

**The Impact of Learning Computer Programming on the
Development of High School Students Cognitive Abilities
in the UAE**

تأثير تعلم برمجة الكمبيوتر على التطور الذهني لطلاب المرحلة الثانوية
في دولة الإمارات العربية المتحدة

by

HEBA ABDEL RAHMAN DARAGHMEH

A thesis submitted in fulfilment
of the requirements for the degree of
DOCTOR OF PHILOSOPHY IN EDUCATION

at

The British University in Dubai

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ABSTRACT

Now more than ever, computer science is becoming an integral discipline globally in a digitized world that links and supports other sciences and leads to different favorable career paths. It equips young generations with knowledge and skills required to lead the knowledge economy and gears them up to the fourth industrial revolution. The prominent change in the K-12 computer science education is characterized by great tendency to foster computational thinking as a set of transferrable skills. computer programming, as a major domain in Computer Science, is ultimately a virtuous strategy used to develop Computational Thinking skills for learners.

This research aims primarily to investigate whether or not learning computer programming has an impact on the development of high school students' cognitive abilities in the UAE. Twelve cognitive abilities were studied in a mixed-methods research; induction, general sequential reasoning, quantitative reasoning, memory span, working memory, visualization, speed rotation, closure speed, flexibility of closure, visual memory, spatial scanning, and serial perceptual integration. additionally, the researcher had studied students' choices, perceptions, and classroom practices and linked them to their cognitive style indices.

The results revealed that students demonstrated a significant improvement in their induction, quantitative reasoning, closure speed, visual memory, and serial perceptual integration cognitive abilities. furthermore, students demonstrated confidence and positive attitude toward learning programming. however, students' awareness of the usefulness of learning programming and their motivation to learn it was not evident. there was no significant impact of gender on students' choices of studying programming. on another hand, students' cognitive style index who chose to study programming was more analytic than intuitive. yet, male students were more analytic than females.

In conclusion, the study exposed urgency to teach computer programming as a core subject for high school students due to its positive impact on the development of their cognitive abilities. Nevertheless, classroom instructions and activities must be carefully designed to maximize that impact.

الخلاصة

الآن، وأكثر من أي وقت مضى، أصبحت علوم الحاسوب تخصصًا متكاملًا على مستوى العالم الرقمي الذي يربط العلوم الأخرى، ويدعمها، ويؤدي إلى مسارات وظيفية مختلفة. إنَّ هذا المجال يزوّد الأجيال الشابة بالمعرفة والمهارات اللازمة لقيادة اقتصاد المعرفة والثورة الصناعية الرابعة. ويميل تعليم علوم الحاسوب من مرحلة رياض الأطفال حتى نهاية التعليم الثانوي ميلاً كبيراً نحو تعزيز التفكير الحسابي باعتباره مجموعة من المهارات القابلة للاستغلال في عدّة مجالات. وتعد البرمجة – بالتحديد- كـمجال رئيسي في علوم الحاسوب، الإستراتيجية الأنجع في تطوير مهارات التفكير الحسابي عند المتعلمين.

يهدف هذا البحث في المقام الأول إلى التحقق من مدى تأثير تعلّم برمجة الحاسوب على تنمية القدرات الذهنية لطلبة المدارس الثانوية في الإمارات العربية المتحدة. انتهجت الباحثة دراسة اثنتي عشرة قدرة معرفية بأساليب بحثية متنوّعة، تتضمن: الاستقراء، الاستدلال المتسلسل العام، التفكير الكميّ، مدى الذاكرة، الذاكرة العاملة، التصوّر، دوران السرعة، سرعة الإغلاق، مرونة الإغلاق، الذاكرة المرئية، المسح المكاني، والتكامل الإدراكي التسلسلي. بالإضافة إلى ذلك، دُرست اختيارات الطلبة، وتصوّراتهم، والممارسات التعليمية في الفصول الدراسية، وربطت بمؤشرات أسلوبهم الذهني.

أظهرت النتائج أن الطلبة قد حقّقوا تحسُّناً كبيراً في الاستقراء، والتفكير الكميّ، وسرعة الإغلاق، والذاكرة البصرية، والقدرات المعرفية للتكامل الإدراكي التسلسلي. علاوة على ذلك، فقد أظهروا الثقة والسلوك الإيجابي تجاه تعلّم البرمجة، إلّا أنّ وغيهم بفائدة تعلّم البرمجة ودوافعهم تجاه تعلّمها لم يكن واضحاً. كما لم يُلاحظ أيُّ تأثير كبير لجنس الطلبة سواء كانوا ذكوراً أم إناثاً على اختيارهم لدراسة البرمجة. ومن ناحية أخرى، كان مؤشّر النمط المعرفي لأولئك الذين اختاروا دراسة البرمجة تحليلياً أكثر منه بديهيّاً. في حين أنّ الذكور كانوا أكثر تحليلاً من الإناث.

وفي صَفوة القول، كشفت الدراسة عن الحاجة الملحة لإدراج مادّة برمجة الحاسوب ضمن المواد الأساسية لطلبة المدارس الثانوية؛ لما لها من تأثير إيجابي في تنمية قدراتهم الذهنية. غير أنّ الاستفادة القصوى تتطلّب مزيداً من الاهتمام بتطوير التعليمات الصفية وجودة الأنشطة التعليمية المتعلقة بالمادّة.

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Chapter 1 Introduction

Developing students' cognitive abilities at the primary and secondary school levels has become a cornerstone of almost every educational policy and practice around the world. Since 1980s, researchers studied the importance of the environment on the individual cognitive abilities which highlighted the importance of teaching and learning practices on students' cognitive development. Plomin (1988) studies the nature and nurture of cognitive abilities and confirmed that the differences in the individual cognitive abilities are affected by environmental influences as well as behavioral genetic factors. Kan et al. (2013) shed the light on the fact the heritable abilities are culture dependent and discussed the "long-standing nature-nurture debate of intelligence". Though, Cromer et al. (2015) confirmed that cognition continues to develop from childhood to adulthood before the central nervous system tend to be mature. They stated that the rate for development varies between the different cognitive domains reflecting the maturation differences.

Modern learners are characterized as energetic and tech-savvy individuals. Therefore, the emerging 21st century skills such as problem solving, creativity, and analytical thinking, seem to be crucial for what is beyond the learners' school life. However, there still a debate on how to tackle those skills within the school system, in addition to what the cognitive abilities underlie those skills are and how we can develop them by informing the offered curricula. Several studies were conducted on Linguistics, Mathematics and Sciences. Yet, Computer Science, and computer programming in particular, is determined to be one of the most attractive subjects used to address this issue. That is due to its challenging nature and the cognitive skills it requires for problem solving i.e. the main objective of studying subject.

Hence, the researcher aims to study this aspect through empirical research and provide evidences on whether or not computer programming is an essential course for high school

students, within this PhD thesis titled “The Impact of Learning Computer Programming on the Development of High School Student Cognitive Abilities in the UAE”.

The first chapter introduces the background of the study followed by an explanation of the research problem statement, and the researcher’s stance as a computer science curriculum specialist. Additionally, the purpose and research questions, as well as the significance of the study were also elaborated. The chapter concludes with a description of the thesis structure and its content.

1.1 Background

Now more than ever, computer science is becoming an integral discipline globally in a digitized world that links and supports other sciences and leads to different favorable career paths. This fact leads to high demand on computer science education (K12 CS Framework 2017). According to Seehorn and Clayborn (2017), Computer Science education is dominating the K-12 school system views nowadays. It equips young generations with knowledge and skills required to lead the knowledge economy and gears them up to foster the fourth industrial revolution.

1.1.1 Computer Science

Bromley (1982) confirmed that Computer Science (CS) was originated in 1871 from the Babbages’ Analytical Engine with Ada Lovelace’s programming. The conception began to spread broadly following World War II. The first CS course was introduced by Cambridge University in 1953 (Fluck et al. 2016). After which the discipline continued to develop in different aspects of life. Contrarily, other researchers argued that there is no specific date for the beginning of the CS as a stand-alone domain. Though, Schneider and Gersting (2019) stated that the theoretical work on its logical foundations started in 1930’s. Compared to other

sciences, CS is considered relatively new.

CS is defined as the study of algorithms including their formal and mathematical properties, hardware realization, linguistic realizations, applications, as well as their impact on the society (Seehorn 2011, Google & Gallup, 2015, Schneider & Gersting 2019, Wilson, Sudol, Stephenson, & Stehlik 2010). Similarly, Gibbs and Tucker (1986) cited in Schneider and Gersting (2019) had defined CS as a science that represents a comprehensible body of scientific principles that would continue to lead the discipline for decades. Educators used to use the term ‘Computer Science’ when they want to refer to computer programming. However, according to Denning (1989), CS is far more than programming, it may also include the study of hardware design, system architecture, operating systems’ structures, and database systems. Proper understanding of the definition is crucial to identifying the discipline priorities and its anticipated outcomes. Within the school context, the term “Computer Science” refers to a particular subject in the school curriculum. While, some researchers have referred to it as ‘Informatics’ or ‘Computing’. Though, a curriculum document will determine the knowledge, skills, and attitudes students shall acquire during their course of study (Fluck et al. 2016).

1.1.2 Computer Science Education

Interest in CS education is increasing around the world due to pressure from industry and lobbying captivated groups (Brown et al. 2014). Yet, the position of its curriculum has been looked at contrarily in different countries. Fluck et al. (2016) suggested considering CS as a core subject for primary and secondary education due to various social, economic, and cultural reasons. Although ‘Information’ was accepted as a domain since 1948, the acceptance of ‘Computing’ is relatively new (Denning 2007).

While many European countries were offering a rigorous CS curriculum to schools for decades, other countries are still working to shift the paradigm of the CS education for primary and

secondary schools from teaching computer literacy, applications, management information systems (MIS), and information and communication technology (ICT) to computing, programming and computational thinking (Hubwieser et al. 2015). Al-Karaki et al. (2016) stated that the reason for the change is not only economic but also moral. Yet, the difference between CS and general computer literacy is still ambiguous to students, teachers, and parents (Google & Gallup 2015).

The prominent revolutionary change in the K-12 CS education is recognized with a great tendency to foster Computational Thinking (CT) as a set of transferrable skills that need to be taught for all students in the 21st century (Ambrosio et al. 2014). Barr and Stephenson (2011) and Webb et al. (2017) confirmed that programming, as one aspect of CS, is ultimately a virtuous strategy used to develop CT skills for learners. Understanding of patterns in programming rather than semantic and syntax would make it easier to learn (Kazimoglu et al. 2010). Similarly, Hanna (2015) pointed out that students need to acquire specific CT skills in order to be able to write computer programs. Hence, programming seems to be a fundamental strategy to teach CT skills (Voogt et al. 2015).

Despite the significant challenges of the new paradigm, it has gained popularity in the different educational systems encouraging educators and curriculum developers to emphasize on computational thinking and programming domains within the CS discipline. That was evident in the literature reviewed about CS education in different countries around the world as elaborated below.

The computing curriculum in the United Kingdom (UK) has gone through radical changes in the last two decades. The latest version is characterized by the replacement of the ‘Information and Communication Technology (ICT)’ with ‘Computer Science (CS)’. Brown et al. (2014)

stated that, in response to various industry voices, the CS curriculum encompasses CT and programming ,both visual and textual forms, as major outcomes.

Yet, according to Brown et al. (2014), as a result of the drastic change in the UK national curriculum during the last few decades, CS has been considered as a school subject named ‘Computer Studies’. It was available for all students in the 1980’s and included hardware and programming aspects of computers (Doyle 1985). Nevertheless, the popularity of the home computers in the 1990’s, made the ‘Information and Communication Technology’ a dominant choice that would enable students acquire the digital literacy needed to deal with computers and computer applications (Ofsted 2011).

In the 2000’s, the education sector started to realize different challenges of the prevalence of ICT. ICT was found unchallenging for students in the secondary level (Brown et al. 2014). According to The Royal Society (2012), this caused the ICT qualification’s results easily achieved. In addition to that, the education sector suffered from the lack of the qualified ICT teachers due to the well-paid alternatives in the market. Therefore, non-ICT specialists were recruited to teach the subject. Furthermore, students, who fallaciously believed that CS and ICT are the same, found no option to continue studying CS at the universities (The Royal Society 2012).

In 2008, a group of interested educators named “Computing At Schools” (CAS), started to promote computing in the UK schools and pushed the national agenda toward reconsidering the CS curriculum (Brown et al. 2013). Yet, until 2010, there was no computing course in the General Certificate of Secondary Education (GCSE) (Jones et al. 2011). In 2012, the UK Department of Education announced a curriculum review introducing a high quality CS curriculum (Department of Education 2012).

There is no single school system for the four developed UK nations; England, Scotland, Wales, and Northern Ireland. However, England and Wales are following almost the same approach. Hence, the latest curriculum update was adopted by England and Wales. Northern Ireland gives less attention to CS while Scotland considers CS as a school subject taught to students aging 3 to 18. This justifies the advances in the CS education in Scotland (Brown et al. 2013).

The American model was quite similar to the UK model. The United States National Research Council (1999) confirmed the significance of CS as an academic field that is as important as reading and writing (Horizon Media 2015).

There were various initiatives to develop a curriculum for CS in the United States of America (USA), one of them was proposed by New Jersey Teachers' Conference (Deek 1999). However, State of Main (1997) cited in Tucker (2003), argued that there was no identified national-level standard curriculum until the beginning of the 2000's.

According to Seehorn (2011), in response to the severe shortage of computer scientists, the Computer Science Teachers Association (CSTA) founded by the Association for Computing Machinery, Inc (ACM) in 2004, initiated the change in 2011 by articulating a set of blended standards that provided a three-level framework; K-6, 6-9, and 9-12. The standards were presented in five strands: Computational Thinking, Collaboration, Computing Practice and Programming, Computers and Communications Devices, and Community, Global, and Ethical Impact. They aim to educate the public about CS as a recognized discipline and reinforce CS fluency and aptitude across primary and secondary schools in order to provide consistency between the provided curriculum and the rapid growth of the modern technological world. The learning outcomes of the first level were designed to be integrated with other academic subjects. The second level was addressed either integrated with the other academic subjects or as a distinct CS course. While the third level was designed to be delivered at three different

courses: CS in the Modern World, CS Principles, and Topics in Computer Science. The CSTA standards were lately revised in 2017 based on current research, to align with the USA K-12 CS Framework. Representatives from all states steered the curriculum revision. Furthermore, experts from the research community, education sector, and professional associations also contributed in developing the revised curriculum framework. In addition to that, the framework was endorsed by researchers, higher education institutes and computer specialists. The latest CS Framework is adapting to the 21st Century Skills, with a detailed description of the CS core concepts and practices including algorithms and programming.

Besides, the revised framework includes five main concepts; Algorithms and Programming, Computing Systems, Data and Analysis, Impacts of Computing, and Networks, and the Internet (Seehorn & Clayborn 2017). A set of practices was developed to enhance the CS curriculum and link the learned knowledge to real life applications. The practices include: Collaborating Around Computing, Communicating about Computing, Creating Computational Artifacts, Developing and Using Abstractions, Fostering an Inclusive Computing Culture, Recognizing and Defining Computational Problems, and Testing and Refining Computational Artifacts (csteachers 2017).

According to K12 CS Framework (2017), most parents in the United States believe that CS is crucial to their children and is as important as reading and writing. Wilson et al. (2010) recommended that all levels of government, including federal, state and local governments support CS education by clearly defining CS education and expand its opportunities within the federal programs. For example, Washington State embraced the CS framework and declared an adoption statement that clarified the CS curriculum, its rationale, and the expected privileges (Thissen & Tylor 2016). The curriculum was aligned with the state learning goals and supported by state policies.

Hence, CS education in the USA was not only encouraged by educators and specialists in the field, but it also gained popularity and support at a presidential level. Barack Obama, the former president of the United States of America and the Office of Science and Technology Policy (OSTP) had launched the “Computer Science for All” initiative for K-12 education (Seehorn & Clayborn 2017). According to Whitehouse (2017), although it was evident that coding skills as well as Science, Technology, Engineering, and Mathematics (STEM) literacy would be critical to achieving well-paid jobs in the future, only few schools in the USA were offering high quality STEM and CS education. Thus, the latter president Donald Trump had signed a “Presidential Memorandum on Increasing Access to High-Quality Science, Technology, Engineering, and Mathematics (STEM) Education” on September 25th, 2017, stressing on the importance of engaging students in high quality STEM and CS education. Subsequently, Ivanka Trump; the senior advisor to the president had also promoted access to high-quality coding and CS education programs in K-12 schools during her visit to a special event to Detroit, Michigan, only two days after signing the memorandum (Whitehouse 2017). This event had influenced stakeholders and decision makers in the field to take further steps toward promoting coding and CS education in the USA.

In addition to UK and USA, many other countries have achieved considerable change in identifying CS education. Heintz, Mannila, and Färnqvist (2016) had reviewed different models for introducing computational thinking, CS and computing in Australia, Estonia, Finland, New Zealand, Norway, Sweden, South Korea, and Poland. They have concluded that the studied countries are introducing CS in addition to a set of digital competencies while computational thinking was not explicitly mentioned within their K-12 school curriculum. Most of the studied countries were introducing CS as a compulsory subject in primary schools and elective in secondary schools. Only few countries considered it compulsory for both.

1.1.3 Computer Science Education in the UAE

Ridge, Kippels, and Farah (2017) stated that the United Arab Emirates (UAE) formal education had started in 1953. However, immediately after the most important event, i.e. the establishment of the UAE country in 1971, the Ministry of Education (MoE) was recognized as the central authority of the educational system starting 1972. At that time, the curriculum was evolved around a variety of standards borrowed from neighboring countries (Suleiman 2000). Ridge (2009) confirmed that only in 1979, the UAE national curriculum project was officially launched. According to Ridge, Kippels and Farah (2017), CS was first introduced to the UAE curriculum in 1994-1995 and was limited only to secondary schools. They have summarized the curriculum changes since 1950 up until now in table 1.1.

| Year(s) | Curriculum Development Highlights |
|-----------|---|
| 1950-1970 | <ul style="list-style-type: none"> • A variety of curricula brought from the original countries of schools, such as Bahrain, Egypt, Kuwait, Qatar, and Saudi Arabia |
| 1971-1990 | <ul style="list-style-type: none"> • Largely based on the Egyptian model • Two-track system: arts and science • Arabic was the language of instruction • In 1979, the national curriculum project started, and a national curriculum was implemented nationwide by 1985 |
| 1991-2000 | <ul style="list-style-type: none"> • In the 1990s, the MoE partnered with UAE University to develop a new English language curriculum and extended it across all grade levels (prior to 1991, a foreign-produced English language curriculum was used) • In 1994, Model Schools were established (Shaheen, 2010) <ul style="list-style-type: none"> ○ These used English as the language of instruction in scientific subjects and mathematics and also emphasized on the use of new technologies • By 1994-95, all secondary schools taught CS |
| 2001-2010 | <ul style="list-style-type: none"> • In 2007, <i>Madares Al Ghad</i> initiative was launched <ul style="list-style-type: none"> ○ English used as the medium of instruction for science and mathematics, plus additional hours were dedicated for English language • In 2010 in Abu Dhabi, the new school model was launched and characterized by: <ul style="list-style-type: none"> ○ Bilingual instruction in Arabic and English ○ Reduction in number of subjects, heavy emphasis on science, technology, engineering, and mathematics (STEM) (Pennington, 2016a) ○ Emphasis on developing 21st century skills |

| Year(s) | Curriculum Development Highlights |
|-----------|---|
| | <ul style="list-style-type: none"> ○ Later renamed the Abu Dhabi School Model (ADSM) |
| 2011-2020 | <ul style="list-style-type: none"> ● In 2012, Mohammed Bin Rashid Smart Learning Program (MBRSLP) was established: <ul style="list-style-type: none"> ○ Emphasizing on technology ○ Aiming to provide all Grade 6-12 students with tablets and teachers and principals with laptops by 2019 ● <i>Madares Al Ghad</i> program discontinued in 2015 ● In 2016, MOE introduced new subjects and created new streams where: <ul style="list-style-type: none"> ○ History, Geography, Economics, and Social Studies were combined ○ New subjects introduced: Innovative Design, Health Sciences, Career Guidance, Life Skills, and Business Management ○ A special ‘Elite’ stream to nurture gifted students was also introduced |

Table 1.1 UAE curriculum changes from 1953 – 2020 (Ridge, Kippels & Farah 2017)

Research about CS education in the UAE was limited. However, based on the available studies and the “Computer Science and Technology Standards” document published on the Ministry of Education website (2017), in addition to reviews of educators and local media, the researcher could conclude a description of the current status.

Regarding the CS education, Al-Karaki et al. (2016) stated that the UAE MoE recommended a set of Information and Communication Technology (ICT) standards in 2008. They intended to outline what students need, to be able to use technology for learning purposes. The ICT standards aimed to “empower student voice and ensure that learning is a student-driven process” (ISTE 2019). The recommended ICT standards for cycle 1 (Grade 1-5) focused on information skills and ICT. Cycle 2 (Grade 6-9) included topics of Core Operations, Communicating and Producing, and Critical Thinking and Problem. Whereas cycle 3 (Grade 10-12) incorporated Advanced Core Operations, Creativity and Innovation, Problem Solving, Programming, and Robotics. The most considerable limitations of the ICT curriculum were the lack of sequence of standards and the minimal focus on computational thinking and programming.

Since then, continuous efforts are being paid to cater for the advances in the field in order to align the outcomes of the educational system with the international standards and demands. According to Al-Karaki et al. (2016), those efforts are driven by the UAE government vision in promoting knowledge and innovation by bringing up a smart educational system.

The MoE introduced the CS and Technology curriculum to replace ICT in 2014. The new curriculum was developed based on research and the experiences of other countries. The rationale behind this substantial change was responding to the international demand and the UAE vision to develop a generation capable of competing globally in all domains. According to the framework document, the curriculum was designed in light of the ministry's educational priorities and the vision of the country. The document incorporated ICT literacy with the basics of computing. It is also aligned with the 21st Century Skills, the International Society for Technology in Education (ISTE), ACM, as well as the Computer Science Teachers Association (CSTA) standards.

In 2015 the CS curriculum revamp took place. The UAE K-12 CS and Technology (CST) Standards (2015) include four main domains: Digital literacy and Competence (DLC), Computational Thinking (CT), Computer Practice and Programming (CPP), and Cyber Security, Cyber Safety, and Cyber Ethics (CCC). According to the CST standards (2015), the CST curriculum ensured proper scope and sequence of the learning outcomes across the three cycles. Al-Karaki et al. stated that the CST curriculum is not only aligned with the UAE vision 2021, but it also bring into line with ISTE, CSTA standards and the 21st Century Skills. However, according to the Assessment Policy Executive Procedures for the academic year 2018/2019 that was published on the MoE website (2018), CS is now partially offered for cycle 3 i.e. Grade 9-10. This indicates discrepancy between the CST standards' document and its implementation. Moreover, a review of the MoE CST textbooks for grade 9-10 reveals further

mismatch of the CST standards and the textbooks content. Tables 1.2 and 1.3 demonstrate the learning outcomes that are covered throughout the three terms for each grade level.

| Level | Term | Learning Outcomes |
|---|-------|--|
| Grade 9 General and Advanced Computer Science | One | <ul style="list-style-type: none"> • Describe a computer network. • Explain what a network topology is. • Discuss the advantages and disadvantages of computer networks • List computer networking media. • Explain transmission bandwidth and duplex. • Discuss the differences between peer-to-peer and client-server models. • State the purpose of network hardware. • Describe a network protocol. • Explain how data packets move across a network. • Design a computer network. • Define the terms: bandwidth, duplex and protocol. • Configure a computer network. • Test and evaluate a computer network. • Design a computer network. • Explain one new type of networking technology. • Convert binary numbers to denary and denary to binary. • Convert binary numbers to hexadecimal. |
| | Two | <ul style="list-style-type: none"> • Explain the impact the internet has had on industry. • Explain how DNS works. • Define an Internet Protocol address. • Investigate the skills needed in the future. • Identify the importance, and purpose, of HTML, CSS, PHP JavaScript • Identify the role of W3C • Explain the purpose of a web browser and how to retrieve a website • List 4 basic principles of web design. • Define branding guidelines for a brand. • Describe some of the key color theories. • Review against criteria to form a judgment on the websites design • Describe considerations for user interface design. • Identity HTML5 structure, including the use of container and stand-alone tags • Format web pages using standard HTML tags • Generate lists, use tables to structure the presentation of text and images and create simple web pages • Hyperlink two or more webpages together |
| | Three | <ul style="list-style-type: none"> • Explain the essentials of CSS and its role in styling webpages • Explain the difference between selectors and declarations • Understand how HEX numbers work and its relation to colors • Apply the use of CSS to style and layout webpages • Identify the four types of CSS positioning: static, relative, fixed and absolute • Create a navigation bar using CSS to position and style it • Identify the use of CSS floats • Be able to implement HTML and CSS to construct a three-column webpage • List example uses of JavaScript programming • Explain the difference between client-side and server-side scripts • Explain what a variable is and how they are used • List and explain the use of operators • Demonstrate the use of an alert in JavaScript • Implement JavaScript into a webpage |

Table 1.2 The CST Learning Outcomes in the UAE Curriculum for Grade 9 (2018)

| Level | Term | Learning Outcomes |
|--|-------|--|
| Grade 10 General and Advanced Computer Science | One | <ul style="list-style-type: none"> • Convert numbers from binary to denary. • Convert numbers from denary to binary. • Convert numbers from binary to hexadecimal • Convert numbers from hexadecimal to binary • Test connectivity using a static IP address • Configure a DHCP server to assign IP addresses • Resolve IP address conflicts • Give examples of industry changes in the future • List the five core priorities of an organization • Explain the use of 'feedback loops' in the IoT • Give examples of how actuators are used in the IoT • Explain what a 'sensor' is used for within the context of IoT • Explain the controller's role within the IoT • Design a control system using inputs, actions and outputs • Create a flowchart to design a system • Design a control system using inputs, actions and outputs • Explain the difference between a closed-loop control system and an open-loop control system" |
| | Two | <ul style="list-style-type: none"> • Explain computer programming • Design and write a program in Python • Describe algorithms to solve problems and represent them in a flowchart • State what a variable is and identify some data types • Design your own functions and use them to solve problems • Understand how selection and repetition statements work • Select the right selection and repetition statements to control execution • Solve problems using selection and repetition statements • Understand what debugging is • Understand the different functions available in the debugger • Understand the different types of bugs that can be present in programs. • Debug programs with multiple errors present |
| | Three | <ul style="list-style-type: none"> • Describe lists and the operations you can perform on them. • Integrate selection, repetition and data structures to solve problems • Develop and test code using lists • Integrate selection, repetition and data structures to solve problems • Analyze basic algorithms using flowcharts • Develop and test code for basic algorithms • Explain the basic principles of computer vision • Analyze the performance of computer vision algorithms • Apply programming concepts learned to solve real-world problems • Develop code to count coins using computer vision |

Table 1.3 The CST Learning Outcomes in the UAE Curriculum for Grade 10 (2018)

1.2 Problem Statement

Wing (2006) indicated that CT fosters the learners' problem-solving skills as well as the understanding of the human's behavior utilizing the fundamental concepts of CS. Wing (2011) cited in Grover and Pea (2013) pointed out that "CT as the thought processes involved in formulating problems and their solutions so that the solutions are represented in a form that can be effectively carried out by an information-processing agent".

Recent literature on CS education is focused on introducing the current trends and practices in teaching and learning programming as a fundamental skill and a basic tool to support the cognitive tasks involved in CT (Grover & Pea, 2013). Ambrosio et al. (2014) identified the CT core cognitive skills, particularly those associated to the programming component as: spatial reasoning, general intelligence, arithmetic reasoning, and attention to details. Yet, very little work pointed out how learning computer programming would impact the development of those core cognitive skills.

There has been no agreement between the different educational systems about the position of the computer programming subject. Sometimes it is mandatory for certain grade levels while it is just integrated with other core subjects in other systems. The underlying assumptions of the importance of computer programming in K-12 education, in addition to how it is related to the development of the core cognitive abilities of learners are still intangible. Also, the UAE experience in implementing computer programming within the school curriculum is yet unstable, which reflects an unclear vision about its importance and the best implementation techniques.

1.3 Rationale

After 10 years of experience teaching CS for high school students in the private sector, the researcher is currently working as a curriculum specialist since 2015 in one of the most reputable public-school systems in the UAE. She is responsible for designing and implementing the CS curriculum for different domains including Computational Thinking, Java programming, Computer Networks, Computer Security, Web Development, Database Systems, Media Technology, and Computer Animation. The developed CS curriculum is aligned with international standards including Advanced Placement from College Board, CSTA, CISCO, and Oracle. Additionally, the researcher integrates the CS curriculum with other disciplines through STEM projects and develops various assessment material. As part of her role, she also provides support to more than 70 CS teachers in 16 schools on teaching pedagogy and quality of teaching and learning. Furthermore, the researcher had conducted and published different research articles in educational technology, educational policies and gifted and talented education.

During her experience in education and curriculum development, the researcher noticed an underrating of CS education and computational thinking and programming particularly in the middle east region compared to other countries around the world. Therefore, she was passionate to provide evidence on the significance of teaching CS and programming on the students' cognitive abilities development that may lead to consider it as a core subject within the school curriculum.

According to Creswell (2017), the researchers' choice of approach is heavily dependent on their experience and personal training. Scientific researchers who are technically trained to use computers for statistical analysis will mostly choose a quantitative design. On the other hand, researchers who find themselves able to manage creative writing and enjoy it will most likely

choose the qualitative approach. The researcher of this study finds herself in both positions and most importantly she is keen to invest in time and resources to collect and analyze both quantitative and qualitative data (Creswell 2017) to achieve the research objectives.

1.4 Purpose and Research Questions

This research aims primarily to investigate whether or not learning computer programming has an impact on the development of high school students' cognitive abilities in the UAE. Achieving this aim will help the researcher fulfill the gap in the literature, understand the relationship between learning computer programming and the students' cognitive abilities' development, and identify other variables that may influence that impact, if found, by answering the main research question and its sub-questions shown below:

Main research question: To what extent does learning computer programming impact the development of high school students' cognitive abilities in the UAE?

- Sub-question 1: What are the students' perceptions of their experience when they learn computer programming?
- Sub-question 2: What cognitive activities and practices may occur in the classroom during a computer programming lesson?
- Sub-question 3: How the cognitive style may affect students' choice of studying computer programming?
- Sub-question 4: How gender differences may affect students' choices, cognitive styles, and perceptions when they learn computer programming?

1.5 Significance of the Study

Zawacki-Richter and Latchem (2018) had analyzed the content of more than 3600 research papers about CS education that were published in the last four decades and concluded that “the articles progressed through four distinct stages, reflecting major developments in educational technology and theories of learning with media: the advancement and growth of computer-based instruction (1976-1986); stand-alone multimedia learning (1987-1996); networked computers as tools for collaborative learning (1997-2006); and online learning in a digital age (2007-2016)”. Their study revealed that research about CT and programming in educational contexts is still unsatisfactory.

Therefore, the value of this research stems from the need to provide evidence on the importance of teaching programming and computational thinking as a set of core skills and abilities required to solve problems in the different disciplines including real-life applications. Considering programming as a major approach used to support and deliver the cognitive tasks involved in CT (Grover & Pea 2013), Burk and Burk (2016) confirmed that it is not only about employing the technical skills of writing computer programs, but it is also about being able to process mentally, what is written as a code, by utilizing the basic CT skills (Bocconi et al. 2016, Burk & Burk 2016). Therefore, identifying the cognitive skills associated with CT, how can they be taught, and how can we evaluate them is crucial and worth further research (Guzdial 2011). The results of this research are expected to illicit a series of findings that support the need to teach CT by providing an evidence of its impact on the development of the students’ cognitive abilities.

1.6 Thesis Structure

This thesis includes six chapters: Introduction, Literature Review, Methodology, Data Analysis, Discussion, Conclusions and Recommendations.

The first chapter introduces the thesis by providing a solid background about CS and CS education globally and locally in the UAE followed by an explanation of the research problem statement, and the rationale. Additionally, the purpose and research questions, as well as the significance of the study are also elaborated. The chapter concludes with a description of the thesis structure and its content.

Chapter 2 includes four main sections, theoretical framework, conceptual framework, literature review, and summary. In the theoretical framework, the researcher discusses cognitive theories, learning theories, and other supporting theories pertinent to the context of the research. Among the various cognitive theories found in the literature, Piaget and CHC were found the most relevant. The learning theories include Vygotsky and Dewey considering the constructivism and behaviorism learning approaches. While the supporting theories that are discussed include: Fuzzy Trace Theory (FTT), Executive Function Theory (EFT), and Cognitive Load Theory (CLT). The second section of the chapter discusses the conceptual framework that relates the different concepts of computational thinking, neuroscience, as well as cognitive and noncognitive functions that are related to the cognitive abilities and individuals' perceptions consecutively. Both theoretical framework and conceptual framework provide a basis for the third section i.e. literature review that summarizes tens of researches and journal articles about cognitive development, cognitive development in neuroscience, cognitive development assessment, cognitive assessment tools, cognitive styles, higher order thinking skills, and computational thinking. the chapter is concludes with a summary of the chapter content.

The third chapter presents the research methodology. The methodology includes the philosophical standpoint and the research approach by introducing an overview of the research paradigms and a justification of the researcher's choice, research design, and a detailed description of the mixed method that will be followed. Additionally, the chapter covers all aspects related to validity and reliability, site and subject selection, sampling, data collection, instruments, data analysis, and ethical considerations.

Both quantitative and qualitative data analyses are demonstrated in chapter 4. The chapter introduces the data analyses and the results obtained for each instrument used within the context of the research study. It consists of seven sections namely: analysis of the demographics data, analysis of the cognitive style index, analysis of the CT-Cognitive Abilities Measure, analysis of the questionnaire, analysis of the class observations, analysis of the interviews, and a summary for all sections. Both descriptive and inferential quantitative data analyses are conducted for the CT-Cognitive Abilities Measure results, Cognitive Style Index, the questionnaire, and the observation quantitative data. Additionally, qualitative data collected from the observations, and interviews are also segmented, cleaned, organized, categorized and analyzed as appropriate.

Chapter 5 presents an in-depth discussion of the data analyses' results in six sections. Each section discusses the findings of the data analysis for each research question including the background information of the key concept, testifying the results of the pertinent data analysis, stating the major findings, referencing the findings to previous research studies that either supports or contradicts with them, if any, explaining the results, and concluding the implications of them. The last section summarizes the discussion that is carried throughout the chapter.

Finally, chapter 6 concludes the thesis by presenting the conclusions and recommendations in different sections including: key findings, implications, and recommendations. Finally, the researcher paves the way for further research in the last section about the scope for further research.

Chapter 2 Literature Review

There has been a revolutionary change in the K-12 CS education around the world with a great tendency to foster CT through programming as a set transferrable skills including algorithmic thinking, logical reasoning and problem solving. Despite the significant challenges of the new paradigm, it has gained popularity in the different educational systems attracting educators and curriculum developers to emphasize on the programming domain within the CS discipline.

As mentioned earlier in chapter 1, the computing curriculum in the United Kingdom (UK) has gone through radical changes in the last few decades. The latest version is characterized by the replacement of the ICT with CS. Brown et al. (2014) stated that, in response to various industry voices, the CS curriculum encompasses CT and programming as major outcomes. The American model was rather similar to the UK model. The latest CS Framework is adapting to the 21st Century Skills, considering algorithms and programming as core concepts. Likewise, the UAE CS curriculum revamp took place in 2015. The UAE K-12 CS and Technology Standards' document has introduced 'Computer Practices and Programming' as one of its four main domains.

Recent literature on the CS education is basically focused on introducing the current trends and practices in teaching and learning programming as a fundamental skill and a basic tool to support the cognitive tasks involved in CT (Grover & Pea, 2013). Burke and Burke (2016) have studied how programming is presented in the CS education in the last three decades claiming that it is one of the major topics students need to learn. Economists and Educators have recognized programming as a basic skill, schools need to teach (Gardiner, 2014). Yet, the underlying assumptions of the importance of computer programming in K-12 education, in addition to how it is related to the cognitive abilities development of learners is incorporeal.

Therefore, while the aim of the research is to investigate the impact of learning computer programming on the development of the students' cognitive abilities, the researcher is keen to answer the research main question and the sub questions and achieve the research objectives by studying the related literature and construct a theoretical framework, upon which the research methodology will be based.

In chapter 2, the theoretical framework is introduced with a clear identification of the related theories and how they fit into the context of this research including: Piaget theory, Cattell-Horn-Carroll theory, Vygotsky theory, Dewey theory, Executive Function Theory, Fuzzy Trace theory, and Cognitive Load theory. The conceptual framework is also presented based on the theoretical framework with a concept map that guides the design of the research. Accordingly, the literature review is conferred in details about cognitive development, cognitive development in neuroscience, cognitive development assessment, cognitive assessment tools, cognitive styles, higher order thinking skills, and computational thinking.

2.1 Theoretical Framework

The theoretical framework is a “blueprint” that serves as a guide to build and support the research study (Osanloo & Grant 2016). According to Creswell (2013) one of the literature review components is the identification of theories that are essential to explore the research questions. In a mixed-method research, the researcher uses the framework as a lens to look at the problem and inform the different design aspects such as collecting, analyzing, and interpreting data (Creswell 2013). LaPlaca, Lindgreen, and Vanhamme (2018) pointed out the importance of the theoretical framework where the research contribution can be substantiated. The choice of theories in a research provides a structure for the whole study (Osanloo & Grant 2016).

Osanloo and Grant (2016) wrote a valuable paper about “understanding, selecting, and integrating a theoretical framework in dissertation research: creating the blueprint for your house”. The authors indicated that although the theoretical framework is the most significant component in the research process, it is misunderstood by researchers particularly doctoral candidates. Though, the researcher’s personal beliefs and understanding of the existing knowledge can be characterized by the theoretical framework (Lysaght 2011 cited in Osanloo & Grant 2016). Also, the researcher’s “theory-Driven thinking” impacts the identification of the problem statement, purpose, research questions, research design, literature review, and data analysis (Osanloo & Grant 2016).

Hence, as a pragmatist, the researcher’s selection of theories for this thesis was based on the research problem. Theories are used as a lens to develop the research questions and steer the research process.

Due to the complexity of this study, different theories were chosen to establish a foundation for the theoretical framework. Brainerd and Reyna (2015) stated that the success of scientific theories depends on its two main functions: explanation and prediction. Therefore, in addition to the scope identified by the research questions, the explanation and prediction of the different theories was a major factor considered for the theories to be selected. Cognitive theories take into consideration the environmental conditions that impact learning (Schunk 2012). Accordingly, three main types of theories are used; cognitive theories, learning theories, and other supporting theories. All theories are mutually related to the set of cognitive abilities that underlie learning computer programming as identified in the reviewed literature.

The cognitive theories are basic theories upon which the researcher will identify students’ cognitive abilities that underlie learning computer programming i.e. Piaget theory and Cattell-Horn-Carroll theory (CHC). While learning theories situate a basis for interpreting students’

cognitive behavior inside the classroom. Vygotsky and Dewey theories are found to be the most relevant, taking into consideration both constructivism and behaviorism perspectives. The researcher also found other supporting theories that will help in further understanding and interpreting of the development of students' cognitive abilities and behaviors including Fuzzy Trace Theory (FTT), Executive Function Theory (EFT), and Cognitive Load Theory (CLT). These theories are incorporated at the different stages of the research. Figure 2.1 illustrates the theoretical framework, demonstrating the utilized theories and the relationship between them. Yet, the detailed description of those theories is elaborated in the following sub sections.

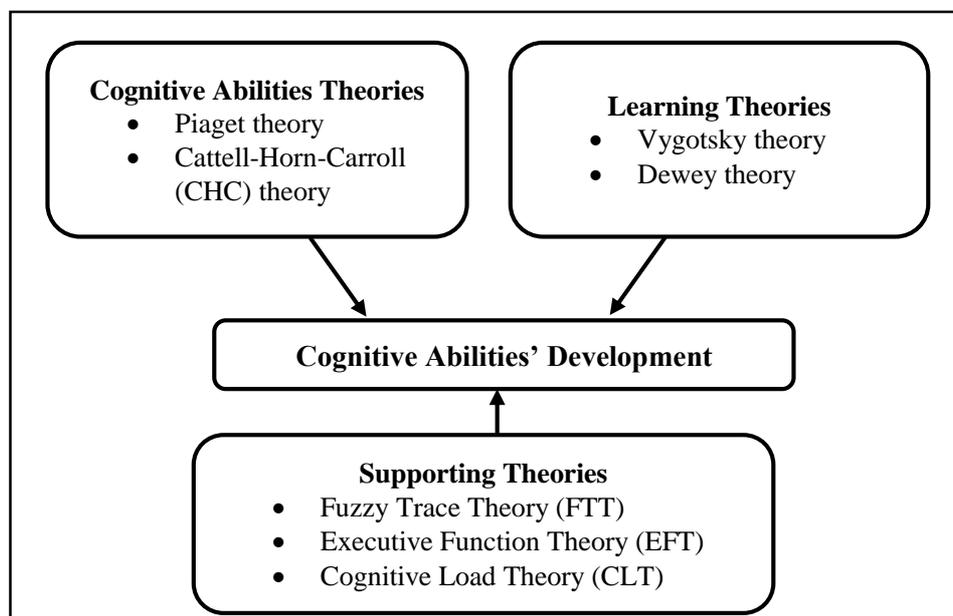


Figure 2.1 Theoretical Framework

2.1.1 Cognitive Theories

Cognitive development theories have become imperative in different education fields and the study of the learning practices for its deal with thought processes including thinking, remembering, reasoning, decision-making and problem solving starting from childhood passing through adolescence and ending in adulthood. Development occurs in various aspects: physical, personality, socioemotional, cognitive, and language (Slavin 2014). The interest in cognition and its development in children, and their growth of intelligence was clearly evident

in the previous decades and attracted the attention of many scholars and psychologists, but till now, no general theory is adopted. Two theories were selected to identify students' cognitive abilities that underlie learning computer programming; Piaget theory and Cattell-Horn-Carroll theory. Piaget theory relevance to this research lies in the stages of cognitive development a child goes through, particularly the formal operation stage (Slavin 2014). The focus on deductive reasoning skills and abstraction skills in the formal operation stage is crucial to this research.

On the other hand, Cattell-Horn-Carroll theory which was developed by Raymond Cattell, John Horn, and John Carrol presents the three strata model that differentiates factors or abilities into three levels: Stratum I, Stratum II, and Stratum III (Flanagan & Dixon 2014). The researcher relies on the description of the identified cognitive abilities in the model to be studied. Further details of these theories are demonstrated in the following sub sections.

2.1.1.1 Piaget theory

Different children develop in different ways. According to Slavin (2014), "the term development refers to how people grow, adapt, and change over time". Development can happen in different aspects: physical, personality, socioemotional, cognitive, and language (Slavin 2014). Among all theories stated in the field of cognition, the most distinguished and recognized theory of cognitive development is of Jean Piaget (McLeod 2009).

The french psychologist from 1896 to 1980 was a major figure in the field of Psychology (Cook & Cook, 2005). His interest in wildlife and its natural settings led him to publish his first article at the age of 10 about an albino sparrow. At the age of 21, Piaget earned his PhD degree in psychology. After which, he started to work in Zurich in a psychiatric clinic. That had widened

his knowledge in the Freudian psychoanalysis and how to conduct a clinical interview. Then, Piaget moved to Paris to work with Theophile Simon and Alfred Binet on developing the French version of the reasoning tasks in standardized intelligence tests (Cook & Cook, 2005).

The first published Piaget theory in 1952 was based on decades of observation of his own children. The theory is generated in a natural environment as opposite to the behaviorist approach of performing tasks in a laboratory, Piaget utilized his house setting as a laboratory (Slavin 2014). The development of his cognitive development theory started with the recognition of the biological interpretation of the children's ability to attempt to understanding the world around them and their cognitive adaptation, unlike the common believes that children were passive recipients of information. (Cook & Cook, 2005). He recognized the age-related patterns in the children's cognitive development, and consequently developed a clinical tool to understand how children think. Piaget relied on his knowledge in biology and observed children articulating his cognitive development theory.

Piaget identified why and how a change can happen in the child's mental ability (Slavin 2014). Piaget (1964) discussed the theory of cognitive development in the first part of his publication "Cognitive Development of Children". He stated that "knowledge is not a copy of reality". It is rather acting to an object you see by modifying and transforming it in the human brain in a process called 'Operation'. Yet, 'Operation' is a reversible action that makes up the logical structures that establishes the basis for knowledge (Piaget 1964). At an early stage of Piaget's studies of cognition, he introduced the four stages of the development: sensory-motor and pre-verbal stage, pre-operational representation i.e. the beginnings of using symbolic function and language, operational where first operations appear, and the last stage when the child reaches the formal deduction hypothetic operation (Piaget 1964). Slavin (2014) described Piaget's theory in a quiet different way. He stated that Piaget defined four stages of development based

on approximate age ranges. The earliest stage is sensorimotor stage that occurs at infancy, for childhood he has the pre-operational stage, for elementary and early adolescence, he described the concrete operational stage, and lastly, he suggested the formal operational stage for late adolescence and adulthood.

The formal operational stage begins at the age of 12 and lasts to adulthood. In this stage, intelligence is established through logical reasoning in addition to the development of abstract concepts and the egocentric thoughts (Huitt & Hummel 2003). According to Piaget, children at this stage are more likely to understand other people's point of view and accept that everyone has the right to share their point of views and try to maintain moral principles though.

Additionally, thought processes become more abstract and guided by theoretical concepts. Children at this stage can come up with creative solutions for different problems by using logic and skills such as, systematic planning, and deductive reasoning. Accordingly, Piaget (1971) stated that there are two major changes happen during the formal operational thought: the development of the ability to use hypothetico-deductive reasoning and the extension of the use of the logical thinking to abstract concepts that are not necessarily related to materialistic representation. According to Cook and Cook (2005) hypothetico-deductive reasoning relies on the use of scientific reasoning to manipulate variables, test them, and reach to correct conclusions. Deductive reasoning starts to develop at the age 12 of the adolescent life with no particular upper age limit (Cook & Cook 2005). It requires an ability to assess general principles to determine a particular outcome. For hypothetical situations and concepts in Science and Math, this kind of thinking is often required. Though, Piaget had shed light on the fact that development leads to learning (Ormrod 2014, Slavin 2014).

At a later stage, Piaget's cognitive development theory had developed when he introduced the term schema (Huitt & Hummel 2003) i.e a small unit of memory saved in the mind of the child based on past experiences. These past experiences become the basis for understanding new ones. Long (2000) and Slavin (2014) pointed out that Piaget introduced four theories on how development occurs: Schemes, Assimilation, Accommodation, and Equilibration. The schemes theory suggests that children process and organize information in certain patterns. Yet, trying to understand a new object in terms of an existing object is called assimilation. An existing scheme is then adjusted in a process called accommodation after which a balance is restored in the equilibration process. This is how memory is saved in the mind according to Piaget (Angilia 2017).

Studying Piaget's theory from another perspective, Cook and Cook (2005) stated that extensive interaction between the person and the environment is essential to cognitive development. Hence, the essential role of the environment in the person's cognitive development. Cook and Cook (2005) confirmed that there are three mutual processes that guide our interactions:

- Organization
- Adaptation
- Reflective abstraction

The first two processes have biological background/physical science. Hence, Piaget had used them in his theory of psychological development.

Organization (also called Assimilation) is a basic unconscious process which expresses the tendency to logically organize knowledge into integrated/patterned structures that are already exist. This process helps people function successfully in their psychological environments. However, if this organization didn't fit within the constructed structures, one may need to apply

adjustments and modifications in a process called adaptation. The diagram below shows the adaptation cycle that includes: assimilation, cognitive disequilibrium, accommodation, and cognitive equilibrium.

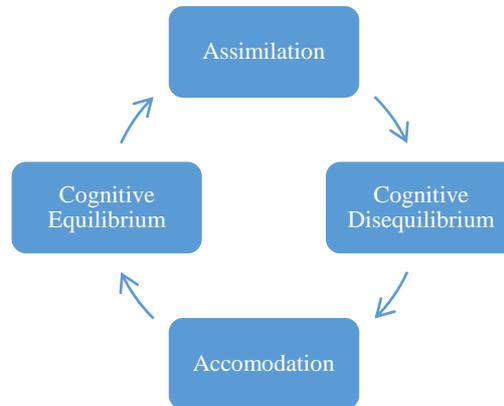


Figure 2.2 Adaptation Cycle. Adapted from Cook and Cook (2005)

According to Beilin (1996) cited in Cook and Cook (2005), Piaget believed that the normal state of the mind is disequilibrium or “moving equilibrium” considering equilibrium as a vigorous process that is, at no time, completely achieved. There is always tendency to learn and develop new structures.

Reflective abstraction is the final process that guides our thinking about the gained information and experiences. Piaget (1971) and Ginsburg & Opper (1988) stated that engaging in reflective abstraction leads to modifications to the current cognitive structures. Reflective abstraction may involve compare and contrast properties of things as well as understanding them.

However, Dodonov and Dodonova (2011) pointed out the missing element in Piaget theory that was basically the exclusion of some non-adaptive components after the development of the new schemas. Similarly, Lourenço (2016), in his critical review, argued Piaget’s conception of development and its “non-received” view. Nevertheless, according to Barrouillet (2015), Piaget’s theories had been evolved. This evolution had rejected its monotonic ascending

function, if the striking reversal that may also occur, to be considered. As a result, neo-Piagetian theories appeared.

