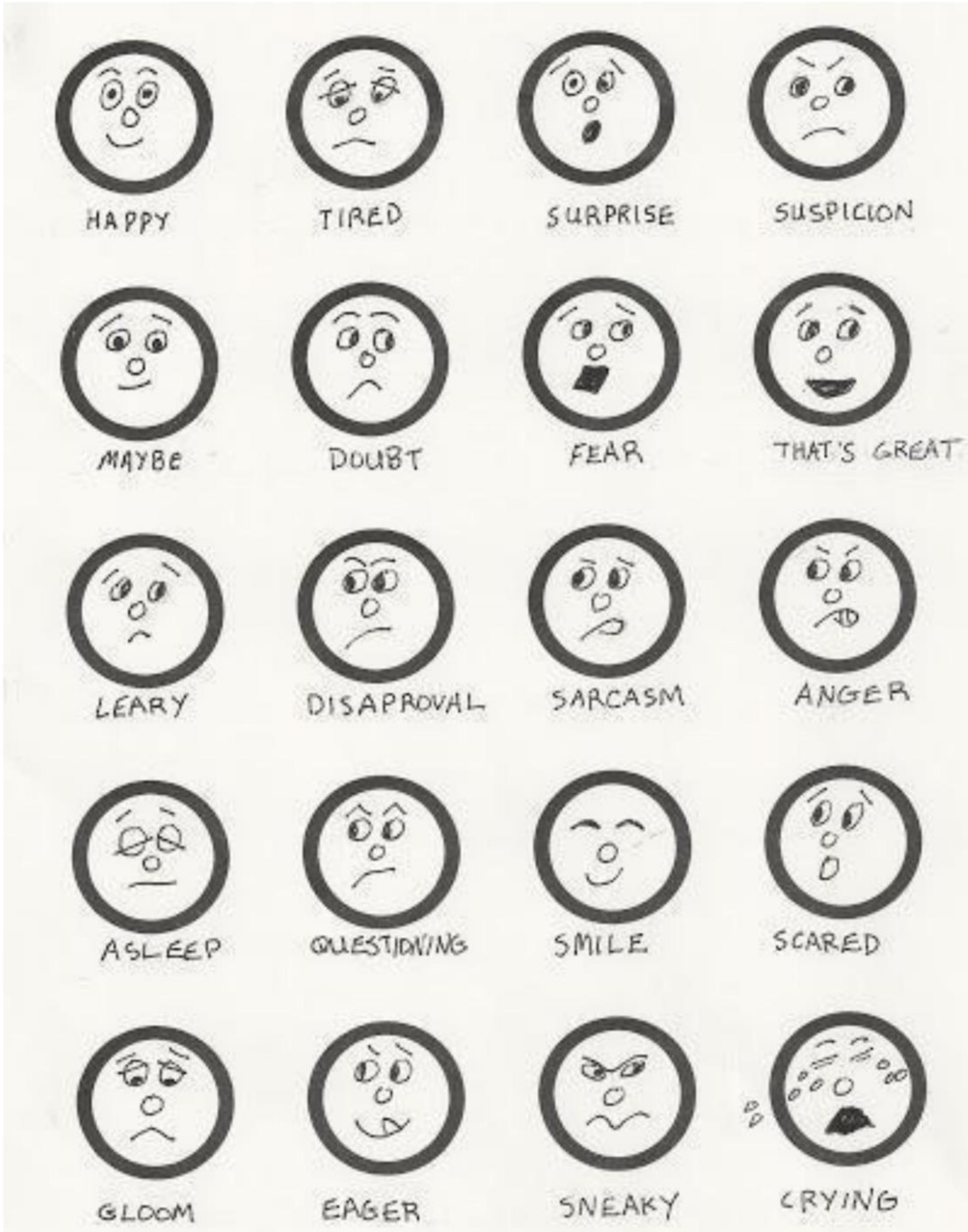
A.2.[5]