After all, this research will be based on Piaget's formal operation stage where systematic planning, deductive reasoning, and abstraction happen (Ormrod 2014, Slavin 2014). These skills are considered essential in the discussion of learning computer programming as they directly link to the computational thinking skills children use when they program. Wing (2006) confirmed that the components of computational thinking include five main cognitive processes: problem reformulation, recursion, decomposition, abstraction, and systematic testing. This clearly justifies the use of Piaget's theory in the context of this research.

2.1.1.2 Cattell-Horn-Carroll theory (CHC)

According to Flanagan and Dixon (2014), the CHC theory is the most recent comprehensive theory that explains the structure of the cognitive abilities. The main idea of the CHC theory is that "intelligence is both multidimensional and functionally integrated" (Flanagan, Genshaft, & Harrison 1997). It was developed by Raymond Cattell, John Horn, and John Carroll. Empirical research about development, neuro-cognition, and outcome-criterion have relied heavily on it. According to Flanagan, Genshaft, and Harrison (1997), multiple overlapping cognition theories are embedded in the CHC theory which provides a framework for researchers to correspond to their findings.

Therefore, the CHC theory has been used to select, organize, and interpret intelligence and cognitive abilities tests. Those tests are classified into:

- Tests that facilitate the interpretation of the individuals' cognitive performance
- Tests that provide a foundation for organizing assessments for individuals suspected of having a learning disability

Therefore, the CHC theory is considered the foundation of the most recent intelligent batteries.

Raymond Cattell had put forth the Fluid-Crystallized theory (*Gf-Gc*) as a dichotomous of two concepts, Fluid Intelligence (*Gf*) and Crystallized Intelligence (*Gc*), in 1940's. Cattell believed that Fluid Intelligence (*Gf*) consists of Inductive and Deductive Reasoning abilities which are affected by biological, neurological and incidental learning through interaction factors. After which he expanded his theory to include the Crystallized Intelligence (*Gc*) which consists of acquired knowledge abilities that reflected, to a large extent, the influences of acculturation (Cattell, 1957).

John Horn then, had expanded the model in the 1990's to include eight more factors including:

1. Visual perception or processing (*Gv*)
2. Short-term memory (Short-term Acquisition and Retrieval—SAR or *Gsm*)
3. Long-term storage and retrieval (Tertiary Storage and Retrieval—TSR or *Glr*),
4. Processing Speed (*Gs*)
5. Auditory processing ability (*Ga*)
6. Reaction time and decision speed (*Gt*)
7. Quantitative (*Gq*)
8. Broad reading-writing (*Grw*)

The theory was known as Cattell-Horn *Gf-Gc* theory (Flanagan & Dixon 2014). Carroll in late 1990's had proposed the three strata model that differentiated factors or abilities into three levels:

1. Stratum I: narrow abilities that represent greater specializations of abilities, often in quite specific ways that reflect the effects of experience and learning, or the adoption of particular strategies of performance

2. Stratum II: broad abilities that form the basic constitutional and long standing characteristics of individuals that can govern or influence a great variety of behaviors in a given domain (*Gf* and *Gc*)
3. Stratum III: the broadest level of cognitive abilities and represented by *g*. It subsumes both Stratum I and Stratum II abilities.

Each level's abilities have nonzero positive inter-correlation. i.e. abilities in each stratum can be predicted and estimated based on certain given abilities. This correlation can be useful in this research in a sense that reasoning and problem solving are correlated to fluid reasoning and crystallized intelligence (Carroll, 1997).

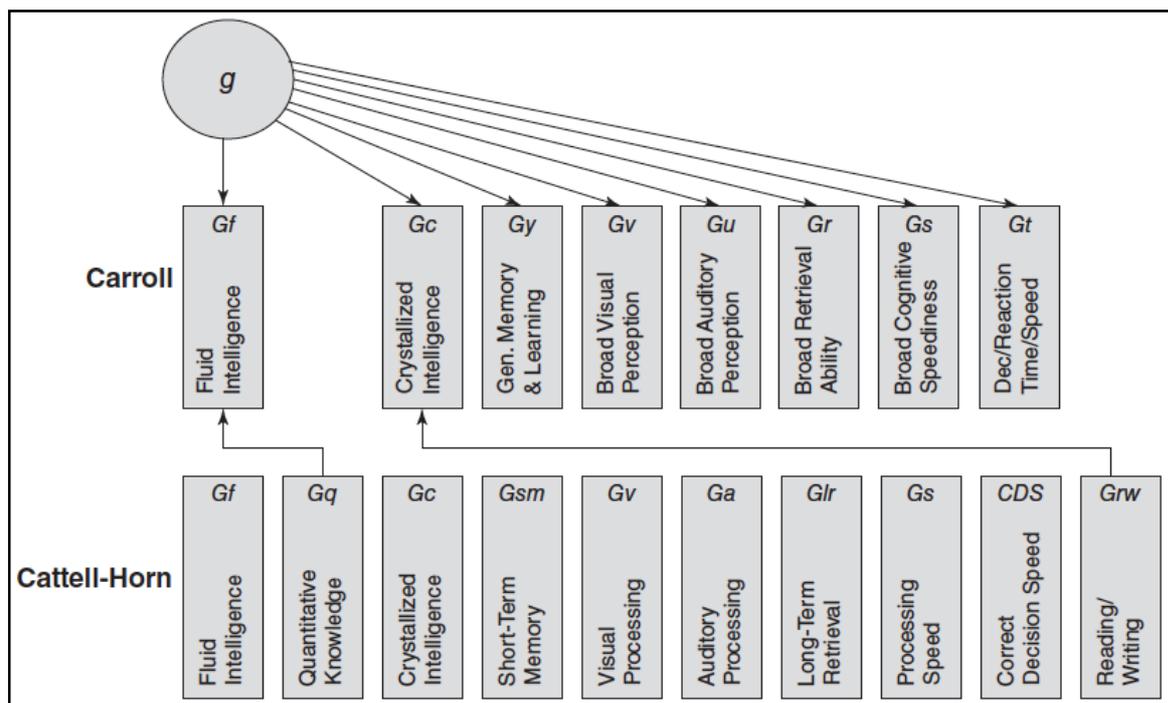


Figure 2.3 Comparison of Cattell-Horn Gf-Gc theory and Carroll's Three-Stratum theory. Adapted from Flanagan and Dixon (2014).

Schneider and McGrew (2012) stated that studies of cognitive abilities is strongly related to development history of exploratory and confirmatory factor analysis. Yet, the non-factor

analytical research, as in developmental and outcome prediction studies, provides more validity for the CHC theory.

According to Román-González, Pérez-González, and Jiménez-Fernández (2017), the CHC theory forms a basis to understand which cognitive abilities underlie computational thinking and programming. Hence, they confirmed that Fluid Intelligence (*Gf*) Reasoning, Short-Term Memory (*Gsm*), and Visual Processing (*Gv*) are the cognitive abilities underlie computational thinking. Therefore, an understanding of the CHC theory helps the researcher identifies the constructs of the CT-Cognitive Abilities Measure that can be used to test the students’ cognitive abilities development when they learn computer programming. The Narrow Stratum I abilities for each Broad Stratum II ability, that are relevant to learning programming, are demonstrated in table 2.1.

| Broad Stratum II Ability | Narrow Stratum I Ability |
|--|---|
| Fluid Intelligence (<i>Gf</i>) Reasoning | Induction (I) |
| | General Sequential Reasoning (RG) |
| | Quantitative Reasoning (RQ) |
| Short-Term Memory (<i>Gsm</i>) | Memory Span (MS) |
| | Working Memory (MW) |
| Visual Processing (<i>Gv</i>) | Visualization (Vz) |
| | Speeded Rotation(Spatial Relations; SR) |
| | Closure Speed (CS) |
| | Flexibility of Closure (CF) |
| | Visual Memory (MV) |
| | Spatial Scanning (SS) |
| | Serial Perceptual Integration (PI) |
| | Length Estimation (LE) |
| | Perceptual Illusions (IL) |
| | Perceptual Alternations (PN) |
| Imagery (IM) | |

Table 2.1 The Narrow Stratum I abilities for each Broad Stratum II ability relevant to learning programming

2.1.2 Learning Theories

The study of theories of learning started early in the first half of the nineteenth century (Hilgard & Bower 1966). Schunk (2012) pointed out that “Learning involves acquiring and modifying knowledge, skills, strategies, beliefs, attitudes, and behaviors. People learn cognitive, linguistic, motor, and social skills, and these can take many forms.” He identified criteria for learning by stating that; learning involves change, sustains over time, and that learning happens through experience. These criteria formulate a foundation for different aspects that are studied in this research. A profound study of the learning theories would help the researcher understand how the learning environment would impact students when they learn computer programming. Additionally, the contemporary application of the different learning theories can be clearly demonstrated by observing students while learning. The researcher chose to study learning theories in two lenses; constructivism and behaviorism. Therefore, Vygotsky theory would explain learning from the constructivism lens and Dewey theory would explain it from the behaviorism lens. Further details of the two theories are elaborated in the following sub sections.

2.1.2.1 Vygotsky theory

Vygotsky proposed his cognitive development theory in the 1920s that linked cognitive development to social interaction with others in the view of constructivism (Ormrod 2014). Vygotsky had identified development based on two fundamental aspects: children’s experience and signs’ system. As a result of Vygotsky’s work, four theories were developed: private speech, the zone of proximal development, scaffolding, and cooperative learning (Slavin 2014).

Vygotsky's theory pointed out two kinds of speeches; the social speech and the private one. Social speech referred to as the speech that children hear or is spoken around and will be adopted by them. While the private speech is what the children use when they talk loudly to themselves. The language or speech contains the concepts of the child, which will become the "psychological tools" that the child will use (Vygotsky, 1962). Vygotsky compared in the zone of proximal development (ZPD), the child's "actual developmental level as determined by independent problem solving" and the child's level of "potential development as determined through problem solving under adult guidance or in collaboration with more capable peers" (Vygotsky, 1978, p. 86). The idea of ZPD is imperative in the classroom since it gives the teacher an idea about the tasks the child can perform without any assistance as well as the tasks that need support. Karpov and Haywood (1998) cited in Slavin and Davis (2006) stated that "According to Vygotsky, for the curriculum to be developmentally appropriate, the teacher must plan activities that encompass not only what children are capable of doing on their own but what they can learn with the help of others".

On the other hand, scaffolding is a useful strategy that approaches ZPD. It is the help that a child is provided with, when learning a specific concept or developing cognitive processes (Wood, Bruner & Ross 1976, Wood & Middleton 1975, Wood, Wood & Middleton 1978). Scaffolding required from teachers to engage children while learning and simplify the information so that it can be easily comprehended. In collaborative learning teachers can impact the student's cognitive development when they encourage collaboration between peers during problem solving, exploring new strategies, and sharing information and skills. (Gillies 2003, Slavin 1995, Wentzel & Watkins 2002, Zimbardo, Butler & Wolfe 2003).

Although Gauvain (2001) pointed out that Vygotsky's description of the development processes is ambiguous. Yet, cooperative learning environment and scaffolding are still two main implications of Vygotsky theory that will heavily impact this research.

The study of Vygotsky theory and its implication on the learning process would help the researcher understand how students learn in the classroom and further interpret their cognitive behaviors. Such data can be obtained by class observations.

2.1.2.2 Dewey theory

In the view of behaviorism, the process of human thinking is something that creates the actions of an individual (Dewey, 1910). From this point of view, when an individual gets in contact with an external stimulus, thinking takes place as a result of it. To shift the behavior in the correct direction, it is the responsibility of the educator to provide such environment to the learner that is rich in stimuli.

Dewey (2014) defined thoughts as "everything that comes to mind" while reflective thought is "Active, persistent, and careful consideration of any belief or supposed form of knowledge in light of the grounds that support it, and the further conclusions to which it tends". In other words, it is referred to as the belief that is intentionally required to support the belief examined. Therefore, reflective thinking is not sequence but successive and will lead to whether acceptance or rejection of the new thought (Dewey 1997). While direct observation is the main source of thought, what goes beyond that, is considered as a restriction for thinking.

Dewey had identified elements of reflective thinking as state of perplexity, hesitation, and doubt .also known as uncertainty, and the act of search or investigation to bring further facts to support or reject the suggested belief. According to Korkmaz (2016), John Dewey's work led to understanding the problem solving concept, as one of the most complex mental skills (Gagne

1985). Awareness of the problem, collecting information, understanding the cause of the problems and identifying possible solutions are basic steps for problem solving as indicated by Mayer (1998).

It is not easy to define what an individual feels about thinking and thought (Dewey, 1910). According to him the thinking skills play a high important role in the development especially in schools and educational systems, he mentioned that “no one doubts, theoretically, the importance of fostering in school good habits of thinking” (Dewey 1916, p.159).

Philosophies of John Dewey are of great importance in the development of education policies and democracies in the schools, which enable to improve the thinking skills of individuals. He also suggested, “Thinking is the method of intelligent learning, of learning that employs and rewards mind”. Thus, “thinking originates in situations where the course of thinking is an actual part of the course of events and is designed to influence the result. The object of thinking is to help reach a conclusion, to project a possible termination on the basis of what is already given” (Dewey 1916, p.154). In his book, he claims that thinking is a process of investigating as one thinks in a doubtful situation, it initiates inquiry, which is the basis of research., In this regard, every research is unique as it consists of an intriguing idea that could be carried on in future (Dewey 1910).

Throughout his career, Dewey focused on the outline of the process of inquiry. He proposed that it was the only complete way to recognize the process of thinking and how a person attains the knowledge even when it is the result of a scientific study. May it be the commonsense knowledge we obtained on day to day basis or may it be the scientific sophisticated studies one acquires from detailed research and analysis (Güçlü 2014).

This argument conforms the theoretical foundation that is necessary, particularly, to understand how students employ problem-solving skills in their computer programming lessons.

2.1.3 Supporting Theories

Other than cognitive and learning theories, there are three more theories that could be linked to the processes of the brain and the cognitive abilities that underlie learning computer programming including: Executive Function theory (EF), Fuzzy-Trace theory (FTT), and the Cognitive Load theory (CLT). The following sub sections demonstrate these theories and how they contribute to understanding the research problem and the interpretation of the results.

2.1.3.1 Executive Function theory (EF)

Zelazo (2015) addressed the Executive Function (EF) theory as a set of self-regulatory skills; cognitive flexibility, working memory, and inhibitory control that are essential for goal-directed modulation of thought, emotion, and action needed for problem solving. These are the self-management skills, which distinguish children from adults (Stadskleiv et al. 2014).

The development of executive functioning occurs a span of time in few children that could take as long as mid-twenties. Although research has shown that, this ability develops in school going children. EF is a cognitive governor accountable for making adaptive changes in social and physical environments. Executive functioning is based on several subsets of skills, but it can be analyzed within three basic categories. To begin with, it can be witnessed in working memory. It is a skill that could be tapped when, for example, a person tries to say the alphabets backwards. It creates an ability to keep and mentally manipulate information. This skill helps a child to memorize rules of a game or take accurate notes in the classroom. The onset of working memory starts from the formal schooling system that is from 5 to 8 years of age. Executive function also involves impulse control, or sometimes called inhibitory control, that is the ability to inhibit actions that does not support achieving the goal. That is to rectify the immediate gratification response. To make a child to sit and focus in the classroom at the school

time whereas they want to stay home and play a video game. Rapid gain of impulse control occurs during elementary school. The third category of executive functioning is the Cognitive Flexibility. It generates the child’s ability to formulate plans, to make them competent in complex problem-solving and to flexibly adapt to change of circumstances. Rapid growth in this area occurs in older elementary school and the bursts of thinking skills emerges in high school. Thoughts like learning another language, solving calculus problems, reading complex literature, and to creatively planning for their future ahead, all require complex thinking skills.

Marcovitch et al. (2008) cited in Zelazo (2008) stated that children with more EF skills learn more and are abler to adapt in a reflective form of learning. Yet, the Piagian legacy is still identifiable in Zelazo’s theory (Carey, Zaitchik, & Bascandziev 2015). Figure 2.4 below demonstrates how effective learning happens as a result of the iterative reprocessing of the neurocognitive skills, defined as EF skills (Barrouillet 2015).

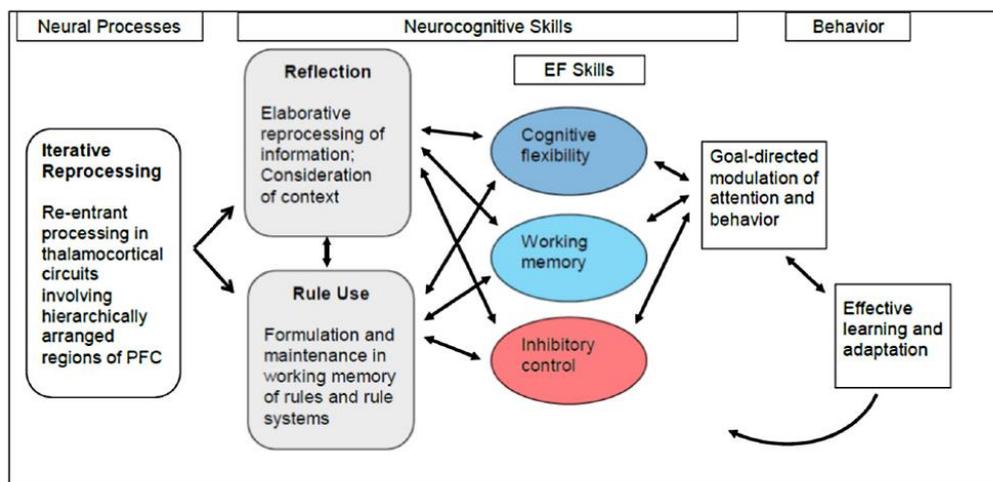


Figure 2.4 Iterative reprocessing resulting in effective learning. Adapted from Zelazo (2015)

According to these examples, few of the abilities acquired by executive functioning are listed below and are exerted from the findings of different studies (Kalkut, 2010).

1. Emotional Control: The ability to modify and control the emotional responses of a person by reason with rational thinking and logical explanations.
2. Inhibition: The idea to hinder the immediate gratification of feelings and desires and rationally acting upon the situation. According to the circumstances, modify the behavior appropriate to the time and place by stopping thoughts and actions.
3. Initiation: The willingness to begin any activity or task freely and independently. It is also to initiate new ideas and responses to perform creative and problem-solving strategies.
4. Shift: The ability to move from one situation to another, and to be able to change topic and to shift from one thought to another. Multi-tasking is one of the examples on this ability.
5. Planning and Organizing: The executive function allows a brain to manage future and current tasks by organizing and planning for the upcoming situations.
6. Working Memory: The increased capacity to bear information in one's mind to fulfil a certain task. In other words, it is one's ability to store information and reuse it when required.
7. Self-Monitoring: The ability to justify one's own deeds and actions and modify them with the demand of the environment. It enhances the will to grow in the competitive world by acquiring new skills.
8. Organization of Materials: The skill to manage and impose order to play, work, and storage of spaces in the best possible manner.

These skills cannot completely explain the function of mind through executive functioning, as they are very diverse and overlapping. Yet, utilizing these skills at the same time and provide immediate problem-solving responses is the prove of executive function in a growing child. This utilization of skills is aligned with what the researcher would like to observe during the computer programming lessons. Particularly when they employ these skills for problem solving.

2.1.3.2 Fuzzy-Trace Theory (FTT)

While former theories had demonstrated limited association between memory and reasoning, the Fuzzy-Trace Theory (FTT) had linked the constructivist and the information-processing approaches in a dual-processing approach. The FTT was first addressed by Brainerd and Reyna in 2015 according to Barrouillet (2015). It is the closest to Piaget's among all current theories. The strength of this theory underlies in its deeper meaning and significance of verbatim and gist traces of events. In addition to its account for cognitive processes at all developmental stages.

This contemporary approach integrates the concepts of memory, meaning, and development and merges the aspects of memory and learning through sensible representation of the knowledge that must be acquired in the long-term memory. The gist is the fuzzy yet advanced information that triggers intuition and enhances the memory based on representation. It also includes the other dimension of FTT that is the collection of memory through verbatim representation of information, which describes the selective knowledge (Reyna & Brainerd, 2004).

In simpler terms, the idea is to represent two types of memory of human mind that are the 'Gist' and 'Verbatim'. The knowledge and information are stored in mind in these two forms. Firstly, the memory verbatim is the accurate and detailed representation of the knowledge learned and experienced in past. While gist memories are based on conceptualization. In most cases, a human can easily remember the gist representation of information rather than the verbatim. To gain the verbatim knowledge, a person can use tactics such as mnemonics or rhyming (Reyna & Brainerd, 2004).

Verbatim representation of the meaningful stimulus encoded could be described as the depiction of the exact words, images or numbers that are included in the stimulus. The gist

representation on the other hand, could be explained by acquiring the meaning of the stimulus in capturing its essence but not the exact words. These two forms of information are initially processed simultaneously in the working memory, for example, a student thinks and hears about the information provided in a lesson. After the initial process, the information of the textbook stimulus is transmitted to the long-term memory (Blalock & Reyna, 2016). Unfortunately, the verbatim representations can only be transferred into the long-term memory through a lot of repetition and practice and it rapidly becomes inaccessible generally, whereas gist representation can easily be transferred in to the long-term memory after the initial process.

From many experiments and researches, evidences are exerted that support that individuals encode multiple representation of a single stimulus that varies in the levels of specificity (Blalock & Reyna 2016). Generally, individuals code the information of the stimulus in both ordinal and categorical representations of the gist. The formation of gist representation would be biased in the encoding based on the person's individual personality. Another part of the theory is that the information might get encoded wrongly and the person might fail to understand the provided information of the stimulus. That would result in an inaccurate gist representation of the stimulus in his mind. Moreover, an individual can also misremember the information encoded as the verbatim representation. Yet it is less problematic as the person remembers the essential meaning of the gist rather than none (Blalock & Reyna, 2016).

The FTT is widely accepted in the development of educational programs for the assessment of adolescents. It is a dual process, comprehensive model of memory, judgment, decision making and reasoning. It is beneficial to assess a person's decision making skills involving reactions to risks (Brainerd, Reyna, & Ceci 2008).

Profound understanding of the FTT will help in understanding and interpreting students' performance in the CT-Cognitive Abilities Measure. Particularly when the working memory constructs are analyzed.

2.1.3.3 Cognitive Load Theory (CLT)

Plass, Moreno, and Brünken (2010) pointed out that the objective of the Cognitive Load Theory (CLT) as “to predict the learning outcomes by taking into consideration the capabilities and the limitations of the human cognitive architecture”. Paas, Renkl, and Sweller (2003) stated that the CLT was first originated in 1980s and “is based on a number of widely accepted theories about how human brains process and store information (Gerjets, Scheiter & Cierniak 2009, p. 44)”. After which the theory went through considerable improvements by researchers around the world. The theory can be applied to a wide range of learning contexts because it links the design of the instructional material to how learners process information (Kirschner 2002).

CLT in simple terms, defines a mind process of deliberately working on one particular aspect out of many going through our minds. This theory is particularly built about learning that the brain can perform so many tasks at the same time, yet we chose to intentionally select activities to perform in order of preference.

The CLT suggests that the memory of a human can be divided into working memory, that is somewhat same as the short term memory, and long-term memory. In the long-term memory, the information is stored in the form of schemas, whereas in working memory, the methods is performed effectively by cognitive load by processing new information and converting it into effective learning.

The theory also suggests, due to the limitation of short-term memory, that the experience of learning must be structured in a way to decrease the burden on working memory to promote the capacities of schemas. Both processes cannot occur simultaneously, so that is why information given for any cognitive activity must be organized in a way that the working memory is utilized first and then the long-term memory (Kirschner, Kirschner, Sweller, Kirschner, & Zambrano, 2018).

Tapping both memories at the same time is considered a higher ordered thinking skill. The provider should not be just focused upon what is being learnt and its sequence, rather to gauge at the nature of what is being learnt. The theory is developed to provide strategies, to assist in acquiring the information and enhance the learning process to optimize intellectual performance. According to this theory, the capacity of working memory is low. It deals with auditory, verbal and visual stimuli, and relies on partial independent subcomponents for information. The long-term memory effectively works on schemas to access the memory for information. These functions and structures of a human cognitive mind use various instructions and procedures. Thus, the theory assumes that the load on working memory should be reduced and the construction of schema should be encouraged.

Educators usually refer to the CLT when students face a problem in acquiring the course objectives due to its complexity. Understanding the CLT facilitates explaining the situation and provides a structure when learning materials are designed. This theory is derived from the extensively accepted model of human information processing (Phillips, Shiffrin, & Atkinson, 1967). The model describes the process of the three memories that are: the sensory memory, the working memory and the long-term memory. A lot of theories are based on this model, but this theory of information processing remains at the core of all the other memories. Each and every day, the human mind is bombarded with sensory interaction, which invokes the sensory

memory. Then, sensory memory filters out most of that information and saves some of the main source of it that is seemed important till it can pass it on the working memory e.g. when a person is playing a game of tennis, he mainly focuses on the ball to hit at it and return it to the other player. He excludes all the other information reaching to him at same moment as the audience standing on the corner, the birds chirping, the children playing nearby. All this information is filtered and the only information reaching to the working memory through sensory memory is the angle and direction of the ball its coming from to hit it back (Pierce, 2008).

From the sensory memory, the information is transmitted to the working memory where it is either kept or discarded. The capacity of the working memory is described by researchers as low as it can only keep between 5 to 9 chunks of information at a single time. When the working memory categorize that knowledge acquired, it processes the information and then transfers it to long term memory to be developed as a schema. When the information is stored in long term memory, it can be revisit and utilized when needed but all the other sensory information, which are not stored, are lost. Schemas could be of concepts that to know the differences between cat, dog or any other animal, or it could be a behavioral schema for acting out on a situation such as how to play a game or how to behave in certain situations. The more an individual utilizes a schema, the more he gets used to it and the behavior becomes effortless, which in turn, known as automation (Unal & Afsarmanesh 2010).

The amount of information a working memory can hold is known as ‘Cognitive Load’. Researchers suggested that the amount of burden to put on a working memory affects the learning. So the educator should avoid overloading the capacity of the working memory by ignore and cancel irrelevant activities/details (Young & Sewell, 2015).

Thoughtful consideration of the Cognitive Load theory will help the researcher interpret students' interactions and cognitive behaviors inside the classroom as well as lead to better understanding of the CT Cognitive Abilities Measure results' analyses.

In summary, there are specific aspects of each of the above mentioned theories that support the aim of this research and help the researcher attend to the research questions. The key concepts of each theory, that are relevant to the context of this research, are summarized in table 2.2.

| Theory | Key Concepts |
|--|---|
| Piaget theory (Slavin 2014) | <ul style="list-style-type: none"> • Deductive Reasoning Skills • Abstraction Skills |
| Cattell-Horn-Carroll theory (Flanagan & Dixon 2014) | <ul style="list-style-type: none"> • Fluid Intelligence Reasoning • Short-Term Memory • Visual Processing |
| Vygotsky theory (Slavin 2014) | <ul style="list-style-type: none"> • Experience • Social Interaction • Cooperative Learning |
| Dewey theory (Dewey, 1910) | <ul style="list-style-type: none"> • Problem Solving • Reflective Thinking |
| Executive Function theory (Zelazo 2015) | <ul style="list-style-type: none"> • Working Memory (Short-Term Memory) • Cognitive Flexibility • Inhibitory Control |
| Fuzzy Trace theory (Barrouillet 2015) | <ul style="list-style-type: none"> • Verbatim • Gist • Memory |
| Cognitive Load Theory (Plass, Moreno & Brünken 2010) | <ul style="list-style-type: none"> • Working Memory (Short-Term Memory) |

Table 2.2 Theories Key Concepts Utilized in the Research

2.2 Conceptual Framework

The conceptual framework is stemmed from the fact that brain processes are linked with cognitive and noncognitive functions. Noncognitive functions may include motivation and emotions. Yet, motivation by itself includes cognitive components e.g. self-efficacy that is defined also as a cognitive belief (Schunk 2012). Figure 2.5 illustrates the conceptual framework that incorporates computational thinking as a major source of developing computer programming knowledge and skills. The learning process cannot be explained without proper

understanding of cognitive and noncognitive functions of neuroscience. Cognitive functions are linked to the cognitive abilities while noncognitive functions are linked to students' perceptions. Additionally, the conceptual framework shows how the theoretical framework leads to the construction of the conceptual framework and how the research problem can be addressed.

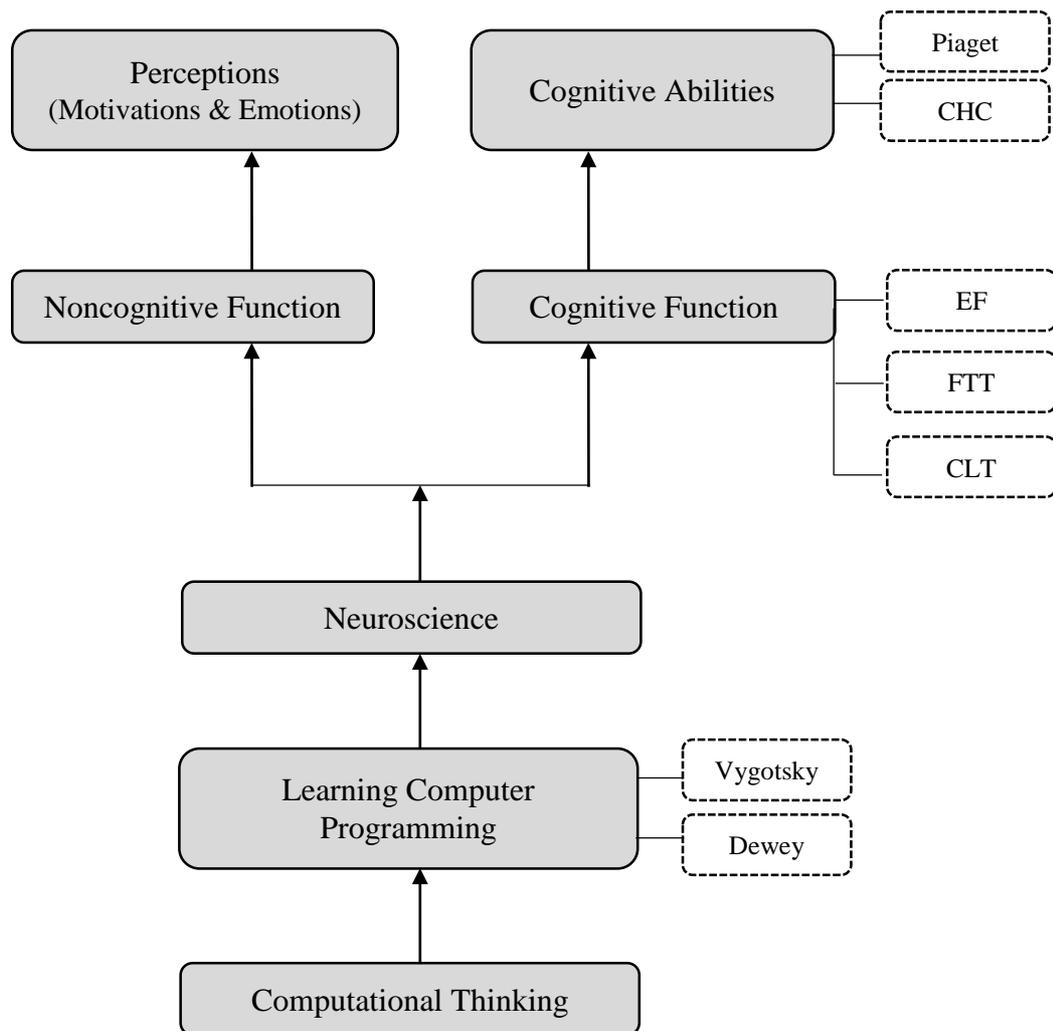


Figure 2.5 Conceptual Framework with Theories

The study of algorithms including their formal and mathematical properties, hardware realization, linguistic realizations, applications, as well as their impact on the society is referred to as CS (Seehorn 2011, Google & Gallup, 2015, Schneider & Gersting 2019, Wilson et al. 2010). As mentioned earlier, CT is a broader framework is defined as the thinking process to

produce solutions for problems that can be automated by information processing agents (Cuny, Snyder, and Wing 2010). It includes the utilization of complex cognitive skills problem solving skills are major ones. This definition is strongly related to computer programming. Denning (1989) defined computer programming as the process of transferring human instructions into command that can be run and processed by a computer in a sequence. Writing a computer program requires a process in the human's brain that utilizes both cognitive and noncognitive functions.

2.3 Literature Review

According to Osanloo and Grant (2016), the literature review is enhanced by the theoretical framework. It does not only enable researchers to locate others' work, but it also helps them evaluate the relevance of the literature to the current research questions (Fraenkel & Wallen 2012). Therefore, in order to address the research questions, an in depth study of the key literature related to cognition and other aspects relevant to the context of this research are presented in subsections including: cognitive development, cognitive development in neuroscience, cognitive development assessment, cognitive assessment tools, cognitive styles, higher order thinking skills, and computational thinking.

2.3.1 Cognitive Development

Cognition could be referred to as the process of mind to gain knowledge and comprehend it. In simpler words, it could be defined as thinking, knowing, judging, problem solving and remembering. These processes are called cognitive processing (Scanlon, O'Shea, O'Caoimh, & Timmons 2014). Cognitive psychology is a scientific field of study to describe mental processes such as memory sensation, perception, attention, language, reasoning, problem solving, language and linguistic, concept formation, consciousness and thinking. The mind is

termed as mental processor, which performs all these tasks. The school of thought, cognitive psychology, started in mid-1900 during the cognitive revolution (Lieberman, 2012). “The term of cognitive psychology did not emerge until 1967”. It has much further roots closely linked with experimental psychology.

The core skills of the brain, which control the entire cognitive processes of a human, are known as cognitive skills (Ghazi, Khan, Shahzada, & Ullah, 2014). These are the skills which enable the brain to think, learn, read, remember, pay attention, analyze and reason. These skills work simultaneously to encode the information perceived from sensory stimulus and transfer it to the knowledge bank stored in long term memory (Dreer, et al. 2009).

Slavin (2012) defined development as “how people grow, adapt, and change over the course of their lifetime”. Four development types were studied by researchers: personality development, socio-emotional development, cognitive development and language development. The focus of this research will be limited to the cognitive development aspects. Well-known development theories clearly define the developmental stages. (Lourenço 2016). Piaget’s work had relied on two thrusts: constructivism and stage theory while both are still relevant to the current studies of cognitive development (Carey, Zaitchik, and Bascandziev 2015). According to Dodonova and Dodonovaa (2011) Piaget described the cognitive development based on the biological concepts of assimilation and accommodation. Piaget’s theory was critically reviewed by the neo-Piagetians. The main aim of the neo-Piagetian theories was to maintain the strength of the original theory and disregard its limitations and pitfalls (Lourenço 2016). Lourenço (2016) argued for a strong conception of development and the “non-received’ view of Piaget’s theory. An argument resulted in the identification of five stages of development: a) hierarchy b) integration, c) consolidation, d) structuration, and e) equilibration. It is the development of thought processes, i.e. the growth of mind in the different

stages of a person life span. Recent studies showed that, from birth, the child is aware of his surroundings and is curious about the things going around him by gathering, sorting and processing information from the environment around him. A child shows interest in exploration and begins his activities to learn. By collecting the data from around him, the child develops perception and thinking skills. Therefore, cognitive development refers to how an individual thinks, perceives and gains understanding of the world through the collaboration of genes and learned factors (Zhang 2002).

Cognitive development in adolescence means emergence of the child's ability to reason and think. The time frame of this growth occurs differently from age 6 to 12 and from 12 to 18. 12 to 18 can be termed as late adolescence. In this period of time, children grow in the way they think. From logical operations, they move to concrete thinking where they induce logic in cognition. Every child grows differently in his own capacity and time. Even though logical thinking emerges at this age, it still takes time to sort emotional issues. Facts and possibilities might impact decision making and actions in both negative and positive manners.

2.3.2 Cognitive Development in Neuroscience

Neuroscience refers to the scientific study of the nervous system (Sanders 2013). It is a subfield of Biology that is integrated with, physiology, molecular biology, cytology, developmental biology, anatomy, and psychology to clearly acquire the understanding of the emergences and fundamental properties of neurons and neural circuits (Purves 2001). In other words, it is the area of study where biology meets psychology to define and understand the psychological, physical and neurological health conditions. The technological advancements and tools used to analyze the brain structure such as imaging and computer simulations give expert medical researchers an insight of the human brain physical anatomy and the relationship it has with the whole mind and body.

According to the neurobiologist, changes in the brain are the core reason for learning. It has been founded that moderate levels of stress are beneficial for learning, where extreme and mild levels of stress can turn out to be detrimental and disadvantageous. Other factors that also impact the quality of learning include: human's diet, adequate sleep, exercise and nutrition. All these factors can develop an automated vigorous learning brain. Multiple neural connections stimulate the process of active learning and promotes memory.

Cognitive development is related to brain development which is referred to as neuro-cognition. It is assumed by the developmental scientists, that there is a considerable amount of relation between brain and behavior (Kirschner, Kirschner, Sweller, Kirschner, & Zambrano 2018). Though researches are still being conducted to establish specific developmental connections. However, the global correlation does exist such as, throughout infancy, myelination occurs in a progressive manner (Peter 1979). During that period of life, the infant becomes progressively intelligent. Yet such proclamation does not scientifically link the relationship between behavioral and brain development. Only correlation has been distinguished in terms of behavior related to age (Goldman-Rakic & Preuss 1987).

The development of brain is a process that includes a lot of edifices which are built-up and torn down over time. The brain develops strong connections and wirings that are valuable (Taghert & Lichtman 1986). Yet the brain is the only part of the body that remains intact after the loss of unusual connections and cells which were part of the nervous system yet inadequate in one way or another.

The Brain is made up of small units called neurons. The whole mechanism of a human brain is based on these little organs i.e. neurons. These are the behaving cells that contemplate each and every task performed by a human in his daily life such as speaking, listening, walking, and thinking. These neurons reside in the human brain and activate the mind and are the essential

factor of being able to perform the task required to live a daily human life. They compete every second with each other to survive in the human brain (Purves 2001). The competition begins before birth where these neurons compete for trophic factors and growth factors and those neurons, which are unable to get a hold of these factors, become unable to survive. No cells die after this stage though they can change or lose the connection developed by these neurons at earlier stages. These cells start to make many new connections with the targeted cells. Consecutively, these cells integrate with each other at a high energy level. A lot of nerve cells merge with the target cells. The target cell cannot converge input from all the neurons and allow them boot off with the best ones and get rid of the others. This phase of pruning creates experience (Cunha & Heckman 2008). The identity of a person is formulated with the basis of the neuron targeted cells.

The genes of a human do not form the language one speaks, it develops with the experiences one faces at young age. Similarly, with every new technology, our brain is formed and molds our mind to use that new technology and then enhance the process of learning through plasticity (Phillips, Shiffrin, & Atkinson 1967). That is why “the old generation was good at writing while the new generation is good at typing” because the brains’ neurons are mold in such format. That is how the entire brain process shapes human’s thinking (Purves 2001).

The impact of neuroscience in childhood education was explored by many theorists and through the medium of neurobiology. The rapid development of synaptogenesis and synaptic pruning occurs in the early childhood (Bruer 2002). In addition to that, there are critical stages in the lifespan of children that requires normal experiences for the development of normal personality. Studies have shown, in few particular behavioral researches, that nurturing animals in complex environment had impact on their brain structure that can be unveiled using technological equipment. That indicated high resting metabolic rate of brain within the period

of peak synaptic density, which enables children to learn at an easy pace, and hardwired these experiences to brain for lifetime (Purves 2001). The more synapses utilized at that time of life, the more retention of knowledge will be saved in the brain in adulthood. Education and parenting are the synaptic conservation, which saves the neuronal connections, and maximizes intelligence to maintain better brains (Goldman-Rakic & Preuss 1987).

According to new researchers, it is suggested that the academic performance of adolescences can be interpreted through understanding of the various neuroscience aspects. The processes like naming, function of language and sustained attention are the cognitive processes, which links with the willingness of the adolescent to acquire the most knowledge at school (Komarraju, Ramsey, & Rinella 2013). Breuer (2002) argues in his study that “cognitive neuroscience is the brain-based discipline that is most likely to generate educationally relevant insights. Cognitive neuroscience presupposes cognitive psychology and, to date, rarely constrains existing cognitive models” (Bruer 2002). This indicates that cognitive models of students can be identified and refined by applying the studies of neuroscience. Implications of neuroscience in the field of education are expanding and currently progressing the learning process of students. An identification of the direct impact of neuroscience on education is still obscure. Hence, bridging the gap and creating such direct relationship seems to be crucial (Angilia 2017).

2.3.3 Cognitive Development Assessment

The frontal lobe of the brain is known to keep on developing in the period of late adolescence, despite the other cortical regions of the brain that reach maturation at the earlier stage of life. The cortical regions reach maturation at different rates (Brainerd, Reyna, & Ceci 2008). Therefore, to examine the developmental trends in cognitive performance of adolescence, various neuropsychological tests are performed which are rather differentially sensitive to the

functioning of particularly cortical regions (Cunha & Heckman 2008). According to a study performed on young adults who have reached pubertal, pre-pubertal and post-pubertal stages of their life, suggested that the task associated with the pre-frontal cortex and the frontal lobe of the brain tends to improve at the maturational stage rather than the task linked with parietal lobe functioning (Sanders 2013).

Cognitive Assessment refers to an individual capacity to collect data, process information, and apply it to resolve a given issue (Backhaus & Liff 2007). Few of the tools are “Kaufman Assessment Battery for Children, Second Edition (KABC-II) and the Taos Pueblo Indian Children of New Mexico”, “General Practitioner Assessment of Cognition (GPGOG)”, “WPPSI-IV”, “Bayley-III child development assessment”, “Bayley-III child development assessment” (Bie, Wilhelm, & Meij 2015). There are many other cognitive assessment tools to evaluate the thinking and knowledge patterns of an individual (Komarraju, Ramsey, & Rinella 2013). For example, WISC and WAIS are IQ tests used to measure the intellectual level of the adolescents. Different assessment tools are used to measure different cognitive abilities (Barbey, Colom, Paul, Chau, Solomon, & Grafman 2014). Tools are utilized on a population for evaluation of a particular aspect of cognition. These tools are used to recognize and identify the intelligent quotient of adolescents. “Wechsler IQ Test, Wechsler Adult Intelligence Scale WAIS, WISC, WPPSI” are the measures to determine the IQ level of young adults. These tests are valid and reliable. They are used in many researches to examine the general intelligence of individuals compared to a population (Calaguas, 2012).

2.3.4 Cognitive Assessment Tools

To diagnose specific conditions, many cognitive assessment tools have been developed that are designed to assess the current cognitive abilities amongst a population (Bie, Wilhelm, & Meij 2015). However, the methods and procedures to develop a tool for assessment requires years

of research, collection of data, testing on numerous patterns, validity and reliability checks, and generalization need to be statistically on point (Barbey, Colom, Paul, Chau, Solomon, & Grafman 2014). Firstly, the developer need to have an objective in mind to be motivated toward the production of the assessment tool, then the initial framework is designed. Test prototypes are developed and then usability of the tool is evaluated keeping in mind the validity and reliability (Başol & Gencel 2013). The tool must provide accurate and authentic evidence that the test meets the requirements of the product been developed. It needs to aim to justify the construct of the test. Statistical valid sampling is considered that would question the error and confidence level of the test (Schou, Høstrup, Lyngsø, Larsen, & Poulsen 2012).

On another hand, some standardized exams can be used to assess the cognitive development of children. The main purpose of cognitive standardized tests is to measure the cognitive abilities amongst students that required the assessment of academic and non-academic tasks (Bie, Wilhelm, & Meij 2015). The scores of these academic tasks determine the outcomes of what the student's grades would be, to record the academic tracks and the placement of the students in colleges (Calaguas 2012). Among many, the Reasoning Scholastic Aptitude Test (SAT Reasoning) is the renowned test to assess the capabilities of the students. These tests include a considerable number of elements to assess the memory in addition to targeted cognitive abilities.

2.3.5 Cognitive Styles

Researchers referred to the terms of 'learning styles' and 'cognitive styles' interchangeably (Cassidy 2004). Kozhevnikov (2007) stated that learning styles are used to explain how individual students learn. Empirical research confirmed that better achievement can be produced if instructions were designed based on the students' learning styles (Pallapu 2007, Sternberg, Grigorenko & Zhang 2008, Bernard et al. 2017). Students' understanding of their

own learning styles would allow them acquire better self-regulated learning. Additionally, teachers' awareness of their students' learning styles can help them provide students with better and more efficient academic intervention (Bernard et al. 2017). Umar and Hui (2012) stated that students' performance in coding classes can be enhanced by understanding their learning styles.

Learning styles were related to cognitive load in a study that was conducted by Abdul-Rahman and Du Boulay in 2014. They concluded that learning styles may have an effect on the cognitive load of an individual. On the other hand, Coffield et al. (2004) stated that learning styles theory failed to explain students' achievement. A claim that was supported by An and Carr (2017). Therefore, such analysis was insufficient to inform this research.

Researchers use learning styles questionnaires to identify students' learning styles. Bernard et al. (2017) pointed out that those questionnaires have remarkable downsides due to students' misconceptions or misinterpretation of one or more of the questionnaire elements. Hence, automatic approaches were used to analyze their behavior in a particular learning environment (Latham et al. 2012, Bernard et al. 2017). Consequently, Bernard et al. (2017) have investigated an automatic learning styles' identification systems that depend on the following computational intelligence algorithms:

- artificial neural network,
- genetic algorithm,
- ant colony system
- particle swarm optimization”

The results of their investigation revealed that the artificial neural network algorithm had achieved the highest precision with 80.7%.

Many researchers have studied learning theories, styles, and models. Thompson (2012) and Balakrishnan and Lay (2016) had categorized learning theories into: behaviorism, cognitivism, humanism, and constructivism. While behaviorism is characterized by the teacher-centered instructional design, cognitivism stresses on students’ engagement in a student-centered and active learning setting (Thurlings et al. 2013). Humanism takes the form of cognitivism with further emphasis on social and critical thinking skills according to Khatib et al. (2013). Whereas constructivism supports self-learning and provides students with tools to acquire further critical thinking and problem-solving skills (Balakrishnan & Lay 2016). Balakrishnan and Lay (2016) pointed out three learning styles’ models as demonstrated in figure 2.6.

- The Myers–Briggs Type Indicator (MBTI)
- Kolb’s Learning Style Inventory (LSI)
- Felder–Silverman Learning Style Dimensions

| The Myers–Briggs Type Indicator (MBTI) (Montgomery and Groat 1998) | Kolb’s Learning Style Inventory (LSI) (Kolb and Kolb 2005) | Felder–Silverman Learning Style (Soloman and Felder 2004) |
|---|--|---|
| <ul style="list-style-type: none"> •Orientation •Perception •Decision Making •Attitude to Outside World | <ul style="list-style-type: none"> •Divergers •Assimilators •Convergers •Accommodators | <ul style="list-style-type: none"> •Perception •Input •Organization •Processing •Understanding |

Figure 2.6 Dimensions of the Learning Styles’ Models

Learning styles vary amongst the children. The styles are described in three dimensions: Visual, Auditory, Kinesthetic and are used, the most, in educational settings. These three dimensions are used to identify the most appropriate teaching style to maximize the learning

process outcomes (Roderique-Davies 2009). Bandler and Grinder (1981), in their research in the subfield of neuro-linguistic programming, pointed out the characteristics of learners as follows:

1. Students with the visual learning style will intently look at the teacher's face. As the gaze of an admirer looking at a painting or a reader looking at the book etc. They would mostly be well-behaved and require performing everything in order. They would aim to organize things in order by the list. By memorizing the text written, they would recall it in exact way it was set out in the book.
2. Kinesthetic students would focus on the activities going around them. The best way to teach them is to keep them active and engage them in different kind of activities. They usually get to restless if asked to sit at one place for a long period of time. As a memory aid, they utilize movements.
3. The students with Auditory learning style would like to use the verbal instruction as the means to gain information and learn out of them. They tend to be eager to get engaged in verbal discussions, dialogues and debates. The solution of their problems can be attained by talking to them. They utilize rhymes, sounds and mnemonics as the memory aid.

Currently, teachers are widely interested in applying the neuro-scientific research findings in their teaching strategies. These interests are rapidly spreading which cause a substantial change in the development of teaching in the education sector (Sutliff & Baldwin 2001). However, in the development of such structures, teachers also utilize some theories, which do seem to have valid evidences and are based on assumptions. Learning style are part of such theories.

There are multiple issues with addressing the learning styles, including no coherent framework for the theories as well as the preferred learning styles model. Researchers found more than 70

identifiable learning styles and models including, but not limited to, visualizer's vs verbalizers, Left brain vs Right Brain, Holistic vs Serialist, and many more. Moreover, identifying the person's fixed learning style may hinder his motivation to learn and adapt to the different learning environments and settings (Evans & Sadler-Smith 2006).

On another hand, cognitive styles were referred to as the way an individual processes information. Other researchers had also indicated that it is the individuals' tendency to act in a certain manner. It is that personality dimension that determines a person belief, attitudes, social interaction and values (Cunha & Heckman 2008). Zhang (2002) pointed out that a cognitive style is defined as the typical thinking mode of a person, which enables him to remember and perform problem solving tasks. Moreover, these styles are the bipolar dimensions, which consist of the unipolar abilities. The more abilities, the more beneficial.

Over the years, cognitive styles have been studied and identified. Field dependence and field independence are the most renowned styles (Thakur 2013). Field independent people approach the environment in an analytical way. They are able to distinguish discrete figures from their background in contrast of the field dependent person who seeks the knowledge from experience in undifferentiated way. Moreover, a field dependent person has high command over social orientation rather than the field independent person (Backhaus & Liff 2007). Many studies have found the link between the cognitive learning and cognitive style. It is suggested that the field independent person is less influenced by social reinforcement. And is able to learn more effectively under the circumstances of intrinsic motivation. For example, self-studies. There are other cognitive styles too that includes:

1. Scanning style that defines the span of awareness and the intensity and extent of attention. That may or may not conclude in variation in the gaudiness of experience.

2. Sharpening versus leveling style, which depicts the tendency to integrate event that are similar. And defines the variations in remembering the pattern with distinct memory.
3. Impulsivity versus reflection in this style the responses are made by the alternative formulation of hypotheses by an individual with consistence in the adequacy and speed.
4. Lastly, the conceptual differentiation style determines, in terms of separate dimension or concepts, the differences in the propensity to organize similarities of a stimulus.

In the education field, cognitive styles and learning styles play important role. As mentioned earlier, these two styles can be utilized interchangeably. The methods to teach students in a classroom are devised by merging the two concepts (Sadeghi, Kasim, Tan, & Abdullah 2012). Cognitive and Learning styles determine the process of how a teacher should direct the student to learn and acquire knowledge. Moreover, a teacher can predict the instructional strategies for the given learning tasks.

Responding to psychological and physical stimulus, an individual cognitive style can be measured upon resulting both internal and external features (Abdi & Abdi 2012). The structure of internal features relies upon the constant thoughts and content of experience residing in the mind of a person. Whereas the structure of the external feature determines the flow of logic that is based on the outward expression of thought, writings, arrangement of symbols, drawing, usage of language and the connection between these skills (Bie, Wilhelm, & Meij 2015). In the exposure of teaching and learning the cognitive style, tend to impact the circumstances more than usual. It influences the decision making and the choices to be made at the time of learning (Thakur 2013).

Research provides the basis of different cognitive styles amongst the students, which leads them towards different outcomes (Mundra 2014). It can enhance the behavioral strategies and

thought of both the teachers and learners. A match between the teachers' strategies and students' cognitive styles can lead to achieving better outcomes for both of them.

Due to the shortage of reasonable assessment tools to identify the cognitive styles, researchers and practitioners developed a tool named Cognitive Style Index (CSI) (Sadler-Smith, Spicer, & Tsang 2000). It is a valid and reliable evaluation instrument, which was originally devised to be adapted in the organizational setting and then its suitability to high school students was confirmed by the authors. The instrument has proven test-retest reliability as well as internal consistency. Similarly, construct, concurrent and criterion validity were also evident. It is a psychometric measure, which is built to meet the need of the organizational sector assessment of the employees to assess their cognitive skills. Because of its reliable results, the test is generalized on the population of students as well as the non-managerial employees.

The CSI is a self-reported questionnaire that consists of 38 items. The response of the items can be given only in true, false or in uncertain. Though the scores of them are 2, 0, and 1, respectively. If the total score of the individual reaches near to 76 that identifies the individual to be analytical, whereas if the score of an individual reaches near to zero the individual is identified as intuitive (Sadler-Smith, Spicer, & Tsang 2000). These 2 cognitive styles are distinguished by the help of this tool. The emphasis of intuitive style is on feelings, global perspective and open-endedness, while the emphasis of the analytical style is on, structure, detail, and reasoning. This tool helps to manage monitor and select the valuable cognitive style of people and utilize their potential in placement, team building, career guidance, conflict management, task design, training and mentoring development (Backhaus & Liff 2007).

The CSI has been used in studies conducted by many researchers. In seven separate studies, researchers describe that there is an existing relationship between CSI and Cognitive styles. Learning through reflection and reasoning is positively correlated with the orientation of the

CSI through the analysis dimension. CSI is negatively correlated with the action dimension such as learning from insight that is a result of experience. That was depicted by Mumford and Honey's Learning Style Questionnaire (Duff & Duffy 2002). In another study, it was discovered from the CSI scores of a business students' cohort, that they would support and favor the strategic approaches of learning more, if they are scoring higher in analytical Skills of CSI. This is used with the Entwistle and Tait's Approaches of learning in the relevant study. In a different study, it was founded that the metacognitive awareness was linked with analytic thinking. It was suggested in that same study that the high score in CSI refers to the individual who is teacher-dependent and appreciating collaborative modes of learning.

Programming skills are linked deeply with cognitive styles. To achieve good analytical and computer programming skills an individual cognitive style does matter a lot, as indicated by researchers in several psychological and educational studies (Prince & Felder 2006). Researchers suggested that the programming skills could be easily addressed by the application of the CLT that enables teachers to create and implement a curriculum based on the introductory knowledge of programming to the students (Sleeman, 1986).

Within the field of CS and programming educational research, there is evidence that the individuals' cognitive abilities are strongly correlated to their achievements in computer programming. Personality traits and cognitive styles have been researched as evidences that may explain the variability of understanding programming, as well as acquiring and utilizing the necessary related knowledge. Computer programming is not a single task but made up of many smaller tasks that require cognitive processing. These computer programming tasks are comprised of coding, debugging, designing, representing, and problem solving.

2.3.6 Higher Order Thinking Skills

Thinking skills can be described as the mental activities to utilize and process the information stored in the mind. It also indicates the mental ability to access the knowledge to make connections of the complex situations to determine solutions to different real life problems (Cunha & Heckman 2008). These activities of mind enhance the creation of new ideas from the information already present in the mind. Thinking skills are utilized when an individual creates sense of his personal experiences. Through that, he gets able to organize information, make decisions, set plans, ask questions, and solve problems (Abdi & Abdi 2012).

Among the many models of thinking, Debono and Lipman's models are mostly utilized in the education sector (Kivunja 2015). Debono has created the concept of the Six Thinking Hats, which can be easily applied in school settings. According to him, the idea of the Six Thinking Hats is simple, effective, and can be used to "improve the productivity of people and make them more focused and mindful" (Kivunja 2015). The first hat is white that explains the information known or needed. The yellow hat is the emblem of brightness and optimism. The black hat is used for judgment. The red hat describes feelings. The green hat signifies creativity whereas the blue hat is used to enable the control of the thinking process which makes sure all the hats work accordingly for the growth of knowledge and personality (Proudlove 1998).

Researchers argued about how people acquire knowledge and how the mind works. They indicated that the environment influences our thinking ability and the configuration of the brain physical structure (Ambrosio, Almeida, Macedo, & Franco 2014). The higher order thinking reflects upon the skills of innovation, creativity and complex evaluation (Abdi & Abdi 2012). This type of thinking goes beyond the basic thinking process such as learning, memorizing or observation of thoughts. It is to rationalize between subjective and objective concepts of thinking and to apply deductive approach of thoughts within the cognitive processes. This kind

of thinking is associated with Piaget's formal operation thoughts where one can have abstract thinking (Ghazi, Khan, Shahzada, & Ullah 2014). The meta-components of higher order thinking enhance the person's ability to plan monitor and evaluate. The high ordered mental process contains critical thinking, reflective thinking, and problem solving (Anderson 2005).

2.3.6.1 Critical Thinking Skills

The ability to rationally and clearly think is considered to be essential part of critical thinking (Anderson 2005). Critical thinking has been linked to logical understanding and developing connection with new ideas. It is a way of thinking about a specific thing on a specific time, it is not the knowledge one can memorize and recall it again when needed, it is more of an analysis for a current situation and the provision of an appropriate response to it. It enhances the ability in a person to be independent and reflective (Abdi & Abdi 2012). It promotes the use of reasoning in the thinking pattern of a human and it is all about being a learner who is active and aware about his surroundings (Bie, Wilhelm, & Meij 2015). Additionally, critical thinking enables a person to attain knowledge and utilize information as a passive recipient. Rather than accepting, the information provided by its face value, critical thinker rigorously question assumptions and ideas. They would inquire about the information being correct or not and decide to evaluate the whole picture rather than seeking some of its parts. Despite of the intuition and instinct, a critical thinker would identify and analyze the complete situation for solving a problem (Smith 1970).

Critical thinking and problem solving are strongly related and are defined by the ability to utilize the facts, data, knowledge to solve the problems effectively (Bie, Wilhelm, & Meij 2015). It does not stand for the quickness of the response or an answer rather, it explains the process by which an individual assess and finds a solution of the particular problem (Rodzalan & Saat, 2015). However, a well thought solution for the given problem within the desired time

could be recognized as critical problem-solving skill. It is an established ability of a good critical thinker to draw sensible and realistic solution from the given set of information about the issue. A critical problem solver, has the ability to identify and abstract the useful material from the given problem and disregard the less useful material from the information.

The thinking style of an individual contributes to the critical thinking disposition, in the academic and non-academics program development (Zhang 2002). Many researches have been conducted to provide statistical evidences to prove the impact of cognitive style on the critical thinking especially in academics. Findings suggested that the critical thinking skills are significantly predicated by the identified cognitive thinking styles. The studies related substantial legislative and substantial thinking style to the critical analytical skill. And it was noted that the people who had judicial thinking style were mostly engaged in analytical and evaluative types of tasks. The importance of these studies impacts the education system on many levels. Such as development of curriculum to nonacademic programs, education and assessment, teaching method, and achieving high academic excellence. To develop critical thinking skills, teachers must take thinking skills into full account of application (Abdi & Abdi 2012).

To address the core cognitive skills in regard of critical thinking, the most utilized tool is The California Critical Thinking Skills Test family of measurement tools (Rodzalan & Saat, 2015). It is called the Gold standard of critical thinking test. It assesses the judgments, reflective approaches, and the believes of individuals specially the youth. Measuring this skill would help students to improve their critical thinking skill in terms of problem solving and decision making (Bie, Wilhelm, & Meij 2015).

2.3.6.2 Reflective Thinking Skills

Reflective thinking can be regarded as a part of critical thinking. It is mainly referred to the process of analyses and judgment about an experience (Dewey 1910). It was suggested in his study, that reflective thinking is a persistent, active and careful consideration of supposed form of knowledge and a belief. It provides a ground that sustains and supports that knowledge. In addition to that, it provides further conclusion and the path where the thought is leading. An individual can control his learning by implementing the pattern of reflective thinking in the assessment of his knowledge, the required knowledge to be obtained and the ways to alter the gaps during the learning situations (Abdi & Abdi 2012).

With the changing times the need to develop flexible problem-solving strategies, switch directions, and rethink and to reflect, the information provided is mandatory structure to conclude to a solution. The society is becoming more complex and the flood of knowledge is prompting students to be more proactive in solving problems in their daily lives (Barbey, Colom, Paul, Chau, Solomon, & Grafman 2014). Reflective thinking helps the students in the development of strategies to implement new knowledge in the complicated day to day activities. It assists the learner to utilize higher order thinking skills by making them able to connect and link the previous knowledge with the new lesson and to put forth their own input into attaining that information in their own way of thinking and learning outcomes (Calaguas 2012).

Judgment, communication, observation, and team working are considered to be important aspects in teaching and assessing reflective thinking skills. To measure the skill, cognitive scales are used. One of such scales is “The Reflective Thinking Open-Ended Questionnaire”, that allows the individual to respond to questions by their own understanding and reflecting on their own knowledge toward the queries stated in the questionnaire. The questionnaire helps in

grasping the strengths and weaknesses of the learner and then providing information about the areas of improvement (Başol & Gencel 2013).

2.3.6.3 Problem Solving Skills

It is a process of resolving complex problems and situations and provide ease to the circumstances. Every day a human encounters many issues from very basic to complex. Problem-solving skills enable him to overcome those issues in a strategically manner (Anderson 2005).

Thinking is an activity or skill that can be affected and improved, usually at multiple levels of abstraction. It is an activity that is less contextual than individuals think. Thinking implies an automatic and controlled treatment (Bie, Wilhelm, & Meij 2015). Control from a philosophical aspect is a delicate concept, because if it controls one's processes or draw, their thoughts and share they are considered as such an idea, which will result in an infinite chain (Barbey, Colom, Paul, Chau, Solomon, & Grafman 2014). It can only be part of the process of thinking that in the case of controlling the thought process, we feel responsible, or what model of direction and reason we have, and we reach a higher level of metacognitive awareness, that is, to say Why Can we explain this when we do this because we feel we think in a controlled way? Anyway, there is a difference between the automated treatment and these two levels of treatment (Başol & Gencel 2013). Converted to long-term memory (memory), automatic processing can be activated by the corresponding inputs, which are performed independently of the control of the subject. They do not require attention, so they do not use the short-term storage capacities used by the supervised process (Blalock & Reyna 2016). Control processes can learn from automated processes that are highly adaptable to change, difficult to change, neglect and suppress, but can learn without significant effort (Blalock & Reyna 2016). Automated processes can include the flow of control information to draw attention to itself, which

generates open reactions immediately, identification of the reactive components, and extended attention to irrelevant locations. The controlled processes are controlled and retained by the subject, use temporary memory and are limited by limits. Short-term memory capacity compensated by the benefits of the control process (Ambrosio, Almeida, Macedo, & Franco 2014). These controlled processes are easy to configure, modify and apply in new situations.

Collaborative problem solving is the skill that brings together a group of people to solve a conflict or problem and collectively come up with a solution (Christensen 2002). The Collaborative problem solving model has proven to be an effective approach with children and adolescents. It has enhanced a wide range of emotional, social, and behavioral changes in various settings of schools, families, and foster care agencies, mentoring organizations, therapeutic programs, juvenile detention facilities and all other sectors, which deal to bring about improvement in kids (Zhang 2002).

Reasoning can be defined as the ability to control thinking and consciously rationalized towards the solution of the problem. The solution is sought in always the reverence of reality rather than being imaginative (Samuel 2011). There are types of reasoning in terms of problem solving. Among those comes inductive reasoning which means to construct a generalized principal by acknowledging similar elements and creating a relation among them. Such as all human beings are mortal since everyone dies. On the other hand, deductive reasoning means to analyze an already known fact and draw logical conclusion from it (Christensen 2002). Other form of reasoning may include categorical reasoning that defines the category of thing for example, all pigeons are birds, birds lay eggs hence all pigeon's lays egg. Liner reasoning which states the direct relationship among elements i.e. finding the tallest person in the room. Lastly, conditioned reasoning implies that the thought relies on some specific conditions for example, nights are dark, then days are bright (Cunha & Heckman 2008).

Huitt and Hummel (2003) stated that solving a problem in an innovative and creative way requires the process of creative problem solving. The idea is to develop innovative responses and solutions to complex problems. Creative problem solving is considered to be a process that redefines the issues and problems faced by an individual and assist to come up with a new and creative solution on which the person takes the action (Abdi & Abdi 2012). It opens doors to new ideas and innovative approaches, which makes problem solving fun, collaborative and engaging. Exercising the process of creative problem solving makes the whole experience more positive, which results in adaptation of new ideas. The two kind of thinking that deemed to be essential to the process of creative thinking are Convergent and Divergent thinking (Dewey 1910). Proudlove (1998) confirmed that the process of convergent thinking is about evaluating the options provided to resolve the problem and then making decisions upon the basis of those options. Whereas divergent thinking can be described as the generation of lot of new ideas. Both of the thinking processes are performed by every human in his mind. Though to create and develop innovative ideas, individuals need to separate the convergent thoughts from the divergent ones. To wisely utilize both thinking processes together, brainstorming is used to train the mind to develop divergent thinking to generate new ideas and thoughts and then find a new solution of the problem by evaluating those ideas and choose the best option amongst them to resolve the issue in the most creative manner (Dreer, et al. 2009).

To measure the problem-solving skills in adolescents, various reliable and validated tools can be utilized (Goldman-Rakic & Preuss 1987). Problem solving is a skill that is vital and educable in adolescent (Anderson 2005). For this purpose, studies are being conducted and tools are being developed to enhance the ability to solve problem positively in the youth. The scale “National Longitudinal Study of Adolescent Health - Problem-solving items” measures the problem solving skills in school going children and reports the strategies identified, selected and evaluated by the youth to provide solution of their problems (Barbey, Colom, Paul, Chau,

Solomon, & Grafman 2014). Moreover, tools like “The Social Problem-Solving Inventory-Revised” provides a more in-depth evaluation of the abilities of problem solving. The tools have separate scales for various types of problem solving skills such as generation of alternative solution and positive problem orientation. These tools were specifically developed for the adolescence to apply creative problem solving methods in their daily lives (Omar, et al. 2012).

2.3.7 Computational Thinking Domains

Seymour Papert had first introduced the concept of CT in 1980. A concept that was neglected by researchers and educators until 2006, when Jeannette M. Wing proposed the concept of CT in a different context as a fundamental skill needed by individuals just as reading and writing. CT is considered as an analytical way of thinking that is featured by a set of transferrable skills used to solve problems through the language of computation. According to Korkmaz, Çakir, and Özden (2017), CT incorporates creativity, algorithmic thinking skills, critical thinking skills, problem solving skills, and communication skills. Lye and Koh (2014), in their review of teaching and learning of computational thinking through programming, they identified three dimensions of CT: concepts, practices, and perspectives. Various definitions for Computational Thinking (CT) were presented in the literature. Wing (2006) defined CT as “a fundamental skill for everyone, not just for computer scientists. To reading, writing, and arithmetic, we should add computational thinking to every child’s analytical ability”. CT is also defined as a thinking process that produces solutions for problems that can be automated by information processing agents (Cuny, Snyder, and Wing 2010). Yet, there is not agreed upon definition of CT up to date (Grover & Pea 2013).

Researchers have studied different ways of thinking. According to Robertson (1999) thinking can be either ‘Mundane’ or ‘Effortful’. While ‘Mundane’ thinking is used for solving everyday routine problems, ‘Effortful’ thinking is used for unfamiliar problems. Yet, Computational

Thinking (CT) indicate another perspective of thinking. This sort of thinking enables a human to understand the problem deeply and then determine a possible solution for it. This solution is devised in such context that it is understandable by both a computer and a human (Voogt, Fisser, Good, Mishra, & Yadav 2015). According to the National Research Council (2010), learning CT is not limited to programmers but an essential set of skills that everyone should attain and will consequently increase the competitiveness between the USA workforces, living in a data-driven era (Burke, O'Byrne, and Kafai 2016). According to Shute, Sun, and Asbell-Clarke (2017), there is no identified curriculum that teaches CT the same way we have for Mathematics and Science, although there are challenges in the current school curricula that can be easily overcome by teaching CT.

Wing (2006) confirmed that the components of CT include 5 main cognitive process:

- Problem Reformulation
- Recursion
- Decomposition
- Abstraction
- Systematic Testing

These processes were described in details by Shute, Sun, and Asbell-Clarke (2017). According to Wing (2008), the main component of CT is abstraction and it means the ability to deduce the relevant information related to a complex system or a problem and disregard the irrelevant ones. Barr, Harrison, and Conery (2011) proposed another set of CT components including data organization, analysis, automation, efficiency, and generalization. Bers et al. (2014) suggested that CT components may also include debugging, in addition to abstraction and generalization. Yet, there is still a lack of a pragmatic evidence in defining the fundamental components that characterize CT. The variations in the definition of CT and the disagreement

on the basic components led to challenges in having a standard CT assessment scheme (Grover & Pea 2013) an area that needs further studies and research.

Considering CT as an essential skill, or set of skills, used for problem solving, Ambrosio et al. (2014) argued that programming is referred to various cognitive processes particularly schemas. A programmer needs to know how to solve a problem before writing its program and therefore the quality of the produced program is directly related to the preceding understanding of the theory. Yet, CT skills are different than programming skills due to the fact that they are transferrable i.e. can be transferred and used in other domains than programming (Shute, Sun, and Asbell-Clarke 2017). CT is the broadest domain where various cognitive activities can be applied to different real-world problems within which CS and programming can be placed. Figure 2.7 demonstrates the relationship between CT, CS, and programming according to Wing (2006).

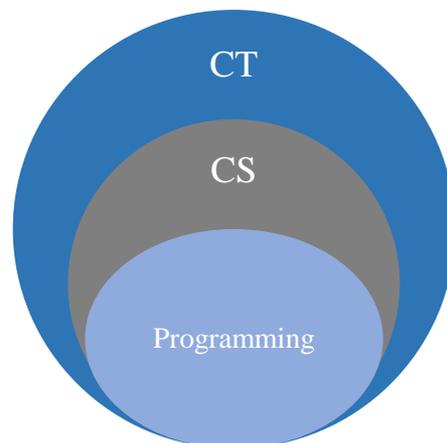


Figure 2.7 Relationship between CT, CS, and programming

According to Shute, Sun, and Asbell-Clarke (2017), the relationship between CT and computer programming is progressing over time and there were numerous intervention programs

described in the literature that are used to develop CT. Figure 2.7 shows a summary of the reviewed articles as perceived by Shute, Sun, and Asbell-Clarke (2017).

| Study | Setting | Participants | Intervention | | Content | Measures |
|--------------------------------|------------------|--|---------------------------|--------------|------------------------|--|
| | | | Program | Duration | | |
| Cetin, 2016 | Higher education | 56 Undergrads (pre-service teachers) | Scratch; C language | 6 weeks | Computer science | Multiple-choice; open-ended questions; surveys; interviews |
| Grover et al., 2015 | Middle school | 54 7th and 8th graders | Scratch | 7 weeks | CT course | Multiple-choice; quizzes; assignments; text-based coding; projects |
| Denner et al., 2014 | Middle school | 320 students | Alice (solo vs. pairs) | One semester | Programming | Surveys; tasks |
| Werner et al., 2012 | Middle school | 311 students | Alice (solo vs. pairs) | One semester | Programming | Surveys; tasks |
| Atmatzidou & Demetriadis, 2016 | High school | 164 students | Lego Mindstorms Robotics | One year | CT course | Questionnaires; think-aloud; interviews |
| Berland & Wilensky, 2015 | Middle school | 78 8th graders | Lego vs. virtual robotics | 5 days | Science | Log files; tests; questionnaires |
| Basu et al. (2017) | Middle School | 98 6th graders | CTSim platform | 13 days | Ecology, CT | Questions; explanations; constructing algorithms |
| Bers et al., 2014 | Kindergarten | 53 students | TangibleK Robotics | 20 h | CT course | Questionnaires |
| | Middle school | 51 students | Snap; Small Basic | 3 h | Poem | Fill-in-the-blanks; questions; Multiple-choice; surveys |
| Kim et al., 2013 | Higher education | 110 sophomores (pre-service elementary teachers) | PPS | 15 weeks | Computer science | Multiple-choice; surveys |
| Yadav et al., 2014 | Higher education | 141 undergrads | CT module | One week | Educational psychology | Questionnaires |

Figure 2.8 Articles Reviewed by Shute, Sun, and Asbell-Clarke (2017)

CS is the field of study that relates the process of interaction with programming and data representation. It combines the concept of developing programs and software based on algorithms, which can store, manipulate and communicate the digital information (Lininger 2008). The CS industry is growing faster than the others are. Over the next 10 years, it would pass the growth of all the other sectors of education spectrum according to the U.S. Bureau of Labor Statistics (2018). In the course enrolments of undergraduate and postgraduate, the field of CS is experiencing high amount of induction every year which creates a huge concern for the academies to respond to such growing demand of the program.

One of the earliest definitions for programming was introduced by Hartree (1950, p. 111) as “The process of preparing a calculation for a machine can be broken down into two parts, ‘programming’ and ‘coding’. programming is the process of drawing up the schedule of the sequence of individual operations required to carry out the calculation”. Similarly, Wilkes

(1956, p.2) defined programming as a sequence of instructions that are performed by a machine without human intervention. One year later, McCracken (1957) stated that programming is the process of converting human language to another one that can be understood by computers.

The concept of programming has changed from describing calculations to a more general data processing issues (Sajaniemi 2008). Collins (2019) stated that programming is “the act or process of writing a program so that data may be processed by a computer”. These instructions can be written in codes or any programming language, which is understood by computers (Knuth 2008). These programs instruct the computers to perform tasks. One of the first programming languages that were developed in the twentieth century was named “Fortran”. It was developed by Stanley Cohen in 1964. It was procedural programming in which the design is structured upon steps and procedures for the composed program. On the other hand, Object-Oriented Programming (OOP) refers to a software design in which programmers define both structure and type of data, as well as the operations and functions employing the concepts of inheritance and polymorphism.

According to Lye and Koh (2014) learning programming is not only learning to code but an opportunity to solve-problems and foster various CT skills such as abstraction, decompositions, and generalization. This form of thinking is considered crucial for school students as indicated by Wing (2006) and more importantly it is aligned with the 21st century skills the world-wide educational system is aiming to achieve (Binkley et al. 2012). Hence, there is an emergent need to develop effective ways for teaching programming in order to maximize the efficiency of the intended outcomes, taking into consideration the students’ learning needs and their learning styles.

Umar and Hui (2012) have studies the effectiveness of two pedagogies for teaching programming in relation to the students’ learning styles; metaphor programming (MP) and pair

programming (PP). According to Cazeaux (2007), MP help students link the newly introduced programming syntax to their previous knowledge. While in PP, two students work together to solve a problem by creating the correct code (Beck 2005). Thus, cooperative learning principles are used in PP. Performance in coding using PP is proved to be better especially when two students of different learning styles are working together (Umar and Hui 2012). Overall, according to Sajaniemi (2008), psychology of programming (PoP) researchers confirmed that programming technologies should be evaluated based on their usability and cognitive impact.

A number of researchers have also reported the importance of understanding the PoP when studying what programming is. PoP is the field of study that analyses the programmer's cognition and the mental and psychological programming related activities. It reveals the psychological aspect of writing computer programs. Therefore, it is crucial for researchers and educators studying the cognitive aspects of programming to dig deep into this domain.

In summary, CT skills are critical for students in the 21st century. They involve a set of cognitive processes associated with the programming component. Therefore, understanding the cognitive development of students, how do they learn best, and how teaching programming can be used to foster CT skills will inform this research and will help the researcher find an answer for the research question. Previous research identified certain cognitive processes related to teaching CT skills and programming such as spatial reasoning and general intelligence (Ambrosio et al. 2014). Yet, further investigation is duly needed.

In the new introduced programs taught at schools, computational thinking sits at the heart of the methods and structure of the curriculum. The subjects are filled with the elements of CS (Voskoglou, 2018). Computational thinking is a cognitive discipline of its own body of knowledge. These skills enable the student to be independent learner, potential innovator of technologies and evaluator of the current ones.

In today's classroom, many teachers are equipped with the required tools to train the student in computational thinking and programming as a mandatory aspect of education (Subrahmanyam, Kraut, Greenfield, & Gross 2000)

2.3.7.1 Computational Thinking and Cognitive Skills

The cognitive skills are related to computational thinking by the analytical skills required to perform computer programming (Ambrosio, Almeida, Macedo, & Franco 2014). The programming cannot be performed if these skills are not acquired. Pattern recognition, decomposition, algorithmic thinking and abstraction are the high order thinking processes that require particular cognitive skills. A brief description of these skills is demonstrated below:

- a. Pattern recognition is the element that identify similarities within and among the problem
- b. Decomposition is the characteristic the breaks down a system or a problem which is complex into step by step process or smaller parts which are manageable
- c. Algorithms is the language of processing the step by step solution of the problem. Through algorithm the rules are developed to which are followed to solve the problem
- d. Abstraction is the process of ignoring the irrelevant details and focusing on the most important ones

Many studies have been conducted to identify the cognitive skills associated with CT. Ambrosio et al. (2014) identified the cognitive process of CT associated with the programming component. This approach will formulate a basis for further discussion about how CT is related to programming to help inform the research questions. According to Ambrosio et al. (2014), computation is considered a key aspect to solving problems. Students need to know how to reason computationally to support their ability to solve problems (Emmott & Rison 2008). Hence, cognitive functions associated with CT are strongly related to problem solving. While

the main cognitive variables related to programming refer to schemas or mental models with considerable variations between expert and novice programmers (Ambrosio et al. 2014).

2.3.7.2 Computational Thinking Assessment

Romero, Lepage and Lille (2017) pointed out three dimensions to be considered when assessing computational thinking skills:

- Computational concepts: including algorithmic thinking, abstraction, decomposition, pattern generalization and parallelism
- Computational practice: including the sorting of data, debugging, simulations, designing and remixing computational models, documenting one's work and breaking down the problem in its parts
- Computational perspectives: including how students can gauge at the learner's sense of action and fluency in technology and the knowledge of how the system works.

Computational thinking compliments critical thinking in many ways, such as the ability to solve problems, interact with the world and to make decisions (Mulnix, 2012). Moreover, it caters for the development and the understanding of the complex concepts like generalization, decomposition, abstraction, algorithmic design, iteration and evaluation.

2.4 Overview of Related Literature and Key Studies

The researcher has reviewed a wide range of literature. However, she identified key studies relevant to the main concepts primarily retained in this research which include cognition, cognitive development, learning styles, computational thinking and how it is related to cognition, and computational thinking and its relationship to programming.

“Educational Psychology: theory and Practice” is a book written by Robert E. Slavin in 2014. Slavin (2014) discussed various characteristics of cognition and cognitive development. He defined development as “how people grow, adapt, and change over the course of their lifetime”. Various cognitive development theories were discussed in his book including Piaget and Vygotsky which constitutes a foundation for the theoretical framework of this research study. Different development types were studied in details: personality development, socio-emotional development, cognitive development and language development. A thoughtful study of such aspects will help the researcher understand how children develop cognitively and identify which cognitive abilities can be addressed within the research context.

On the other hand, the researcher has developed proper understanding of cognitive processes including attention and consciousness, memory processes, representation of knowledge, language acquisition, decision-making, reasoning, problem solving, and creativity by studying the “Cognitive Psychology” book written by Robert J. Sternberg and Karin Sternberg. Sternberg and Sternberg (2016) had discussed the three cognitive models of intelligence: Carroll’s Three Stratum model, Gardner’s theory of Multiple Intelligences, and Triarchic theory of Intelligence. Among these three models, the researcher will rely on Carroll’s Three Stratum model to construct the CT Cognitive Abilities Measure that will be used to investigate the impact of learning computer programming on students’ cognitive abilities’ development. This will contribute to the understanding of what aspects of cognitive development can be identified. Additionally, the authors of the book had discussed Problem Solving and Creativity as complex cognitive activities which will also help in understanding students’ cognitive behaviors and practices during their computer programming lessons.

Furthermore, in order to fully understand cognition as a mental process and the contradicting views about it, the researcher had referred to the article titled “Cognition” that was written by Maria A. Brandimonte, Nicola Bruno, and Simona Collina. Brandimonte, Bruno, and Collina in 2006. The authors of this article pointed out that the study of cognition can be addressed using different tools used in CS where programming is undeniably on the top of them. They have also discussed the contradicting views about how cognitive processes happen in the brain and how cognition can develop.

For further extension of understanding the research problem and how to address it, the researcher would also study the cognitive styles. Researchers referred to the terms of ‘learning styles’ and ‘cognitive styles’ interchangeably (Cassidy 2004). Abdul-Rahman and Du Boulay related the learning styles to cognitive load in a study that was conducted in 2014. They concluded that learning styles might have effect on the cognitive load of an individual by comparing the effects of the learning styles during the learning phase and the transfer phase. However, no significant difference was observed in performance during the posttest. The researcher is keen to further study the effect of the learning style on the cognitive load of an individual particularly for a high school student by using a different cognitive style model i.e. Cognitive Style Index which was developed by Allinson and Hayes (2012).

In a similar context, Ambrosio et al. (2014) identified the cognitive processes of computational thinking associated with the programming component. The researchers confirmed that computer programming is a core aspect of computational thinking since it fosters new ways of thinking that require problem solving and advanced cognitive skills in addition to the machine capacity. In their study, Ambrosio et al. (2014) had selected an assessment test to identify the cognitive process associated with computer programming including spatial reasoning, general

intelligence, arithmetic reasoning, and attention. They have found that spatial reasoning and general intelligence are the cognitive processes associated with computer programming while arithmetic reasoning and attention are proven to be irrelevant.

Román-González, Pérez-González, and Jiménez-Fernández (2017) had proven previous research findings and added problem solving as a third cognitive ability underlie computational thinking. Proper understanding of computational thinking and its relationship to cognition constructs a basis for further discussion about how CT is related to programming to help inform the research questions. The authors had developed and used the Computational Thinking test (CTt) then concluded that spatial ability, reasoning ability, and problem solving ability are associated with computational thinking and programming. The psychological constructs were based on Cattell-Horn-Carroll (CHC) model of intelligence. Those identified constructs are going to be used to develop the CT Cognitive Abilities Measure which will be utilized to find the development in the students' cognitive abilities, if found.

Finally, Lye and Koh (2014) stated that learning programming is not only learning to code but an opportunity to solve-problems and foster various computational thinking skills such as abstraction, decompositions, and generalization. There are three dimensions for computational thinking: computational concepts, computational practices and computational perspectives. Computer programming is currently available on different attractive platforms that makes its inclusion in K-12 education easier than before. Additionally, students' computational thinking skills can be assessed while programming. This form of thinking is considered crucial for school students as indicated by Wing (2006) and more importantly it is aligned with the 21st century skills the world-wide educational system is aiming to achieve (Binkley et al. 2012).

Table 2.3 summarizes the related literature and key studies discussed earlier with a clear connection to the context of this thesis.

| Author(s) | Publication Date | Title | Specific Perspective | Related Part in the thesis |
|--|------------------|---|---|---|
| Robert J. Sternberg Karin Sternberg | 2016 | Cognitive Psychology | The book introduced the main concepts of cognition and cognitive Psychology including intelligence, perception, attention, memory, representation of knowledge, language, reasoning, problem solving, and creativity. | <ul style="list-style-type: none"> • The discussion of cognition and intelligence and the introduced three models of intelligence including Carroll, Gardner, and Sternberg will inform the identification of the cognitive abilities related to learning Computer programming • Problem Solving and Creativity chapter will contribute to the understanding of the cognitive practices students may demonstrate when they learn Computer programming |
| Robert E. Slavin | 2014 | Educational Psychology: theory and Practice | The book provided a detailed description of Piaget and Vygotsky theories of cognitive development. It also discussed behavioral, learning, and information processing theories | <ul style="list-style-type: none"> • Piaget and Vygotsky theories will consolidate the theoretical framework • Behavioral, learning, and information processing theories will help in interpreting students' classroom practices and behaviors when they learn Computer Programing |

| Author(s) | Publication Date | Title | Specific Perspective | Related Part in the thesis |
|--|------------------|---|---|--|
| Maria A. Brandimonte Nicola Bruno Simona Collina | 2006 | Cognition | The authors had conceptualized cognition in relation to CS. They confirmed that “If cognitive processes are the software of the mind, then cognition can be studied using the tools of CS, ... This notion was critical to the cognitive revolution in psychology, and has now found wide acceptance in philosophical circles”. | <ul style="list-style-type: none"> • The detailed explanation of how cognitive processes happen inside the human’s brain and the evolution of the concepts related to cognition and cognitive development defining cognition as a mental process is crucial to the general understanding of the research problem • The discussion of the contradicting views about cognition and cognitive development will give the researcher an insight about the anticipated results |
| Siti-Soraya Abdul- Rahman Benedictdu Boulay | 2014 | Learning programming via worked-examples: Relation of learning styles to cognitive load | In this study, the researcher tried to investigate the relationship between the learning styles and the cognitive load when learners were studying computer programming. They have identified the learning styles of the learners then they studied the variations in their cognitive load. | <ul style="list-style-type: none"> • The study is very much similar to one aspect of this research when the researcher wants to relate the students’ cognitive style index to their cognitive abilities’ development • Additionally, the researcher wants to use a different cognitive style model to study this relationship i.e. Cognitive Style Index which results may deviate from the results of the previous study. |

| Author(s) | Publication Date | Title | Specific Perspective | Related Part in the thesis |
|---|------------------|--|---|--|
| Ambrosio, Ana Paula Almeida, Leandro S. Macedo, Joaquim Franco, Amanda Helena Rodrigues | 2014 | Exploring core cognitive skills of Computational Thinking | The authors confirmed that computer programming is a core aspect of computational thinking since it fosters new ways of thinking that requires problem solving and advanced cognitive skills in addition to machine capacity. In their study, Ambrosio et al. (2014) had selected an assessment test to identify the cognitive process associated with computer programming. They have identified spatial reasoning and general intelligence as the addresses core cognitive processes. | <ul style="list-style-type: none"> • The researcher will benefit from Amborsio et al. research findings and include spatial reasoning and general intelligence as constructs when developing the CT Cognitive Abilities Measure. • In addition to other constructs based on other research studies such as the study conducted by Román-González, Pérez-González, and Jiménez-Fernández (2017) “Which cognitive abilities underlie computational thinking? Criterion validity of the Computational Thinking Test”. Other cognitive abilities were also identified. |
| Marcos Roman-Gonzalez Juan-Carlos Perez-Gonzalez Carmen Jimenez-Fernandez | 2017 | Which cognitive abilities underlie computational thinking? Criterion validity of the Computational Thinking Test | Román-González, Pérez-González, and Jiménez-Fernández (2017) added problem solving to the previous research findings of the cognitive abilities associated with computational thinking and programming. Using Cattell-Horn-Carroll (CHC) model of intelligence, they have developed the Computational thinking test (CTt) and found that spatial ability, reasoning ability, and problem solving ability are associated computational thinking and programming. | <ul style="list-style-type: none"> • The researcher will benefit from the findings of this research particularly that it relies on CHC theory i.e. the main theory considered for identifying the cognitive abilities in the theoretical framework. • Additionally, the researcher will develop the CT Cognitive Abilities Measure based on the identified cognitive abilities associated with computational thinking and programming. |

| Author(s) | Publication Date | Title | Specific Perspective | Related Part in the thesis |
|---------------------------------------|------------------|---|---|--|
| Sze Yee Lye Joyce Hwee Ling Koh | 2014 | Review on teaching and learning of computational thinking through programming: What is next for K-12? | In this study, the authors confirmed that computational thinking can be fostered by teaching computer programming. However, despite the increased interest in programming, K-12 education still need to focus on including it as a main subject within the school curriculum. They had discusses the three dimensions of computational thinking including computational concepts, computational practices and computational perspectives. | <ul style="list-style-type: none"> • The study had provided the researcher with an insight and further certainty about the relationship between Computational Thinking and programming. • programming is proved to be an efficient way to develop students computational thinking skills. Which in turn strongly related to students' cognitive abilities. |

Table 2.3 Key Literature and its connection with the current thesis

2.5 Summary

Chapter 2 presented three main components of the thesis; theoretical framework, conceptual framework, and literature review. The integration between these components constructs a skeleton for the research and provides the researcher with a proper understanding of the research problem and how to address the research questions.

In the theoretical framework, the researcher had discussed cognitive theories, learning theories, and other supporting theories pertinent to the context of the research. Among the various cognitive theories found in the literature, Piaget and CHC were found the most relevant. Piaget formal stage of cognitive development is directly linked to the age group targeted in the research while CHC explains the cognitive abilities that are relevant to learning computer programming.

The learning theories that were discussed are those of Vygotsky and Dewey. Both explain how people learn. However, Vygotsky theory and its implication on the learning process would help

the researcher identify how students learn in the classroom and further interpret their cognitive behaviors from the constructivism view. While Dewey explains how people learn from the behaviorism view. The aspect that makes Dewey theory relevant to this research is its interpretation to the problem solving concept and the individuals' reflection on their own thinking when learning computer programming.

The supporting theories that were discussed are: Fuzzy Trace Theory (FTT), Executive Function Theory (EFT), and Cognitive Load Theory (CLT). The supporting theories will help in further understanding and interpreting students' cognitive abilities and behaviors while learning computer programming.

The second section of the chapter discusses the conceptual framework that relates the different concepts of CT, neuroscience, as well as cognitive and noncognitive functions. cognitive and noncognitive functions are related to the cognitive abilities and students' perceptions consecutively. both of which are variables tackled in the research questions.

Both theoretical framework and conceptual framework provide a basis for the literature review that is presented in the third section of the chapter. The literature review summarized tens of researches and journal articles about cognitive development, cognitive development in neuroscience, cognitive development assessment, cognitive assessment tools, cognitive styles, higher order thinking skills, and computational thinking.

This research is focused on the impact of teaching computer programming on the development of the students' cognitive abilities. The researcher has explored tens of articles related to the topic of the study. Few research studies were conducted about the correlation between learning programming and cognitive development, particularly, in the USA. A study was found on the effect of programming on the cognitive level was conducted by Pea and Kurland (1984). Cafolla (1987) conducted another study to determine the relationship between students'

achievement in programming and their cognitive development particularly their verbal abilities and mathematics reasoning. The results of this research revealed that mathematics reasoning and verbal abilities are predictors for success in computer programming. Likewise, Flannery (2011) had studies how cognitive development levels may predict programming achievement. Similar results were found.

Still, none of the studies was conducted about the direct impact of learning computer programming on the corresponding cognitive abilities that underlie computational thinking. Furthermore, none of the studies was conducted in the Arab region nor any of the Mediterranean countries. Therefore, it is crucial to conduct such research in order to enrich the educational system in this context and support educators and psychologist in the field.

Chapter 3 Methodology

The purpose of this study is to investigate the impact of learning computer programming on the development of high school students' cognitive abilities in the UAE. Therefore, the researcher will use the mixed method approach to achieve this purpose and to answer the main research question and its sub-questions. The previous chapter had introduced the theoretical framework upon which this study was established. It included theories of cognitive development, learning theories, and other supporting theories. In addition to the conceptual framework that relates the different concepts of computational thinking, neuroscience, as well as cognitive and noncognitive functions. Furthermore, it demonstrated a review of a varied collection of related literature about cognitive development, cognitive development in neuroscience, cognitive development assessment, cognitive assessment tools, cognitive styles, higher order thinking skills, and computational thinking that had helped the researcher decide on the value of the studied topic in addition to limit the scope of inquiry (Creswell 2012) to maintain focus on the main research objective.

This chapter will extend the discussion to uncover the research methodology. Cohen, Manion and Morrison (2013) stated that the method refers to the techniques used to gather data while research methodology has a broader scope to include the approach and design in addition to the method itself. According to Johnson and Christensen (2012), the methodology includes an “identification, study, and justification of the research method”. Hence, chapter 3 includes an overview of the research paradigm and the research paradigm of this particular research, research design, data collection methods, ethical considerations and limitations. Each of these sections has sub-sections that are well-divided to ensure, in the broadest terms, coverage of the process of inquiry.

3.1 Overview of Research Paradigms

Creswell (2014) indicated three main components in a research approach; the philosophical view, the research design, and the research methods. According to Creswell (2009) the philosophical views section includes the basic definition, and how does it shape the approach of the proposed study. Researchers have put forward many worldviews. However, Creswell (2014) has proposed four of them; Postpositivist, Constructivist, Transformative, and Pragmatic. A researcher should be able to identify his/her philosophical standpoint based on the research objectives, hypotheses, and questions. Similarly, the research design options; quantitative, qualitative, or mixed methods are also dependent on the research objectives, hypotheses, and questions. Additionally, the research methods and procedures refer to the research questions within which a discuss of data collection, data analysis, interpretation and validation must be elaborated. The sections below demonstrate the details of the research approach, design, and methodology.

Johnson and Christensen (2012) pointed out the significance of understanding epistemology as the study of knowledge. They classified the sources of knowledge based on the two philosophical ideas; Empiricism where knowledge comes from experience and Rationalism where reasoning is the primary source of knowledge. Deductive reasoning is used to draw conclusions that are necessarily true while inductive reasoning is used to draw conclusions that are probably true. A set of common assumptions made by educational researchers may include but limited to: the inner world of individuals can be studied, the complexity of the world that can vary between its uniqueness and predictable pattern, and that the researcher should try to follow the agreed-upon norms and practices. Yet, these assumptions imply that science cannot always provide answers to all questions, particularly the philosophical ones.

Kuhn (1970) had described the structure of scientific revolutions and the various activities in a scientific method that might lead to changes in the world views. Making observations, testing hypotheses, and justifying theories are some of them. Johnson and Christensen (2012) distinguished between two scientific methods: Exploratory and Confirmatory. The basic Exploratory method suggests that the researcher make observations and study its patterns, upon which tentative conclusions and generalizations can be made. However, a researcher using the Confirmatory method starts with stating hypotheses, testing them empirically, and then decide to accept or reject them. ‘The research wheel’ shown in figure 3.1 demonstrates the construction of both methods.

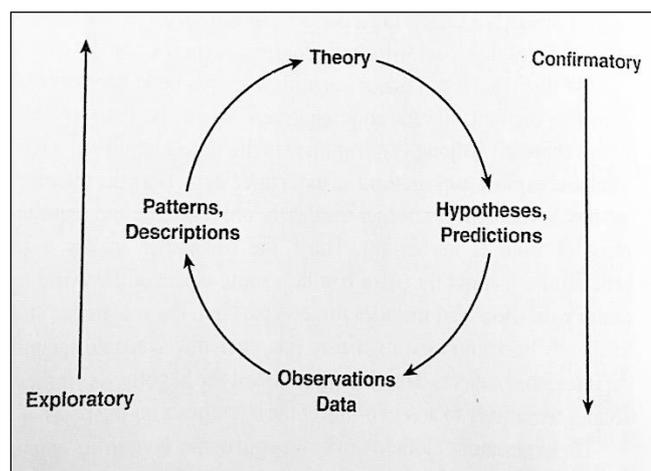


Figure 3.1 The research wheel. Adapted from Johnson and Christensen (2012)

Quantitative researchers use the confirmatory method and the “logic of justification” to draw conclusions while qualitative researchers use the exploratory method and the “logic of discovery”.

Creswell (2009) stated that different worldviews, sometimes called ‘paradigms’, guide researchers to the way they approach their studies and influence the practice of the research. Mertens (2014) referred to paradigm in its simplest form “as a way of looking at the world.” Guba (1990) had defined the term ‘worldviews’ as the researcher’s beliefs that guide action.

Views related to the nature of reality and the process of the research itself decides the methodology that is going to be used (Fraenkel & Wallen 2012, Saunders, Lewis, & Thornhill 2012).

The quantitative method is associated with the philosophy of the positivism paradigm that denotes that there is always a reality that needs to be discovered empirically using a scientific method (Fraenkel & Wallen 2012, Creswell 2014). Mouly (1978) cited in Cohen and Manion, and Morrison (2013) pointed out five steps of empirical science: experience, classification, quantification, discovery of relationships, and approximation to the truth. However, this paradigm was heavily criticized by different researchers and philosophers indicating that it emasculates life and mind.

Similarly, post-positivists believed in the existent of reality. According to Creswell (2009), several key assumptions underlie the post-positivism approach: the notional nature of knowledge, the research is conducted to accept or reject a hypothesis but not to prove it, and the researcher's objectivity as an essential aspect of inquiry. Moreover, this approach relies heavily on the fact that outcomes are determined by causes based on rules that manage the world (Creswell 2014). Phillips and Burbules (2000) in their book titled 'Postpositivism and Educational Research', argued key assumptions of post-positivism including the conjectural of the absolute reality and the fact that quantitative research is used to test a claim by relating variables, where evidences can shape the knowledge utilizing an objective approach.

According to Mertens (2014) experimental, quasi-experimental, correlational, casual comparative, quantitative, and randomized control trials are labels associated with the post-positivism worldview. Although this approach seems to have attractive features that may help in achieving the objectives of this research. It is still not sufficient to answer all the research questions. Therefore, the researcher tends to find a more suitable position.

Qualitative researchers opposed both positivism and post-positivism approaches, emphasizing the role of individuals in interpreting of events, and thus, adopting the interpretivism paradigm instead (Fraenkel & Wallen 2012, Cohen, Manion & Morrison 2013). Unlike positivists, Cohen, Manion, and Morrison (2013) and Creswell (2014) pointed out that interpretive researchers assume that a theory should follow research, while it relies basically on the researcher's view of the situation as well as his background (Crotty 1989). According to Creswell (2014), qualitative researchers often adopt the interpretivism worldview to form a subjective meaning for a certain phenomenon based on the participants' views. Still, those meanings are debatable. In 1998, Crotty argued that researchers use open-ended questions to construct meanings based on their social perspectives and their interaction with the studied subjects. Hence, this approach is much used in ethnographic studies when the subject's behavior is closely observed. Creswell (2014) and Mertens (2014) had referred to this worldview as constructivism upon which naturalistic, phenomenological, hermeneutic, symbolic interaction, ethnographic, qualitative, and participatory action research studies can be conducted.

Similarly, these qualitative macro-sociological perspectives of interpretivism were also criticized that they limit the subjects' behavior and isolate it from the outside world around them.

On another hand, Creswell (2014) and Mertens (2014) stated that a qualitative researcher might also embrace the transformative worldview particularly in a research that needs narrative design. Critical theorists advocated this worldview (Creswell 2014). While Mertens (2010) confirmed that "the transformative paradigm provides a philosophical framework that focuses on ethics in terms of cultural responsiveness, recognizing those dimensions of diversity that are associated with power differences, building trusting relationships, and developing mixed methods that are conducive to social change." Guba and Lincoln (2005) cited in Mertens

(2010) stated that the transformative paradigm relies primarily on the assumptions of axiology, ontology, epistemology, and methodology. According to Creswell (2014), this worldview shed the light on individuals or minorities who find themselves paralyzed or ineffectual. Therefore, researchers studying feminists' views, racial discourse, and political and social inequities may choose this stance. Thus, the transformative worldview will not serve the purpose of this research and consequently the researcher avoided such position.

Bridging the divide between the paradigms seemed to be crucial. Guba (1990) argued the paradigm dialogue between quantitative and qualitative research. He stated that the research paradigms are characterized by its ontology, axiology, epistemology, methodology, and rhetoric. Since then, researchers started to advocate a pragmatic position that states that both qualitative and quantitative methods can be mixed thoughtfully in a single research study.