[5] https://supersimple.com/free-printables/if-youre-happy-color/

A.3

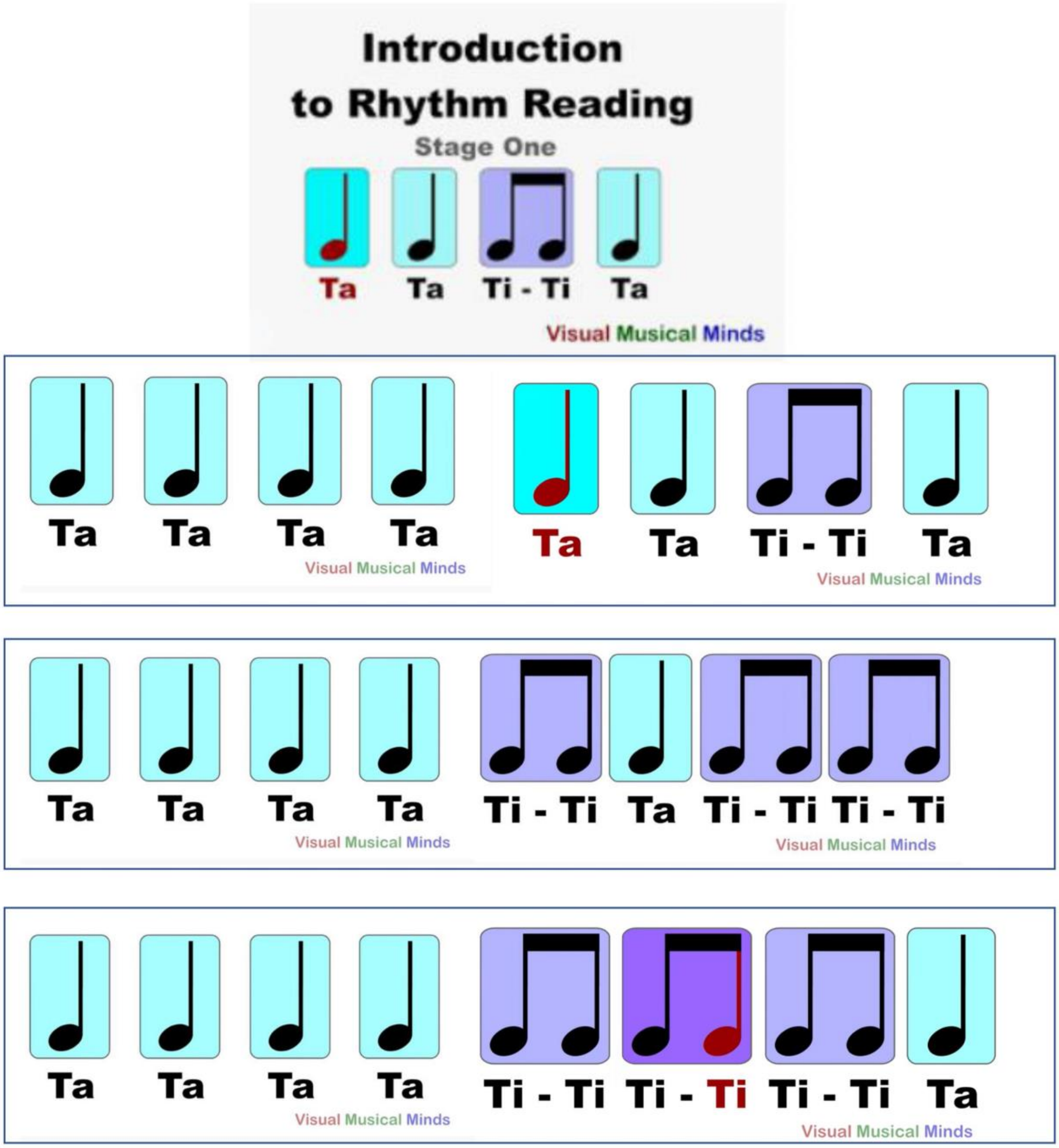


A.4[6]



[6] http://clipart-library.com/cartoon-facial-expressions.html

A.5[7]



[7] https://www.youtube.com/watch?v=4vZ5mlfZlgk

A.6 Designing Sheet

Story title

Scene

Characters

Script

Appendix C - Laila's Lesson

Laila's interaction over lesson one, the theater and the puppet show

Me: do you remember when we saw frozen show at Disney land.