This paradigm was predominantly influenced by the work of C.S. Pierce, William James, George Herbert Mead, John Dewey, W. V. O. Quine, Richard Rorty, Cornel West, and Richard Bernstien (Cherryholmes 1992). According to Creswell (2009), pragmatism is not obligated to whichever system of reality; the researcher has the choice to choose the appropriate methods and techniques to achieve the research objective. Moreover, the use of qualitative and quantitative methods together provides the researcher with a comprehensive understanding of the research problem. A mixed method researcher adopting the pragmatist position looks to what and how to research based on the intended consequences. Cherryholmes (1992), Morgan (2007), and Creswell (2014) pointed out that pragmatic research, including its objectives, how to achieve them, and the choice of the various methods and procedure to meet their needs, is driven by the anticipated/intended results in its broadest sense.

Thus, Creswell (2014) indicated the importance of collecting different types of data that leads to better understanding of the research problem. He confirmed that a pragmatist researcher initiates a research with a broad survey then in a latter phase, qualitative data can be collected

by open-ended interviews which results will help in explaining the quantitative data collected from the survey. Yet, a researcher needs to provide a rationale for the selection of methods and forms of data collection as well as analysis techniques.

Mertens (2014) had identified the basic believes of axiology, ontology, epistemology, and methodology associated with the pragmatic paradigm. As mentioned earlier, the research axiology indicates that knowledge is influenced by the researcher's values and ethics. Ontology designates that individuals have unique interpretations of a single reality. Epistemology labels that the researcher's beliefs determine relationships in a particular research. Lastly, Methodology indicates that multiple methods and approaches are used to answer various research questions. Mertens (2014) pointed out issues related to the pragmatic paradigm. Pragmatism researchers tend to disregard ontology and epistemology and emphasize on "what-words" to serve their research agenda and achieve the intended purpose.

3.2 Research Paradigm

Based on the discussion in the previous section, the researcher found that the approach of this mixed method research is conceptualized from the pragmatism paradigm. Special emphasis was laid upon the situation of learning computer programming and the actions of both students and teachers while less attention was given to the antecedent conditions. The philosophical underpinning of the mixed method research indicates an emphasis on the research problem rather than the methods. Accordingly, the researcher has focused on the research problem that is basically to investigate the impact of learning Computer Programming on the students' cognitive abilities development to decide on the approaches and procedures. Hence, the selection of this approach was evolved around the main research question and its sub-questions. The main question: To what extent does learning computer programming impact student cognitive abilities development, has steered the approach toward the selection of the quasi-

experiment that will support the investigation process. Additionally, the researcher will use various qualitative and quantitative methods including observation, interviews, and mixed questionnaire seeking answers for the research sub-questions. Therefore, as stated by Guba (1990), the methods are thoughtfully mixed in the single research study.

According to Creswell (2014), researchers following the mixed method approach use the pragmatic knowledge claims as a philosophical assumption. Both inductive and deductive logic routes are going to be used to study the objective and subjective point of views. The axiology of the study implies that values play a vital role in interpreting the results with proper ontology of accepting reality and choosing different explanation that produces the desired outcomes. This can be revealed and confirmed upon the data analyses' results. Johnson and Christensen (2012) referred to this position as “dialectical pragmatism” due to the dynamicity of the multiple perspectives which is evident in the study design that will be elaborated later in this chapter.

3.3 Research Design

Creswell (2014) referred to research designs as types of inquiries or strategies of inquires within the chosen methodologies that specify particular directions and procedures used to achieve the research objectives. On another hand, Cohen, Manion, and Morrison (2007) referred to the research design as a set of elements that includes, but not limited to, a statement of the research problems, the intended outcomes, a description of the methodology, the instruments, validity, and reliability. The overall feasibility of the research is heavily influenced by the decisions about these elements.

Creswell (2014) stated that quantitative research designs are invoked by the postpositivism worldview that may include experimental design to assess attitudes before and after a treatment which data can be collected and statistically analyzed e.g. applied behavioral analysis and

single-subject experiments, and non-experimental designs e.g. casual comparative research, correlational designs. These designs aim to elaborate relationships between different variables using simple and complex techniques.

On the other hand, approaches to qualitative research designs were clearly defined in the 1990's (Creswell 2014). Narrative, phenomenological, grounded theory, ethnography, and case studies are examples of qualitative design of inquiry.

3.3.1 Mixed Method Research Design

According to Creswell (2014), mixed methods research design integrates both qualitative and quantitative research and data collection in a single study or a series of studies. This design leads to better understanding the research problem particularly when one type of data is not enough to achieve that understanding. Also, a mixed method design is used when one type of data is not enough to address the research question(s). Creswell (2014) had discussed a mixed method research design from another perspective. That is how do qualitative and quantitative methods work together. In this regard he discussed three different mixed-method research designs: Convergent parallel, explanatory sequential, and exploratory sequential. Additionally, Creswell (2012) had also discussed the embedded, transformative, and multiphase designs.

The blend between the two methodologies was originated in the 1950's. Yet, major work in defining the characteristics of this design was conducted in the 1980's. Multiple forms of data can be collected and analyzed using different tools. Creswell (2014) pointed out that this design helps researchers overcome the weaknesses that underlie each individual method i.e. qualitative and quantitative. Thus, qualitative and quantitative methods complement each other in the mixed method design (Jick 1979).

Correspondingly, the convergence between qualitative and quantitative data can be achieved by triangulating different data sources. Denzin (1978) cited in Jick (1979) had defined

triangulation as combining different methodologies to study the same phenomenon. The concept of triangulation was originally used by Campbell and Fiske (1959) in multiple-operationism social sciences to indicate cross validation processes. Jick (1979) pointed out the continuum triangulation design that ranges from simple to complex as shown in figure 3.2.

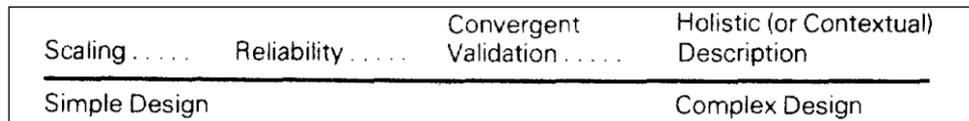


Figure 3.2 A continuum of Triangulation design adapted from Jick (1979)

The simplest form of the continuum triangulation is scaling. It is primitive and refers to the quantification of the qualitative measures. Within-method triangulation is used to ensure the reliability of the results using a single type of data i.e. quantitative or qualitative. Yet, a more evident interpretation of the results can be achieved by using the multi-independent measures through convergent validation. A systematic convergent of qualitative and quantitative data was well-defined in 1990’s (Creswell 2014). Lastly in this continuum range, the holistic contextual approach prevails to help uncover a new variance that cannot be revealed using a single method. Table 3.1 summarizes the different triangulation designs as stated by Jick (1979).

| Triangulation Design | Description | Limitations |
|-----------------------|---|--|
| Scaling | <ul style="list-style-type: none"> • Quantification of qualitative measures triangulations approach | No Diverse observations No mix of independent methods |
| Reliability | <ul style="list-style-type: none"> • Within-method triangulation approach • Variations of the same method lead to diverse variations of triangulated data | Only one method is used |
| Convergent Validation | <ul style="list-style-type: none"> • Between Methods triangulation approach • Leads to convergent validation and more valid results | Not Identified |
| Holistic (Contextual) | <ul style="list-style-type: none"> • Use of multiple measures to reveal unique variance that cannot be emerged using a single method • Study the same phenomena from different angles | Not Identified |

Table 3.1 Triangulation Designs adopted from Jick (1979)

Figure 3.3 demonstrates the research plan that merges the collection and analysis of the qualitative and quantitative data in order to find the impact of learning computer programming on the cognitive abilities development. Testing and assessment research style aims to evaluate achievement and potential based on cognitive, academic and non-academic performance. Different instructional materials are designed to have an in-depth diagnosis of abilities (Cohen, Manion, & Morrison 2007).

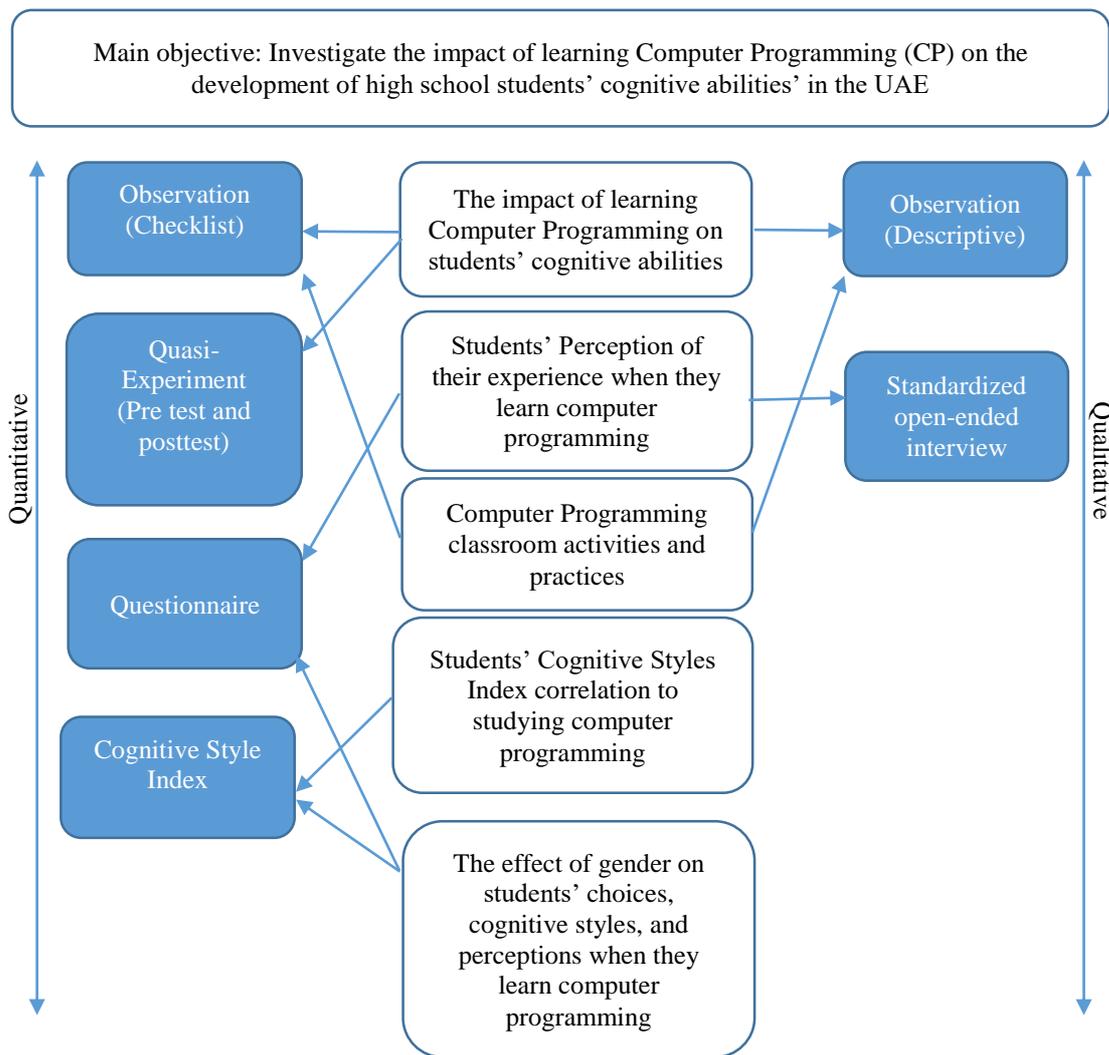


Figure 3.3 Research Design Summary

Therefore, according to this research design, various triangulation designs are going to be used to ensure validity and reliability of the obtained results. Convergent validation triangulation design is used to ensure triangulation between the different method used. Additionally, multiple

measures are used to reveal the unique variance via holistic triangulation design that cannot be transpired using one method whether qualitative nor quantitative. Hence, the impact of learning programming on the students' cognitive abilities' development was studied from different angles including students' cognitive behavior and students' attitudes. Further details of triangulation of data and its results will be discussed in depth in chapter 4.

It is worth noting that the weakness in each single method is adjusted by using another as demonstrated in table 3.2. The table demonstrates how data will be collected and analyzed, mixed-method designs, participants and sampling designs, and analysis techniques for each research question consecutively. The various techniques and instruments are used in a logical pattern in this research seeking converged, consistent, and better-defined results.

As demonstrated in table 3.2, in addition to the quasi-experiment, the convergent parallel design is used for the observation; structured and natural unstructured to help answer the main research question: To what extent does learning computer programming impact high school students' cognitive abilities development in the UAE and sub-question 2: What cognitive activities and practices may occur in the classroom during a computer programming lesson? According to Creswell (2014), in the convergent parallel research design, both types of data qualitative and quantitative are collected concurrently and merged to postulate a comprehensive analysis of the problem. Creswell (2012) pointed out the rationale behind using this design that is one type of data can strengthen the weakness in the other. Therefore, the researcher found it essential to collect the qualitative data within the observation form to support the quantitative data.

On another hand, an explanatory sequential mixed method design is used to answer sub-question 1: What are the students' perceptions of their experience when they learn computer programming? The quantitative data collection phase is followed by a qualitative data collection phase that will help to further explain its results. According to Creswell (2012) the

explanatory sequential design requires the researcher to prioritize the collection of the quantitative data followed by the qualitative data in a well-defined sequence. The qualitative data can then be used to “refine, extend or explain the general picture”. Hence, the researcher will collect the quantitative data using a questionnaire closed ended questions, and analyze it. The results will then be compared to the qualitative data that is collected from the interview open ended questions. The advantage of this design underlies the clear identification and sequence of both types of data. In addition to the value given to the quantitative results obtained from the analysis. However, one downside of this design is that the researcher needs to specify the aspects of the quantitative data that need to be followed up by the qualitative data collection phase. Such decision would ultimately affect the instrument used to collect the qualitative data as well as the targeted sample (Creswell 2012). Hence the researcher had decided on the interview questions based on the questionnaire quantitative data results.

| Research Question(s) | Instrument | Method | Mixed-Method Design | Participants & Sampling Design | Analysis |
|------------------------|--|------------------------------|--------------------------|---|---|
| Research Main Question | Test (CT Cognitive Abilities Measure) | Quasi-Experimental Treatment | | <ul style="list-style-type: none"> • S1 Control group (643) • S1 Experiment group (127) • S2 Control group (21) • S2 Experiment group (8) | <ul style="list-style-type: none"> • Descriptive Statistical Analysis • Inferential Statistical Analysis |
| | Observation (Structured, Checklist) | Quantitative | Convergent Parallel | S1 → N=770 n=127 S2 → N=29 n=8 | <ul style="list-style-type: none"> • Descriptive Statistical Analysis • Thematic Analysis • Data Consolidation |
| | Observation (Natural Unstructured) | Qualitative | | Identical Concurrent | |
| Sub-Question 1 | Questionnaire (Closed Ended Questions) | Quantitative | Explanatory Sequential | S1 → N=770 n=127 S2 → N=29 n=8 | <ul style="list-style-type: none"> • Descriptive Statistical Analysis • Inferential Statistical Analysis • Thematic Analysis • Data Consolidation |
| | Interview (Standardized Open-Ended Interview) | Qualitative | | Nested Concurrent | |
| Sub-Question 2 | Observation (Structured, Checklist) | Quantitative | Convergent Parallel | S1 → N=770 n=127 S2 → N=29 n=8 | <ul style="list-style-type: none"> • Descriptive Statistical Analysis • Thematic Analysis • Data Consolidation |
| | Observation (Natural Unstructured) | Qualitative | | Identical Concurrent | |
| Sub-Question 3 | Test (Cognitive Style Index test) | Quantitative | Correlational Prediction | S1 → N=770 n=127 S2 → N=29 n=8 | <ul style="list-style-type: none"> • Descriptive Statistical Analysis • Inferential Statistical Analysis |
| | Test (CT Cognitive Abilities Measure-Demographic Data) | Quantitative | | Identical Concurrent | |
| Sub-Question 4 | Test (CT Cognitive Abilities Measure-Demographic Data) | Quantitative | Correlational Prediction | S1 → N=770 n=127 S2 → N=29 n=8 | <ul style="list-style-type: none"> • Descriptive Statistical Analysis • Inferential Statistical Analysis |
| | Questionnaire | Quantitative | | Identical Concurrent | |
| | Test (Cognitive Style Index test) | Quantitative | | | |

Table 3.2 Comprehensive Research Design. S1 refers to School 1 and S2 refers to School 2

Contrarily, Creswell (2014) discussed the exploratory sequential mixed method design that has technically the reverse order of the explanatory. A researcher begins with the qualitative data

collection followed by quantitative data collection. The qualitative data analysis can be used to design the instrument used for collecting the quantitative data. However, such design is not used in this research.

Additionally, Creswell (2012) pointed out two correlational designs; the explanatory design and the prediction design. Cohen and Manion (1994) referred to the explanatory research as relational research where researchers are interested to know how two variables co-vary. In this context, Creswell (2012) pointed out that a correlational explanatory research requires the researcher to collect data at one setting from all participants as one group. Two different scores for the two different variables must be collected for each participant and correlated using statistical test. Consequently, interpretations and conclusions are drawn.

On another hand, using the correlational prediction design, researchers are supposed to use variables as predictors to anticipate results or outcomes. In other words, predictor variables are used to predict outcomes, which are also called criterion variables (Creswell 2012). A researcher need to measure the predictor variable at a certain point of time followed by the criterion variable later upon which predictions about future performance can be identified. Hence, correlational research relies primarily on a statistical relationship between the two sets of quantitative data. The two variable co-vary i.e. a score can be detected if the other is known. According to Gall, Borg, and Gall (1996) as the value of the variance increases, the prediction of the correlation between the two variables will also increase. Correlation statistical tests are needed to use this design.

Therefore, to answer sub-question 3: How the cognitive style may affect students' choice of studying computer programming; the researcher chose to follow the correlational prediction research design to compare and correlate the two sets of data: The Cognitive Style Index and the demographic data collected through the CT Cognitive Abilities Measure. The cognitive style index will be the predictor variable while student's choice to learn computer programming

is the criterion variable. Generally, students' choice to study computer programming will be predicted based on their cognitive style index.

Similarly, for sub-question 4: How gender differences may affect students' choices, cognitive style, and perceptions when they learn computer programming, the researcher will also use a prediction correlational design. In this case students' gender will be the predictor variable while their choices and perceptions will be the criterion variable.

3.3.2 Quasi-Experimental Design

Creswell (2012) argued a set of concepts that are essential to understand an experimental design; "Random assignment, Control over extraneous variables, Manipulation of the treatment conditions, Outcome measures, Group comparisons, and Threats to validity". Cohen, Manion, and Morrison (2007) argued that in experimental research, or in other words true experiment research, researchers control the conditions, define events, introduce the intervention, and then identify the difference it may make. Dependent and independent variables need to be explicitly labeled in true experiments (Creswell 2012, Cohen, Manion, and Morrison 2007). However, Cohen, Manion, and Morrison (2007) and Johnson and Christensen (2008) confirmed that true experiments are not easy to undertake in educational research.

Therefore, the researcher chose to conduct a quasi-experiment due to the limitation of the true experiment i.e. difficulty to have an artificial group that can be randomly assigned and controlled. According to Johnson and Christensen (2008), a researcher does need to provide full control if potential confounding variables are there as in this quasi-experiment.

According to Creswell (2012), quasi-experimental designs can have a pre- and posttest design or posttest-Only design as demonstrated in figures 3.4 a and b below.

| | | | | | |
|---------------------------|---------|------------------------|----------|------|---|
| Pre- and posttest Design | | | | Time | → |
| Select Control Group | Pretest | No Treatment | Posttest | | |
| Select Experimental Group | Pretest | Experimental Treatment | Posttest | | |

Figure 3.4 a Pre- and posttest Design-Between Groups Design Adapted from Creswell (2012)

| | | | | |
|---------------------------|------------------------|--|----------|---|
| Posttest-Only Design | | | Time | → |
| Select Control Group | No Treatment | | Posttest | |
| Select Experimental Group | Experimental Treatment | | Posttest | |

Figure 3.4 b Posttest-Only Design-Between Groups Design Adapted from Creswell (2012)

On the other hand, Cohen, Manion, and Morrison (2007) had classified quasi-experiments into Pre-experimental design: one group pre test-posttest, Pre test-posttest non-equivalent group design, and One-group time series. The one group pre test-posttest is represented by: $O_1 X O_2$ Where O_1 is the dependent variable, X is the experimental manipulation, and O_2 is the measure of the dependent variable after the treatment.

The pre test-posttest non-equivalent group design is widely used in educational research and represented as shown in figure 3.5.

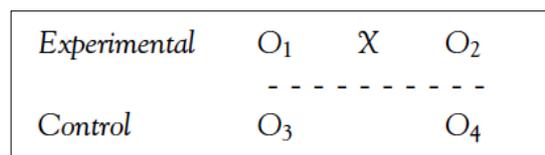


Figure 3.5 The pre test-posttest non-equivalent group design. Adapted from (Cohen, Manion, and Morrison 2007)

A similar representation was also presented by Johnson and Christensen (2008) and had referred to it as the non-equivalent comparison group design as demonstrated in figure 3.6.

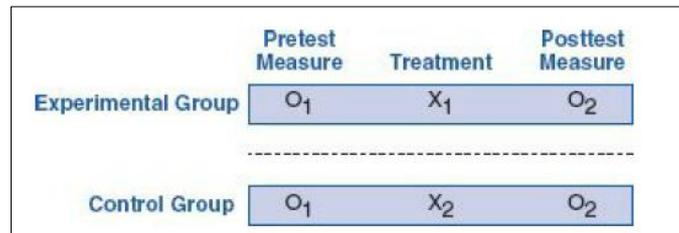


Figure 3.6 Non-equivalent comparison group design. Adapted from Johnson and Christensen (2008)

In this design the experiment and control groups are “not equated by randomization” (Cohen, Manion, and Morrison 2007). Also, this design is equivalent to the Pre- and posttest design presented by Creswell (2012) and shown in figure 3.4 a.

Finally, the one-group time series design indicates that a series of pre test and posttest are conducted over a certain period of time to monitor the tendency of the results (Cohen, Manion, and Morrison 2007). Though this design is not going to be utilized for this research due to its incompatibility to the research objectives.

The researcher had applied the pre test-posttest non-equivalent group design suggested by Cohen, Manion, and Morrison (2007) and Creswell (2012). The pre test and posttest were given to both control and experiment groups.

The process that is followed for the quasi-experiment is that the researcher first conducted the Cognitive Style Index test to classify students according to their cognitive styles. Students then, in both groups experiment and control, have done the CT Cognitive Abilities Measure O1 and O3. After which intervention X is applied i.e. learning computer programming. Each group was monitored and studies separately. Consecutively, the posttest results’ analysis will provide information about the dependent variables through O2 and O4.

In order to avoid potential bias in the nonequivalent comparison group design, Johnson and Christensen (2012) suggested that a researcher should try to minimize the differences in the pre test results because bigger difference in the pre test results will hypothetically cause a

difference in the posttest results. Otherwise, statistical adjustments will be needed such as using ANCOVA. Hence, the researcher will decide on the use of the statistical adjustment after the data analysis that will be unveiled in chapter 4.

After all, studying the research design including the quasi-experiment and the other qualitative and quantitative methods, carefully and thoughtfully, table 3.3 demonstrates the independent and dependent variables upon which the research methodology is constructed.

| Independent Variables | Dependent Variables |
|---|---|
| <ul style="list-style-type: none"> • Type of Intervention (Learning computer programming) • Cognitive Style Index • Gender | <ul style="list-style-type: none"> • Students' Cognitive Abilities (Fluid Reasoning (G_f), Visual Processing (G_v), Short-Term Memory (G_{sm})) • Students' perception about learning programming • Students' classroom activities • Students' choices |

Table 3.3 List of independent and dependent variables

3.4 Data Collection Methods

This section presents an overview of the research method as well as a description of the site, sampling, subject selection, data collection methods/instruments, data analysis, and ethical considerations.

3.4.1 Research Method

The researcher will use the Mixed Method Research (MMR) methodology in order to achieve purpose of the research and answer its questions. The following subsections present a detailed explanation of the mixed method research, why is it used, and the challenges of using it, providing a clear justification of the researcher's choice.

3.4.1.1 What is Mixed Method Research

Johnson and Christensen (2008) had defined mixed method research as the use of a combination of qualitative and quantitative methods and approaches in a single or a set of

studies. Different methods can be conducted concurrently or sequentially based on the research questions and the study needs. It is relatively, a new methodology used in research. Fraenkel, Wallen, and Hyun (2011) pointed out that mixed method research had begun in 1950s. However, Creswell (2014) confirmed that mixed method research was originated in late 1980s and early 1990s and went through different developmental stages that were outlined by Teddlie & Tashakkori (2009) and Creswell & Plano Clark (2011).

Fraenkel, Wallen, and Hyun (2011) and Creswell (2014) stated the main features of the mixed method research as the collection of both qualitative and quantitative data, the development of a rationale for mixing, the integration of data at different stages of inquiry, and the presentation of the different procedures in the study. To answer the research question, both open-ended and closed-ended questions that will meet the emerging and predetermined approaches shall be used (Creswell 2014). Cohen, Manion, and Morrison (2007) stated that a mixed method research is used for empirical data collection; a survey can be used to understand the overall picture followed by other methodology for further “fine-grained analysis”. The characteristics of mixed-method research were discussed by Creswell (2012); stating that it has to have a clear rationale, an identification of both qualitative and quantitative data, how are they collected and analyzed, and the sequence and priority of those data throughout the different stages of the study.

Yet, Creswell (2014) pointed out the existence of the features of both qualitative and quantitative research features in a mixed-method single study i.e. in qualitative research a researcher needs to position himself, collects participants meaning, focus on a single concept or phenomena, brings personal values into the study, studies context or setting of the participants, validates the accuracy of findings, makes interpretation of data, creates an agenda for change, and collaborates with the participants. While in a quantitative research, a researcher uses tests or verifies and explains theories, identifies variables to study, relates variables in

questions, uses standards of validity and reliability, observes and measure numerical information, uses unbiased approaches, and employs statistical procedures. On the contrary, Fraenkel, Wallen, and Hyun (2011) argued that the main difference is not the instrument used, nor the data analysis conducted, it is the “emphasis on thick rather than selective description”. Different strategies of inquiry can be used in mixed-methods research. Creswell (2014), pointed out that sequential, concurrent, and transformative strategies of inquiry are the most dominant.

3.4.1.2 Why Mixed Method Research?

A large body of literature pointed out several advantages of using mixed-method research. Studying multiple sets of data indicated in the study design, thoughtfully and strategically, using different research methods and epistemologies, will provide the researcher with a profound understanding of the problem while testing the various theoretical models (Fraenkel, Wallen & Hyun 2011). According to Creswell (2012), a mixed-method research is used to better understand and rationalize the research problem.

Greene, Caracelli, and Graham (1989) pointed out another advantage of using mixed method over either qualitative or quantitative which is triangulation that allows the researcher to look for endorsement and convergence of the research results, complementarity by examining and strengthening coinciding phenomena, finding contradictions, and expanding the study’s breadth and scope. Cross-validation can be achieved when qualitative and quantitative data interpretation converges (Fraenkel, Wallen & Hyun 2011). Otherwise, further investigation will be required.

The third advantage of using mixed method research is the combination of the strengths drawn from both qualitative and quantitative methods and the limitations of their identified weaknesses Creswell (2014). In this regard, Johnson and Christensen (2012) stated that using

the mixed method approach produces an inclusive design with appreciative strengths and non-overlapping weaknesses.

Fraenkel, Wallen, and Hyun (2011) and Creswell (2014) discussed a fourth advantage i.e. a mixed method helps researchers explain and thoroughly describe relationship between variables. For example, qualitative data may help in understanding the correlation between quantitative data. Or when the qualitative data is used to identify the variables that are going to be studied quantitatively.

Moreover, the fifth advantage of mixed method research was argued by Johnson and Christensen (2012) that is the researcher's provision of the ability to address more than one purpose. Hence, different types of knowledge can be obtained. Creswell et al. (2011) stated that a multiphase mixed method research is used when the researcher wants to tackle a set of incremental research questions that helps to achieve one objective. The use of multiphase mixed method research strengthens the researcher's argument. Yet, a researcher needs to distinctly identify the phases of the study.

Therefore, bringing these advantages to the context of this research, the researcher conducted the multiphase mixed methods research that allowed for collecting both qualitative and quantitative data and led for better understanding of the research problem i.e. the impact of learning Computer Programming on high school students' cognitive abilities development. Consequently, convergence, differences and combinations, between quantitative and qualitative data interpretation results in endorsements and complementarity. i.e. based on the research design, one can see that the questionnaire quantitative data will complement and converge with the interview qualitative data. Similarly, the CT Cognitive Abilities Measure quantitative data can also be endorsed and triangulated by the observation qualitative data to study the cognitive abilities development of students. Such combinations, will help in describing the relationships and correlations between the variables; learning Computer

Programming, gender, Cognitive Style Index, and students' cognitive abilities, perception, and behaviors.

Finally, the mixed method multiphase design has heled in answering the incremental sub-questions which answers are necessary to answer the main research question and therefore achieve the aim of this research.

3.4.1.3 Challenges of Mixed Method Research

Fraenkel, Wallen, and Hyun (2011) and Creswell (2014) pointed out challenges of mixed method research including, but not limited to:

- Extensive data collection and analysis
- Time consumption
- High cost
- Expertise needed for both qualitative and quantitative research methods that may need time to develop
- Skills, potential and ability needed to visualize the mixed method research flow of activities

These challenges can be overcome if more than one researcher work on the mixed method research (Fraenkel, Wallen, & Hyun 2011).

However, for this particular research, the main challenge lied in retaining coherence between the different stages of the research due its intricate design. Therefore, the researcher's tied together the different phases of the study (Creswell 2012) using a thoughtful design, and maintained a clear relationship between the variables within the study that helps in simplifying analysis and interpretation of results.

3.4.2 Validity and Reliability

Researchers have the option to use an existing tool, develop a new tool, or adapt an existing tool to measure a specific characteristic (Johnson & Christensen 2008). However, the researcher needs to be aware of any measurement error i.e. the difference between a true score and a measured one. Systematic errors that are usually present whenever an instrument is used must also be taken into consideration.

According to Johnson and Christensen (2008) validity and reliability are the most important properties that need to be considered before choosing to use any measurement instrument. Creswell (2014) also confirmed that a sound research must indicate the validity and reliability of the instruments and test scores. Attention to validity and reliability will minimize their impact on the obtained results (Cohen, Manion, & Morrison 2007). Though, reliability is a precondition for validity (Cohen, Manion, & Morrison 2007).

According to Creswell (2014), when a researcher combines or adapt and instrument in a research study, its original validity and reliability are not necessarily maintained. Hence, it is important to establish them again within the current study.

A large body of literature defined both terms differently. In brief, reliability is defined as “the consistency and the stability of the test scores” (Johnson & Christensen 2008). Test-retest, equivalent form, internal consistency, and interscorer are different types of reliability. Yet, test-retest and internal consistency are mostly reported by high quality research (Johnson & Christensen 2008).

Validity is defined as the test’s fitness to the purpose of the research (Cohen 2007, Creswell 2012, Johnson & Christensen 2012). Researchers suggested different methods to ensure the different types of validity. Yet, for this study, content validity, criterion-related validity, construct validity, and face validity can be considered for the different instruments that are

used for the propose of this research.

Therefore, the researcher of this study had worked to prove the instruments' validity and reliability through different methods. Further details will be elaborated within the discussion of each instrument later in this chapter.

3.4.2.1 Threats to internal and external validity

Creswell (2012) argued that a quasi-experiment is exposed to more threats of internal validity than an experiment due to the non-random assignment of participants to the groups. In addition to internal validity, a quasi-experiment may also include uncontrolled selection factors that might impact the individual assignment. Other threats can be treatment threats and “pre- and posttest history, testing, instrumentation, and regression”.

Cohen, Swerdlik, and Phillips (1996) stated that the main purpose of the experimental design is to control the conditions that would influence the true effect of the independent variables. While quasi-experiments are used when the researcher has no control over some conditions. Though, the nonrandom assignment of the subjects in the quasi-experiment for this research might be the major threat to the validity.

Campbell and Stanley (1963) cited in Cohen, Swerdlik, and Phillips (1996) stated that internal validity is concerned with the question “Do the experimental treatments, in fact, make a difference in the specific experiments under scrutiny?”. While the external validity is concerned with the question “Given these demonstrable effects, to what populations or settings can they be generalized?”. They have indicated a list of threats to both internal and external validity. Therefore, the following seem to be the most important ones to consider.

Threats to internal validity were identified as follows:

- The existence of other factor affecting the students' cognitive abilities development during the period between the pre test and posttest. Studying other courses in addition to the social and

emotional development factors might have affected the cognitive development levels. In order to minimize the impact of this threat, the researcher was keen to collect different data throughout the period between the pre test and posttest such as observations and interviews. This helps in capturing the status of the students' cognitive abilities development in shorter time slots.

- The time laps between the pre test and posttest might not be enough to achieve noticeable improvement on the students' cognitive abilities. Yet, students' maturation might also affect the results. Wasserman (2010) suggested a minimum of 3 months for normative gradation. Hence, the researcher made sure the posttest takes place enough time after the pre test by 19 weeks i.e. around 4 months and a half.
- The level of concentration during class observations was varying. Therefore, there might be some considerable notes that were not documented. Hence, missing information. To ensure minimal impact of this threat, the researcher had collected an amount of data that is enough to answer the corresponding research questions i.e. data saturation.
- The fact that the Java Programming course was an elective course in the second school. Therefore, students' selection of the course might be based on their high cognitive abilities and confidence that programming is their preferred domain of study. The researcher is fully aware of this threat and is able to record the students' cognitive abilities progression rather than a capture of a single value at a single point of time. Working on analyzing the difference between pre test scores and posttest scores rather than a single test score will minimize the effect of this threat.

On the other hand, one threat to external validity was identified that might affect the research results' generalizability which is:

- Lack of representativeness of the population. Although, the research was targeting high school students, the two schools were conducted on Grade 11 students which might alter the generalizability of the study results. However, due to the nature of the grades 10 and 12

programs and its incompatibility with the research objective, this threat seems to continue existing. Yet, according to Pilliner (1973), external validity cannot be achieved without internal validity. Therefore, the researcher paid adequate efforts to overcome the threats to internal validity and therefore improve the external validity.

3.4.3 Site and Subject Selection

Literature had identified different factors for the site selection. According to Patton (1990) and Creswell (2012) an “information rich” site is a major factor that determines the site selection. Creswell (2012) stated that the researcher’s ability to access the site determines if the issue can be studied or not. Thus, the researcher chose to undertake the research in two different sites. Both sites meet the researcher’s requirements in terms of course offerings and accessibility to the appropriate data. The two sites offer the Java Computer Programming course for a group of grade 11 students. Additionally, the researcher could obtain a written approval from the director of the first site and the principal of the second site who had facilitated the researcher’s work and provided open access to the needed data.

The first site in which the research was conducted is a reputable semi-government school system that offers career-based-technical education for Emirati-youth. It was founded in 2005 through Royal decree of His Highness Sheikh Khalifa bin Zayed Al Nahyan, President of the United Arab Emirates. The system consists of fourteen schools across the UAE and provides a high quality set of core subjects along with cluster-based courses for grades 9 to 12.

Generally, apart from the Advanced Science Program (ASP) that starts for an elite group of students in grade 9 upon acceptance for joining the system, the school system allows the other grade 9 students to choose a cluster among four; Engineering Science (ES), Applied Engineering (AE), Computer Science (CS), and Health Science Technology (HST). Cluster’s

selection is based on the student's preference and interest. Each cluster receives a structured program that consists of a different matrix of courses. Yet, some common courses are offered in between.

The CS course is common for all students in the four clusters through grade 10 to 12. However, in grade 11, the ES and the CS students are offered the Object Oriented Programming course i.e. Java Object Oriented Programming. While AE and HST students are offered a general CS course that contains basic components of procedural programming in addition to other different CS topics.

A written approval to undertake the research and access the available data was obtained from the director of the high school system. Gratefully, the director offered access to the classes, teachers, and students. As well as any necessary data that were needed to complete this research. The approval of the director is attached in appendix 1.

The second site is a private school in Abu Dhabi in the UAE that offers the american curriculum based on the Common Core State Standards (CCSS) from KG1 to Grade 12. Additionally, the school offers the Advanced Placement (AP) courses according to College Board offerings. One of the AP courses offered is the Computer Science A course that is basically about Java programming. The school has approximately 1990 student from different nationalities, 123 students are in the high school i.e. grades 9 to 12. The school prepares students for different external exams including SAT, MAP, AP, and TOEFL. According to latest inspection report published by Abu Dhabi Department of Education and Knowledge (ADEK) (ADEK 2017, pg. 7), the school's "curriculum offers wide range of extra-curricular activities reflecting students' interests as well as curricular choices, especially in the higher grades". The school was rated as 'Very Good' for the academic year 2018-2019 (ADEK 2019).

The school offers a set of elective courses for grades 10 to 12. Java Object Oriented Programming course 'Java Programming' is one of them. The course is offered as a pre-AP course for the Computer Science A AP course.

Similarly, a written approval was obtained from the principal of the school to undertake the research in the school site. The principal was fully cooperative and offered full support and access to the Java programming lessons, teacher, and students. The approval is attached in appendix 2.

3.4.4 Sampling

Cohen (2007) stated that the appropriateness of the sampling strategy is as important as the suitability of the methodology in a research. A researcher should decide on the sampling strategy based on the sampling size, the representativeness of the sample, and the accessibility to the sample (Cohen 2007).

Researchers argued the appropriate sample size for a research. Yet, they agreed that a larger sample would increase the research reliability and enable more acceptable results of the statistical analyses (Cohen 2007). Johnson and Christensen (2012) suggested different sampling techniques used for quantitative research: random and non-random. Random sampling includes: simple random sampling, systematic sampling, stratified random sampling, proportional stratified sampling, disproportional stratified sampling, cluster random sampling, one stage cluster sampling and two stage random sampling. While nonrandom sampling techniques include: convenience sampling, quota sampling, purposive sampling, and snowball sampling. While in qualitative research, a researcher can use comprehensive sampling, maximum variation sampling, homogeneous sampling, extreme case sampling, typical case

sampling, critical case sampling, negative case sampling, opportunistic sampling, and mixed purposeful sampling (Johnson & Christensen 2012).

Johnson and Christensen (2012, pg. 373) indicated that sampling in mixed-method research is based on two criteria: time orientation and sample relationship. A researcher can choose one or a combination of eight sampling designs i.e. “(1) identical concurrent, (2) identical sequential, (3) parallel concurrent, (4) parallel sequential, (5) nested concurrent, (6) nested sequential, (7) multilevel concurrent, and (8) multilevel sequential.”

Hence, purposive sampling was used for the quasi-experiment, due to the shared characteristics between the participants (Johnson & Christensen 2012). Similarly, purposive sampling was used for the CT Cognitive Abilities Measure, Cognitive Style Index test, and the questionnaire. However, one limitation of purposive sampling is its restricted ability to generalize to a population based on a single research study (Creswell 2012, Johnson & Christensen 2012). The researcher had avoided this limitation by triangulation of data that was obtained by comparing the results obtained from school 1 and school 2.

Convenience sampling was used for the interviews of the first school. The researcher had communicated with the students through an official consent form explaining the study, its purpose, risks of participation and other details as stated in the literature. Only those who have agreed to participate were interviewed.

On the other hand, comprehensive sampling was used for the observation and interviews of the second school. An advantage of this sampling method is its high representativeness. Yet, it is sometimes expensive as described by Johnson and Christensen (2012), which does not apply to the context of this research due to the access to the participants based on the consent provided by the school principals.

The sample design depends on the sampling method and size as shown in table 3.2 above.

Table 3.4 demonstrates a description of the population in schools 1 and 2.

| Study | Population | Male | Female |
|--------------|-------------------|-------------|---------------|
| School 1 | N = 770 | 463 (60%) | 307 (40%) |
| School 2 | N = 29 | 17 (59%) | 12 (41%) |

Table 3.4 Population Description

Tables 3.5 and 3.6 demonstrate the description of students in the experiment and the control groups for both studies in the quasi experiment.

| Quasi Experiment | | | |
|-------------------------|-------------------|------------------|------------------|
| Group | Total | Male | Female |
| Experiment Group | 127 (17%) | 58 (46%) | 69 (54%) |
| Control Group | 643 (83%) | 405 (63%) | 238 (37%) |
| Total | 770 (100%) | 463 (60%) | 307 (40%) |

Table 3.5 School 1 Experiment and Control Groups' Description

| Quasi-Experiment | | | |
|-------------------------|------------------|-----------------|-----------------|
| Group | Total | Male | Female |
| Experiment Group | 8 (28%) | 6 (75%) | 2 (25%) |
| Control Group | 21 (72%) | 11 (52%) | 10 (48%) |
| Total | 29 (100%) | 17 (59%) | 12 (41%) |

Table 3.6 School 2 Experiment and Control Groups' Description

Tables 3.7 and 3.8 demonstrate a description of the sample for each phase of the research including CT Cognitive Abilities Measure, Cognitive Style Index test, questionnaire, observation, and interviews.

| Method | Population N | Sample n | Male | Female | Sampling Technique |
|---|--------------|-----------|----------|----------|--------------------|
| CT Cognitive Abilities Measure (Quantitative) | 770 (100%) | 127 (17%) | 58 (46%) | 69 (54%) | Purposive |
| Cognitive Style Index test (Quantitative) | 770 (100%) | 127 (17%) | 58 (46%) | 69 (54%) | Purposive |
| Questionnaire (Quantitative) | 770 (100%) | 127 (17%) | 58 (46%) | 69 (54%) | Comprehensive |
| Observations (Qualitative) | 770 (100%) | 127 (17%) | 58 (46%) | 69 (54%) | Convenience |
| Interviews (Qualitative) | 770 (100%) | 20 (2.6%) | 8 (40%) | 12 (60%) | Convenience |

Table 3.7 School 1 Mixed methods sampling techniques

| Method | Population N | Sample n | Male | Female | Sampling Technique |
|--|--------------|-----------|----------|----------|--------------------|
| CT Cognitive Abilities Measure (Quantitative) | 29 (100%) | 29 (100%) | 17 (59%) | 12 (41%) | Purposive |
| Cognitive Style Index Questionnaire (Quantitative) | 29 (100%) | 29 (100%) | 17 (59%) | 12 (41%) | Purposive |
| Questionnaire (Quantitative) | 8 (100%) | 8 (100%) | 6 (75%) | 2 (25%) | Purposive |
| Observations (Qualitative) | 8 (100%) | 8 (100%) | 6 (75%) | 2 (25%) | Comprehensive |
| Interviews (Qualitative) | 8 (100%) | 8 (100%) | 6 (75%) | 2 (25%) | Comprehensive |

Table 3.8 School 2 Mixed methods sampling techniques

3.4.5 Data Collection Instruments

Johnson and Christensen (2008) pointed out a list of assumption a researcher needs to consider before deciding on the instruments that are going to be used in his/her research including:

- Traits of individual can be quantified,
- A single test is not enough to decide about an individual's trait,
- There are different sources of errors in any measurement,
- Non-test related attitudes can be predicted based in test-related attitudes,
- Unbiased tests require extra work,

- and Standardized tests developed by experts can be used when they are administered and analyzed by professionals

The assumptions are found to be applicable to the context of this study.

In addition to those assumptions, Cohen, Manion, and Morrison (2007) pointed out that a researcher needs to recognize the level of culture in order to be able to identify the most appropriate instrument to use. Figure 3.7 demonstrates the different levels of culture and the instruments used from different aspects; easiness to uncover, tangibility, superficiality, and the position of the researcher as an observer.

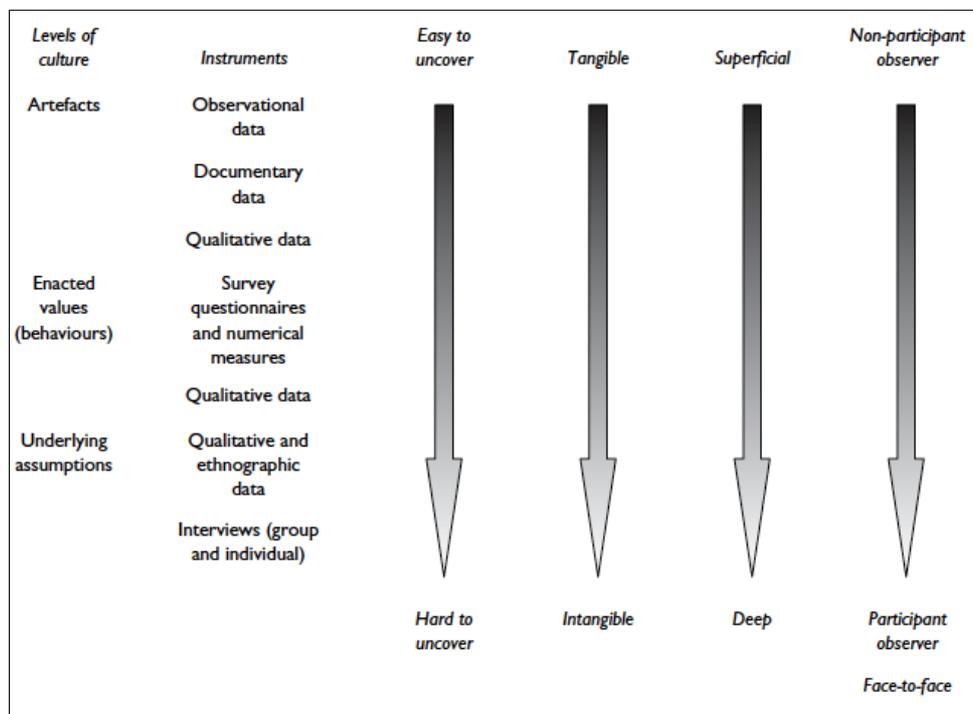


Figure 3.7 Levels of Organizational Cultures Adapted from Cohen, Manion, and Morrison (2007)

Therefore, the selection of the data collection methods relied essentially on the structure shown in figure 3.7. An observation form was used to collect tangible data that is easy to uncover. The test and the mixed questionnaire were used to access quantitative and qualitative data that seem hidden and/or unclear to the researcher. While interviews were used to uncover hidden intangible data that required a one-to-one interaction.

On another hand, Creswell (2012) indicated that a researcher can use an existing instrument, adopt an existing instrument and modify it, or develop one from scratch. The researcher of this study had adapted standardized tests to develop and construct the cognitive abilities' test, construct the mixed-questionnaire, the observation tool, and the structured interview protocol. additionally, an existing test is used to identify the Cognitive Style Index as elaborated below.

Johnson and Christensen (2008) defined measurement as “Assigning symbols or numbers to something according to a specific set of rules”. They stated that variables such as dyslexia, gender, and intelligence can be investigated through quantitative measurements.

Four-level schemes of measurement were discussed: Nominal, ordinal, interval, and ratio. The nominal scale measurement is used when labels, number or classifications are used to categorize variables. Hence, it is also called categorical variables. In this research, students are classified according to their gender. The variable i.e. gender is considered categorical variable.

The ordinal scale of measurement is a rank-order scale that ranks a variable's values with no indication to the difference between the different values.

The interval scale of measurement has “equal intervals of distances between adjacent numbers”. This scale of measurement is used to identify the students' Cognitive style index. Further details of the interval scale will be elaborated in another section of this chapter.

The highest level of quantitative measurement is the ratio scale. It is a combination of ordinal scale and the interval scale. However, it “has a true zero point”. That is when the characteristic being measured is absent. Which does not apply to any of this research measurements.

Cohen, Swerdlik, and Phillips (1996) had identified the difference between testing and assessment. Testing is defined as the process of measuring variables using different means of instruments. While, assessment is defined as the collection and integration of data to make a particular evaluation. Hence, the researcher used testing to identify different variables such as

cognitive abilities and Cognitive Style Index. While interviews and observations are used to assess students' reflection on their learning experiences.

The data was collected in a sequence that would fulfill the objectives of the research and make sense of the data that is being collected from each phase to answer the research questions in chronological order. At the beginning of the research, the researcher had conducted the Cognitive Style Index test to be able to categorize students into different cognitive styles. This categorization had helped in generating the factorial design of the studied groups. Then, a pre test was conducted for students to identify their cognitive abilities at the beginning of quasi experiment. Afterward, observations were conducted to observe students' cognitive behavior. By the end of the quasi experiment time, the questionnaire was sent and interviews were conducted. Finally, students had taken the posttest to measure the achieved development in their cognitive abilities after studying the Java Object Oriented Programming course. It is also worth mentioning that the instruments were developed using the English language as it is the language of instructions used in both schools. Figure 3.8 demonstrates the sequence of data collection based on the details shown in table 3.2.

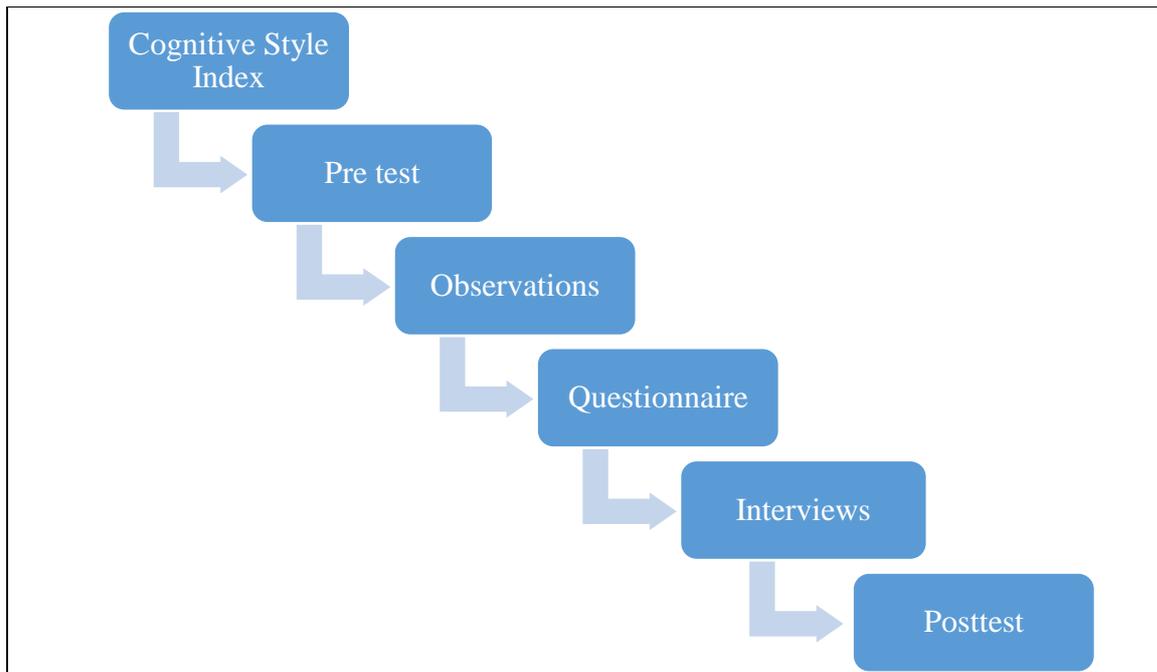


Figure 3.8 Sequence of data collection

The most important aspect to be considered when selecting a test or a measurement instrument is its accuracy to provide data about the intended variable (Johnson & Christensen 2008). Creswell (2014) pointed out that a researcher need to report the development of the instruments, and the items and scales they include. There are six major methods for data collection: Tests, Questionnaires, Interviews, Focus Groups, Observation, and Existing or Secondary Data (Johnson & Christensen 2012). According to Johnson and Christensen (2012), a thoughtful mix of using these methods is fundamental to high quality mixed method research. Hence, the researcher chose sensibly to consider using intermethod and intramethod mixing i.e. more than one method is used to collect different types of data and one method might also be used to obtain both qualitative and quantitative data. Further details are demonstrated in the following sub sections.

The instruments used in this research were meant to answer the main research questions as shown in the research design and to specifically evaluate the cognitive abilities that underlie learning computational thinking and programming. According to Román-González, Pérez-

González and Jiménez-Fernández (2017), computational thinking is related to the following cognitive abilities:

- Fluid Reasoning (G_f)
- Visual Processing (G_v)
- Short-Term Memory (G_{sm})

Table 3.9 demonstrates those abilities as Broad Stratum II abilities as stated in the CHC theory, and their corresponding Conceptual Group, Narrow Stratum I Abilities, and Definitions. The narrow stratum I abilities highlighted in grey represent the narrow abilities that can be assessed through cognitive and academic abilities tests (Flanagan and Dixon 2014). Therefore, the CT Cognitive Abilities Measure that was developed by the researcher aimed to assess narrow stratum I abilities.

| Conceptual Group | Brood Stratum II Ability | Narrow Stratum I Ability | Definitions |
|-----------------------|--|---|---|
| Reasoning | Fluid Intelligence (Gf) Reasoning | Induction (I) | Ability to discover the underlying characteristic (e.g., rule, concept, process, trend, class membership) that governs a problem or a set of materials. |
| | | General Sequential Reasoning (RG) | Ability to start with stated rules, premises, or conditions, and to engage in one or more steps to reach a solution to a novel problem. |
| | | Quantitative Reasoning (RQ) | Ability to inductively and deductively reason with concepts involving mathematical relations and properties. |
| Memory and Efficiency | Short-Term Memory (Gsm) | Memory Span (MS) | Ability to attend to and immediately recall temporarily ordered elements in the correct order after a single presentation |
| | | Working Memory (MW) | Ability to temporarily store and perform a set of cognitive operations on information that requires divided attention and the management of the limited capacity of short-term memory |
| Sensory | Visual Processing (Gv) | Visualization (Vz) | The ability to perceive complex patterns and mentally simulate how they might look when transformed (e.g., rotated, changed in size, partially obscured). |
| | | Speeded Rotation(Spatial Relations; SR) | The ability to solve problems quickly by using mental rotation of simple images. |
| | | Closure Speed (CS) | Ability to quickly combine disconnected, vague, or partially obscured visual stimuli or patterns into a meaningful whole, without knowing in advance what the pattern is. |
| | | Flexibility of Closure (CF) | Ability to find, apprehend, and identify a visual figure or pattern embedded in a complex visual array, when knowing in advance what the pattern is. |
| | | Visual Memory (MV) | Ability to form and store a mental representation or image of a visual stimulus and then recognize or recall it later. |
| | | Spatial Scanning (SS) | Ability to accurately and quickly survey a spatial field or pattern and identify a path through the visual field or pattern. |
| | | Serial Perceptual Integration (PI) | Ability to apprehend and identify a pictorial or visual pattern when parts of the pattern are presented rapidly in serially or successive order. |
| | | Length Estimation (LE) | Ability to accurately estimate or compare visual lengths and distances without using measurement instruments. |
| | | Perceptual Illusions (IL) | Ability to resist being affected by perceptual illusions involving geometric figures. |
| | | Perceptual Alternations (PN) | Consistency in the rate of alternating between different visual perceptions. |
| Imagery (IM) | Ability to vividly mentally manipulate abstract spatial forms. (Not clearly defined by existing research.) | | |

Table 3.9 Broad and Narrow Stratum Abilities

3.4.5.1 Cognitive Style Index (CSI) Questionnaire

Creswell (2012) pointed out that finding a suitable instrument to adopt, that measures the exact research independent and dependent variables, is not an easy task. However, he suggested that if an instrument is found to be suitable to the research objectives, it has to be widely cited by researchers, reviewed and evaluated, has appropriate validity and reliability, has procedures of recording data that fit the research objective, and has accepted scales of measurements.

Additionally, the instrument should be used by researchers in less than 5 years from the current date of the research.

The CSI is the individual's preference to gather, process, and evaluate data. Identifying the CSI of the participants, along with the demographic data collected from the CT Cognitive Abilities Measure about students' choices, would potentially help the researcher address the research sub question 3 on how the cognitive style may affect students' choice of studying computer programming. Also the CSI questionnaire will also help answer the fourth sub question about how gender differences may affect students' choices, cognitive styles and perceptions when they learn computer programming. The CSI questionnaire is a psychometric measure that meets the criteria mentioned earlier. It has been successfully used by students and professional groups and proved useful in different situations (Allinson & Hayes 2012). The CSI is attached in appendix 3.

The researcher was able to communicate via email with authors of the Cognitive Style Index. Professor John Hayes - Emeritus Professor of Change Management in Leeds University Business School in the United Kingdom replied to the email, copying Professor Allinson, with the approval. He also attached the test, a guide on how to use it, a manual, and a scoring guide. In his reply, Professor Hayes stressed on that the test is:

1. used purely for academic research and not in any commercial application.
2. not passed on to anyone other than your research subjects. If you know of anyone else who wishes to use it in research, please ask them to contact us directly.

A copy of the email is attached in appendix 4.

The questionnaire has 38 elements, each has three options: 'true', 'uncertain', and 'false'. Each response is assigned a value that add up to 76. Participants are asked to answer the questions quickly as a response of their first reaction. According to the test authors, the test requires 10-

15 minutes to be completed. Construct, concurrent, and predictive validity as well as the test reliability are evident. Figure 3.9 demonstrates the continuum of the cognitive style as indicated by the authors Allinson and Hayes (2012).

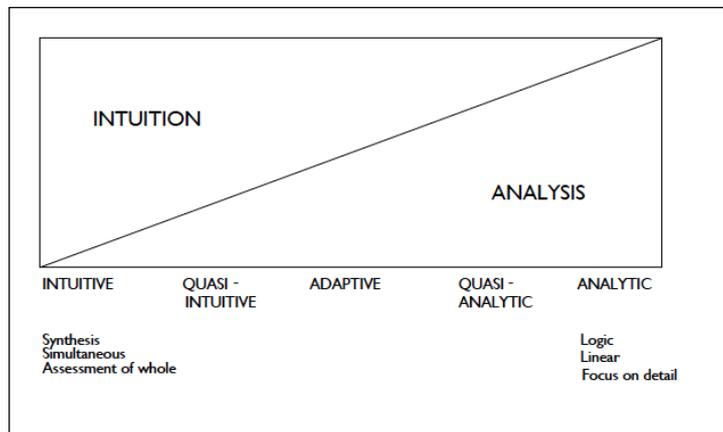


Figure 3.9 A continuum of Cognitive Style. Adapted from Allinson and Hayes (2012)

On another hand, the reliability of the Cognitive Style Index was proven by Allinson and Hayes (1996). Test-retest reliability and internal consistency of the same test was measure in more than 100 research studies. The test-retest reliability ranged between 0.78 and 0.92. Similarly, the internal consistency ranged between 0.32 and 0.92 achieving a median of 0.84 which appeared to be excellent for the authors. Such results indicate that the test is consistent and reliable.

Similarly, the concurrent validity of test was also proven (Allinson & Hayes 1996). That means the questionnaire should be capable of discriminating between groups which are presumed to differ in cognitive style. Areas that have received particular attention from researchers are gender, job level, occupation, culture and entrepreneurship. Hence, the researcher will use it to differentiate between males and females’ cognitive styles.

According to the questionnaire developers of the Cognitive Style Index, “there was shortage of valid and reliable instrument which can easily measure the cognitive style”. Hence, the test

“was developed with the idea that it will measure single continuum cognitive style means that it is uni-dimensional in nature to measure the whole/part processing dimension of cognitive style which is intuition and analysis” (Allinson & Hayes 1996).

3.4.5.2 CT Cognitive Abilities Measure (CT-CAM)

According to Johnson and Christensen (2012), tests are used to measure self-perceptions, aptitudes, and performance of participants. Standardized tests are commonly used in educational research. However, experimental researchers need to generate and construct their own tests that are uniquely used to achieve the research objective. Yet, they need to verify its reliability and validity (Johnson & Christensen 2012). Tests are classified to: tests that facilitate interpretation of cognitive performance and tests that provide a foundation for organizing assessments for individuals suspected of having a learning disability. The first type is the one that will be utilized for the purpose of this research.

Cohen (2007) pointed out the strength of using tests as powerful tools to collect data. Yet, he suggested that a test should adhere to a set of questions such as what are we testing and whether they are norm referenced or criterion referenced.

Therefore, the researcher had developed the CT Cognitive Abilities Measure that included twelve sections to assess the development of the identified cognitive abilities as different constructs: Induction (I), General, Sequential Reasoning (RG), Quantitative Reasoning (RQ), Memory Span (MS), Working Memory (MW), Visualization (Vz), Speeded Rotation (Spatial Relations; SR), Closure Speed (CS), Flexibility of Closure (CF), Visual Memory (MV), Spatial Scanning (SS), Serial Perceptual Integration (PI). Each section consisted of four questions of four different difficulty levels. Hence, CT-CAM consisted of 48 different questions. The same test is used as a pre test and a posttest. The CT-CAM is an essential instrument for this research

that will help the researcher answer the main research question about the extent to which learning Computer Programming would impact high school students' cognitive abilities development in the UAE. The answer to the main research question will be supported by the data that will also be collected from the class observations.

The CT-CAM is heterogeneous, multidimensional and was primarily based on Cattell-Horn-Carroll (CHC) theory; the most recent comprehensive theory that explained the structure of the cognitive abilities. Ambrósio, Xavier, and Georges, (2014) have developed a cognitive testing tool based in the CHC framework of intelligence. Yet, they have used a special platform that is not yet available to the researcher.

Additionally, the development of the CT-CAM was also adapted from the “Woodcock-Johnson IV Tests of Cognitive Abilities” (WJ IV) which is a full battery assessment that is used as pre/post measure of cognitive skills' acquisition and cognitive abilities in the domains of Picture Vocabulary, Spatial Relations, Memory for sentences, Visual-auditory Learning, Blending, and Quantitative Concepts. The CT-CAM questions also involved elements based on different standardized tests that are used to assess individual cognitive processes. For example, “Wechsler Adult Intelligence Scale-Fourth Edition (WAIS IV)”, the general intelligence test, that is used to assess the intellectual functional and memory for adolescents and adults. In addition to the standardized Scholastic Assessment Test SAT-Reasoning that is used to assess the students reasoning, analytical and problem solving skills (Collegeboard 2018).

An online platform, namely flexiquiz.com, was used to administer the test. This platform provides users with many features to create and configure the test. One of its main features is the time limit not only for the whole test but also for every single question. This feature was extremely important for Working Memory (MW), Memory Span (MS), and Visual Memory

(MV) questions where test takers must look at a specific image before it disappears, then answer the following questions. A copy of the test questions is attached in appendix 5.

In order to measure the CT-CAM reliability, the test was piloted and given initially to a group of students (n=40). Two testing sessions were conducted to establish the test-retest reliability. The same test form was used for both sessions and the correlation coefficient i.e. reliability coefficient (Johnson & Christensen 2008) between the results of the two tests was strong and positive and is equal to 0.82. Further details about the results of the pilot test will be elaborated in Chapter 4. However, the reliability coefficient value might be affected by the time lapse between the two sessions which was about 25 days.

Additionally, internal consistency reliability was also established through split-half reliability measure. Data was collected from the first session of the test pilot study. The purpose of this activity was to ensure that each construct was measured appropriately. The test questions were divided by content and difficulty into two halves. Tests were scored and the correlation coefficient Cronbach's alpha (r_{σ}) was calculated and was equal to 0.93.

In order to ensure the test's construct, content, and face validity, the test was reviewed by two experts. Both work as curriculum specialists in the ministry of education. One holds a PhD degree in education and the other holds a Masters degree in CS. After a careful review of the test, the reviewers had shared their feedback with the researcher and the researcher had discussed those recommendations with them and amended the test questions accordingly.

3.4.5.3 Observation

Cohen (2007) and Johnson and Christensen (2012) stated that observations are used to gather data on verbal and non-verbal behavior in real-life situations and events happening in social settings. Johnson and Christensen (2012) stated that observing students' behavior in the

classroom is called naturalistic observation since it reflects a natural behavior. Fraenkel, Wallen, and Hyun (2011), stated that Jean Piaget had achieved much of the conclusions about children's cognitive development in the formal operational stage through naturalistic observations. According to them, a naturalistic observer makes no inference to influence the variables or control the individuals' behavior, hence the name 'Onlooker', but observe and record what is naturally happening. The purpose of the observation was explained to the participants and they were aware of when it is happening and who is making it.

Quantitative observation is used to obtain reliable data following a standardized form that involves who is observed, what is observed, when and where observations are happening, and how observations are done. While qualitative observation is intended to observe a phenomena and take notes of all relevant details in a natural unstructured setting. A researcher should follow the guidelines for naturalistic qualitative observations that are similar to those of the quantitative observation (Johnson & Christensen 2012).

The researcher was unobtrusive and acted as a 'complete observer' (Johnson & Christensen 2012) without affecting or interfering in what is going to happen and will use an observation form/checklist that has a structured observation schedule for the quantitative data. Additionally, notes were taken about students' reactions and interactions during CT lessons.

The main aim of the observation is to support the answer of the main research question: To what extent does learning computer programming impact the development of high school students' cognitive abilities in the UAE? As well as to find an answer to the second sub question: What cognitive activities and practices may occur in the classroom during a computer programming lesson?

Additionally, to collect data about the students' cognitive activities that reflect their cognitive abilities and then correlate it to the students' perceptions that are captured through the

questionnaire at a latter stage.

Following the observation construction protocols suggested by Johnson and Christensen (2012), the observation form was composed and included 4 sections with different items in each one to collect both quantitative and qualitative data. The sections are: setting's description i.e. date, time, location, grade level, number of students, and the lesson's title, progression of cognitive activities, teacher's instructions, and records of cognitive activities and behaviors. The observation protocol is attached in appendix 6.

Time interval sampling or interval recording was used to record the progression of the cognitive activities. That is the record of the occurrences of the different cognitive activities in 9 time intervals during the 45 minutes' lesson with 5 minutes' span for each time slot. Also, interval recording was used for the teacher' instructions and the cognitive activities to record an event after it had been occurred (Johnson & Christensen 2012). Besides, qualitative data was collected for progression of cognitive activities, teacher's instructions, and records of cognitive activities where the researcher had written extensive field notes about each item to elaborate on the quantitative apprehended data.

According to Cohen (2007) there are two types of validity for observation research; external validity and internal validity. The external validity is about the individual distinctive nature of the participants that leads to question about if this research can still be applicable on other situations. While internal validity of the method is about the researcher's judgment that might be affected by his/her involvement in this piece of research. Accordingly, threats to validity and reliability might be caused by the researcher's unawareness of antecedent events and details, the subjects' unnatural behavior due to the presence of the researcher, the researcher's attachment with the group. Therefore, in order to avoid those threats, Denzin (1970) cited in Cohen (2007), suggested that triangulation of data and methodologies could be used to overcome those threats.

According to Cohen (2007), the pilot of the observation help the researcher decide on what is the focus of the observation, the frequency of the observation i.e. the time interval that needs to be considered, the length of the observation, and what needs to be considered as an evidence. The validity and reliability of the observation instrument was assured through a pilot study. Intra-rater Correlation Coefficient (ICC) was calculated and found to be equal to 0.92 which indicates a strong correlation and hence proven reliability. Furthermore, to ensure the validity, the observational categories were thoughtfully studied and made sure that they are appropriate, unambiguous, and clearly address the objective of the research. Consequently, the observation form was informed and made ready to be used for the formal observations. All potentially relevant phenomena were observed and extensive notes were written.

3.4.5.4 Questionnaire

Johnson and Christensen (2012) confirmed that questionnaires are used to gather information from the participants as self-reporters on behavior, experience, attitudes, opinions, knowledge, background and demographics, where retrospective, current, and prospective are clearly identified as the time dimension. Johnson and Christensen (2012) had thoroughly discussed fifteen questionnaire construction principles including, but not limited to: alignment of the questionnaire elements with the research objectives, use of language, and the use of multiple items to measure abstract concepts.

The questionnaire was used to investigate how students in the experiment group would reflect on their learning experience after studying the Java Object Oriented Programming course by identifying their perceptions in order to answer the first sub question. Also the questionnaire will help answer the fourth sub questions about how gender may affect students' perceptions. According to Johnson and Christensen (2012), questions in a questionnaire may focus on behaviors, experiences, attitudes, opinions, beliefs, values, knowledge, process, and

background and demographics. Hence, the researcher chose to use a questionnaire to answer the first sub-question about students' perceptions of their experience when they learn computer programming? and the fourth sub-question about the effect of gender differences on students' choices and perceptions when they learn computer programming.

Principles of questionnaire construction were stated by Cohen (2007) and confirmed by Johnson and Christensen (2012). The principles include, but not limited to:

- deciding on the questionnaire purpose and how it is aligned with the research objective,
- understanding of participants,
- using of clear, precise, and language,
- avoiding of barreled and double negative questions,
- considering of the various types of responses such as checklists, rating scales, and open responses
- piloting a test study
- reflecting on the questionnaire as a consequence,
- and administering the final instrument.

Furthermore, a checklist for questionnaire construction was considered (Johnson & Christensen 2012). The checklist suggested by Johnson and Christensen (2012) included 20 items to ensure construction appropriateness, questions' accuracy, questionnaire appearance, Questions' clarity, formatting and closing. A similar checklist was also proposed by Cohen (2007). 'The Principle of Standardization' i.e. providing each participant with exactly the same stimulus as stated by Johnson and Christensen (2012), was also followed.

Therefore, the researcher was keen to study a wide range of literature to identify the best practices for questionnaire construction, write the questionnaire items, design the layout, and conduct the pilot study, just before administering the questionnaire itself.

The questionnaire was developed based on the ‘Programming and Computer Science Attitude Survey’ developed by Wiebe Et al. (2003) which was originally derived from the “Fennema-Sherman Mathematics Attitudes Scales” (Fennema, 1976). It works as an Attitude Scale to discover the students’ attitude by responding to a set of questions related to each dimension (Fraenkel, Wallen, & Hyun 2011). Baser (2013) used a similar survey and considered four dimensions: Confidence, Attitude, Usefulness, and Motivation considering only items related to computer programming.

The cross-sectional questionnaire, used for the research, includes 5 sections, the first section for the demographic data i.e. students’ gender in addition to four other sections:

1. Confidence in Learning Computer Programming
2. Attitude toward Learning Computer Programming
3. Usefulness of Learning Computer Programming
4. Motivation to Learn Computer Programming

There are 7 closed-ended elements in each section. Elements of the closed-ended questions require students to respond to dichotomous/check boxes and fully-anchored rating scale i.e. 5-point-likert scale. Tables 3.10a -3.10d demonstrates the questions for each dimension.

The wording of two elements in each section is reversed in order to avoid a “Response set” i.e. the respondents’ tendency to follow a particular direction while answering the questionnaire (Johnson & Christensen 2012). Statements 3 and 6 are reversed in the Confidence section, statements 3 and 5 are reversed in the Attitude section, statements 4 and 7 are reversed in the Usefulness section, and statements 4 and 6 are reversed in the Motivation section.

| No. | Confidence | Strongly Agree | Agree | Neutral | Disagree | Strongly Disagree |
|-----|--|----------------|-------|---------|----------|-------------------|
| 1 | I am sure I can learn programming | | | | | |
| 2 | I think at the end of the programming course; I will be able to solve complex programming problems | | | | | |
| 3 | Programming is the most difficult subject for me | | | | | |
| 4 | I can get excellent grades in this programming course | | | | | |
| 5 | I feel secure when I am asked to solve problems in programming | | | | | |
| 6 | If given the choice, I will not take the advanced level of the programming course | | | | | |
| 7 | I plan to study programming or any other related discipline in the college | | | | | |

Table 3.10a Confidence Questionnaire Questions

| No. | Attitude | Strongly Agree | Agree | Neutral | Disagree | Strongly Disagree |
|-----|---|----------------|-------|---------|----------|-------------------|
| 1 | I wait for the programming class with passion | | | | | |
| 2 | Being recognized as a smart programmer would make me feel happy | | | | | |
| 3 | I think being good in programming is not something to be proud of | | | | | |
| 4 | I feel proud when I solve programming questions | | | | | |
| 5 | I don't like people to know I am good in programming | | | | | |
| 6 | I wish I can participate in a programming competition and win | | | | | |
| 7 | Programming is my favorite subject | | | | | |

Table 3.10b Attitude Questionnaire Questions

| No. | Usefulness | Strongly Agree | Agree | Neutral | Disagree | Strongly Disagree |
|-----|---|----------------|-------|---------|----------|-------------------|
| 1 | I think programming is useful for me | | | | | |
| 2 | Learning programming will help me get a well-paid job in the future | | | | | |
| 3 | Learning programming is necessary to everyone these days | | | | | |
| 4 | I don't think everyone must learn programming | | | | | |
| 5 | Learning programming will help me solve daily problems | | | | | |
| 6 | It is important for me to learn programming before I go to college | | | | | |
| 7 | Programming is not related to any of the real-life problems | | | | | |

Table 3.10c Usefulness Questionnaire Questions

| No. | Motivation | Strongly Agree | Agree | Neutral | Disagree | Strongly Disagree |
|-----|---|----------------|-------|---------|----------|-------------------|
| 1 | I enjoy studying programming | | | | | |
| 2 | I explore resources to learn programming other than the textbook | | | | | |
| 3 | If I have a programming problem, I insist to solve it even if it takes me long time | | | | | |
| 4 | I wonder how people may spend long hours to learn programming | | | | | |
| 5 | I usually solve programming problems at home even if they are not required for my class | | | | | |
| 6 | Programming lessons are usually boring | | | | | |
| 7 | I pay good efforts to understand programming | | | | | |

Table 3.10d Motivation Questionnaire Questions

According to Cohen (2007), a questionnaire needs to be piloted to ensure its validity and reliability, check on the questions clarity, to gain feedback on the questions and the time it may take, to identify any other issues, and try-out the data analysis techniques that will be used later. Hence, the researcher conducted a pilot study and invited 90 participants to take it. 63 respondents replied back. Collected data was analyzed for reliability, collinearity, and multiple regression (Cohen 2007). The internal consistency reliability was positive and strong with Cronbach's alpha value equals to 0.96. For collinearity and multiple regression, very strongly correlated items that ask about the same construct were removed while ensuring the objectives of the questionnaire are necessarily met. Additionally, the questionnaire was reviewed by two colleagues. Both hold Master's degree in Education, one of them is currently pursuing her PhD in Science Education. Their comments and recommendations were used to modify the questionnaire questions before launching it.

The validity of the questionnaire was considered in two aspects; the accurate completion of the questionnaire and the reasons for the none-response. Both aspects were resolved by follow up

emails and phone calls to the teachers and schools' administrators to encourage students take the questionnaire.

It was intended to administer the questionnaire in the absence of the researcher in both sites. Respondents were able to complete it in private and take as much time as they want avoiding any pressure that could be caused by the researcher's presence (Cohen 2007).

The questionnaire was administered electronically using Google Forms. Participants were strongly encouraged to take the questionnaire, only 77.1 % (n=98) from School 1 i.e. confidence level 95%, after a few follow up reminders and 100% of School 2 students (n=8) responded i.e. confidence level=99% and. An acceptable response level according to Cohen (2007). A copy of the questionnaire is attached in appendix 7.

3.4.5.5 Interviews

A standardized open-ended interview, also called qualitative survey interview (Creswell 2012) was conducted to support and help in the interpretation of the questionnaire results. Patton (2005) stated that a standardized open-ended interview questions are predetermined and shall be asked in the same order. One-to-one interviews were conducted with a group of the participants who were selected using the convenience Sampling. Yet, Creswell (2012) stated that there are specific steps that must be followed to conduct an interview; planning, constructing the interview questions, and gaining access to the participants. Johnson and Christensen (2012) pointed out tips for conducting an effective interview including but limited to: training the interviewer, being reflexive, and utilize probes and follow up questions to get clear and deep responses.

The strength of this tool is the use of the standardized interview protocol, which assists in data organization and analysis using a rigor structure. Nevertheless, it might be difficult to relate

the interview to the particular individual's conditions and circumstances; a challenge that can be avoided by varying from the protocol using the standard interviewer probes.

The qualitative interview aimed at supporting the answer to the first research sub question about students' perceptions of their experience when they learn computer programming the results of the interviews will triangulate the questionnaire results. Although the same dimensions were addressed through the questionnaire, yet, the researcher found that it is crucial to minimize the threat on the collected data validity by triangulating the questionnaire data with the interview data. Hence the name "depth interviews" was given in literature (Johnson & Christensen 2012). The interview will help in identifying students' critical reflection on their cognitive abilities development through the period when they were taking the programming course using the Reflective Judgment Model (Kitchener & King 1990). Lundgren and Poell (2016) suggested that different critical reflection traditions should be integrated together, in addition to the use of opting thematic entrenching and attention to feelings.

According to Johnson and Christensen (2012), interviews can have one of four types; informal conversational interview, interview guide approach, standardized open ended interview, or closed quantitative interview. The standardized open ended interview seemed to be the best approach to achieve the aim of this phase where questions are worded in advance in an open ended format based on the participants' responses of the questionnaire. The strength of this type stems from the fact that the researcher had asked the same question for all the interview participants which had reduced the interviewer' bias and facilitated organizing and analyzing its data (Johnson & Christensen 2012). However, this type of interviews might have limited the naturalness of the conversation. Therefore, the researcher, while conducting the interview, was deliberate and allowed participants to elaborate freely on their answers.

The interview protocol was developed after collecting and analyzing the questionnaire questions. The reason for this delay in developing the interview protocol is to achieve its

purpose in further interpreting the responses of the students to questionnaire questions about student perception about their computer programming experience. The researcher had identified the areas that needed more details and elaboration and then developed the interview questions.

According to Stewart, Shamdasani, and Rook (2009) cited in Johnson and Christensen (2012) focus group interviews can be conducted to obtain information about a specific topic of interest, generate hypotheses, stimulate thoughts, diagnose a problem, collect information about certain impressions, learn about participants' opinions about a specific topic, and interpret previously obtained quantitative data. Hence, as mentioned earlier, the researcher will conduct the focus group interviews to triangulate the data collected from the questionnaire about the students' perception about their Java Programming learning experience. Fraenkel, Wallen, and Hyun (2011) pointed out six types of interview questions: Background/Demographics, Knowledge, Experience, Opinions, Feelings, and Sensory. For the purpose of this research, the researcher had designed the interview questions to further understand the students' perception about their experience when they learn computer programming.

In-person interviews were conducted. The researcher met the participants prior to the official interview day, introduced herself and the research objective. She also guaranteed the participants anonymity and the confidentiality of the collected data. The pre-interview activity had helped in establishing rapport and trust between the researcher and the interviewees (Johnson & Christensen 2012) which encouraged them to come to the official interview comfortably.

The 'face-validity' for the interview questions was established. The interview questions were reviewed by 3 expert educators in the education field. The three of them are the researcher's colleagues. Two of them hold Masters degree in education and the third colleague was pursuing her PhD degree in education. This type of validity is common for interviews (Cohen 2007) to

ensure that the questions and prompts measuring what they were meant to measure. Feedback was collected from the reviewers and the interview questions were informed accordingly. Additionally, a pilot study was conducted to measure the interview ‘convergent validity’. The results of the pilot study were compared to the results of the questionnaire results. Which validity was already proven.

On the other hand, the researcher had established the interview reliability by ensuring a “highly structured” one (Cohen 2007). All participants were asked the same questions. Yet, given enough freedom and time to answer each in his/her unique way. The researcher had dealt with the participants’ acquiescence carefully by asking them to elaborate more on their answers if they answered with a ‘yes’ or a ‘no’ for any of the questions. Furthermore, the researcher managed to reduce bias by carefully formulating the interview questions so that they are not leading participants to a particular answer (Cohen 2007).

The interview questions, sub questions, and the targeted dimensions are shown in table 3.11.

| Interview Question | Follow up Questions | Dimension |
|---|---|------------------|
| Question 1: What would stand in your mind when you think about yourself as a student learning Java programming? | <ul style="list-style-type: none"> • Can you explain to me more about that? • How can learning Java Programming makes you different than other students? • Have you ever thought of dropping the Java Programming course? | Confidence |
| Question 2: How can you apply the computational thinking skills you learned in the Java Programming class on problems you face in your real-life? | <ul style="list-style-type: none"> • Can you give me example? • How could your computational thinking skills help you in this case? • What other strategies you may use to solve the problem if it is not solved using your computational thinking skills? | Usefulness |
| Question 3: How do you feel when you solve a complex programming problem correctly? | <ul style="list-style-type: none"> • How do you feel if your colleague asks you to help him/her solve a complex programming problem that you are able to solve? | Attitude |
| Questions 4: What would you do if your teacher challenged you to solve a programming problem that none of your colleagues could solve it? | <ul style="list-style-type: none"> • Would you sacrifice a time out with your friend and stay home to study for Programming? | Motivation |

Table 3.11 Interview questions, sub questions, and dimensions

The interview protocol is attached in appendix 8 Further details of the data organization and analysis will be elaborated in the next chapter.

It is worth mentioning that the researcher managed to conduct the interview with all Grade 11 students in School 2 since they were studying Java OOP in one class. Yet, for School 1, the researcher interviewed focus groups. 6-8 students each. Johnson and Christensen (2012) stated that the concept of the focus groups interviews was originally introduced by Robert K. Merton and his Columbia University students in 1946. Johnson and Christensen (2012) indicate that a focus group consists of 6-12 participants. Yet, Fraenkel, Wallen, and Hyun (2011) mentioned that a focus groups usually consists of 4-8 participants.

The qualitative interviews were recorded via iPad Voice Recording app and were transcribed and prepared for the data analysis. During the four interviews, the researcher was keen to respect all participants and their opinions and maintain an appropriate rapport with them (Fraenkel, Wallen, & Hyun 2011).

Students have signed the informed consent prepared the researcher prior to the interview day that provided them with information about the research and the objective for the interview. Additionally, the consent included information about the researcher's commitment to the confidentiality of the collected data and the protection against any misunderstanding of the provided data. A sample signed consent is attached in appendix 9.

According to Fraenkel and Wallen (2009), the strength of the interview guide approach prevails in its outline that provides comprehensive data collected in a systematic way while the interview remains conversational and contextual. However, its weakness lies in the interviewer's flexibility in rewording and sequencing the questions that might lead to considerable different responses.

3.4.6 Data analysis

Although collecting both quantitative and qualitative data was done for many decades, formal protocols and procedures to analyze both types of data within the same framework is relatively new (Johnson & Christensen 2012). Johnson and Christensen (2012) pointed out few techniques used for mixed-method data analysis including concurrent, sequential, and iterative mixed data analysis.

Johnson and Christensen (2012) confirmed that a mixed-method researcher must identify the number of data types that will be analyzed for both quantitative and qualitative data. For example; test scores, rating scales, and check lists are considered different types of quantitative data, while interview responses, questionnaire responses and field notes are considered as qualitative data types. The use of both quantitative and qualitative data is referred to as ‘*multidata*’ while ‘*monodata*’ is referred to when only one of them is used. (Johnson & Christensen 2012). Additionally, a researcher must also decide on the data analysis types i.e. statistical analysis for quantitative data and/or qualitative. Similarly, the term ‘*multianalysis*’ is used when both types of analyses are analyzed while ‘*monoanalysis*’ is used when only one type of data analysis is used. See table 3.12.

Onwuegbuzie, Slate, Leech, and Collins (2007) had introduced the ‘Mixed Analysis Matrix’ that combines the four previously introduced terms as shown below.

| | Analysis Type | |
|------------------|--|--|
| Data Type | <i>Monoanalysis</i> | <i>Multianalysis</i> |
| <i>Monodata</i> | <i>Monodata</i> and <i>Monoanalysis</i> Not a mixed data analysis | <i>Monodata</i> and <i>Multianalysis</i> Quantitative data: QUAN and QUALITIZE Qualitative data: QUAL and QUANTITIZE |
| <i>Multidata</i> | <i>Multidata</i> and <i>Monoanalysis</i> Rarely used | <i>Multidata</i> and <i>Multianalysis</i> Combination of the two types in the above cell |

Table 3.12 Mixed Analysis Matrix. Adapted from Johnson and Christensen (2012)

Due to the complex nature of this research, the researcher will use the *multidata* and *multianalysis* in order to achieve the research objectives.

According to Johnson and Christensen (2012) and Onwuegbuzie and Teddlie (2003) mixed method data analysis require special strategies that include data reduction, data display, data transformation, data correlation, data consolidation, data comparison, and data integration. On another hand, Becker and Geer (1960) cited in Cohen (2007) pointed out a systematic approach to analyzing data that includes: comparing data simultaneously and sequentially, matching responses from using different instruments e.g. interviews and observations, analyzing negative cases, calculating occurrences, and providing adequate data.

Cohen (2007) stated that the analysis of the qualitative data is interpretive but yet subjective to the researcher's individual interpretation, preconceptions, and biases. This view was also confirmed by Lincoln and Guba (1985). They added that it may include, but not limited to, data overload, first impressions, uneven reliability, mistaking co-occurrences, and inconsistency. Therefore, the researcher had to be cautious and exercise qualitative data analysis. Miles, Huberman, Huberman, and Huberman (1994) suggested twelve tactics to make sense of transcribed data. They included counting frequencies, identifying patterns and themes, being reasonable, clustering, constructing metaphors, identifying variables, including details within broad concepts, factoring, identifying related variables, identifying intervening variables, creating logical relationships, and creating constructs. Cohen (2007) pointed out four methodological tools used to analyze qualitative data: "analytic induction, constant comparison, typological analysis and enumeration".

Krathwohl's (2008) cited in Madani (2017) stated that qualitative data analysis can be achieved in three stages: Familiarization and Organization, Coding and Recoding, and Summarizing and interpreting. Therefore, the researcher aims to collect the qualitative data i.e. field notes in class observations and interviews and then organize the data in a way that facilitates the coding and

recoding process that would lead to the generation of themes. Then, the researcher will summarize and interpret the data accordingly. According to Cohen (2009), qualitative data that are relevant to a particular issue can be organized and presented. However, the issue need to derived clearly. This economical approach has few drawbacks such as the impact of the loss of integrity of the wholeness of the individual observations/notes, decontextualized data, and the unresponsive analysis to responsive factors exist in the data. Enumeration qualitative data analysis techniques will be used (Cohen 2009).

On the contrary, the analysis of the quantitative data depends on the fitness of the data with the research purpose (Cohen 2007). Statistical techniques are used to organize, analyze, and correlate the data. Johnson and Christensen (2012) pointed out two types of statistics used in quantitative data analysis; descriptive and inferential. Descriptive statistical procedures aim to describe, summarize, and explain data. Whereas inferential statistics aim to identify the characteristics of a population based on the sample's data analysis.

The researcher is keen to collect and analyze both qualitative and quantitative data as designed and presented earlier in this chapter. Data will be reduced, displayed, transformed, correlated, consolidated, compared and integrated to inform the research questions and get a clear insight about the multiple-angles' arguments about the impact of learning computer programming (CP) on the high school students' cognitive abilities.

Two computer software will be used for analyzing the data; NVivo and SPSS. NVivo[®] is software application that is used to analyze qualitative and mixed methods data. Unstructured data can be stored, organized, categorized, classified, analyzed, and visualized. The software allows researchers manage and navigate the qualitative data and hence find connections between them by providing them with deeper insight from the data (qsinternational 2019). Additionally, NVivo[®] software will be used to transcribe the recorded audio for the interviews

and then organize, analyze and visualize the transcription. While the SPSS[®] software platform is developed by the well-known computer company IBM. It offers advanced tools used for statistical analysis of data. It provides researchers with flexibility and scalability to manage storing, organizing, and analyzing large amount of quantitative data. it improves the efficiency of data analysis and minimizes probabilities of errors.

3.4.6.1 Main Research Question

To answer the main research question: To what extent does learning computer programming impact the development of high school students' cognitive abilities in the UAE? Both CT-CAM quantitative data and the class observation quantitative and qualitative data are analyzed. The CT-CAM results i.e. pre test and posttest for both control and experiment groups, will be analyzed by conducting descriptive statistics that include the Mean, Standard Deviation, and Standard Error Mean. Students' scores in Induction (I), General, Sequential Reasoning (RG), Quantitative Reasoning (RQ), Memory Span (MS), Working Memory (MW), Visualization (Vz), Speeded Rotation (Spatial Relations; SR), Closure Speed (CS), Flexibility of Closure (CF), Visual Memory (MV), Spatial Scanning (SS), Serial Perceptual Integration (PI) abilities will be analyzed separately.

According to Muijs (2004), central tendency measures give the researcher proper understanding when it comes to describing a variable. Hence, the researcher aims to describe the variable 'students' cognitive abilities development' by describing the results obtained from the test. As mentioned earlier, quantitative data analysis depends mainly on the fitness of data with the purpose of the research (Cohen 2007), which applies in this case. Descriptive statistical analysis of the CT Cognitive Abilities Measure data helps the researcher analyze and explain the results. Additionally, the inferential statistics are conducted to identify the significance level of the CT Cognitive Abilities Measure results between the pre test and the posttest as well

as the effect size. Muijs (2004) stated that the inferential statistical test t-test is used to compare the means of two groups. Hence, the t-test in this study is used to compare the means of the students who study Java OOP as the experiment group and students who do not study Java OOP as the control group.

Hence, the inferential statistics may include: Levene's Test for equality of variance, t-test, degree of freedom df , and Cohens' d . The p -value of the Levene's Test for equality of variance is used to identify if the variance is significantly different between the two groups or not, upon which the researcher selects the appropriate t-test. The computed t-test value and the degree of freedom df are not of a great interest for the researcher (Muijs 2004). Yet, the asymptotic significance i.e. the p value of the t-test is the indicator to whether a significant difference exists or not. If $p < 0.05$, then there is a significant difference, otherwise, there is not.

On the other hand, the effect size can be identified by calculating the value of Cohen's d . Although SPSS does not provide a specific feature to find it, the researcher will calculate it manually using the formula shown below (Muijs 2004):

$$\text{Cohen's } d = (\text{Mean of Group 1} - \text{Mean of Group 2}) / \text{Pooled Standard Deviation}$$

Where the Pooled Standard Deviation is the mean of the two standard deviation values for groups 1 and group 2.

Furthermore, the mixed data obtained from the observation is also analyzed and compared to the test results. Descriptive and frequency analyses of the occurrences of the various cognitive activities that are happening during the programming class, are conducted for the quantitative data. In addition to the thematic analysis of the qualitative data collected from the field. The qualitative data is linked to the clearly identified issues i.e. the teachers' instructions, reasoning activities, memory activities, and sensory activities (Cohen 2007). Therefore, the data will be segmented and coded before developing the inductive categories upon which a logical chain of

evidence can be obtained. The main purpose of this mixed data analysis is to compare and consolidate the data (Becker and Geer 1960), and then integrate it with the results of the test data for better identification of the cognitive abilities development, if any.

The results of those analyses will reveal facts about:

- if students in the experiment group have achieved any development in any of the twelve constructs
- if the achievement of the control group is significantly different than the achievement of the experiment group

3.4.6.2 Sub Question 1

To identify students' perceptions of their experience when they learn computer programming, the questionnaire quantitative data is collected and analyzed in addition to the interview qualitative data. The descriptive statistical techniques, frequency analysis and percentages, are used to identify students' perceptions in the four dimensions; confidence when learning computer programming, attitude while learning computer programming, awareness of the usefulness of learning computer programming, and motivation to learn computer programming. Besides, the interview qualitative data will also be cleaned, segmented, coded, and analyzed prior to generating the categories (Johnson & Christensen 2012). As mentioned earlier, mixed data analysis provides consolidation and better understanding of the results.

3.4.6.3 Sub Question 2

To answer second sub-question about the cognitive activities and practices that may occur in the classroom during a computer programming lesson, the observation quantitative and qualitative data will be analyzed. Descriptive statistical analysis of the quantitative data will be strengthened by the thematic qualitative data analysis. According to Fraenkel, Wallen, and

Hyun (2011), the frequencies of the activities can be recoded as quantitative data. Hence the researcher will count the occurrences of specific teacher’s instructions, reasoning cognitive activities, memory cognitive activities, and sensory cognitive activities. Furthermore, the qualitative data, that is collected in the form of field notes and comments on the previously mentioned aspects including that cognitive activities during computer programming lessons, will be segmented and coded to generate the different themes and categories in a thematic analysis process. The logical chain of evidences (Cohen 2007) that will be obtained from the qualitative data analysis results will be compared to the quantitative data analysis results for further understanding of the human and interactional settings (Cohen 2007).

3.4.6.4 Sub Question 3

To answer the third sub questions: How the Cognitive Style may affect students’ choice of studying computer programming? The Cognitive Style Index questionnaire results will be analyzed through descriptive statistics that will provide the researcher with an idea about characteristics of the subjects i.e. what cognitive styles do students, in both experiment and control groups, demonstrate. This can be achieved by finding the percentages of students who are intuitive, quasi-intuitive, adaptive, quasi-analytic, and analytic.

It is also worth mentioning that the researcher will consider the scoring key suggested by the Cognitive Style Index authors (Allinson and Hayes 2012). The responses of the participants will be codes as shown in table 3.13.

| Response | Scoring Points | | |
|-----------|----------------|----------------|-----------------|
| | Key | Analytic Items | Intuitive items |
| True | T | 2 | 0 |
| Uncertain | ? | 1 | 1 |
| False | F | 0 | 2 |

Table 3.13 CSI Scoring Key. Adapted from Allinson and Hayes (2012)

Based on the scoring key shown above, the notional Cognitive Style can be identified by as demonstrated in table 3.14.

| Style | Score Range |
|-----------------|-------------|
| Intuitive | 0-28 |
| Quasi-Intuitive | 29-38 |
| Adaptive | 39-45 |
| Quasi-Analytic | 46-52 |
| Analytic | 53-76 |

Table 3.14 CSI Score range for the cognitive styles. Adapted from Allinson & Hayes (2012)

3.4.6.5 Sub Question 4

Finally, the fourth sub-question about how gender differences may affect students' choices, cognitive styles, and perceptions when they learn computer programming. The first part of this sub question about how gender differences may affect students' choice of studying computer programming will be answered by studying the categorical data of the participants. Cross tabulation will be used to compare between the two nominal variables gender and studying computer programming by demonstrating the actual numbers and percentages of students studying programming and the expected ones according to their genders. Additionally, Pearson chi square test is used to calculate the significance level and *phi* will be calculated to find the effect size based on the explanation that was introduced in the previous sections.

The second part of this sub question can be answered by the inferential statistical analysis of the Cognitive Style Index questionnaire results. The analysis will show the significance of the difference in cognitive styles between genders. Hence, the results will be analyzed through cross tabulation to find the relationship between the nominal variables Cognitive Style Index and students' gender. Muijs (2004) stated that chi square test is used to identify the significant difference between the two nominal variables. Hence, the researcher will use SPSS to find

conduct the chi square test on the data and find the level of significance by looking at the value of p . A value of p that is less than 0.05 indicates a confidence level of 95% (Muijs 2004). Additionally, the effect size will also be found by calculating the value of ϕ which is the square root of the chi square value divided by the sample size (Muijs 2004). SPSS does not find ϕ value, therefore, the researcher will calculate it manually.

On another hand, to answer the third part of this sub question about how gender may affect students' perceptions while studying computer programming, the researcher will analyze the quantitative questionnaire data. Each dimension of the questions including confidence when learning computer programming, attitudes while toward the learning programming experience, awareness of the usefulness of learning computer programming, and motivation to learn computer programming, descriptive statistics will be conducted to identify students' perceptions. However, the inferential statistical test chi square will be used to identify whether there is a significant difference between males and females or not. As mentioned in the previous section, ϕ value will be calculated manually to find the effect size. The researcher will also construct the Cross break (Contingency) tables to demonstrate the number of male and female respondents for each of the questionnaire statements (Fraenkel, Wallen, & Hyun 2011). The relationship will be acknowledged by demonstrating the results of such analyses.

3.5 Ethical Considerations

Hammersley and Traianou (2012) stated the ethical principles in educational research. They confirmed that a researcher needs to minimize the harm, respect autonomy and privacy of the participants, treat people equally, offer reciprocity and illuminate the mutual benefits from conducting such research. On the other hand, many associations have published codes of

educational researchers' ethics and professional conduct such as the American Educational Research Association (AERA). AERA (2011) have listed another list of principles including "Professional Competence, Integrity, Professional, Scientific, and Scholarly Responsibility, Respect for People's Rights, Dignity, and Diversity, and Social Responsibility". Such principles regulate the educational research domain, maintain the individuals' rights, and guarantees the researchers' professional conduct of the code is followed.

The AERA council have listed the ethical standards, researchers need to consider, when conduction educational research. According to AERA (2011) and Johnson and Christensen (2012), researchers need to adhere to the highest level of professionalism and should demonstrate continuous efforts to develop their competence. Researchers must also manage conflicts of interest and maintain the confidentiality of the participants. Similarly, Cohen (2007) had listed the ethical considerations of educational research that looks very similar to the AERA standards. Yet, the sensitivity of the questions and the reaction of respondents to offensive questions were given adequate focus.

Different literature confirmed that human beings cannot be involved in any research without informed consent (Cohen 2007, AERA 2011, Johnson & Christensen 2012). According to Cohen (2007) and Johnson and Christensen (2012), an informed consent must include the purpose and the procedures of the research, expected risks if any, participation consequences if any, benefits of participation, rights to withdrawal, obligations to confidentiality, and the participants' rights to ask about any aspect of the research.

The researcher had followed the 'deontological approach' (Johnson & Christensen 2012) considering the most common universal codes of ethics. Hence, after reviewing a wide range of literature discussing the educational research ethics and carefully reviewing the 'Guidelines of Ethics in Educational Research' published by The British University in Dubai, the ethics forms were submitted. An approval was obtained before initiating the study.

The process started by sending the application for an approval on the Research Ethics Form (Low Risk Research) to the Ethics Committee of the British University in Dubai, attaching the research proposal, and the Letter of Consent. Upon communication with concerned doctors in the committee, the approval was obtained from Dr. John McKenny, the nominated Faculty Representative and Dr. Ashly Pinnington, the Chair of the Research Ethics Committee. See appendix 10.

Another communication was established with the Faculty Administrator of the British University in Dubai to get the research letter that would be sent to the schools' administrations. The letter was received as requested. See appendix 11.

Consequently, the researcher had contacted the principal of private school i.e. the first site and the Director of the High School System i.e. the second site and requested a one-to-one meeting to explain the research purpose, the risks, and the needed data. Upon which, a written active consent was obtained from the two parties just before inaugurating the data collection. Furthermore, passive consent was sent to the students' parents/caregivers. Students were asked to return the form back only if their parents/caregivers did not accept their participation. Signed consent letters are attached in appendices 1, 2, and 9.

Besides, the researcher had also submitted a written consent to the teachers who were supposed to be observed before the observation. The consent also included all needed information as per internationally agreed standards. A sample of a signed consent is attached in appendix 12.

Additionally, the researcher took care of the potential participants' and ensured to protect them from any withdrawal consequences. Yet, participants can be strongly encouraged to do so (Cohen 2007). Hence, the researcher had included all necessary information stated and agreed upon in the literature in the preamble of CT Cognitive Abilities Measure, questionnaire,

observation and the Cognitive Style Index forms. It was made explicit to the participants that they might drop at any time without consequences.