Laila: yeah, I do are we going there again?

Me: maybe I can ask your sister to act the show for you.

Laila: No Not Horrey no thank you.

Me: What do you remember about the show can you draw it for me?

Laila: is has a lot of people and Elsa singing that's it?

Me: was it similar to when saw that at the cinema?

Laila: No Disney had really people dancing and singing in the stage cinema had Movie when they have a big TV, and they turn off the light.

Me: so you were an "Audience" or an "Actor"

Laila: of course, audience silly mother. Did you see me dance?

Me: can you make a show for me I want to be your audience and if you may I will record that.

Laila: sure, but you will let me use your monkeys

(I have a monkey toys I brought to teach math that I didn't let them touch them yet)

Me: sure, go ahead you may use them but be very careful with them.

Laila opened the box toke all the monkeys out and put the small monkeys as audiens.

Laila: which song you want?

Me: mmmm 5 little monkeys

Appendix D - Literature Reviews References

publish year	paper title	paper objectives	paper type
2021	The use of Programming Tools in Teaching and Learning Material by K-12 Teachers	context	conference
2017	Computational Thinking in K-2 Classrooms: Evidence from Student Artifacts (Fundamental)	content	conference
2017	Promoting Computational Thinking in children Using Apps	tools	conference
2020	Mobile learning applications in early childhood education	tools	book
2020	Fostering computational thinking and creativity in early childhood education: Play-learn-construct-program-collaborate	context	book
2020	Apps to promote Computational Thinking concepts and coding skills in children of preschool and pre-primary school age	tools	conference
2020	Learning computational thinking development in young children with bee-bot educational robotics	tools	book
2021	Handbook of research on using educational robotics to facilitate student learning	context	book
2018	Activities for Developing Explain Computational Thinking	pedagogy	conference
2015	Code and Tell: An Exploration of Peer Interviews and Computational Thinking With ScratchJr in the Early Childhood Classroom	pedagogy	Dissertations
2017	Big Robots for Little Kids: Investigating the Role of Scale in Early Childhood Robotics Kits	tools	Dissertations
2019	Designing child-robot interaction with Robotito	tools	conference
2019	Computational Thinking Meets Student Learning : Extending the ISTE Standards	pedagogy	conference
2020	Handbook of research on tools for teaching computational thinking in P-12 education	mix	book
2020	Coding Training Proposal for Kindergarten	pedagogy	conference
2018	Assessing Young Children's Computational Thinking Abilities	evaluation	thesis
2021	TechCheck-K: A Measure of Computational Thinking for Kindergarten Children	evaluation	conference
2018	K-2 Students' Computational Thinking Engagement in Formal and Informal Learning Settings: A Case Study (Fundamental)	content	conference
2021	Draw2Code: Low-Cost Tangible Programming for Young Children to Create Interactive AR Animations	tools	thesis
2021	The use of Programming Tools in Teaching and Learning Material by K-12 Teachers	context	conference
2020	Fostering computational thinking and creativity in early childhood education: Play-learn-construct-program-collaborate	pedagogy	book
2017	Educational robotics for the formation of programming skills and computational thinking in childish	pedagogy	conference
2018	Initial Problem Scoping in K-2 Classrooms (Fundamental)	evidence	conference
2019	Inspiring Young Children to Engage in Computational Thinking In and Out of School (Research to Practice)	pedagogy, evidence	conference
2019	Robotito: programming robots from preschool to undergraduate school level	tools	conference
2021	Educational Robotics Applied to Computational Thinking Development: A Systematic Mapping Study	tools	conference
2019	Teachers' attitudes towards implementing coding at schools	teachers	conference
2012	Creativity and Science, Technology, Engineering, and Mathematics (STEM) in early childhood education	pedagogy	book