Moreover, regarding the quasi-experiment, the researcher was fully aware of the fact that the research procedures should not, in any way, impact the school and the class operations. For the first study, the Java Programming class was part of the school offerings and it was luckily, serving the purpose of the study. While, in the second study, the school system had the feature of clustering students into different clusters, CS is one of them where students were offered the Java Object Oriented Programming course. Therefore, the ethical concern of the researcher's intervention would not be an issue.

3.6 Summary

In summary, this chapter presents the methodology used in this research study. It started with an overview of the different research paradigms including Postpositivist, Constructivist, Transformative, and Pragmatic demonstrating the characteristics of each one of them based on their ontology, axiology, epistemology, methodology. The aim of that discussion was to justify the researcher's pragmatic philosophical views that bridge the divide between qualitative and quantitative research. The next section presented the mixed research design that incorporated the quantitative and qualitative data collection methods that will essentially contribute to answering the main research question about the impact of the learning computer programming on students' cognitive abilities development and the other four sub questions. The research design section also introduced each research question with the corresponding instruments, method/mixed method design, participants and sampling design as well as the analysis techniques.

Additionally, the researcher argued the quasi experiment design using the non equivalent comparison group design which would serve the aim of the research, upon which factorial design groups were constructed particularly for the Cognitive Style Index and Gender. Then, the mixed method research was discussed in depth by demonstrating what is meant by a mixed method research, why is it used, and the challenges of using it. Also, validity and reliability were discussed showing that the threats to internal validity as the existence of different factors that may affect students' cognitive abilities development, the time laps between the pre test and posttest, level of the researcher's concentration during class observations, and the fact that the programming course is an elective course offered for grade 11 students. On another hand, Lack of representativeness of the population is found to be a threat to external validity. Regarding the sites and subject selection, two schools were selected to conducted the research, one is a school system that has a total of 14 schools across the Emirates, and the second is a private school in Abu Dhabi.

Furthermore, the researcher discussed the selection of the instruments that was basically based on the level of the organizational culture and the data that need to be uncovered. Hence, the Cognitive Style Index questionnaire, the CT Cognitive Abilities Measure, Observation, Questionnaire, and Interviews were used to collect the needed data. Data analysis techniques were also presented to show how those instruments will help in answering the research questions. Finally, the ethical considerations were presented based on broad literature review and international educational research standards. The following section will present the results of the data analysis.

Chapter 4 Data Analysis and Results

In the previous chapter, different research paradigms were discussed and the researcher's pragmatic world view was clearly justified. An explanation of the mixed method research was presented and elaborated within the context of this research study. Furthermore, the research design, the instruments, data analysis techniques, and ethical considerations were also discussed in details. This chapter introduces the data analyses and the results obtained for each instrument used within the context of the research study. It consists of seven sections namely: Analysis of the Demographics Data, Analysis of the Cognitive Style Index, Analysis of the CT Cognitive Abilities Measure, Analysis of the Questionnaire, Analysis of the Class Observations, Analysis of the Interviews, and Summary. Both descriptive and inferential quantitative data analyses were conducted on the CT Cognitive Abilities Measure results, Cognitive Style Index, the questionnaire, and the observation quantitative data. Additionally, qualitative data collected from the observations, and interviews were also segmented, cleaned, organized, categorized and analyzed. Both results are used to answer the following main research question and its sub-questions:

Main research question: To what extent does learning computer programming impact the development of high school students' cognitive abilities in the UAE?

Sub-question 1: What are the students' perceptions of their experience when they learn computer programming?

Sub-question 2: What cognitive activities and practices may occur in the classroom during a computer programming lesson?

Sub-question 3: How the Cognitive Style may affect students' choice of studying computer programming?

Sub-question 4: How gender differences may affect students' choices, cognitive styles and perceptions when they learn computer programming?

The used data analysis techniques are demonstrated in table 4.1.

| Data Source | Process | Statistical Technique |
|---|---|--|
| Demographic Data | Students' choice to study Java OOP | Descriptive Statistics <ul style="list-style-type: none"> Percentages |
| | Significance level of Gender Differences and the effect size | Inferential Statistics <ul style="list-style-type: none"> Pearson Chi-Square ϕ |
| Cognitive Style Index (CSI) | Cognitive Style Index and students' selection to Studying Java OOP | Descriptive Statistics <ul style="list-style-type: none"> Percentages |
| | Significance level of students' selection to study Java OOP and the effect size | Inferential Statistics <ul style="list-style-type: none"> Pearson Chi-Square ϕ |
| | Cognitive Style Index and Gender | Descriptive Statistics <ul style="list-style-type: none"> Percentages |
| | Significance level of Gender Differences and the effect size | Inferential Statistics <ul style="list-style-type: none"> Pearson Chi-Square ϕ |
| CT Cognitive Abilities Measure ((CT-CAM)) | CT Cognitive Abilities Measure Results for students who study Java OOP and students who do not study Java OOP | Descriptive Statistics <ul style="list-style-type: none"> Mean Standard Deviation Standard Error Mean |
| | Significance level of the CT Cognitive Abilities Measure results and the effect size | Inferential Statistics <ul style="list-style-type: none"> Levene's Test for equality of variance t-test Degree of Freedom df Cohens' d |
| Questionnaire | Students perceptions about learning computer programming | Descriptive Statistics <ul style="list-style-type: none"> Frequency Analysis Percentages |
| | Significance level of gender differences and the effect size | Inferential Statistics <ul style="list-style-type: none"> Pearson Chi-Square ϕ |
| Class Observation | Cognitive activities during computer programming lessons | Descriptive Statistics-Frequency Analysis |
| | Comments on cognitive activities during computer programming lessons | Thematic Analysis |
| Interviews | Students Perceptions about Learning computer programming | Thematic Analysis |

Table 4.1 Statistical Techniques Used in the Analysis. Adapted from Boz and Çalışkan (2018)

Van Buuren (2018) indicated that deleting the records pertinent to missing data is a common approach. Hence, to ensure the accuracy of the data analysis, the researcher has deleted the responses with missing data achieving a complete case analysis with 95% confidence level.

4.2 Demographics Data Analysis

This section presents the descriptive quantitative data analysis of the demographic data collected from the participating students as well as the inferential statistical tests Pearson Chi-Square and *Phi*. The purpose of these analyses is to help answer the first part of the fourth sub-research question about how gender differences may affect students' choices, cognitive styles and perceptions when they learn computer programming and to identify the significance of the differences if it exists. Categorical data was collected from Grade 11 students in both schools. Tables 4.2 and 4.3 below demonstrate the results of the cross tabulation of the nominal variables Students' Gender and their choice of Studying Java OOP or Not Studying Java OOP. The results of School 1, 60.1% (n=463) of all grade 11 students were males while 39.9% (n=307) were females. Yet, 45.7% (n=58) of the students who were studying Java Object Oriented Programming were males and 54.3% (n=69) were females. On the other hand, for School 2, it is shown that 58.6% (n=17) of all grade 11 students were males while 41.4% (n=21) were female. However, 75% (n=6) of the students who were studying Java Object Oriented Programming were males and only 25% (n=2) were females.

| | Male | Female | Total |
|------------------------------|--------------------|--------------------|-------------------|
| Studying Java OOP | | | |
| Actual | 58 (45.7%) | 69 (54.3%) | 127 (100%) |
| Expected | 76.4 (60.2%) | 50.6 (39.8%) | |
| Not Studying Java OOP | | | |
| Actual | 405 (63.0%) | 238 (37.0%) | 643 (100%) |
| Expected | 386.6 (60.1%) | 256.4 (39.9%) | |
| Total | 463 (60.1%) | 307 (39.9%) | 770 (100%) |

Table 4.2 School 1 Demographic Data

| | Male | Female | Total |
|------------------------------|-------------------|-------------------|------------------|
| Studying Java OOP | | | |
| Actual | 6 (75.0%) | 2 (25.0%) | 8 (100%) |
| Expected | 4.7 (58.8%) | 3.3 (41.2%) | |
| Not Studying Java OOP | | | |
| Actual | 11 (52.4%) | 10 (47.6%) | 21 (100%) |
| Expected | 12.3 (58.6%) | 8.7 (41.4%) | |
| Total | 17 (58.6%) | 12 (41.4%) | 29 (100%) |

Table 4.3 School 2 Demographic Data

The statistical test Pearson Chi-Square is used to calculate the significance level. There is a significant difference between males and females' selection of Studying Java OOP for the School 1 (chi square = 13.265, df = 1, p = 0.000). However, for School 2, there was no significant difference (chi square = 1.222, df = 1, p = 0.269).

On another hand *phi* value was calculated to find the effect size. Therefore, for School 1 *phi* was found as 0.131. While *phi* for School 2 is found to be 0.205. in both cases the effect is found to be modest.

4.3 Cognitive Style Index Data Analysis

This section presents the quantitative data analysis of the Cognitive Style Index questionnaire results. The purpose of this analysis is answer the research third sub question about how the Cognitive Style may affect students' choice of studying computer programming and to identify the Cognitive Style Index differences between males and females, which will also contribute to answer the fourth sub question: How gender differences may affect students' choices, cognitive activities and perceptions when they learn computer programming? Descriptive statistical analyses are used to identify the Cognitive Style Index of students in both groups; experiment and control, and the Cognitive Style Index for males and females in both groups. Additionally, inferential statistical tests Pearson Chi-Square and *phi* are used to identify the

significance levels and the effect size of the identified Cognitive Style Index between the two groups.

The researcher had used the Cognitive Style Index questionnaire developed by Professor Christopher Allinson and Professor John Hayes in 2012 with minor customizations. The questionnaire consists of 38 items. According to Allinson and Hayes (2012), scores of the Cognitive Style Index are calculated for each item where ‘True’ is given a score of 2, ‘Not Sure’ is given a score of 1, and ‘False’ is given a score of 0 for Analytic items and ‘True’ is given a score of 0, ‘Not Sure’ is given a score of 1, and ‘False’ is given a score of 2 for Intuitive items. A maximum score of 76 indicates the most analytical cognitive style and a minimum score of 0 indicates the most intuitive cognitive style. The ranges of scores that are used to identify the Cognitive Style Index of a person are shown in table 4.4 below:

| Style | Score Range |
|-----------------|-------------|
| Intuitive | 0-28 |
| Quasi-Intuitive | 29-38 |
| Adaptive | 39-45 |
| Quasi Analytic | 46-52 |
| Analytic | 53-76 |

Table 4.4 cognitive Style Index Score Ranges

The Cognitive Style Index results were analyzed through cross tabulation to find the relationship between the Cognitive Style Index and students’ selection of Studying Java OOP as well as the relationship between the Cognitive Style Index and students’ gender.

As shown in tables 4.5 and 4.6 below, for School 1, 46.67% (n=56) were either Analytic or Quasi Analytics and 29.70% (n=180) of the students who are Not Studying Java OOP were either Analytic or Quasi-Analytic. Similarly, 50% (n=4) of School 2 students who are Studying Java OOP are of an Analytic Cognitive Style Index, 25% (n=2) are quasi-analytic and a similar

percentage are Adaptive. While 38% (n=8) of students who are Not Studying Java OOP are of a Quasi-Intuitive style.

| Studying Java Programming * Cognitive Style Index School 2 | | | | | | |
|---|-----------------------|-----------------|--------------|----------------|--------------|------------|
| | Cognitive Style Index | | | | | Total |
| | Intuitive | Quasi-Intuitive | Adaptive | Quasi-Analytic | Analytic | |
| Studying Java Programming | 10 (8.33%) | 28 (23.33%) | 26 (21.67%) | 26 (21.67%) | 30 (25.00%) | 120 (100%) |
| Not Studying Java Programming | 106 (17.49%) | 200 (33.00%) | 120 (19.80%) | 105 (17.33%) | 75 (12.38%) | 606 (100%) |
| Total | 116 (15.98%) | 228 (31.40%) | 146 (20.11%) | 131 (18.04%) | 105 (14.46%) | 726 (100%) |

Table 4.5 Cognitive Style Index for Students who Study Java OOP Vs. Students who do Not Study Java OOP for School 1

| Studying Java Programming * Cognitive Style Index School 1 | | | | | | |
|---|-----------------------|-----------------|------------|----------------|------------|-----------|
| | Cognitive Style Index | | | | | Total |
| | Intuitive | Quasi-Intuitive | Adaptive | Quasi-Analytic | Analytic | |
| Studying Java Programming | 0 (0.00%) | 0 (0.00%) | 2 (25%) | 2 (25%) | 4 (50%) | 8 (100%) |
| Not Studying Java Programming | 4 (19.04%) | 8 (38.10%) | 5 (23.81%) | 2 (9.52%) | 2 (9.52%) | 21 (100%) |
| Total | 4 (13.79%) | 8 (27.59%) | 7 (24.14%) | 4 (13.79%) | 6 (20.69%) | 29 (100%) |

Table 4.6 Cognitive Style Index for Students who Study Java OOP Vs. Students who do Not Study Java OOP for School 2

Using the Chi-Square statistical test, a significant difference was found between students who are Studying Java OOP and students who are Not Studying Java OOP for both schools. The significance level for School 1 is found (chi square = 20.496, df = 4, p = 0.000) and for School 2 (chi square = 10.168, df = 4, p = 0.038).

Another statistical test was also conducted to study the relationship between the two nominal variables; students' Gender and their Cognitive Style Index. Tables 4.7 and 4.8 present an overview of the males and females Cognitive Style Index.

For school 1, it is apparent from the table that 30.02% (n=130) of the males have Analytic Cognitive Style Index while more than 50% of the females are Quasi-Intuitive or Intuitive. Interestingly, school 2 results were similar to school 1 results. Male students 29.41% (n=5) with Analytic Cognitive Style Index are more than females 8.33% (n=1). Most of the females

33.33% (n=4) are of the Quasi-Intuitive Cognitive Style Index. This is indicated in Table 4.8 below.

| Male/Female * Cognitive Style Index School 1 | | | | | | | |
|---|--------|-----------------------|-----------------|--------------|----------------|--------------|------------|
| | | Cognitive Style Index | | | | | Total |
| | | Intuitive | Quasi-Intuitive | Adaptive | Quasi-Analytic | Analytic | |
| Male/Female | Male | 59 (13.63%) | 67 (15.47%) | 93 (21.48%) | 84 (19.40%) | 130 (30.02%) | 433 (100%) |
| | Female | 57 (19.45%) | 98 (33.45%) | 53 (18.09%) | 47 (16.04%) | 38 (12.97%) | 293 (100%) |
| Total | | 116 (15.98%) | 165 (22.73%) | 146 (20.11%) | 131 (18.04%) | 168 (23.14%) | 726 (100%) |

Table 4.7 Cognitive Style Index for Males and Females for School 1

| Male/Female * Cognitive Style Index School 2 | | | | | | | |
|---|--------|-----------------------|-----------------|------------|----------------|------------|-----------|
| | | Cognitive Style Index | | | | | Total |
| | | Intuitive | Quasi-Intuitive | Adaptive | Quasi-Analytic | Analytic | |
| Male/Female | Male | 2 (5.88%) | 4 (23.53%) | 4 (23.53%) | 2 (5.88%) | 5 (29.41%) | 17 (100%) |
| | Female | 2 (16.67%) | 4 (33.33%) | 3 (25.00%) | 2 (16.67%) | 1 (8.33%) | 12 (100%) |
| Total | | 4 (13.79%) | 8 (27.59%) | 7 (24.14%) | 4 (13.79%) | 6 (20.69%) | 29 (100%) |

Table 4.8 Cognitive Style Index for Males and Females for School 2

Pearson Chi-Square analysis revealed a significant difference between males and females in both schools. school 1 (chi square = 7.216, df = 4, p = 0.01) and for school 2 (chi square = 2.007, df = 4, p = 0.030).

4.4 CT Cognitive Abilities Measure (CT-CAM) Data Analysis

This section presents the quantitative data analysis of the CT-CAM results. The same test was done as pre test and posttest by the two groups; students who study Java OOP and students who do not study Java OOP. The purpose of this analysis is to answer the research main question about the impact of studying computer programming on the students' cognitive abilities development. Therefore, all Grade 11 students in school 1 and school 2 were invited to take the test. Descriptive and inferential statistical techniques are used to analyze the results. mean, standard deviation, and standard error mean were calculated for the descriptive statistical

analysis of the CT-CAM results for students who study Java OOP and students who do not study Java OOP. While for the inferential statistical analysis; Levene’s Test for equality of variance, t-test, Degree of Freedom df, and Cohens’ d were calculated to identify the significance level of the differences and the effect size between the two groups.

Responses for the questions of Induction, General Sequential Reasoning, Quantitative Reasoning, Memory Span, Working Memory, Visualization, Speeded Rotation, Closure Speed, Flexibility of Closure, Visual Memory, Spatial Scanning, and Serial Perceptual Integration were analyzed and studied separately to identify the impact of studying Java OOP on each cognitive ability. The order of the questions for the different abilities differs between the pre test and the posttest. Yet, the order of the questions for the same ability was maintained the same. This was done intentionally because questions were ordered according to their difficulty level from easy to difficult. Additionally, questions for specific cognitive abilities were related to an illustration or an image e.g. Spatial Scanning. Details will be elaborated in the following sub sections. Table 4.9 below demonstrates each cognitive ability, its abbreviation in pre test and posttest, as well as the test questions measuring it.

| Cognitive ability | Pre test | | Posttest | |
|-------------------------------|--------------|----------------|--------------|----------------|
| | Abbreviation | Questions | Abbreviation | Questions |
| Induction | I | 1, 2, 3, 4 | Ip | 17, 18, 19, 20 |
| General Sequential Reasoning | RG | 29, 30, 31, 32 | RGp | 9, 10, 11, 12 |
| Quantitative Reasoning | RQ | 13, 14, 15, 16 | RQp | 1, 2, 3, 4 |
| Memory Span | MS | 21, 22, 23, 24 | MSp | 33, 34, 35, 36 |
| Working Memory | MW | 41, 42, 43, 44 | MWp | 29, 30, 31, 32 |
| Visualization | Vz | 5, 6, 7, 8 | Vzp | 45, 46, 47, 48 |
| Speeded Rotation | SR | 25, 26, 27, 28 | SRp | 41, 42, 43, 44 |
| Closure Speed | CS | 33, 34, 35, 36 | CSp | 13, 14, 15, 16 |
| Flexibility of Closure | CF | 45, 46, 47, 48 | CFp | 21, 22, 23, 24 |
| Visual Memory | MV | 9, 10, 11, 12 | MVp | 37, 38, 39, 40 |
| Spatial Scanning | SS | 37, 38, 39, 40 | SSp | 5, 6, 7, 8 |
| Serial Perceptual Integration | PI | 17, 18, 19, 20 | PIp | 25, 26, 27, 28 |

Table 4.9 CT Cognitive Abilities Measure Questions’ Distribution

The following 12 sub-sections include the quantitative data analysis of the participants' responses for questions of each cognitive ability followed by the summary of the obtained results.

4.4.1 Cognitive Ability 1: Induction

Students were asked four multiple choice questions to evaluate their Induction ability as shown in figure 4.1 below.

Figure 4.1 CT-CAM - Induction Questions

Tables 4.10 and 4.11 show the descriptive statistics of the responses including the number of respondents, the mean, the standard deviation, and the standard error for both School 1 and School 2.

| Group Statistics School 1 | | | | | |
|---------------------------|-------------------------------|-----|--------|----------------|-----------------|
| Studying Java Programming | | N | Mean | Std. Deviation | Std. Error Mean |
| I | Studying Java Programming | 127 | 0.4055 | 0.16038 | 0.01423 |
| | Not Studying Java Programming | 642 | 0.3995 | 0.12658 | 0.00500 |
| Ip | Studying Java Programming | 127 | 0.6201 | 0.21328 | 0.01893 |
| | Not Studying Java Programming | 640 | 0.4941 | 0.14889 | 0.00589 |

Table 4.10 Descriptive Statistics Results for School 1 - Induction

| Group Statistics School 2 | | | | | |
|---------------------------|-------------------------------|----|--------|----------------|-----------------|
| Studying Java Programming | | N | Mean | Std. Deviation | Std. Error Mean |
| I | Studying Java Programming | 8 | 0.4063 | 0.12939 | 0.04575 |
| | Not Studying Java Programming | 21 | 0.3690 | 0.15040 | 0.03282 |
| Ip | Studying Java Programming | 8 | 0.7188 | 0.20863 | 0.07376 |
| | Not Studying Java Programming | 21 | 0.5000 | 0.20917 | 0.04564 |

Table 4.11 Descriptive Statistics Results for School 2 - Induction

For the pre test, School 1 students who study Java OOP (M=0.4055, SD=0.16038) scored a bit higher than students who do not study Java OOP (M=0.3995, SD=0.12658). Yet, the difference in the means between the two groups in the pre test for School 2 students was less. Students who study Java OOP scored (M=0.4063, SD=0.12939) and students who do not study Java OOP (M=0.3690, SD=0.15040).

The correlation between the results for School 1 and School 2 in the posttest is interesting because learning Java OOP seems to impact students Induction abilities. Students who study Java OOP in School 1 scored (M=0.6201, SD=0.21328) while school 2 students scored (M=0.7188, SD=0.20863). Students who do not study Java OOP in School 1 and School 2 scored (M=0.4941, SD=0.14889) and (M=0.5000, SD=0.20917) respectively.

Levene's Test for equality of variance for School 1 is found to be >0.05 for both pre test and posttest. The t-test results indicate no significant difference between the two groups in the pre test ($t = 0.396$, $df = 158.489$, $p > 0.05$). Yet there was a significant difference between the two groups in the posttest ($t = 6.354$, $df = 151.271$, $p < 0.05$). Similar results were found for School 2 where there was no significant difference in the pre test ($t = 0.617$, $df = 27$, $p > 0.05$) while in the posttest ($t = 2.519$, $df = 27$, $p < 0.05$). SPSS software, unluckily, does not show results that indicate the effect size. Hence, in order to find the effect size, Cohen's d was calculated manually for the posttest results and found to be 0.6957 i.e. a moderate effect size for School 1 and 1.047 i.e. strong effect size for School 2.

4.4.2 Cognitive Ability 2: General Sequential Reasoning

The same statistical analysis was conducted to investigate the impact of learning Java OOP on the General Sequential Reasoning ability. Figure 4.2 below demonstrates the questions used to measure this ability.

5 Choose the best answer.

If some students are talented and some talented are piano players. Which statement is correct?

A. Some students are piano players

B. All students are piano players

C. Some piano players are talented

D. All talented are piano players

6 Choose the best answer.

Khalid, twelve years old, is three times as old as his brother. How old will Khalid be when he is twice as old as his brother?

A. 15

B. 16

C. 18

D. 20

7 Choose the best answer.

The price of a mobile phone was cut 60% for a sale. By what percent must the phone be increased to, again sell the mobile phone at the original price?

A. 50%

B. 100%

C. 150%

D. 250%

8 Choose the best answer.

Maryam had a number of cookies. After eating 2, she gave half the remainder to her sister. After eating another 2 cookies, she gave half of what was left to her brother. Maryam now had only 10 cookies left. How many cookies did she start with?

A. 11

B. 24

C. 36

D. 44

Figure 4.2 General Sequential Reasoning Questions

Tables 4.12 and 4.13 show the descriptive statistics of the responses on the General Sequential Reasoning ability questions. The tables include the number of respondents, the mean, the standard deviation, and the standard error for both School 1 and School 2.

| Group Statistics School 1 | | | | | |
|---------------------------|-------------------------------|-----|--------|----------------|-----------------|
| Studying Java Programming | | N | Mean | Std. Deviation | Std. Error Mean |
| RG | Studying Java Programming | 121 | 0.4194 | 0.12589 | 0.01144 |
| | Not Studying Java Programming | 636 | 0.4064 | 0.13419 | 0.00532 |
| RGp | Studying Java Programming | 121 | 0.4669 | 0.14047 | 0.01277 |
| | Not Studying Java Programming | 629 | 0.4543 | 0.17393 | 0.00694 |

Table 4.12 Descriptive Statistics Results for School 1 – General Sequential Reasoning

| Group Statistics School 2 | | | | | |
|---------------------------|-------------------------------|----|--------|----------------|-----------------|
| Studying Java Programming | | N | Mean | Std. Deviation | Std. Error Mean |
| RG | Studying Java Programming | 8 | 0.4688 | 0.08839 | 0.03125 |
| | Not Studying Java Programming | 21 | 0.4286 | 0.11573 | 0.02525 |
| RGp | Studying Java Programming | 8 | 0.5000 | 0.13363 | 0.04725 |
| | Not Studying Java Programming | 21 | 0.5476 | 0.10059 | 0.02195 |

Table 4.13 Descriptive Statistics Results for School 2 - General Sequential Reasoning

For the pre test, School 1 students who study Java OOP (M=0.4194, SD=0.12589) while students who do not study Java OOP scored (M=0.4064, SD=0.13419). School 2 results were very close. Students who study Java OOP scored (M=0.4688, SD=0.08839). Yet, students who do not study Java OOP scores were (M=0.4286, SD=0.11573).

The increase in the students' posttest mean scores was not significant between the two groups in both School 1 and School 2. In School 1, students who study Java OOP scores were (M=0.4669, SD=0.14047) while students who do not study Java OOP scores were (M =0.4543, SD=0.17393). Likewise, students who study Java OOP in School 2 scores (M=0.5000, SD=0.13363) were close to the scores of the students who do not study Java OOP (M=0.5476, SD=0.10059). The results disclose no significant effect of learning Java OOP on students' General Sequential Ability.

In order to confirm this insignificant effect, for School 1, Levene's Test for equality of variance was slightly > 0.05 for the pre test and < 0.05 for the posttest. The t-test results of RG in the pre test ($t=0.984$, $df=755$, $p>0.05$) while the posttest results were ($t= 0.870$, $df=197.934$, $p>0.05$). Hence, the impact of learning Java OOP is found to have no significant effect on students General Sequential Reasoning ability. For School 2, Levene's Test for equality of variance is found to be < 0.05 for the pre test and > 0.05 for the posttest. The t-test results

indicate no significant difference between the two groups in the pre test ($t = 1.000$, $df = 16.644$, $p > 0.05$). The t-test also revealed no significant difference between the two groups in the posttest ($t = -1.041$, $df = 27$, $p > 0.05$). Hence, the impact of learning Java OOP is found to have no significant effect on students General Sequential Reasoning ability.

4.4.3 Cognitive Ability 3: Quantitative Reasoning

The Quantitative Reasoning ability was measure using the four questions demonstrated in figure 4.3. The questions required students to use high level mathematical and calculation skills to choose the best answer.

Figure 4.3 displays four quantitative reasoning questions, each in a separate box. The correct answer for each question is highlighted with a red box.

Question 9: Compare two quantities - Quantity A and Quantity B - and then determine which of four statements describes the comparison.
 • Quantity A: $x^2 + 1$
 • Quantity B: $2x - 1$
 A. Quantity A is greater
 B. Quantity B is greater
 C. The two quantities are equal
 D. The relationship cannot be determined from the information given
 Correct answer: A

Question 10: Rashid is older than Hamda, and Maryam is younger than Rashid. Which of the following statements would be most accurate?
 A. Maryam is older than Hamda
 B. Maryam is younger than Hamda
 C. Maryam is as old as Hamda
 D. It is impossible to tell
 Correct answer: D

Question 11: Mohammad and Nasir each saved AED 5,000 in 2018. In 2019 Mohammad saved 10 percent more than in 2018, and together he and Nasir saved a total of AED 10,000. Approximately what percent less did Nasir save in 2019 than in 2018?
 A. 5%
 B. 8%
 C. 10%
 D. 15%
 Correct answer: C

Question 12: Rashid is training for a race. He runs at 8 Kilometer per Hour and completed the track in 120 minutes. His Friend Salim, completes the same track in 2.5 Hours. How much faster was Rashid running?
 A. 1.6
 B. 1.8
 C. 2.0
 D. 2.2
 Correct answer: A

Figure 4.3 Quantitative Reasoning Questions

Tables 4.14 and 4.15 show the descriptive analysis of School 1 and School 2 pre test and posttest results. The number of respondents, the mean, the standard deviation, and the standard error are presented.

| Group Statistics School 1 | | | | | |
|---------------------------|-------------------------------|-----|--------|----------------|-----------------|
| Studying Java Programming | | N | Mean | Std. Deviation | Std. Error Mean |
| RQ | Studying Java Programming | 121 | 0.4091 | 0.15478 | 0.01407 |
| | Not Studying Java Programming | 635 | 0.4130 | 0.14322 | 0.00568 |
| RQp | Studying Java Programming | 123 | 0.6199 | 0.21075 | 0.01900 |
| | Not Studying Java Programming | 630 | 0.4810 | 0.16985 | 0.00677 |

Table 4.14 Descriptive Statistics Results for School 1 – Quantitative Reasoning

| Group Statistics School 2 | | | | | |
|---------------------------|-------------------------------|----|--------|----------------|-----------------|
| Studying Java Programming | | N | Mean | Std. Deviation | Std. Error Mean |
| RQ | Studying Java Programming | 8 | 0.4688 | 0.16022 | 0.05665 |
| | Not Studying Java Programming | 21 | 0.3929 | 0.14940 | 0.03260 |
| RQp | Studying Java Programming | 8 | 0.6563 | 0.12939 | 0.04575 |
| | Not Studying Java Programming | 21 | 0.4881 | 0.14740 | 0.03216 |

Table 4.15 Descriptive Statistics Results for School 2 - Quantitative Reasoning

Surprisingly, the pre test results show that School 1 students who do not study Java OOP scored higher ($M=0.4130$, $SD=0.14322$) than students who study Java OOP ($M=0.4091$, $SD=0.14322$). Yet, for School 2, students who study Java OOP scored relatively higher ($M=0.4688$, $SD=0.16022$) than students who do not study Java OOP ($M=0.3929$, $SD=0.14940$). Contrarily, in School 2,

The posttest results were interesting and showed a significant increase in the means for the group who study Java OOP and a slight increase for students who do not study Java OOP for both schools. School 1 students who study Java OOP scored higher ($M=0.6199$, $SD=0.21075$) than students who do not study Java OOP ($M=0.4810$, $SD=0.16985$). While School 2 students who study Java OOP scored ($M=0.6563$, $SD=0.14740$) also high compared to those who do not study Java OOP ($M=0.4881$, $SD=0.14740$).

In School 1, the Levene's test for equality of variance was > 0.05 for the pre test but < 0.05 for the posttest. The t-test results for the pre test (-0.271 , $df=754$, $p>0.05$). Yet, the posttest t-test results were ($t=6.889$, $df=154.423$, $p<0.05$). the results indicate a significant effect of the treatment i.e. studying Java OOP in both schools. Levene's test for equality of variance was found to be > 0.05 for both pre test and posttest in School 2. Hence, the t-test results for the pre test ($t=1.200$, $df=27$, $p>0.05$). However, a significant difference was found in the posttest results between the two groups ($t=2.831$, $df=27$, $p<0.05$).

The effect size was measured by calculating Cohen's d. For School 1, Cohen's d is found to be moderate and equal to 0.7299 for School 1 and 1.2154 i.e. strong effect size for School 2.

4.4.4 Cognitive Ability 4: Memory Span

The Memory Span Cognitive Ability was measured through four questions demonstrated in figure 4.4. For each questions, students were given a construction of words, numbers, or shapes for a certain period of time and then asked about it in a different question later.

Look at the words below for 5 seconds.

Rabbit
Horse
Bird
Eagle

41 Which of the following is the correct order of the words?

| A | B | C | D |
|----------------------------------|----------------------------------|----------------------------------|----------------------------------|
| Horse Rabbit Bird Eagle | Horse Bird Rabbit Eagle | Rabbit Bird Eagle Horse | Rabbit Horse Bird Eagle |

Look at the numbers below for 5 seconds.

7 6 4 6 3 9 2

42 Which of the following is the correct order of the numbers?

| A | B | C | D |
|---------------|---------------|---------------|---------------|
| 7 4 6 3 7 9 2 | 7 6 4 6 2 9 3 | 7 6 4 6 3 9 2 | 7 6 4 2 3 9 6 |

Look at the following shapes for 5 second.

43 How many dark blue circles were there?

| A | B | C | D |
|---|---|---|---|
| 3 | 4 | 5 | 6 |

Look at the following sentence for 5 second.

Meera plays basketball everyday with her friends.

44 How many times does letter 'e' appear in the sentence?

| A | B | C | D |
|---|---|---|---|
| 4 | 5 | 6 | 7 |

Figure 4.4 Memory Span Questions

The assessment platform used to create and publish the CT Cognitive Abilities Measure has features that allow the display of a certain content for a limited period of time which had help the researcher achieve the goal of Memory Span Questions. Tables 4.16 and 4.17 present the results of the responses' descriptive analysis.

| Group Statistics School 1 | | | | | |
|---------------------------|-------------------------------|-----|--------|----------------|-----------------|
| Studying Java Programming | | N | Mean | Std. Deviation | Std. Error Mean |
| MS | Studying Java Programming | 119 | 0.4097 | 0.15172 | 0.01391 |
| | Not Studying Java Programming | 637 | 0.4121 | 0.13271 | 0.00526 |
| MSp | Studying Java Programming | 122 | 0.5984 | 0.19433 | 0.01759 |
| | Not Studying Java Programming | 621 | 0.5415 | 0.18292 | 0.00734 |

Table 4.16 Descriptive Statistics Results for School 1 – Memory Span

| Group Statistics School 2 | | | | | |
|---------------------------|-------------------------------|----|--------|----------------|-----------------|
| Studying Java Programming | | N | Mean | Std. Deviation | Std. Error Mean |
| MS | Studying Java Programming | 8 | 0.4375 | 0.17678 | 0.06250 |
| | Not Studying Java Programming | 21 | 0.4762 | 0.15622 | 0.03409 |
| MSp | Studying Java Programming | 8 | 0.5938 | 0.12939 | 0.04575 |
| | Not Studying Java Programming | 21 | 0.4881 | 0.20119 | 0.04390 |

Table 4.17 Descriptive Statistics Results for School 2 – Memory Span

The results of the pre test in School 1 between the two groups took a different trend. Students who study Java OOP scored ($M=0.4097$, $SD=0.15172$) while students who do not study Java OOP scores were ($M=0.4121$, $SD=0.13271$). For School 2, the results were quite similar. Students who do not study Java OOP scored considerably higher ($M=0.4762$, $SD=0.15622$) than students who study Java OOP ($M=0.4375$, $SD=0.17678$).

Surprisingly, the results of the posttest were different between the two schools.

In School 1, students who study Java OOP scores ($M=0.5984$, $SD=0.19433$) and students who do not study Java OOP ($M=0.5415$, $SD=0.18292$). While for School 2, students who study Java OOP scores ($M=0.5938$, $SD=0.12939$) and students who do not study Java OOP scores were ($M=0.4881$, $SD=0.20119$). Nevertheless, It is apparent that although students who do not study Java OOP in other schools scored higher in the pre test, they couldn't achieve a noticeable progress and their scores were lower than the group which study Java OOP.

Further inferential statistical analysis was conducted to investigate the impact of teaching Java OOP. For School 1, the Levene's Test of Equality of Variance was < 0.05 in the pre test and > 0.05 in the posttest. The pre test t-test results ($t=-0.163$, $df=153.561$, $p>0.05$) and the posttest t-test results were ($t=3.108$, $df=741$, $p<0.05$). The Levene's Test of Equality of Variance was > 0.05 in both pre test and posttest for School 2. The t-test results of the pre test were ($t=-0.576$, $df=27$, $p>0.05$) and for the posttest ($t=1.373$, $df=27$, $p>0.05$). These results reveal an impact of learning Java OOP in School 1 but not in School 2. Therefore, Cohen's d was calculated for School 1 and found an effect size of 0.30166. This indicates a modest effect.

4.4.5 Cognitive Ability 5: Working Memory

The CT Cognitive Abilities Measure includes four questions about the Working Memory. For the first two question, students were given a groups of 20 words and were asked about them. The next two questions were related to a part of a traditional story that has information within the text. Students were supposed to remember that information after reading the paragraph for a specific period of time. Figure 4.5 presents these questions.

The descriptive statistical analysis of the responses is demonstrated in tables 4.18 and 4.19 below. In School 1, students who study Java OOP scored also better ($M=0.4814$, $SD=0.18587$) than students who do not study Java OOP ($M=0.4608$, $SD=0.19819$). Likewise, in School 2, students who study Java OOP score better ($M=0.5625$, $SD=0.17678$) than students who do not study Java OOP ($M=0.5000$, $SD=0.23717$).

Look at these words for 10 seconds then answer the following two questions.

| | | | |
|------|--------|---------|------|
| coin | table | carpet | pen |
| rain | fire | weather | car |
| cat | time | nail | soap |
| car | mark | minute | fire |
| pen | second | money | car |

37 Which of the following words was in the group of words shown?

| | | | |
|------|------|--------|-----|
| A | B | C | D |
| time | hour | winter | sun |

38 How many times was the word 'car' repeated?

| | | | |
|---|---|---|---|
| A | B | C | D |
| 1 | 2 | 3 | 4 |

Read the following paragraph and answer the following two questions.

"The family's first wish is Herbert's: he asks for enough money to make the final mortgage payment which is 200 pounds. The next day, Herbert goes to work and is killed at the local factory in a horrible accident. His employer refuses to claim responsibility, but makes a goodwill settlement of exactly the same amount of the mortgage payment. Though horrified by the mutilated outcome of their first wish being granted, Mrs. White talks her reluctant husband into a second wish: asking for Herbert to come back to life. There are three dramatic knocks on the door, Mrs. White fumbles down the stairs and with the door chain; meanwhile Mr. White is able to grasp the talisman just in time for one final wish, which is..."

39 What was the mortgage payment Herbert wanted to pay?

| | | | |
|-----|-----|-----|-----|
| A | B | C | D |
| 200 | 250 | 280 | 300 |

40 How many characters, their names were mentioned in the story?

| | | | |
|---|---|---|---|
| A | B | C | D |
| 2 | 3 | 5 | 6 |

Figure 4.5 Working Memory Questions

The mean scores in the posttest MWp for School 1 students who study Java OOP scores was ($M=0.5894$, $SD=0.21975$) and students who do not study Java OOP scores were ($M=0.5266$, $SD=0.19833$). While in School 2, the situation seems to be similar. Students who study Java OOP ($M=0.6563$, $SD=0.18601$) and for students who do not study Java OOP ($M=0.5476$, $SD=0.26948$). Yet, the significance of this increase requires further inferential statistical analysis.

| Group Statistics School 1 | | | | | |
|---------------------------|-------------------------------|-----|--------|----------------|-----------------|
| Studying Java Programming | | N | Mean | Std. Deviation | Std. Error Mean |
| MW | Studying Java Programming | 121 | 0.4814 | 0.18587 | 0.01690 |
| | Not Studying Java Programming | 638 | 0.4608 | 0.19819 | 0.00785 |
| MWp | Studying Java Programming | 123 | 0.5894 | 0.21975 | 0.01981 |
| | Not Studying Java Programming | 630 | 0.5266 | 0.19833 | 0.00790 |

Table 4.18 Descriptive Statistics Results for School 1 – Working Memory

| Group Statistics School 2 | | | | | |
|---------------------------|-------------------------------|----|--------|----------------|-----------------|
| Studying Java Programming | | N | Mean | Std. Deviation | Std. Error Mean |
| MW | Studying Java Programming | 8 | 0.5625 | 0.17678 | 0.06250 |
| | Not Studying Java Programming | 21 | 0.5000 | 0.23717 | 0.05175 |
| MWp | Studying Java Programming | 8 | 0.6563 | 0.18601 | 0.06576 |
| | Not Studying Java Programming | 21 | 0.5476 | 0.26948 | 0.05881 |

Table 4.19 Descriptive Statistics Results for School 2 – Working Memory

For School 1. The Levene's Test for Equality of Variances was >0.05 in the pre test and <0.05 in the posttest. Hence, the t-test results of the pre test ($t=1.058$, $df=757$, $p>0.05$) and for the posttest ($t=2.946$, $df=163.091$, $p<0.05$). Therefore, there was a significant difference in the cores of the two groups in School 1. The effect size Cohen's d was calculated and equals to 0.3004 i.e. modest effect size. Though, the case seems to be different for School 2. The Levene's Test for Equality of Variances was >0.05 for both pre test and posttest. Consequently, the t-test results of the pre test ($t=0.674$, $df=27$, $p>0.05$) and for the posttest ($t=0.674$, $df=27$, $p>0.05$). This indicates no significant difference between the scores of students who study Java OOP and students who do not study Java OOP in the Working Memory ability.

4.4.6 Cognitive Ability 6: Visualization

Visualization questions were meant to measure students' visual ability. Four questions were asked that include abstract shapes. Figure 4.6 demonstrated the questions.

13 Choose the best answer.

g is to 6 as R is to?

| A | B | C | D |
|---|---|---|---|
| R | Ɔ | R | Ɔ |

14 If the transparent piece of paper is folded along the middle (dotted line), which of the following illustrations will result?

| A | B | C | D |
|---|---|---|---|
| X | ◆ | ◆ | ◆ |

15 Which is a mirror image of the below image? Assume that the dotted line is the mirror.

| A | B | C | D |
|---|---|---|---|
| ◆ | ☾ | ☾ | ◆ |

16 Which of the following shows a reflection of the image below? Assume that the dotted line is the line of reflection.

| A | B | C | D |
|---|---|---|---|
| ↙ | ● | ● | ↘ |
| ⊙ | ◇ | ◇ | ⊙ |

Figure 4.6 Visualization Questions

The descriptive analysis of students' scores for the visualization questions is shown in tables 4.20 and 4.21. School 1 students who study Java OOP scored higher ($M=0.5021$, $SD=0.18398$) than students who do not study Java OOP ($M= 0.4601$, $SD=0.12894$). However, for School 2; students who study Java OOP scored slightly better in the Vz pre test ($M=0.5313$, $SD=0.16022$) than students who do not study Java OOP score ($M=0.5238$, $SD=0.22227$).

For the posttest Vz, School 1 students who study Java OOP scores were ($M=0.5467$, $SD=0.18206$) and students who do not study Java OOP ($M=0.5276$, $SD=0.19272$). Yet, in School 2, students who study Java OOP scores were ($M=0.5938$, $SD=0.12939$) and students who do not study Java OOP ($M=0.5357$, $SD=0.19821$).

| Group Statistics School 1 | | | | | |
|---------------------------|-------------------------------|-----|--------|----------------|-----------------|
| Studying Java Programming | | N | Mean | Std. Deviation | Std. Error Mean |
| Vz | Studying Java Programming | 121 | 0.5021 | 0.18398 | 0.01673 |
| | Not Studying Java Programming | 639 | 0.4601 | 0.12894 | 0.00510 |
| Vzp | Studying Java Programming | 123 | 0.5467 | 0.18206 | 0.01642 |
| | Not Studying Java Programming | 626 | 0.5276 | 0.19272 | 0.00770 |

Table 4.20 Descriptive Statistics Results for School 1 – Visualization

| Group Statistics School 2 | | | | | |
|---------------------------|-------------------------------|----|--------|----------------|-----------------|
| Studying Java Programming | | N | Mean | Std. Deviation | Std. Error Mean |
| Vz | Studying Java Programming | 8 | 0.5313 | 0.16022 | 0.05665 |
| | Not Studying Java Programming | 21 | 0.5238 | 0.22227 | 0.04850 |
| Vzp | Studying Java Programming | 8 | 0.5938 | 0.12939 | 0.04575 |
| | Not Studying Java Programming | 21 | 0.5357 | 0.19821 | 0.04325 |

Table 4.21 Descriptive Statistics Results for School 2 – Visualization

Although the difference in means between the two groups was apparent in the descriptive results particularly in the posttest. The inferential statistical analysis revealed that the difference is not significant between the two groups in the posttest in both schools.

For School 1, the Levene's Test for Equality of Variances was < 0.05 in the pre test Vz and >0.05 in the posttest. Surprisingly, although the difference was significant in the pre test between the two groups ($t=2.400$, $df=143.127$, $p<0.05$), the posttest, the difference was not significant ($t=1.058$, $df=179.931$, $p>0.05$).

On the other hand, the Levene's Test for Equality of Variances was > 0.05 for the pre test Vz and posttest Vzp in School 2. The t-test of the pre test results ($t=0.086$, $df=27$, $p>0.05$) and for the posttest results ($t=764$, $df=27$, $p>0.05$). Such significance cannot be considered significant. Hence, learning Java OOP doesn't seem to have an impact on students Visualization ability in School 2.

4.4.7 Cognitive Ability 7: Speed Rotation

Four questions were asked to measure the Speed Rotation ability. The questions require students to rotate a given 2D or 3D shape in different directions and find the answer. The questions are presented in figure 4.7 below.

17 Which figure is NOT identical to the figure below?

18 Which one is different than the others?

19 Which of the following is a rotation for the following shape?

20 If wheel A moves anticlockwise, how many wheels will also moves anticlockwise other than A?

A. 2
B. 3
C. 4
D. 5

Figure 4.7 Speed Rotation Questions

The descriptive analysis of the Responses to the Speed Rotation questions reveals slight differences in the means between the two groups particularly in the posttest for both schools as shown in tables 4.22 and 4.23 below.

School 1 students who study Java OOP score almost the same ($M=0.4380$, $SD=0.14172$) as students who do not study Java OOP ($M=0.4398$, $SD=0.14931$). On the other hand, School 2,

students who study Java OOP scores ($M=0.5938$, $SD=0.26517$) and students who do not Java OOP score ($M=0.4524$, $SD=0.15040$).

The results of the two groups in posttest SRp for School 1 were close to each other. Java OOP students score ($M=0.5285$, $SD=0.17880$) and students who do not study Java OOP score ($M=0.5207$, $SD=0.20044$). However, interestingly, the posttest SRp results differ between the two groups in School 2. Students who study Java OOP score ($M=0.6563$, $SD=0.26517$) higher than students who do not study Java OOP ($M=0.5357$, $SD=0.21339$).

| Group Statistics School 1 | | | | | |
|---------------------------|-------------------------------|-----|--------|----------------|-----------------|
| Studying Java Programming | | N | Mean | Std. Deviation | Std. Error Mean |
| SR | Studying Java Programming | 121 | 0.4380 | 0.14172 | 0.01288 |
| | Not Studying Java Programming | 635 | 0.4398 | 0.14931 | 0.00593 |
| SRp | Studying Java Programming | 123 | 0.5285 | 0.17880 | 0.01612 |
| | Not Studying Java Programming | 629 | 0.5207 | 0.20044 | 0.00799 |

Table 4.22 Descriptive Statistics Results for School 1 – Speed Rotation

| Group Statistics School 2 | | | | | |
|---------------------------|-------------------------------|----|--------|----------------|-----------------|
| Studying Java Programming | | N | Mean | Std. Deviation | Std. Error Mean |
| SR | Studying Java Programming | 8 | 0.5938 | 0.26517 | 0.09375 |
| | Not Studying Java Programming | 21 | 0.4524 | 0.15040 | 0.03282 |
| SRp | Studying Java Programming | 8 | 0.6563 | 0.26517 | 0.09375 |
| | Not Studying Java Programming | 21 | 0.5357 | 0.21339 | 0.04657 |

Table 4.23 Descriptive Statistics Results for School 2 – Speed Rotation

The Levene's Test for Equality of Variances is > 0.05 for both Schools. The t-test of the pre test in School 1 is ($t=-0.119$, $df=174.650$, $p>0.05$) and the t-test of the posttest result is ($t=0.401$, $df=750$, $p>0.05$). School 1 pre test t-test results ($t=1.819$, $df=27$, $p>0.05$) while the posttest t-test results is ($t=1.273$, $df=27$, $p>0.05$). Hence the difference in means is not significant.

4.4.8 Cognitive Ability 8: Closure Speed

The next four questions in the CT Cognitive Abilities Measure were about Closure Speed that is related to the person's ability to visualize a flat shape or template when it is closed. Figure 4.8 demonstrates the questions.

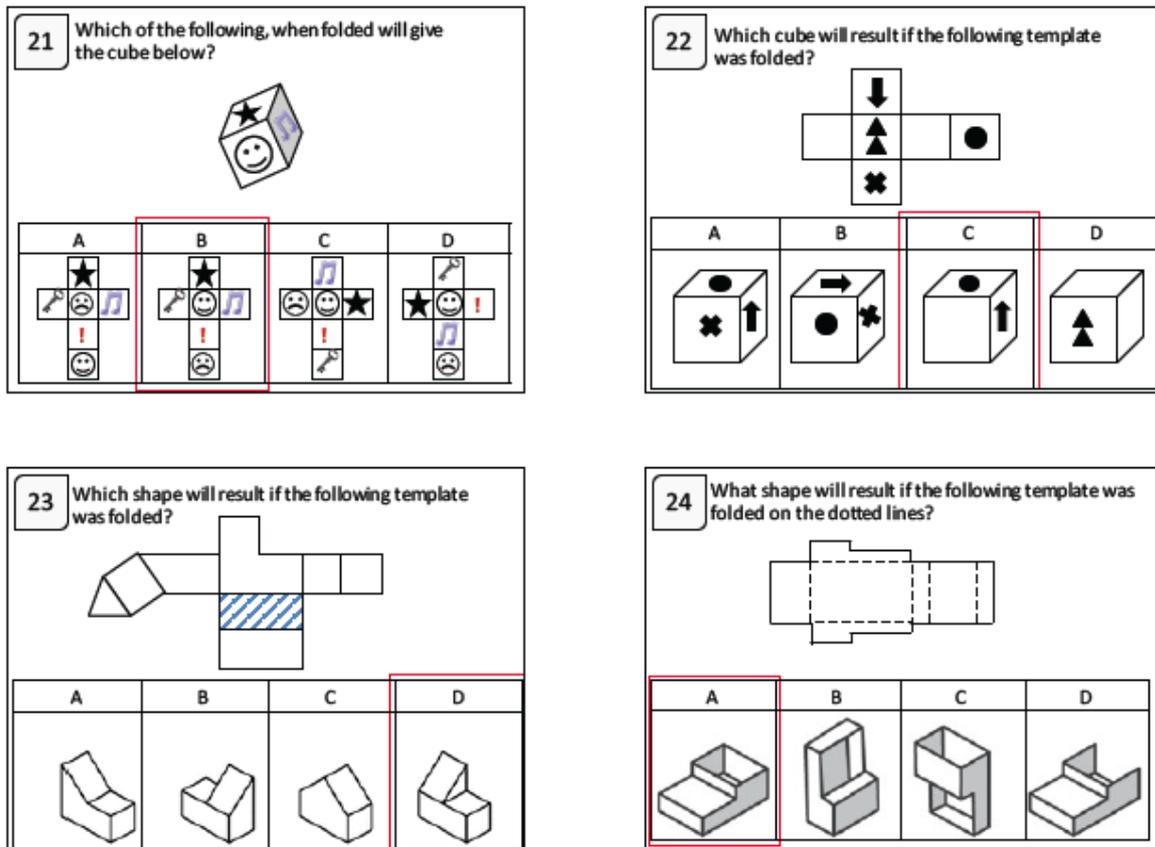


Figure 4.8 Closure Speed Questions

The descriptive analysis of the participants to the Closure Speed questions revealed remarkable results as shown below in tables 4.24 and 4.25. The pre test results of School 1 students who study Java OOP ($M=0.3873$, $SD=0.14411$) and students who do not study Java OOP results are ($M=0.3824$, $SD=0.13465$). Yet, School 2 students' results of the pre test are quiet similar. Students who study Java OOP are slightly higher ($M=0.4063$, $SD=0.18601$) than students who

do not study Java OOP (M=0.3810, SD=0.15040). This analysis disclosed a difference in means in the posttest in both Schools.

School 1 posttest results for students who study Java OOP scores are (M=0.5630, SD=0.18827) whereas students who do not study Java OOP scores are (M=0.3972, SD=0.14930). likewise, School 2, students who study Java OOP are (M=0.6875, SD=0.17678) and students who do not study Java OOP (M=0.4643, SD=0.18176).

| Group Statistics School 1 | | | | | |
|---------------------------|-------------------------------|-----|--------|----------------|-----------------|
| Studying Java Programming | | N | Mean | Std. Deviation | Std. Error Mean |
| CS | Studying Java Programming | 122 | 0.3873 | 0.14411 | 0.01305 |
| | Not Studying Java Programming | 642 | 0.3824 | 0.13465 | 0.00531 |
| CSp | Studying Java Programming | 123 | 0.5630 | 0.18827 | 0.01698 |
| | Not Studying Java Programming | 632 | 0.3972 | 0.14930 | 0.00594 |

Table 4.24 Descriptive Statistics Results for School 1 – Closure Speed

| Group Statistics School 2 | | | | | |
|---------------------------|-------------------------------|----|--------|----------------|-----------------|
| Studying Java Programming | | N | Mean | Std. Deviation | Std. Error Mean |
| CS | Studying Java Programming | 8 | 0.4063 | 0.18601 | 0.06576 |
| | Not Studying Java Programming | 21 | 0.3810 | 0.15040 | 0.03282 |
| CSp | Studying Java Programming | 8 | 0.6875 | 0.17678 | 0.06250 |
| | Not Studying Java Programming | 21 | 0.4643 | 0.18176 | 0.03966 |

Table 4.25 Descriptive Statistics Results for School 2 – Closure Speed

Further, the inferential statistical analysis reveals significant differences between the two groups in both schools. The Levene's Test for Equality of Variances is > 0.05 for the pre test and posttest in both schools. School 1 t-test result of the pre test CS ($t=0.364$, $df=762$, $p>0.05$) yet the t-test result of the posttest ($t=10.769$, $df=753$, $p<0.05$). Similarly, School 2 t-test result of the pre test CS ($t=0.380$, $df=27$, $p>0.05$) and for the posttest CSp ($t=2.977$, $df=27$, $p<0.05$). This indicates an impact of learning Java OOP on students Closure Speed ability.

SD=0.20863) is similar to the mean score of the students who do not study Java OOP (M=0.4643, SD=0.16366).

The posttest results of students who study Java OOP in School 1 (M=0.5900, SD=0.19417) is somewhat higher than the mean score of the students who do not study Java OOP (M=0.5877, SD=0.19713). Also, School 2 students who study Java OOP mean score (M=0.6875, SD=0.11573) and for students who do not study Java OOP (M=0.6548, SD=0.26782) are close.

| Group Statistics School 1 | | | | | |
|---------------------------|-------------------------------|-----|--------|----------------|-----------------|
| Studying Java Programming | | N | Mean | Std. Deviation | Std. Error Mean |
| CF | Studying Java Programming | 121 | 0.4525 | 0.18061 | 0.01642 |
| | Not Studying Java Programming | 635 | 0.4382 | 0.14326 | 0.00569 |
| CFp | Studying Java Programming | 125 | 0.5900 | 0.19417 | 0.01737 |
| | Not Studying Java Programming | 636 | 0.5877 | 0.19713 | 0.00782 |

Table 4.26 Descriptive Statistics Results for School 1 – Flexibility of Closure

| Group Statistics School 2 | | | | | |
|---------------------------|-------------------------------|----|--------|----------------|-----------------|
| Studying Java Programming | | N | Mean | Std. Deviation | Std. Error Mean |
| CF | Studying Java Programming | 8 | 0.4688 | 0.20863 | 0.07376 |
| | Not Studying Java Programming | 21 | 0.4643 | 0.16366 | 0.03571 |
| CFp | Studying Java Programming | 8 | 0.6875 | 0.11573 | 0.04092 |
| | Not Studying Java Programming | 21 | 0.6548 | 0.26782 | 0.05844 |

Table 4.27 Descriptive Statistics Results for School 2 – Flexibility of Closure

The Levene's Test for Equality of Variances is > 0.05 for the pre test and < 0.05 for the posttest in School 2. Hence, the t-test result of the pre test is ($t=0.06$, $df=27$, $p>0.05$) and ($t=0.459$, $df=26.334$, $p>0.05$) for the posttest. Yet, in School 1, the Levene's Test for Equality of Variances is > 0.05 for both pre test and posttest. While, the t-test results of the pre test is ($t=0.962$, $df=754$, $p>0.05$) and ($t=0.122$, $df=759$, $p>0.05$) for the posttest. Therefore, the difference in the mean scores is not significant.

4.4.10 Cognitive Ability 10: Visual Memory

To measure the students' Visual Memory ability, they were given an image that contains a lot of details and then asked 4 different questions about it. Figure 4.10 shows the image and the questions.

Look at the image below for 5 seconds.



45 How many students were wearing blue blouse?

| | | | |
|---|---|---|---|
| A | B | C | D |
| 1 | 2 | 4 | 7 |

46 What is the color of the camera man t-shirt?

| | | | |
|-------|-----|-------|-------|
| A | B | C | D |
| white | red | green | black |

48 How many empty seats were there in the front row?

| | | | |
|---|---|---|---|
| A | B | C | D |
| 2 | 3 | 4 | 5 |

47 How many doors were in the back of the classroom?

| | | | |
|---|---|---|---|
| A | B | C | D |
| 1 | 2 | 3 | 4 |

Figure 4.10 Visual Memory Questions

Students' responses to the Visual Memory questions were not as accurate as their responses to other constructs. Tables 4.28 and 4.29 show that the pre test mean score of School 1 students who study Java OOP score ($M=0.3843$, $SD=0.14449$) and students who do not study Java OOP ($M=0.3908$, $SD=0.15243$). Likewise, School 2 students who study Java OOP ($M=0.3438$, $SD=0.18601$) is almost the same as the mean score of the students who do not study Java OOP ($M=0.3452$, $SD=0.20119$).

Interestingly, the responses to the posttest in School 1 students who study Java OOP score ($M=0.6057$, $SD=0.20992$) and students who do not study Java OOP ($M=0.5207$, $SD=0.15519$). Whereas School 2 were considerably better than the pre test. Students who study Java OOP score ($M=0.6875$, $SD=0.22160$) and students who do not study Java OOP ($M=0.4286$,

SD=0.19594). This indicates a significant difference that can be confirmed by the inferential statistical analysis.

| Group Statistics School 1 | | | | | |
|---------------------------|-------------------------------|-----|--------|----------------|-----------------|
| Studying Java Programming | | N | Mean | Std. Deviation | Std. Error Mean |
| MV | Studying Java Programming | 121 | 0.3843 | 0.14449 | 0.01314 |
| | Not Studying Java Programming | 639 | 0.3908 | 0.15243 | 0.00603 |
| MVp | Studying Java Programming | 123 | 0.6057 | 0.20992 | 0.01893 |
| | Not Studying Java Programming | 628 | 0.5207 | 0.15519 | 0.00619 |

Table 4.28 Descriptive Statistics Results for School 1 – Visual Memory

| Group Statistics School 2 | | | | | |
|---------------------------|-------------------------------|----|--------|----------------|-----------------|
| Studying Java Programming | | N | Mean | Std. Deviation | Std. Error Mean |
| MV | Studying Java Programming | 8 | 0.3438 | 0.18601 | 0.06576 |
| | Not Studying Java Programming | 21 | 0.3452 | 0.20119 | 0.04390 |
| MVp | Studying Java Programming | 8 | 0.6875 | 0.22160 | 0.07835 |
| | Not Studying Java Programming | 21 | 0.4286 | 0.19594 | 0.04276 |

Table 4.29 Descriptive Statistics Results for School 2 – Visual Memory

School 1 Levene's Test for Equality of Variances is > 0.05 for the pre test and < 0.05 for the posttest. Hence, while the pre test t-test result is ($t=-0.437$, $df=758$, $p>0.05$), the t-test result of the posttest ($t=4.268$, $df=149.186$, $p<0.05$). On the other hand, Levene's Test for Equality of Variances is > 0.05 for the pre test and posttest in School 2. The t-test result of the pre test ($t=-0.018$, $df=27$, $p>0.05$) while the t-test of the posttest is ($t=3.071$, $df=27$, $p<0.05$) which confirms the significant difference between the two groups.

Consequently, Cohen's d is calculated to identify the effect size. Though, for School 1, it is 0.4656 i.e. modest effect. While for School 2, Cohen's d value is 1.2401 which indicates a strong effect.

4.4.11 Cognitive Ability 11: Spatial Scanning

Spatial Scanning questions depend on the person's ability to locate himself at a specific point and follow directions to reach another point. A location map is given to the participants and were asked four different questions about it.

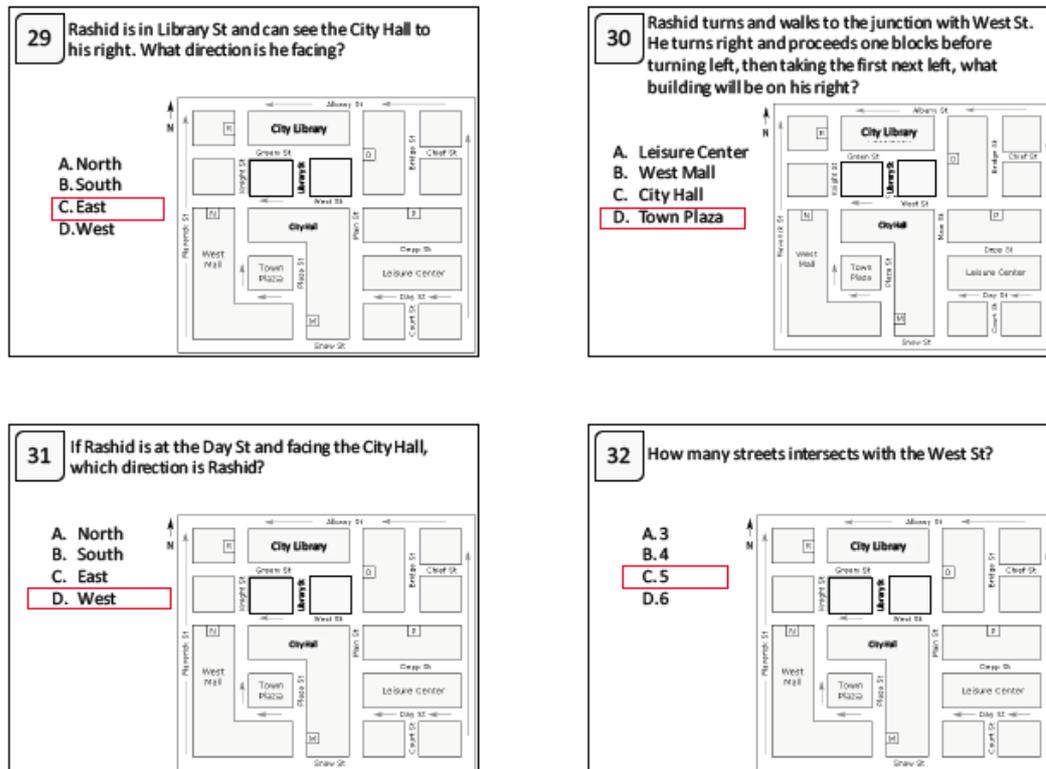


Figure 4.11 Spatial Scanning Questions

The descriptive statistical analysis of the pre test responses shown in table 4.30 reveals that the mean score of School 1 students who study Java OOP ($M=0.6488$, $SD=0.18979$). Yet students who do not study Java OOP score lower ($M=0.6104$, $SD=0.19567$). Very similar results were obtained from students who study Java OOP in School 2 ($M=0.6563$, $SD=0.12939$) is slightly higher than students who do not study Java OOP ($M=0.6429$, $SD=0.12677$).

On the other hand, the descriptive analysis of the posttest responses for School 2 also discloses a small difference in means between the two groups as shown in table 4.31. Students who study

Java OOP mean score (M=0.7188, SD=0.20863) and the mean score for students who do not study Java OOP (M=0.7143, SD=0.16366). Similarly, School 1 students who study Java OOP mean (M=0.7053, SD=0.13593) is also higher than those who do not study Java OOP (M=0.6823, SD=0.17352). Yet, the difference is not significant.

| Group Statistics School 1 | | | | | |
|---------------------------|-------------------------------|-----|--------|----------------|-----------------|
| Studying Java Programming | | N | Mean | Std. Deviation | Std. Error Mean |
| SS | Studying Java Programming | 121 | 0.6488 | 0.18979 | 0.01725 |
| | Not Studying Java Programming | 641 | 0.6104 | 0.19567 | 0.00773 |
| SSp | Studying Java Programming | 123 | 0.7053 | 0.13593 | 0.01226 |
| | Not Studying Java Programming | 635 | 0.6823 | 0.17352 | 0.00689 |

Table 4.30 Descriptive Statistics Results for School 1 – Spatial Scanning

| Group Statistics School 2 | | | | | |
|---------------------------|-------------------------------|----|--------|----------------|-----------------|
| Studying Java Programming | | N | Mean | Std. Deviation | Std. Error Mean |
| SS | Studying Java Programming | 8 | 0.6563 | 0.12939 | 0.04575 |
| | Not Studying Java Programming | 21 | 0.6429 | 0.12677 | 0.02766 |
| SSp | Studying Java Programming | 8 | 0.7188 | 0.20863 | 0.07376 |
| | Not Studying Java Programming | 21 | 0.7143 | 0.16366 | 0.03571 |

Table 4.31 Descriptive Statistics Results for School 2 – Spatial Scanning

To further study the significance of the difference, the Levene's Test for Equality of Variances for School 1 is > 0.05 for the pre test and < 0.05 for the posttest. Hence, the pre test t-test result is ($t=1.989$, $df=760$, $p>0.05$) and for the posttest it is ($t=1.636$, $df=207.200$, $p>0.05$). Hence, there is no significant difference. Levene's Test for Equality of Variances is > 0.05 for School 2 pre test and posttest. The t-test result for the pre test is ($t=0.253$, $df=27$, $p>0.05$) and for the posttest is ($t=0.061$, $df=27$, $p>0.05$). Therefore, there is no significant difference in means particularly in the posttest.

4.4.12 Cognitive Ability 12: Serial Perceptual Integration

Four Serial Perceptual Integration questions were given to the participants in the pre test and posttest. Each question includes an abstract set of shapes that misses one. The respondent has to find the missing shape by understanding the relationship between the given shapes. Figure 4.12 presents the four questions.

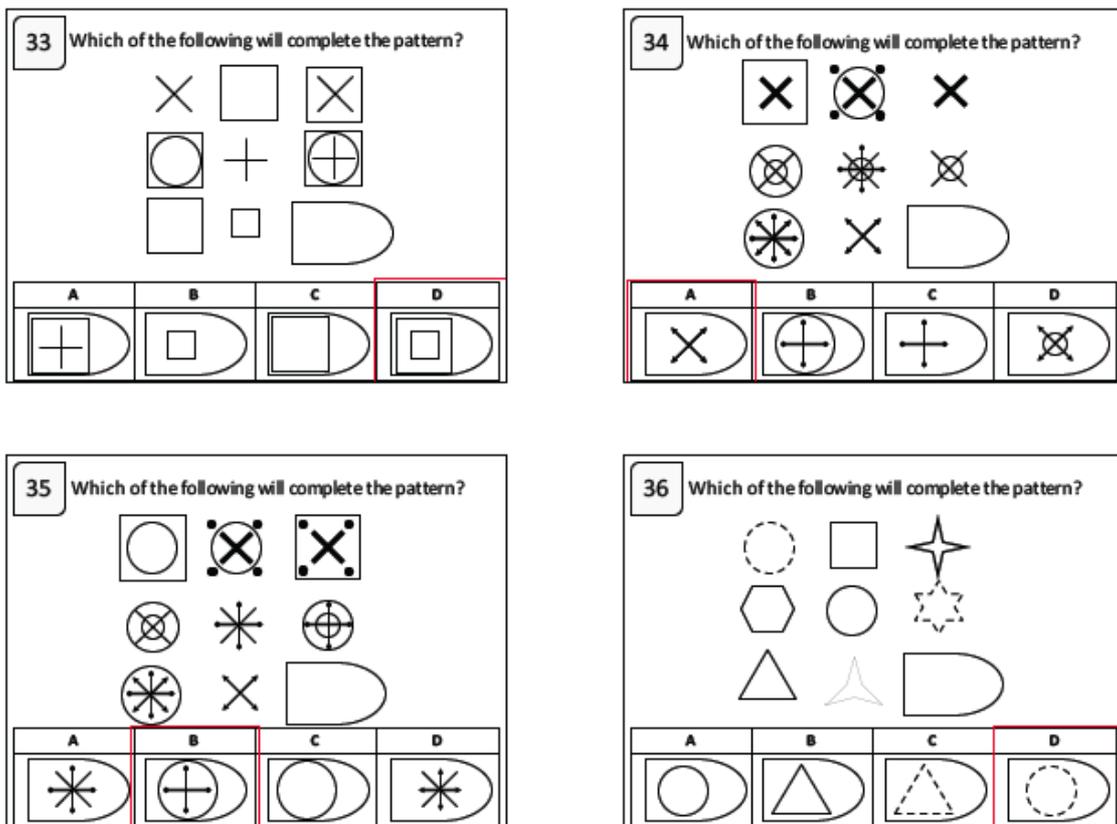


Figure 4.12 Serial Perceptual Integration Questions

The descriptive statistical analyses of the participants' responses in School 1 and 2 are shown in tables 4.32 and 4.33 below. School 1 students who study Java OOP score ($M=0.40713$, $SD=0.40713$) slightly higher in the pre test than students who do not study Java OOP ($M=0.3929$, $SD=0.19465$). Likewise, School 2 students who study Java OOP pre test mean score ($M=0.4375$, $SD=0.22160$) is quite higher than the students who do not study Java OOP ($M=0.4010$, $SD=0.12794$).

Interestingly, in the posttest, School 1, students who study Java OOP score ($M=0.6630$, $SD=0.18827$) also remarkably higher than students who do not study Java OOP ($M=0.4272$, $SD=0.17970$). Similarly, in School 2 students who study Java OOP score ($M=0.6875$, $SD=0.22160$) better than students who do not study Java OOP ($M=0.4405$, $SD=0.10911$).

The inferential statistical analysis revealed noteworthy results. The Levene's Test for Equality of Variances is > 0.05 for the pre test and the posttest in School 1 and < 0.05 in School 2. Therefore, the t-test results of the pre test in School 1 is ($t=0.362$, $df=762$, $p>0.05$) and for the posttest ($t=11.709$, $df=753$, $p<0.05$). Similar results are obtained in School 2, the pre test t-test result is ($t=0.780$, $df=27$, $p>0.05$). While the t-test of the posttest result is ($t=3.017$, $df=8.328$, $p<0.05$). Such results indicate a significant difference between the two groups scores in the posttest. The effect size in the posttest can be recognized by calculating Cohen's d which found to be 1.3013 for School 1 and for School 2 1.4938. The two results indicate a strong effect size.

| Group Statistics School 1 | | | | | |
|---------------------------|-------------------------------|-----|---------|----------------|-----------------|
| Studying Java Programming | | N | Mean | Std. Deviation | Std. Error Mean |
| PI | Studying Java Programming | 122 | 0.40713 | 0.20411 | 0.01305 |
| | Not Studying Java Programming | 642 | 0.3929 | 0.19465 | 0.00531 |
| PIp | Studying Java Programming | 123 | 0.6630 | 0.18827 | 0.01688 |
| | Not Studying Java Programming | 632 | 0.4272 | 0.17970 | 0.01594 |

Table 4.32 Descriptive Statistics Results for School 1 – Serial Perceptual Integration

| Group Statistics School 2 | | | | | |
|---------------------------|-------------------------------|----|--------|----------------|-----------------|
| Studying Java Programming | | N | Mean | Std. Deviation | Std. Error Mean |
| PI | Studying Java Programming | 8 | 0.4375 | 0.22160 | 0.07835 |
| | Not Studying Java Programming | 21 | 0.4010 | 0.12794 | 0.02792 |
| PIp | Studying Java Programming | 8 | 0.6875 | 0.22160 | 0.07835 |
| | Not Studying Java Programming | 21 | 0.4405 | 0.10911 | 0.02381 |

Table 4.33 Descriptive Statistics Results for School 2 – Serial Perceptual Integration

4.4.13 Summary of the CT Cognitive Abilities Measure Data Analysis

In summary, as a result of the quasi experiment, students in both School 1 and School 2 demonstrated a significant improvement in their Induction, Quantitative Reasoning, Closure Speed, Visual Memory, and Serial Perceptual Integration abilities. However, only students in School 2 have achieved a significant improvement in Memory Span and Working Memory Abilities. Table 4.34 presents the summary of the posttest results' inferential statistical analyses.

| | Site | t-test | df | p |
|--|----------|--------|---------|--------|
| Induction (I) General Sequential Reasoning (RG) | School 1 | 6.354 | 151.271 | <0.05 |
| | School 2 | 2.519 | 27 | <0.05 |
| Quantitative Reasoning (RQ) Induction (I) | School 1 | 0.870 | 197.934 | p>0.05 |
| | School 2 | 1.041 | 27 | p>0.05 |
| General Sequential Reasoning (RG) | School 1 | 6.889 | 154.423 | p<0.05 |
| | School 2 | 2.831 | 27 | p<0.05 |
| Working Memory (MW) | School 1 | 3.108 | 741 | < 0.05 |
| | School 2 | 1.373 | 27 | >0.05 |
| Working Memory (MW) | School 1 | 2.946 | 163.091 | <0.05 |
| | School 2 | 0.674 | 27 | >0.05 |
| Visualization (Vz) | School 1 | 1.058 | 179.931 | >0.05 |
| | School 2 | 764 | 27 | >0.05 |
| Speeded Rotation(Spatial Relations; SR) | School 1 | 0.401 | 750 | >0.05 |
| | School 2 | 1.273 | 27 | >0.05 |
| Closure Speed (CS) | School 1 | 10.769 | 753 | <0.05 |
| | School 2 | 2.977 | 27 | <0.05 |
| Flexibility of Closure (CF) | School 1 | 0.122 | 759 | >0.05 |
| | School 2 | 0.459 | 26.334 | >0.05 |
| Visual Memory (MV) | School 1 | 4.268 | 149.186 | <0.05 |
| | School 2 | 3.071 | 27 | <0.05 |
| Spatial Scanning (SS) | School 1 | 1.636 | 207.200 | >0.05 |
| | School 2 | 0.061 | 27 | >0.05 |
| Serial Perceptual Integration (PI) | School 1 | 11.709 | 753 | <0.05 |
| | School 2 | 3.017 | 8.328 | <0.05 |

Table 4.34 Summary of the posttest results' inferential statistical analyses

4.5 Questionnaire Data Analysis

This section presents the quantitative data analysis of the participants' responses to the questionnaire questions. The purpose of the cross-sectional questionnaire is to answer the first sub-question about students' perception about learning computer programming and the fourth sub-question about how gender differences may affect students' choices, cognitive styles and perceptions when they learn computer programming. The questionnaire was "piloted and refined so that the final version contains as full a range of possible responses as can be reasonably foreseen" (Fraenkel, Wallen, & Hyun 2011). Grade 11 students who study Java OOP in both schools were invited to answer the questionnaire i.e. School 1 students (n=98), which achieved a confidence level = 77.1% and 99% (n=8) and School 2 which achieved a confidence level 95%. Collected data was cleaned and analyzed using SPSS Version 24.

The closed ended questionnaire questions allowed the statistical treatment of the quantitative data and the provision of more focused analysis. Using the descriptive statistical technique i.e. frequency analysis, the researcher could investigate students' perception toward learning computer programming. Furthermore, the researcher had used the inferential statistical analyses Chi-Square test and *Phi* to find how perceptions are different between males and females.

According to Baser (2013), evaluation of attitudes is based on "cognitive, affective, and behavioral information". There is no standard method to measure attitudes toward computer programming. Different researchers develop their own scales. Hence, since attitudes toward programming cannot be directly observed, Likert scales are the best way to measure it which was already done by the researcher.

The questionnaire includes five sections. The first section targets the participants' demographics while the other four sections target the students'

- Confidence when learning computer programming
- Attitude toward learning computer programming
- Awareness of the usefulness of learning computer programming
- Motivation to learn computer programming

Each of those dimension is investigated through seven different statements. Respondents had to respond to a 5-point Likert Scale. Responses were coded as shown in table 4.35 below.

| Response | Code |
|-------------------|------|
| Strongly Agree | 5 |
| Agree | 4 |
| Neutral | 3 |
| Disagree | 2 |
| Strongly Disagree | 1 |

Table 4.35 Questionnaire Responses Codes

It is worth noting, as mentioned earlier in Chapter 3, responses to the statements with reversed wording were inverted before conducting the analysis. New variables with the new values were added to the data tables using SPSS software.

For each dimension in the questionnaire, descriptive statistics including frequency analyses and percentages were calculated to identify the perception of students who study computer programming and the differences in perceptions between males and females. Furthermore, through cross tabulation, the inferential statistical analyses Pearson Chi-Square and Phi are used to identify the significance of the differences, if found, and the effect size. Additionally,

Cross break (Contingency) tables were created to demonstrate the number of Male and Female respondents for each of the questionnaire statements (Fraenkel, Wallen, & Hyun 2011).

This section includes 4 sub sections namely; Confidence when learning computer programming, Attitude toward learning computer programming, Awareness of the usefulness of learning computer programming, and Motivation to learn computer programming. Each sub-section discusses the previously mentioned dimensions with the results of the conducted statistical analyses.

4.5.1 Confidence When Learning Computer Programming

This sub-section discusses the analysis of responses to the following seven questionnaire statements about students' confidence in learning computer programming:

AC1. I am sure I can learn programming

AC2. I think at the end of the programming course; I will be able to solve complex programming problems

AC3*. Programming is the most difficult subject for me

AC4. I can get excellent grades in this programming course

AC5. I feel secure when I am asked to solve problems in programming

AC6*. If given the choice, I will not take the advanced level of the programming course

AC7. I plan to study programming or any other related discipline in the college

Statements 3 and 6 were worded negatively to avoid the response set (Johnson & Christensen 2012). Hence, the researcher had used the Recoding Function in SPSS to recode the responses of those statements and analyze the results accordingly.

Tables 4.36 and 4.37 demonstrate the descriptive statistics of the overall data collected about the students' confidence when learning computer programming in both School 1 and School 2. Frequency analysis and percentages are shown for the 5-Likert Scale options. Generally, the analysis of School 1 and School 2 results show that students demonstrate high confidence when they learn computer programming. Around 40% or more students either agree or strongly agree with the statements provided for the Confidence in Learning Compute Programming Dimension.

| Response | AC1 | | AC2 | | AC3* | | AC4 | | AC5 | | AC6* | | AC7 | |
|-------------------|-----------|------------|-----------|------------|-----------|------------|-----------|------------|-----------|------------|-----------|------------|-----------|------------|
| | Frequency | Percentage |
| Strongly Disagree | 13 | 13.3 | 10 | 10.2 | 1 | 1.0 | 4 | 4.1 | 14 | 14.3 | 3 | 3.1 | 4 | 4.1 |
| Disagree | 25 | 25.5 | 29 | 29.6 | 12 | 12.2 | 21 | 21.4 | 33 | 33.7 | 17 | 17.3 | 14 | 14.3 |
| Neutral | 18 | 18.4 | 17 | 17.3 | 37 | 37.8 | 34 | 34.7 | 10 | 10.2 | 29 | 29.6 | 32 | 32.7 |
| Agree | 18 | 18.4 | 31 | 31.6 | 35 | 35.7 | 19 | 19.4 | 26 | 26.5 | 39 | 39.8 | 29 | 29.6 |
| Strongly Agree | 24 | 24.5 | 11 | 11.2 | 13 | 13.3 | 20 | 20.4 | 15 | 15.3 | 10 | 10.2 | 19 | 19.4 |
| Total | 98 | 100 | 98 | 100 | 98 | 100 | 98 | 100 | 98 | 100 | 98 | 100 | 98 | 100 |

Table 4.36 Descriptive Statistics of the Questionnaire Results – Confidence - School 1

| Response | AC1 | | AC2 | | AC3* | | AC4 | | AC5 | | AC6* | | AC7 | |
|-------------------|-----------|------------|-----------|------------|-----------|------------|-----------|------------|-----------|------------|-----------|------------|-----------|------------|
| | Frequency | Percentage |
| Strongly Disagree | 1 | 12.5 | 1 | 12.5 | 0 | 0 | 0 | 0 | 2 | 25.0 | 0 | 0 | 1 | 12.5 |
| Disagree | 1 | 12.5 | 1 | 12.5 | 0 | 0 | 1 | 12.5 | 0 | 0 | 0 | 0 | 0 | 0 |
| Neutral | 1 | 12.5 | 0 | 0 | 2 | 25.0 | 2 | 25.0 | 1 | 12.5 | 3 | 37.5 | 2 | 25.0 |
| Agree | 1 | 12.5 | 5 | 62.5 | 3 | 37.5 | 3 | 37.5 | 3 | 37.5 | 3 | 37.5 | 2 | 25.0 |
| Strongly Agree | 4 | 50.0 | 1 | 12.5 | 3 | 37.5 | 2 | 25.0 | 2 | 25.0 | 2 | 25.0 | 3 | 37.5 |
| Total | 8 | 100 | 8 | 100 | 8 | 100 | 8 | 100 | 8 | 100 | 8 | 100 | 8 | 100 |

Table 4.37 Descriptive Statistics of the Questionnaire Results – Confidence - School 2

Regarding the difference in confidence between males and females in both schools, tables 4.38-4.44 demonstrate the frequency analysis of the responses for the two groups followed by table 4.45 that demonstrates the Chi-Square test results and the value of *Phi* to show the correlation

between the nominal variable “Gender” and the ordinal variables AC1, AC2, AC3*, AC4, AC5, AC6*, and AC7. The * indicates the inversely coded statement.

| AC1 | | | | | | | | | | | | | |
|--------|--------|-------------------|---|----------|---|---------|---|-------|---|----------------|---|-------|---|
| | | Strongly Disagree | | Disagree | | Neutral | | Agree | | Strongly Agree | | Total | |
| School | | 1 | 2 | 1 | 2 | 1 | 2 | 1 | 2 | 1 | 2 | 1 | 2 |
| Gender | Male | 2 | 0 | 2 | 0 | 6 | 1 | 10 | 1 | 23 | 4 | 43 | 6 |
| | Female | 11 | 1 | 23 | 1 | 12 | 0 | 8 | 0 | 1 | 0 | 55 | 2 |
| Total | | 13 | 1 | 25 | 1 | 18 | 1 | 18 | 1 | 24 | 4 | 98 | 8 |

Table 4.38 Frequency Analysis of Males and Females’ Responses to AC1

| AC2 | | | | | | | | | | | | | |
|--------|--------|-------------------|---|----------|---|---------|---|-------|---|----------------|---|-------|---|
| | | Strongly Disagree | | Disagree | | Neutral | | Agree | | Strongly Agree | | Total | |
| School | | 1 | 2 | 1 | 2 | 1 | 2 | 1 | 2 | 1 | 2 | 1 | 2 |
| Gender | Male | 0 | 0 | 2 | 0 | 4 | 0 | 27 | 5 | 10 | 1 | 43 | 6 |
| | Female | 10 | 1 | 27 | 1 | 13 | 0 | 4 | 0 | 1 | 0 | 55 | 2 |
| Total | | 10 | 1 | 29 | 1 | 17 | 0 | 31 | 5 | 11 | 1 | 98 | 8 |

Table 4.39 Frequency Analysis of Males and Females’ Responses to AC2

| AC3* | | | | | | | | | | | | | |
|--------|--------|-------------------|---|----------|---|---------|---|-------|---|----------------|---|-------|---|
| | | Strongly Disagree | | Disagree | | Neutral | | Agree | | Strongly Agree | | Total | |
| School | | 1 | 2 | 1 | 2 | 1 | 2 | 1 | 2 | 1 | 2 | 1 | 2 |
| Gender | Male | 0 | 0 | 2 | 0 | 8 | 1 | 21 | 2 | 12 | 3 | 43 | 6 |
| | Female | 1 | 0 | 10 | 0 | 29 | 1 | 14 | 1 | 1 | 0 | 55 | 2 |
| Total | | 1 | 0 | 12 | 0 | 37 | 2 | 35 | 3 | 13 | 3 | 98 | 8 |

Table 4.40 Frequency Analysis of Males and Females’ Responses to AC3*

| AC4 | | | | | | | | | | | | | |
|--------|--------|-------------------|---|----------|---|---------|---|-------|---|----------------|---|-------|---|
| | | Strongly Disagree | | Disagree | | Neutral | | Agree | | Strongly Agree | | Total | |
| School | | 1 | 2 | 1 | 2 | 1 | 2 | 1 | 2 | 1 | 2 | 1 | 2 |
| Gender | Male | 0 | 0 | 1 | 0 | 7 | 1 | 15 | 0 | 20 | 2 | 43 | 6 |
| | Female | 4 | 0 | 20 | 1 | 27 | 1 | 4 | 0 | 0 | 0 | 55 | 2 |
| Total | | 4 | 0 | 21 | 1 | 34 | 2 | 19 | 0 | 20 | 2 | 98 | 8 |

Table 4.41 Frequency Analysis of Males and Females’ Responses to AC4

| AC5 | | | | | | | | | | | | | |
|--------|--------|-------------------|---|----------|---|---------|---|-------|---|----------------|---|-------|---|
| | | Strongly Disagree | | Disagree | | Neutral | | Agree | | Strongly Agree | | Total | |
| School | | 1 | 2 | 1 | 2 | 1 | 2 | 1 | 2 | 1 | 2 | 1 | 2 |
| Gender | Male | 0 | 0 | 0 | 0 | 5 | 1 | 23 | 3 | 15 | 2 | 43 | 6 |
| | Female | 14 | 2 | 33 | 0 | 5 | 0 | 3 | 0 | 0 | 0 | 55 | 2 |
| Total | | 14 | 2 | 33 | 0 | 10 | 1 | 26 | 3 | 15 | 2 | 98 | 8 |

Table 4.42 Frequency Analysis of Males and Females’ Responses to AC5

| AC6* | | | | | | | | | | | | | |
|--------|--------|-------------------|---|----------|---|---------|---|-------|---|----------------|---|-------|---|
| | | Strongly Disagree | | Disagree | | Neutral | | Agree | | Strongly Agree | | Total | |
| School | | 1 | 2 | 1 | 2 | 1 | 2 | 1 | 2 | 1 | 2 | 1 | 2 |
| Gender | Male | 1 | 0 | 4 | 0 | 3 | 1 | 26 | 3 | 9 | 2 | 43 | 6 |
| | Female | 2 | 0 | 13 | 0 | 26 | 2 | 13 | 0 | 1 | 0 | 55 | 2 |
| Total | | 3 | 0 | 17 | 0 | 29 | 3 | 39 | 3 | 10 | 2 | 98 | 8 |

Table 4.43 Frequency Analysis of Males and Females’ Responses to AC6*

| AC7 | | | | | | | | | | | | | |
|--------|--------|-------------------|---|----------|---|---------|---|-------|---|----------------|---|-------|---|
| | | Strongly Disagree | | Disagree | | Neutral | | Agree | | Strongly Agree | | Total | |
| School | | 1 | 2 | 1 | 2 | 1 | 2 | 1 | 2 | 1 | 2 | 1 | 2 |
| Gender | Male | 1 | 0 | 2 | 0 | 10 | 1 | 16 | 2 | 14 | 3 | 43 | 6 |
| | Female | 3 | 1 | 12 | 0 | 22 | 1 | 13 | 0 | 5 | 0 | 55 | 2 |
| Total | | 4 | 1 | 14 | 0 | 32 | 2 | 29 | 2 | 19 | 3 | 98 | 8 |

Table 4.44 Frequency Analysis of Males and Females' Responses to AC7

| Variable | School | Chi-Square Tests | | | Symmetric Measures - <i>Phi</i> | |
|----------|----------|---------------------|----|-----------------------|---------------------------------|--------------|
| | | Value | df | Asymp. Sig. (2-sided) | Value | Approx. Sig. |
| AC1 | School 1 | 45.472 ^a | 4 | .000 | .681 | .000 |
| | School 2 | 8.000 ^a | 4 | .092 | 1.000 | .092 |
| AC2 | School 1 | 60.177 ^a | 4 | .000 | .784 | .000 |
| | School 2 | 8.000 ^a | 3 | .046 | 1.000 | .046 |
| AC3* | School 1 | 27.909 ^a | 4 | .000 | .534 | .000 |
| | School 2 | 1.778 ^a | 2 | .411 | .471 | .411 |
| AC4 | School 1 | 58.735 ^a | 4 | .000 | .774 | .000 |
| | School 2 | 5.333 ^a | 3 | .149 | .816 | .149 |
| AC5 | School 1 | 77.071 ^a | 4 | .000 | .887 | .000 |
| | School 2 | 8.000 ^a | 3 | .046 | 1.000 | .046 |
| AC6* | School 1 | 33.100 ^a | 4 | .000 | .581 | .000 |
| | School 2 | 4.444 ^a | 2 | .108 | .745 | .108 |
| AC7 | School 1 | 15.987 ^a | 4 | .003 | .404 | .003 |
| | School 2 | 5.333 ^a | 3 | .149 | .816 | .149 |

Table 4.45 Inferential Statistics of Males and Females Responses to AC1-AC7 questions

According to the Chi-Square test results and the value of *Phi*, the results show that there is significant difference between males and females in School 1 i.e. $p < 0.05$. However, the difference was evident only for AC2 and AC5 for School 2 students. While AC1, AC3, AC4, AC6, and AC7 $p > 0.05$ which indicate no significant difference.

4.5.2 Attitude Toward Learning Computer Programming

This sub section discusses the analysis of responses to the following seven questionnaire statements about students' Attitudes toward learning computer programming:

AA1. I wait for the programming class with passion

AA2. Being recognized as a smart programmer would make me feel happy

AA3*. I think being good in programming is not something to be proud of

AA4. I feel proud when I solve programming questions

AA5*. I don't like people to know I am good in programming

AA6. I wish I can participate in a programming competition and win

AA7. Programming is my favorite subject

Similar to the previous analysis, statements 3 and 5 were worded negatively. Hence, the Recoding Function in SPSS was used to recode the responses of those statements and analyze the results accordingly.

Tables 4.46 and 4.47 present the descriptive statistics of the data collected about the students' attitudes toward learning computer programming in both School 1 and School 2. Frequency analysis and percentages are shown for the 5-Likert Scale options. Overall, the frequency analysis of the responses in School 1 and School 2 shows that the students possess positive attitude toward learning computer programming.

| Response | AA1 | | AA2 | | AA3* | | AA4 | | AA5* | | AA6 | | AA7 | |
|-------------------|-----------|------------|-----------|------------|-----------|------------|-----------|------------|-----------|------------|-----------|------------|-----------|------------|
| | Frequency | Percentage |
| Strongly Disagree | 4 | 4.1 | 1 | 1.0 | 1 | 1.0 | 4 | 4.1 | 2 | 2.0 | 1 | 1.0 | 7 | 7.1 |
| Disagree | 8 | 8.2 | 1 | 1.0 | 9 | 9.2 | 4 | 4.1 | 4 | 4.1 | 3 | 3.1 | 20 | 20.4 |
| Neutral | 10 | 10.2 | 14 | 14.3 | 14 | 14.3 | 14 | 14.3 | 20 | 20.4 | 7 | 7.1 | 31 | 31.6 |
| Agree | 54 | 55.1 | 43 | 43.9 | 45 | 45.9 | 51 | 52.0 | 49 | 50.0 | 55 | 56.1 | 23 | 23.5 |
| Strongly Agree | 22 | 22.4 | 39 | 39.8 | 29 | 29.6 | 25 | 25.5 | 23 | 23.5 | 32 | 32.7 | 17 | 17.3 |
| Total | 98 | 100 | 98 | 100 | 98 | 100 | 98 | 100 | 98 | 100 | 98 | 100 | 98 | 100 |

Table 4.46 Descriptive Statistics of the Questionnaire Results – Attitude - School 1

| Response | AA1 | | AA2 | | AA3* | | AA4 | | AA5* | | AA6 | | AA7 | |
|-------------------|-----------|------------|-----------|------------|-----------|------------|-----------|------------|-----------|------------|-----------|------------|-----------|------------|
| | Frequency | Percentage |
| Strongly Disagree | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Disagree | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 12.5 | 0 | 0 |
| Neutral | 1 | 12.5 | 0 | 0 | 1 | 12.5 | 0 | 0 | 1 | 12.5 | 1 | 12.5 | 3 | 37.5 |
| Agree | 5 | 62.5 | 4 | 50.0 | 4 | 50.0 | 4 | 50.0 | 4 | 50.0 | 5 | 62.5 | 3 | 37.5 |
| Strongly Agree | 2 | 25.0 | 4 | 50.0 | 3 | 37.5 | 4 | 50.0 | 3 | 37.5 | 1 | 12.5 | 2 | 25.0 |
| Total | 8 | 100 | 8 | 100 | 8 | 100 | 8 | 100 | 8 | 100 | 8 | 100 | 8 | 100 |

Table 4.47 Descriptive Statistics of the Questionnaire Results – Attitude - School 2

However, the difference in attitude toward learning computer programming between males and females in both schools is demonstrated in tables 4.48-4.54. Table 4.55 presents the Chi-Square

test results and the value of *Phi* to show the correlation between the nominal variable “Gender” and the ordinal variables AA1, AA2, AA3*, AA4, AA5*, AA6, and AA7. The * indicates the inversely coded statement.

| AA1 | | | | | | | | | | | | | |
|--------|--------|-------------------|---|----------|---|---------|---|-------|---|----------------|---|-------|---|
| | | Strongly Disagree | | Disagree | | Neutral | | Agree | | Strongly Agree | | Total | |
| School | | 1 | 2 | 1 | 2 | 1 | 2 | 1 | 2 | 1 | 2 | 1 | 2 |
| Gender | Male | 1 | 0 | 2 | 0 | 2 | 1 | 25 | 4 | 13 | 1 | 43 | 6 |
| | Female | 3 | 0 | 6 | 0 | 8 | 0 | 29 | 1 | 9 | 1 | 55 | 2 |
| Total | | 4 | 0 | 8 | 0 | 10 | 1 | 54 | 5 | 22 | 2 | 98 | 8 |

Table 4.48 Frequency Analysis of Males and Females’ Responses to AA1

| AA2 | | | | | | | | | | | | | |
|--------|--------|-------------------|---|----------|---|---------|---|-------|---|----------------|---|-------|---|
| | | Strongly Disagree | | Disagree | | Neutral | | Agree | | Strongly Agree | | Total | |
| School | | 1 | 2 | 1 | 2 | 1 | 2 | 1 | 2 | 1 | 2 | 1 | 2 |
| Gender | Male | 1 | 0 | 1 | 0 | 7 | 0 | 13 | 3 | 21 | 3 | 43 | 6 |
| | Female | 0 | 0 | 0 | 0 | 7 | 0 | 30 | 1 | 18 | 1 | 55 | 2 |
| Total | | 1 | 0 | 1 | 0 | 14 | 0 | 43 | 4 | 39 | 4 | 98 | 8 |

Table 4.49 Frequency Analysis of Males and Females’ Responses to AA2

| AA3* | | | | | | | | | | | | | |
|--------|--------|-------------------|---|----------|---|---------|---|-------|---|----------------|---|-------|---|
| | | Strongly Disagree | | Disagree | | Neutral | | Agree | | Strongly Agree | | Total | |
| School | | 1 | 2 | 1 | 2 | 1 | 2 | 1 | 2 | 1 | 2 | 1 | 2 |
| Gender | Male | 1 | 0 | 3 | 0 | 6 | 0 | 20 | 3 | 13 | 3 | 43 | 6 |
| | Female | 0 | 0 | 6 | 0 | 8 | 1 | 25 | 1 | 16 | 0 | 55 | 2 |
| Total | | 1 | 0 | 9 | 0 | 14 | 1 | 45 | 4 | 29 | 3 | 98 | 8 |

Table 4.50 Frequency Analysis of Males and Females’ Responses to AA3*

| AA4 | | | | | | | | | | | | | |
|--------|--------|-------------------|---|----------|---|---------|---|-------|---|----------------|---|-------|---|
| | | Strongly Disagree | | Disagree | | Neutral | | Agree | | Strongly Agree | | Total | |
| School | | 1 | 2 | 1 | 2 | 1 | 2 | 1 | 2 | 1 | 2 | 1 | 2 |
| Gender | Male | 2 | 0 | 2 | 0 | 5 | 0 | 25 | 3 | 9 | 3 | 43 | 6 |
| | Female | 2 | 0 | 2 | 0 | 9 | 0 | 26 | 1 | 16 | 1 | 55 | 2 |
| Total | | 4 | 0 | 4 | 0 | 14 | 0 | 51 | 4 | 25 | 4 | 98 | 8 |

Table 4.51 Frequency Analysis of Males and Females’ Responses to AA4

| AA5* | | | | | | | | | | | | | |
|--------|--------|-------------------|---|----------|---|---------|---|-------|---|----------------|---|-------|---|
| | | Strongly Disagree | | Disagree | | Neutral | | Agree | | Strongly Agree | | Total | |
| School | | 1 | 2 | 1 | 2 | 1 | 2 | 1 | 2 | 1 | 2 | 1 | 2 |
| Gender | Male | 1 | 0 | 4 | 0 | 8 | 1 | 20 | 3 | 10 | 2 | 43 | 6 |
| | Female | 1 | 0 | 0 | 0 | 12 | 0 | 29 | 1 | 13 | 1 | 55 | 2 |
| Total | | 2 | 0 | 4 | 0 | 20 | 1 | 49 | 4 | 23 | 3 | 98 | 8 |

Table 4.52 Frequency Analysis of Males and Females’ Responses to AA5*

| AA6 | | | | | | | | | | | | | |
|--------|--------|-------------------|---|----------|---|---------|---|-------|---|----------------|---|-------|---|
| | | Strongly Disagree | | Disagree | | Neutral | | Agree | | Strongly Agree | | Total | |
| School | | 1 | 2 | 1 | 2 | 1 | 2 | 1 | 2 | 1 | 2 | 1 | 2 |
| Gender | Male | 0 | 0 | 1 | 1 | 3 | 1 | 26 | 3 | 13 | 1 | 43 | 6 |
| | Female | 1 | 0 | 2 | 0 | 4 | 0 | 29 | 2 | 19 | 0 | 55 | 2 |
| Total | | 1 | 0 | 3 | 1 | 7 | 1 | 55 | 5 | 32 | 1 | 98 | 8 |

Table 4.53 Frequency Analysis of Males and Females’ Responses to AA6

| AA7 | | | | | | | | | | | | | |
|--------|--------|-------------------|---|----------|---|---------|---|-------|---|----------------|---|-------|---|
| | | Strongly Disagree | | Disagree | | Neutral | | Agree | | Strongly Agree | | Total | |
| School | | 1 | 2 | 1 | 2 | 1 | 2 | 1 | 2 | 1 | 2 | 1 | 2 |
| Gender | Male | 2 | 0 | 2 | 0 | 11 | 1 | 13 | 3 | 15 | 2 | 43 | 6 |
| | Female | 5 | 0 | 18 | 0 | 20 | 2 | 10 | 0 | 2 | 0 | 55 | 2 |
| Total | | 7 | 0 | 20 | 0 | 31 | 3 | 23 | 3 | 17 | 2 | 98 | 8 |

Table 4.54 Frequency Analysis of Males and Females' Responses to AA7

| Variable | School | Chi-Square Tests | | | Symmetric Measures - Phi | |
|----------|----------|---------------------|----|-----------------------|--------------------------|--------------|
| | | Value | df | Asymp. Sig. (2-sided) | Value | Approx. Sig. |
| AA1 | School 1 | 6.248 ^a | 4 | .181 | .252 | .181 |
| | School 2 | 1.067 ^a | 2 | .587 | .365 | .587 |
| AA2 | School 1 | 7.596 ^a | 4 | .108 | .278 | .108 |
| | School 2 | .000 ^a | 1 | 1.000 | .000 | 1.000 |
| AA3* | School 1 | 1.708 ^a | 4 | .789 | .132 | .789 |
| | School 2 | 4.000 ^a | 2 | .135 | .707 | .135 |
| AA4 | School 1 | 1.678 ^a | 4 | .795 | .131 | .795 |
| | School 2 | .000 ^a | 1 | 1.000 | .000 | 1.000 |
| AA5* | School 1 | 5.457 ^a | 4 | .244 | .236 | .244 |
| | School 2 | .444 ^a | 2 | .801 | .236 | .801 |
| AA6 | School 1 | 1.315 ^a | 4 | .859 | .116 | .859 |
| | School 2 | 1.600 ^a | 3 | .659 | .447 | .659 |
| AA7 | School 1 | 25.951 ^a | 4 | .000 | .515 | .000 |
| | School 2 | 4.444 ^a | 2 | .108 | .745 | .108 |

Table 4.55 Inferential Statistics of Males and Females Responses to AA1-AA7 questions

According to the Chi-Square test results and the value of *Phi*, the results show that there is no significant difference between males and females in AA1-AA6 for both schools i.e. $p > 0.05$.

However, for AA7. Programming is my favorite subject the difference was significant in School 1 $p < 0.5$ but not for School 2.

4.5.3 Awareness of Computer Programming Learning Usefulness

This sub-section discusses the analysis of responses to the following seven questionnaire statements about students' awareness of computer programming learning usefulness:

AU1. I think programming is useful for me

AU2. Learning programming will help me get a well-paid job in the future

AU3. Learning programming is necessary to everyone these days

AU4*. I don't think everyone must learn programming

AU5. Learning programming will help me solve daily problems

AU6. It is important for me to learn programming before I go to college

AU7*. Programming is not related to any of the real-life problems

It is worth noting that statements 4 and 7 were recoded inversely using SPSS before the analyzing the data.

Tables 4.56 and 4.57 present the descriptive statistics of the data collected about the students' awareness of computer programming usefulness in both School 1 and School 2. Frequency analysis and percentages are shown for the 5-Likert Scale options.

The frequency analysis of the responses in School 1 and School 2 shows that many students are not aware of the usefulness of learning computer programming particularly for AU3 and AU4*. 69.4% and 87.5% of students in School 1 and School 2 consecutively disagree or strongly disagree that learning programming is necessary to everyone these days. Additionally, 79.6% and 75% of students in School 1 and School 2 successively don't think that everyone must learn programming.

| Response | AU1 | | AU2 | | AU3 | | AU4* | | AU5 | | AU6 | | AU7* | |
|-------------------|-----------|------------|-----------|------------|-----------|------------|-----------|------------|-----------|------------|-----------|------------|-----------|------------|
| | Frequency | Percentage |
| Strongly Disagree | 5 | 5.1 | 1 | 1.0 | 23 | 23.5 | 39 | 39.8 | 11 | 11.2 | 10 | 10.2 | 4 | 4.1 |
| Disagree | 2 | 2.0 | 2 | 2.0 | 45 | 45.9 | 39 | 39.8 | 28 | 28.6 | 32 | 32.7 | 19 | 19.4 |
| Neutral | 10 | 10.2 | 14 | 14.3 | 16 | 16.3 | 15 | 15.3 | 44 | 44.9 | 40 | 40.8 | 24 | 24.5 |
| Agree | 46 | 46.9 | 39 | 39.8 | 10 | 10.2 | 2 | 2.0 | 11 | 11.2 | 8 | 8.2 | 39 | 39.8 |
| Strongly Agree | 35 | 35.7 | 42 | 42.9 | 4 | 4.1 | 3 | 3.1 | 4 | 4.1 | 8 | 8.2 | 12 | 12.2 |
| Total | 98 | 100 | 98 | 100 | 98 | 100 | 98 | 100 | 98 | 100 | 98 | 100 | 98 | 100 |

Table 4.56 Descriptive Statistics of the Questionnaire Results – Usefulness - School 1

| Response | AU1 | | AU2 | | AU3 | | AU4* | | AU5 | | AU6 | | AU7* | |
|-------------------|-----------|------------|-----------|------------|-----------|------------|-----------|------------|-----------|------------|-----------|------------|-----------|------------|
| | Frequency | Percentage |
| Strongly Disagree | 0 | 0 | 0 | 0 | 2 | 25.0 | 2 | 25.0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Disagree | 1 | 12.5 | 0 | 0 | 5 | 62.5 | 4 | 50.0 | 2 | 25.0 | 2 | 25.0 | 1 | 12.5 |
| Neutral | 1 | 12.5 | 1 | 12.5 | 1 | 12.5 | 2 | 25.0 | 4 | 50.0 | 4 | 50.0 | 4 | 50.0 |
| Agree | 4 | 50.0 | 1 | 12.5 | 0 | 0 | 0 | 0 | 2 | 25.0 | 2 | 25.0 | 3 | 37.5 |
| Strongly Agree | 2 | 25.0 | 4 | 50.0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Total | 8 | 100 | 2 | 25.0 | 8 | 100 | 8 | 100 | 8 | 100 | 8 | 100 | 8 | 100 |

Table 4.57 Descriptive Statistics of the Questionnaire Results – Usefulness - School 2

However, the difference in the students’ awareness of computer programming learning usefulness between males and females in both schools is demonstrated in tables 4.58-4.64. followed by table 4.65 that demonstrates the Chi-Square test results and the value of *Phi* to show the correlation between the nominal variable “Gender” and the ordinal variables AU1, AU2, AU3, AU4*, AU5, AU6, and AU7*. The * indicates the inversely coded statement. The results show that there is no significant difference between males and females’ awareness of Computer Science usefulness $p > 0.05$ for all given statements.

| AU1 | | | | | | | | | | | | | |
|--------|--------|-------------------|---|----------|---|---------|----|-------|----|----------------|----|-------|----|
| | | Strongly Disagree | | Disagree | | Neutral | | Agree | | Strongly Agree | | Total | |
| School | | 1 | 2 | 1 | 2 | 1 | 2 | 1 | 2 | 1 | 2 | 1 | 2 |
| Gender | Male | 0 | 2 | 1 | 1 | 1 | 6 | 3 | 20 | 1 | 14 | 6 | 43 |
| | Female | 0 | 3 | 0 | 1 | 0 | 4 | 1 | 26 | 1 | 21 | 2 | 55 |
| Total | | 0 | 5 | 1 | 2 | 1 | 10 | 4 | 46 | 2 | 36 | 8 | 98 |

Table 4.58 Frequency Analysis of Males and Females’ Responses to AU1

| AU2 | | | | | | | | | | | | | |
|--------|--------|-------------------|---|----------|---|---------|----|-------|----|----------------|----|-------|----|
| | | Strongly Disagree | | Disagree | | Neutral | | Agree | | Strongly Agree | | Total | |
| School | | 1 | 2 | 1 | 2 | 1 | 2 | 1 | 2 | 1 | 2 | 1 | 2 |
| Gender | Male | 0 | 0 | 0 | 0 | 1 | 6 | 2 | 13 | 3 | 24 | 6 | 43 |
| | Female | 0 | 1 | 0 | 2 | 0 | 8 | 1 | 26 | 1 | 18 | 2 | 55 |
| Total | | 0 | 1 | 0 | 2 | 1 | 14 | 3 | 39 | 4 | 42 | 8 | 98 |

Table 4.59 Frequency Analysis of Males and Females’ Responses to AU2

| AU3 | | | | | | | | | | | | | |
|--------|--------|-------------------|----|----------|----|---------|----|-------|----|----------------|---|-------|----|
| | | Strongly Disagree | | Disagree | | Neutral | | Agree | | Strongly Agree | | Total | |
| School | | 1 | 2 | 1 | 2 | 1 | 2 | 1 | 2 | 1 | 2 | 1 | 2 |
| Gender | Male | 2 | 8 | 3 | 21 | 1 | 8 | 0 | 4 | 0 | 2 | 6 | 43 |
| | Female | 0 | 15 | 2 | 24 | 0 | 8 | 0 | 6 | 0 | 2 | 2 | 55 |
| Total | | 2 | 23 | 5 | 45 | 1 | 16 | 0 | 10 | 0 | 4 | 8 | 98 |

Table 4.60 Frequency Analysis of Males and Females’ Responses to AU3

| AU4* | | | | | | | | | | | | | |
|--------|--------|-------------------|----|----------|----|---------|----|-------|---|----------------|---|-------|----|
| | | Strongly Disagree | | Disagree | | Neutral | | Agree | | Strongly Agree | | Total | |
| School | | 1 | 2 | 1 | 2 | 1 | 2 | 1 | 2 | 1 | 2 | 1 | 2 |
| Gender | Male | 1 | 11 | 3 | 24 | 2 | 6 | 0 | 1 | 0 | 1 | 6 | 43 |
| | Female | 1 | 28 | 1 | 15 | 0 | 9 | 0 | 1 | 0 | 2 | 2 | 55 |
| Total | | 2 | 39 | 4 | 39 | 2 | 15 | 0 | 2 | 0 | 3 | 8 | 98 |

Table 4.61 Frequency Analysis of Males and Females' Responses to AU4*

| AU5 | | | | | | | | | | | | | |
|--------|--------|-------------------|----|----------|----|---------|----|-------|----|----------------|---|-------|----|
| | | Strongly Disagree | | Disagree | | Neutral | | Agree | | Strongly Agree | | Total | |
| School | | 1 | 2 | 1 | 2 | 1 | 2 | 1 | 2 | 1 | 2 | 1 | 2 |
| Gender | Male | 0 | 5 | 2 | 12 | 3 | 19 | 1 | 4 | 0 | 3 | 6 | 43 |
| | Female | 0 | 6 | 0 | 16 | 1 | 25 | 1 | 7 | 0 | 1 | 2 | 55 |
| Total | | 0 | 11 | 2 | 28 | 4 | 44 | 2 | 11 | 0 | 4 | 8 | 98 |

Table 4.62 Frequency Analysis of Males and Females' Responses to AU5

| AU6 | | | | | | | | | | | | | |
|--------|--------|-------------------|----|----------|----|---------|----|-------|---|----------------|---|-------|----|
| | | Strongly Disagree | | Disagree | | Neutral | | Agree | | Strongly Agree | | Total | |
| School | | 1 | 2 | 1 | 2 | 1 | 2 | 1 | 2 | 1 | 2 | 1 | 2 |
| Gender | Male | 0 | 7 | 1 | 14 | 3 | 19 | 2 | 2 | 0 | 1 | 6 | 43 |
| | Female | 0 | 3 | 1 | 18 | 1 | 21 | 0 | 6 | 0 | 7 | 2 | 55 |
| Total | | 0 | 10 | 2 | 32 | 4 | 40 | 2 | 8 | 0 | 8 | 8 | 98 |

Table 4.63 Frequency Analysis of Males and Females' Responses to AU6

| AU7* | | | | | | | | | | | | | |
|--------|--------|-------------------|---|----------|----|---------|----|-------|----|----------------|----|-------|----|
| | | Strongly Disagree | | Disagree | | Neutral | | Agree | | Strongly Agree | | Total | |
| School | | 1 | 2 | 1 | 2 | 1 | 2 | 1 | 2 | 1 | 2 | 1 | 2 |
| Gender | Male | 0 | 2 | 1 | 7 | 3 | 13 | 2 | 12 | 0 | 9 | 6 | 43 |
| | Female | 0 | 2 | 0 | 12 | 1 | 11 | 1 | 27 | 0 | 3 | 2 | 55 |
| Total | | 0 | 4 | 1 | 19 | 4 | 24 | 3 | 39 | 0 | 12 | 8 | 98 |

Table 4.64 Frequency Analysis of Males and Females' Responses to AU7*

| Variable | School | Chi-Square Tests | | | Symmetric Measures - Phi | |
|----------|----------|--------------------|----|-----------------------|--------------------------|--------------|
| | | Value | df | Asymp. Sig. (2-sided) | Value | Approx. Sig. |
| AU1 | School 1 | 1.333 ^a | 3 | .721 | .408 | .721 |
| | School 2 | 1.333 ^a | 4 | .856 | .117 | .856 |
| AU2 | School 1 | .444 ^a | 2 | .801 | .236 | .801 |
| | School 2 | 7.113 ^a | 4 | .130 | .269 | .130 |
| AU3 | School 1 | 1.600 ^a | 2 | .449 | .447 | .449 |
| | School 2 | 1.280 ^a | 4 | .865 | .114 | .865 |
| AU4* | School 1 | 1.333 ^a | 2 | .513 | .408 | .513 |
| | School 2 | 9.087 ^a | 4 | .059 | .305 | .059 |
| AU5 | School 1 | 1.333 ^a | 2 | .513 | .408 | .513 |
| | School 2 | 1.857 ^a | 4 | .762 | .138 | .762 |
| AU6 | School 1 | 1.333 ^a | 2 | .513 | .408 | .513 |
| | School 2 | 7.341 ^a | 4 | .119 | .274 | .119 |
| AU7* | School 1 | .444 ^a | 2 | .801 | .236 | .801 |
| | School 2 | 8.916 ^a | 4 | .063 | .302 | .063 |

Table 4.65 Inferential Statistics of Males and Females Responses to AU1-AU7* questions

4.5.4 Motivation Toward Learning Computer Programming

This sub-section discusses the analysis of responses to the seven questionnaire statements about students' motivation toward learning computer programming:

AM1. I enjoy studying programming

AM2. I explore resources to learn programming other than the textbook

AM3. If I have a programming problem, I insist to solve it even if it takes me long time

AM4*. I wonder how people may spend long hours to learn programming

AM5. I usually solve programming problems at home even if they are not required for my class

AM6*. Programming lessons are usually boring

AM7. I pay good efforts to understand programming

Also, statements 4 and 6 were recoded inversely using SPSS before the analyzing the data.

Tables 4.66 and 4.67 demonstrate the descriptive statistics of the data collected about the students' motivation toward learning computer programming in both School 1 and School 2.

Frequency analysis and percentages are shown for the 5-Likert Scale options.

The frequency analysis of the responses in School 1 and School 2 shows that students are moderately motivated to learn computer programming. Their responses to AM3, AM4*, and AM5 show that some students are not willing to spend long hours learning programming nor solving programming problems. This was evident for School 1 and School 2 students.

| Response | AM1 | | AM2 | | AM3 | | AM4* | | AM5 | | AM6* | | AM7 | |
|-------------------|-----------|------------|-----------|------------|-----------|------------|-----------|------------|-----------|------------|-----------|------------|-----------|------------|
| | Frequency | Percentage |
| Strongly Disagree | 5 | 5.1 | 4 | 4.1 | 13 | 13.3 | 17 | 17.3 | 10 | 10.2 | 0 | 0 | 0 | 0 |
| Disagree | 21 | 21.4 | 3 | 3.1 | 28 | 28.6 | 23 | 23.5 | 25 | 25.5 | 11 | 11.2 | 1 | 1.0 |
| Neutral | 31 | 31.6 | 11 | 11.2 | 16 | 16.3 | 24 | 24.5 | 44 | 44.9 | 41 | 41.8 | 15 | 15.3 |
| Agree | 21 | 21.4 | 44 | 44.9 | 24 | 24.5 | 16 | 16.3 | 15 | 15.3 | 27 | 27.6 | 39 | 39.8 |
| Strongly Agree | 20 | 20.4 | 36 | 36.7 | 17 | 17.3 | 18 | 18.4 | 4 | 4.1 | 19 | 19.4 | 43 | 43.9 |
| Total | 98 | 100 | 98 | 100 | 98 | 100 | 98 | 100 | 98 | 100 | 98 | 100 | 98 | 100 |

Table 4.66 Descriptive Statistics of the Questionnaire Results – Motivation - School 1

| Response | AM1 | | AM2 | | AM3 | | AM4* | | AM5 | | AM6* | | AM7 | |
|-------------------|-----------|------------|-----------|------------|-----------|------------|-----------|------------|-----------|------------|-----------|------------|-----------|------------|
| | Frequency | Percentage |
| Strongly Disagree | 0 | 0 | 0 | 0 | 1 | 12.5 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Disagree | 1 | 12.5 | 0 | 0 | 2 | 25.0 | 2 | 25.0 | 2 | 25.0 | 0 | 0 | 0 | 0 |
| Neutral | 2 | 25.0 | 2 | 25.0 | 0 | 0 | 0 | 0 | 5 | 62.5 | 3 | 37.5 | 0 | 0 |
| Agree | 2 | 25.0 | 5 | 62.5 | 2 | 25.0 | 4 | 50.0 | 1 | 12.5 | 1 | 12.5 | 5 | 62.5 |
| Strongly Agree | 3 | 37.5 | 1 | 12.5 | 3 | 37.5 | 2 | 25.0 | 0 | 0 | 4 | 50.0 | 3 | 37.5 |
| Total | 8 | 100 | 8 | 100 | 8 | 100 | 8 | 100 | 8 | 100 | 8 | 100 | 8 | 100 |

Table 4.67 Descriptive Statistics of the Questionnaire Results – Motivation - School 2

Tables 4.68-4.74 demonstrates the difference in the students' motivation to learn computer programming between males and females in both schools. Table 4.75 demonstrates the Chi-Square test results and the value of *Phi* to show the correlation between the nominal variable "Gender" and the ordinal variables AM1, AM2, AM3, AM4*, AM5, AM6*, and AM7. The * indicates the inversely coded statement. The results show that the analysis of AM1, AM3, and AM6* show slightly contradicting results between School 1 and School 2 where the difference between males and females is evident in School 1 $p < 0.05$ but not in School 2 $0 > 0.05$. However, for AM4* the difference is significant in both schools. Table 4.71 clearly illustrates this significance.

| AM1 | | | | | | | | | | | | | |
|--------|--------|-------------------|---|----------|---|---------|---|-------|---|----------------|---|-------|---|
| | | Strongly Disagree | | Disagree | | Neutral | | Agree | | Strongly Agree | | Total | |
| School | | 1 | 2 | 1 | 2 | 1 | 2 | 1 | 2 | 1 | 2 | 1 | 2 |
| Gender | Male | 0 | 0 | 0 | 0 | 8 | 1 | 16 | 2 | 19 | 3 | 43 | 6 |
| | Female | 5 | 0 | 21 | 1 | 23 | 1 | 5 | 0 | 1 | 0 | 55 | 2 |
| Total | | 5 | 0 | 21 | 1 | 31 | 2 | 21 | 2 | 20 | 3 | 98 | 8 |

Table 4.68 Frequency Analysis of Males and Females' Responses to AM1

| AM2 | | | | | | | | | | | | | |
|--------|--------|-------------------|---|----------|---|---------|---|-------|---|----------------|---|-------|---|
| | | Strongly Disagree | | Disagree | | Neutral | | Agree | | Strongly Agree | | Total | |
| School | | 1 | 2 | 1 | 2 | 1 | 2 | 1 | 2 | 1 | 2 | 1 | 2 |
| Gender | Male | 2 | 0 | 1 | 0 | 5 | 1 | 19 | 4 | 15 | 1 | 43 | 6 |
| | Female | 2 | 0 | 2 | 0 | 5 | 1 | 25 | 1 | 21 | 0 | 55 | 2 |
| Total | | 4 | 0 | 3 | 0 | 11 | 2 | 44 | 5 | 36 | 1 | 98 | 8 |

Table 4.69 Frequency Analysis of Males and Females' Responses to AM2

| AM3 | | | | | | | | | | | | | |
|--------|--------|-------------------|---|----------|---|---------|---|-------|---|----------------|---|-------|---|
| | | Strongly Disagree | | Disagree | | Neutral | | Agree | | Strongly Agree | | Total | |
| School | | 1 | 2 | 1 | 2 | 1 | 2 | 1 | 2 | 1 | 2 | 1 | 2 |
| Gender | Male | 1 | 0 | 5 | 1 | 4 | 0 | 16 | 2 | 17 | 3 | 43 | 6 |
| | Female | 12 | 1 | 23 | 1 | 12 | 0 | 8 | 0 | 0 | 0 | 55 | 2 |
| Total | | 13 | 1 | 28 | 2 | 16 | 0 | 24 | 2 | 17 | 3 | 98 | 8 |

Table 4.70 Frequency Analysis of Males and Females' Responses to AM3

| AM4* | | | | | | | | | | | | | |
|--------|--------|-------------------|---|----------|---|---------|---|-------|---|----------------|---|-------|---|
| | | Strongly Disagree | | Disagree | | Neutral | | Agree | | Strongly Agree | | Total | |
| School | | 1 | 2 | 1 | 2 | 1 | 2 | 1 | 2 | 1 | 2 | 1 | 2 |
| Gender | Male | 0 | 0 | 2 | 0 | 9 | 0 | 14 | 4 | 18 | 2 | 43 | 6 |
| | Female | 17 | 0 | 21 | 2 | 15 | 0 | 2 | 0 | 0 | 0 | 55 | 2 |
| Total | | 17 | 0 | 23 | 2 | 24 | 0 | 16 | 4 | 18 | 2 | 98 | 8 |

Table 4.71 Frequency Analysis of Males and Females' Responses to AM4*

| AM5 | | | | | | | | | | | | | |
|--------|--------|-------------------|---|----------|---|---------|---|-------|---|----------------|---|-------|---|
| | | Strongly Disagree | | Disagree | | Neutral | | Agree | | Strongly Agree | | Total | |
| School | | 1 | 2 | 1 | 2 | 1 | 2 | 1 | 2 | 1 | 2 | 1 | 2 |
| Gender | Male | 5 | 0 | 10 | 1 | 20 | 4 | 7 | 1 | 1 | 0 | 43 | 6 |
| | Female | 5 | 0 | 15 | 1 | 24 | 1 | 8 | 0 | 3 | 0 | 55 | 2 |
| Total | | 10 | 0 | 25 | 2 | 44 | 5 | 15 | 1 | 4 | 0 | 98 | 8 |

Table 4.72 Frequency Analysis of Males and Females' Responses to AM5

| AM6* | | | | | | | | | | | | | |
|--------|--------|-------------------|---|----------|---|---------|---|-------|---|----------------|---|-------|---|
| | | Strongly Disagree | | Disagree | | Neutral | | Agree | | Strongly Agree | | Total | |
| School | | 1 | 2 | 1 | 2 | 1 | 2 | 1 | 2 | 1 | 2 | 1 | 2 |
| Gender | Male | 0 | 0 | 3 | 0 | 13 | 1 | 13 | 1 | 14 | 4 | 43 | 6 |
| | Female | 0 | 0 | 8 | 0 | 28 | 2 | 14 | 0 | 5 | 0 | 55 | 2 |
| Total | | 0 | 0 | 11 | 0 | 41 | 3 | 27 | 1 | 19 | 4 | 98 | 8 |

Table 4.73 Frequency Analysis of Males and Females' Responses to AM6*

| AM7 | | | | | | | | | | | | | |
|--------|--------|-------------------|---|----------|---|---------|---|-------|---|----------------|---|-------|---|
| | | Strongly Disagree | | Disagree | | Neutral | | Agree | | Strongly Agree | | Total | |
| School | | 1 | 2 | 1 | 2 | 1 | 2 | 1 | 2 | 1 | 2 | 1 | 2 |
| Gender | Male | 0 | 0 | 1 | 0 | 8 | 0 | 16 | 4 | 18 | 2 | 43 | 6 |
| | Female | 0 | 0 | 0 | 0 | 7 | 0 | 23 | 1 | 25 | 1 | 55 | 2 |
| Total | | 0 | 0 | 1 | 0 | 15 | 0 | 29 | 5 | 43 | 3 | 98 | 8 |

Table 4.74 Frequency Analysis of Males and Females' Responses to AM7

| Variable | School | Chi-Square Tests | | | Symmetric Measures - Phi | |
|----------|----------|---------------------|----|-----------------------|--------------------------|--------------|
| | | Value | df | Asymp. Sig. (2-sided) | Value | Approx. Sig. |
| AM1 | School 1 | 54.569 ^a | 4 | .000 | .746 | .000 |
| | School 2 | 5.333 ^a | 3 | .149 | .816 | .149 |
| AM2 | School 1 | .785 ^a | 4 | .940 | .089 | .940 |
| | School 2 | 1.067 ^a | 2 | .587 | .365 | .587 |
| AM3 | School 1 | 43.732 ^a | 4 | .000 | .668 | .000 |
| | School 2 | 5.333 ^a | 3 | .149 | .816 | .149 |
| AM4* | School 1 | 60.635 ^a | 4 | .000 | .787 | .000 |
| | School 2 | 8.000 ^a | 2 | .018 | 1.000 | .018 |
| AM5 | School 1 | .976 ^a | 4 | .913 | .100 | .913 |
| | School 2 | 1.067 ^a | 2 | .587 | .365 | .587 |
| AM6* | School 1 | 10.753 ^a | 3 | .013 | .331 | .013 |
| | School 2 | 4.444 ^a | 2 | .108 | .745 | .108 |
| AM7 | School 1 | 2.024 ^a | 3 | .568 | .144 | .568 |
| | School 2 | .178 ^a | 1 | .673 | .149 | .673 |

Table 4.75 Inferential Statistics of Males and Females Responses to AM1-AM7 questions

4.5.5 Summary of the Questionnaire Data Analysis

In summary, the quantitative data analysis of the questionnaire responses reveals that students who study Java OOP demonstrate confidence when learning computer programming. There is significant difference between males and females' confidence dimension in School 1 i.e. $p < 0.05$. However, the difference was evident only for AC2 and AC5 for School 2 students. While AC1, AC3, AC4, AC6, and AC7 $p > 0.05$ which indicate no significant difference.

Similarly, students who study Java OOP show positive attitude toward learning computer programming with no significant difference between males and females in AA1-AA6 for both schools i.e. $p > 0.05$. Yet, for AA7. 'Programming is my favorite subject' the difference was significant in School 1 $p < 0.5$ but not for School 2.

Regarding students' awareness of the usefulness of learning computer programming, the analysis shows that many students are not aware of the usefulness of learning computer programming particularly for AU3 and AU4*. 69.4 % and 87.5% of students in School 1 and School 2 consecutively disagree or strongly disagree that learning programming is necessary

to everyone these days. Additionally, 79.6% and 75% of students in School 1 and School 2 successively don't think that everyone must learn programming. Yet, there is no evidence of significant differences between males and females' awareness of Computer Science usefulness $p > 0.05$ for all given statements AU1-AU7*.

Finally, students don't seem to be highly motivated to learn computer programming. Their responses to AM3, AM4*, and AM5 show that some students in both School 1 and School 2 are not willing to spend long hours learning programming nor solving programming problems. While for the difference between the males and females' motivation to learn computer programming, the analysis show contradicting results between School 1 and School 2 particularly for AM1, AM3, and AM6*. The difference between males and females is evident in School 1 $p < 0.05$ but not in School 2 $p > 0.05$. However, for AM4*, the difference is significant in both schools. The standardized residual '*Std Residual*' was found to be greater 2 for all statements which have a p value > 0.05 .

4.6 Class Observation Data Analysis

This section presents the class observation qualitative data analysis. Data on verbal and non-verbal behaviors can be collected and analyzed through naturalistic observations that reflect the students' natural behavior in the classroom (Cohen 2007, Johnson & Christensen 2012). Merriam (2009) pointed out that students' activities and interactions can be captured and investigated through classroom observation methods. Therefore, the main purpose of the class observation is to support the answer to the main research question about the impact of learning computer programming on the students' cognitive abilities development by observing their cognitive activities inside the classroom. Additionally, class observation data will help to

answer the second research sub question about what cognitive activities and practices may occur during a computer programming lesson.

The 'coding scheme' is set by the researcher where frequencies of the subjects' activities were recorded as quantitative data (Fraenkel, Wallen, & Hyun 2011). On the other hand, notes on each observed element were taken as qualitative data that is also coded into different categories. Cohen (2007) stated that an observation can be used to gather data about the physical setting, the human setting, the interactional setting, and the program setting. Data about the four settings were necessary to help answer the previously mentioned research questions. Therefore, the researcher had developed the structured-observation protocol that allowed her observe classes, take notes, and add comments on the different elements that were targeted.

The observation protocol consists of 5 sections, Setting Description, Teacher's Instructions, Reasoning Activities, Memory Activities, and Sensory Activities that are considered as conceptual groups as in the CHC theory (Román-González, Pérez-González & Jiménez-Fernández 2017). The setting's Description includes general information about the lesson including: Observer's Name, Date & Time, Location, Grade Level/Cluster, Number of Students, and Lesson Title. This information was collected to facilitate the researcher's work to document the recorded observations and reference the discussion of the results' analyses.

The observation protocol was reviewed by two professional colleagues; one holds a Masters degree in Education Leadership and the other is pursuing her PhD in Science Education in the British University in Dubai. The researcher had revised the protocol after considering the reviewers' comments and piloted it. The protocol was again revised against any overlap between the observation elements before it was launched. 10 lesson observations were

conducted in each school with broad focus on the students' cognitive activities and behaviors in a holistic view; each lesson lasts for 45 minutes. Interval recording was used to record the teachers' instructions and the students' activities i.e. 9 time intervals with 5 minutes each. A tick (√) is used to record the occurrences of each activity (Cohen 2007). Additionally, general comments about each one of them are also recorded. According to Charmaz (2006), researcher's ideas and notes should not be neglected as they might lead to the emergence of further themes.

However, in order to avoid the expected observer effect (Fraenkel, Wallen, & Hyun 2011), the researcher had started to record the observation data from the third visit onward. On the other hand, to ensure an actual representative sampling for the classroom activities, each observed class was visited at different points during the first term of the academic year. The researcher has shared the class visits' schedule with the schools' managements at the beginning of the term and tried to adhere to it. Yet, the schedule had to be modified occasionally due to different reasons. Hence, 10 lessons were observed in each school. 8 observations were recorded for each. On another hand, for school 1, the 8 observations were conducted in 8 different schools therefore 8 different teachers. While in school 2, the 8 observations were conducted for the same teacher because it was only one class that was observed during the duration of the research.

The following 4 sub-sections demonstrate the class observation qualitative data analysis. According to Cohen (2007, p. 470), frequencies of the occurrences of ideas and themes count toward qualitative data analysis. Hence, frequencies of the various activities were recorded and compared between School 1 and School 2. The sub-sections are: Teacher's Instructions,

Cognitive Activities-Reasoning, Cognitive Activities-Memory, and Cognitive Activities-Sensory.

4.6.1 Teacher's Instructions Data Analysis

In this sub-section the researcher aimed to identify the features of the teachers' instructions during the computer programming lessons seeking further understanding of what stimulate students' cognitive activities and how to explain them. Elements of the teachers' instructions that were observed include:

- Provision of concrete props
- Provision of visual aids, such as models and/or time line
- Use of familiar examples to facilitate learning more complex ideas, such as story problems in math
- Allowance for opportunities to classify and group information with increasing complexity
- Use of outlines and hierarchies to facilitate assimilating new information with previous knowledge
- Present problems that require logical analytic thinking

Table 4.76 demonstrates this section in the observation protocol.

| Teachers' Instructions | | | | | | | | | | | |
|--|--|----------------------|------|-------|-------|-------|-------|-------|-------|----------------------|-------|
| <i>Limited to the time when the teacher is explaining a concept or giving instructions</i> | | | | | | | | | | | |
| Indicate the occurrences of each item/activity by X | | | | | | | | | | | |
| Item/Activity (Two or more items/activities may happen concurrently) | | Time slots (minutes) | | | | | | | | Evidences / Comments | |
| | | 1-5 | 6-10 | 11-15 | 16-20 | 21-25 | 26-30 | 31-35 | 36-40 | | 41-45 |
| 1 | Provision of concrete props | | | | | | | | | | |
| 2 | Provision of visual aids, such as models and/or time line | | | | | | | | | | |
| 3 | Use of familiar examples to facilitate learning more complex ideas, such as story problems in math | | | | | | | | | | |
| 4 | Allowance for opportunities to classify and group information with increasing complexity | | | | | | | | | | |
| 5 | Use of outlines and hierarchies to facilitate assimilating new information with previous knowledge | | | | | | | | | | |
| 6 | Present problems that require logical analytic thinking | | | | | | | | | | |

Table 4.76 Teacher's Instructions- Observation Protocol

The results of the teacher's instructions frequency analysis show moderate anticipation of proper instructions during the computer programming lessons. Provision of concrete props existed during most of the lessons. However, School 1 teachers were able to provide more concrete props that could that would explain the difference in the use of outlines and hierarchies to facilitate assimilating new information with previous knowledge and the presentation of problems that require logical analytical thinking.

On another hand, provision of visual aids such as models and/or timeline was minimal in both schools. Differently, School 2 teacher was able to use familiar examples to facilitate learning complex ideas and allow for opportunities to classify and group information with increasing complexity. Chart 4.1 below demonstrates a summary of the teachers' instructions observations.

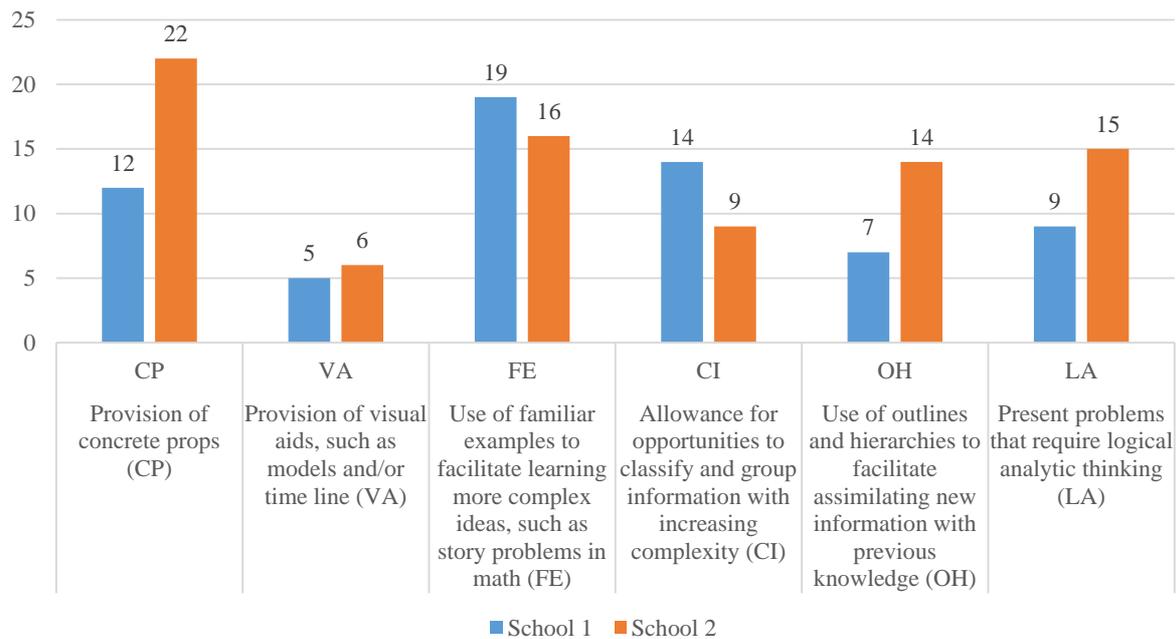


Chart 4.1 Frequency of Various Teachers' Instructions During Programming Lessons

4.6.2 Reasoning Cognitive Activities Data Analysis

In this sub-section, the researcher aimed to identify the students' cognitive activities pertinent to the Reasoning abilities particularly; Induction (I), General Sequential Reasoning (RG), and Quantitative Reasoning (RQ). The frequency of the following activities was observed and recorded:

- Students' ability to realize the characteristics, rules, and concepts when solving problems
- Students' ability to generate rules and follow guidance in a step-by-step approach to find a solution for a problem
- Students' ability to use mathematical relationships and properties for inductive and deductive reasoning

Table 4.77 below presents the Reasoning activities as appeared in the observation protocol.

| Reasoning <i>The use of both deductive and inductive approaches about a topic</i> Indicate the occurrences of each item/activity by X | | | | | | | | | | | |
|---|---|----------------------|------|-------|-------|-------|-------|-------|-------|----------------------|-------|
| Item/Activity <i>(Two or more items/activities may happen concurrently)</i> | | Time slots (minutes) | | | | | | | | Evidences / Comments | |
| | | 1-5 | 6-10 | 11-15 | 16-20 | 21-25 | 26-30 | 31-35 | 36-40 | | 41-45 |
| 1 | Ability to realize the characteristics, rules, and concepts when solving problems (Induction) | | | | | | | | | | |
| 2 | Ability to generate rules and follow guidance in a step-by-step approach to find a solution for a problem. (General Sequential Reasoning) | | | | | | | | | | |
| 3 | Ability to use mathematical relationships and properties for inductive and deductive reasoning. (Quantitative Reasoning) | | | | | | | | | | |

Table 4.77 Reasoning Cognitive Activities - Observation Protocol

The results of the frequency analysis, shown in chart 4.2 below, reveal more occurrences of the Quantitative Reasoning activities than Induction and General Sequential Reasoning. RQ activities were 19 and 21 in School 1 and School 2 consecutively. While only 13 and 12 Induction activities and 11 and 12 General Sequential Reasoning activities in School 1 and School 2 successively.

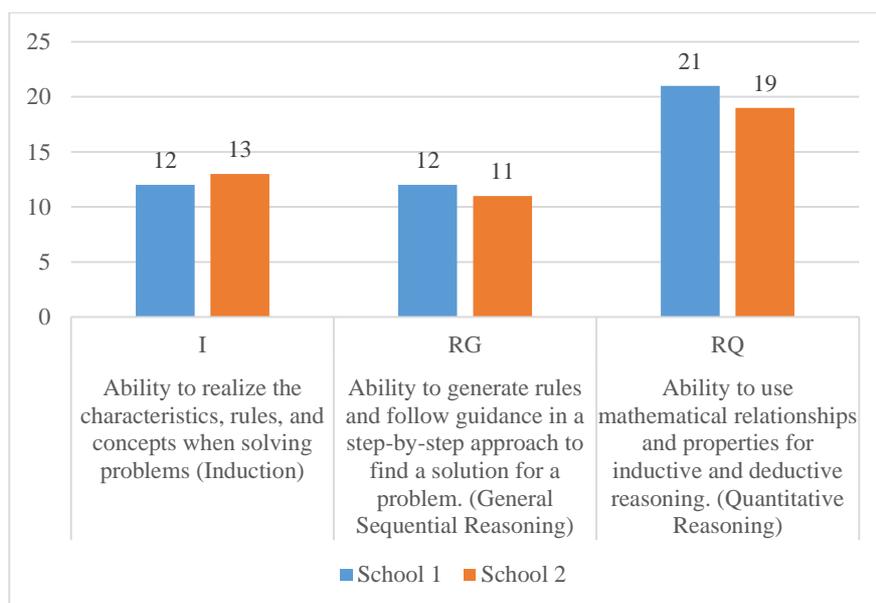


Chart 4.2 Frequency of Various Reasoning Cognitive Activities During Programming Lessons

4.6.3 Memory Cognitive Activities Data Analysis

This sub-section presents the frequency analysis of the Memory cognitive activities that took place during the observed lessons. Memory Span and Working Memory activities were observed and recorded. The researcher looked for activities that demonstrates the following:

- Students’ ability to recall provisionally ordered elements after they are presented once to the subject
- Students’ ability to manage the capacity of the short term memory and perform different cognitive operations on a temporarily stored information

Table 4.78 shows the Memory cognitive activities in the observation protocol.

| Memory | | | | | | | | | | | |
|---|--|------|-------|-------|-------|-------|-------|-------|-------|----------------------|--|
| <i>The use of the memory to recall a topic and perform tasks based on the capacity of the short term memory</i> | | | | | | | | | | | |
| Indicate the occurrences of each item/activity by X | | | | | | | | | | | |
| Item/Activity <i>(Two or more items/activities may happen concurrently)</i> | Time slots (minutes) | | | | | | | | | Evidences / Comments | |
| | 1-5 | 6-10 | 11-15 | 16-20 | 21-25 | 26-30 | 31-35 | 36-40 | 41-45 | | |
| 1 | Ability to recall provisionally ordered elements after they are presented once to the subject. (Memory Span) | | | | | | | | | | |
| 2 | Ability to manage the capacity of the short term memory and perform different cognitive operations on a temporarily stored information. (Working Memory) | | | | | | | | | | |

Table 4.78 Memory Cognitive Activities - Observation Protocol

The frequency analysis of the Memory activities shows that teachers in School 1 were able to expose students to more memory activities than in School 2. Working Memory activities in School 2 were much less than those in School 1.

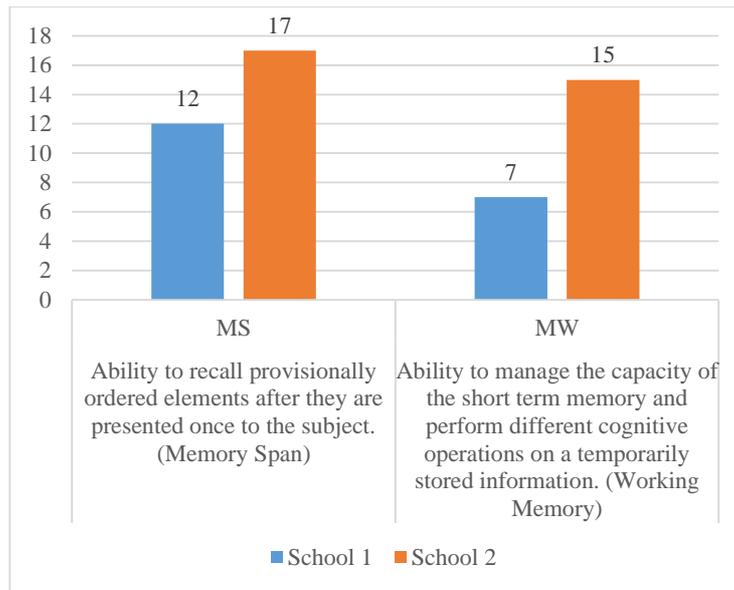


Chart 4.3 Frequency of Various Memory Cognitive Activities During Programming Lessons

4.6.4 Sensory Cognitive Activities Data Analysis

This sub-section presents the frequency analysis of the Sensory cognitive activities; Visualization, Speeded Rotation, Closure Speed, Flexibility of Closure, Visual Memory, Spatial Scanning, and Serial Perceptual Integration as demonstrated in table 4.79 below. The following activities were observed and recorded:

- Students’ ability to mentally simulate complex objects and patterns when they are rotated, changed in size, and partially hidden
- Students’ ability to simulate mental rotation of simple objects
- Students’ ability to formulate and identify a whole object when given its disconnected or partially hidden parts with no previous knowledge of the object
- Students’ Ability to formulate and identify an object or a pattern within a complex visual array with previous knowledge of the pattern
- Students’ ability to recognize and recall an image or a visual stimulus
- Students’ ability to scan a spatial visual field and then accurately identify a path or a pattern on it

- Students' ability to identify a symbolic or visual pattern when parts of the pattern are presented in a continuous order

| Sensory <i>The use of visual stimuli to solve problems</i> Indicate the occurrences of each item/activity by X | | | | | | | | | | | |
|--|--|----------------------|------|-------|-------|-------|-------|-------|-------|----------------------|-------|
| Item/Activity <i>(Two or more items/activities may happen concurrently)</i> | | Time slots (minutes) | | | | | | | | Evidences / Comments | |
| | | 1-5 | 6-10 | 11-15 | 16-20 | 21-25 | 26-30 | 31-35 | 36-40 | | 41-45 |
| 1 | The ability to mentally simulate complex objects and patterns when they are rotated, changed in size, and partially hidden. (Visualization) | | | | | | | | | | |
| 2 | The ability to simulate mental rotation of simple objects. (Speeded Rotation) | | | | | | | | | | |
| 3 | Ability to formulate and identify a whole object when given its disconnected or partially hidden parts with no previous knowledge of the object. (Closure Speed) | | | | | | | | | | |
| 4 | Ability to formulate and identify an object or a pattern within a complex visual array with previous knowledge of the pattern. (Flexibility of Closure) | | | | | | | | | | |
| 5 | Ability to recognize and recall an image or a visual stimulus. (Visual Memory) | | | | | | | | | | |
| 6 | Ability to scan a spatial visual field and then accurately identify a path or a pattern on it. (Spatial Scanning) | | | | | | | | | | |
| 7 | Ability to identify a symbolic or visual pattern when parts of the pattern are presented in a continuous order. (Serial Perceptual Integration) | | | | | | | | | | |

Table 4.79 Sensory Cognitive Activities - Observation Protocol

The frequency analysis shows modest number of sensory activities for Visualization, Speeded Rotation, Closure Speed, Flexibility of Closure, Spatial Scanning, and Serial Perceptual Integration in both Schools. However, Visual Memory activities were more frequent 12 and 15 in School 1 and School 2 consecutively.

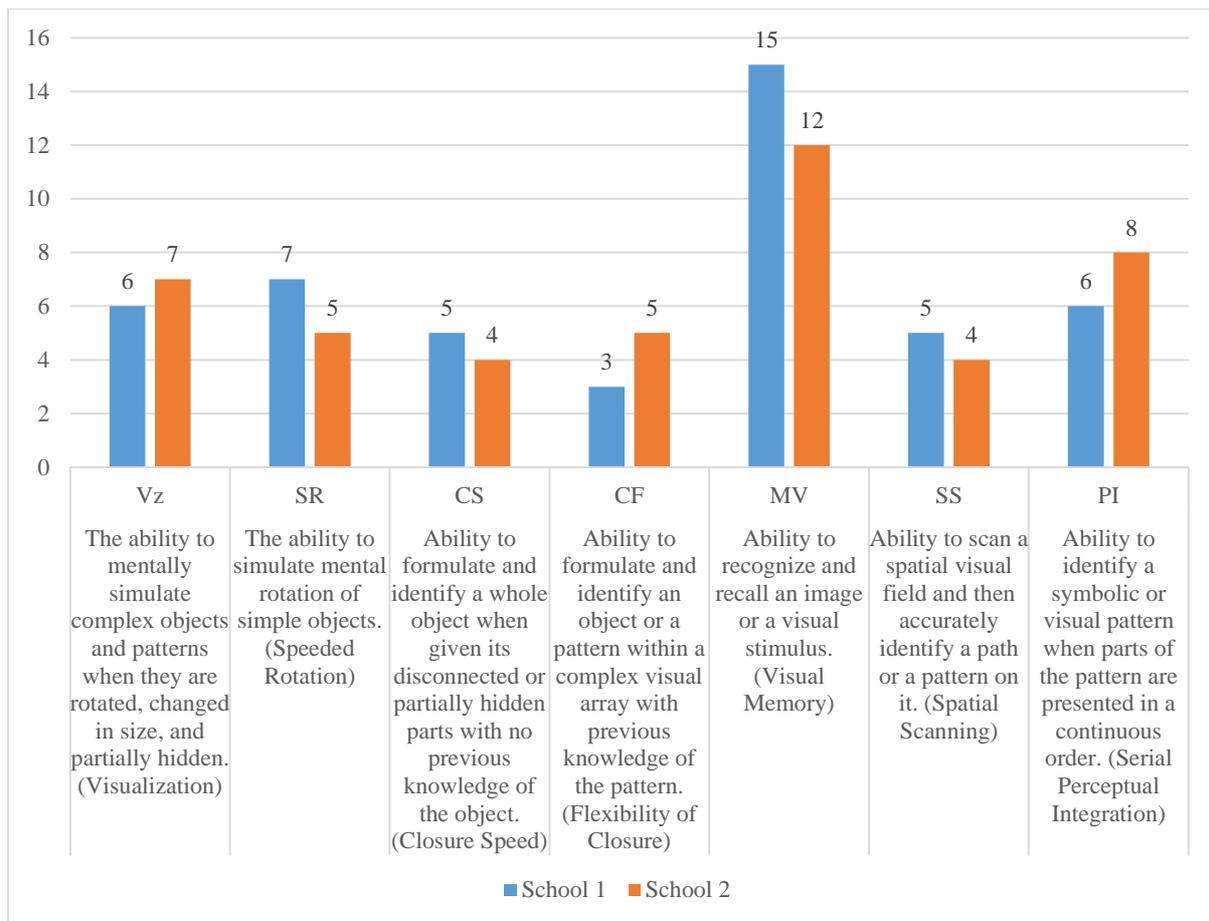


Chart 4.4 Frequency of Various Sensory Cognitive Activities During Programming Lessons

4.6.5 Evidences and Comments-Class Observation

This sub-section demonstrates the class observation qualitative data analysis of the evidences and comments written on each of the observation four sections; Teacher’s Instructions, Reasoning Cognitive Activities, Memory Cognitive Activities, and Sensory Cognitive Activities. Collected data were organized, coded and summarized. Cohen (2007) stated that qualitative data relevant to a certain issue can be organized and presented. Yet, the issue need to clearly defined. Hence, the researcher considers the four sections in the observation protocol as the four defined issues.

Johnson and Christensen (2012) confirmed that qualitative data must be segmented and coded before developing inductive categories. Cohen (2007) stated that, in qualitative data analysis,

a researcher can build a logical chain of evidence by making connections and interpretations. In order to achieve such logical chain, the researcher coded the data based on the four sections of the observation protocol. The first symbol in the code represents the section in the observation protocol: Teacher's Instructions (TI), Cognitive Activities-Reasoning (CAR), Cognitive Activities-Memory (CAM), and Cognitive Activities-Sensory (CAS). The second symbol in the code refers to the school, where S1 is for School 1 and S2 is for School 2. The third symbol refers to the lesson number e.g. L1 refers to Lesson 1 out of the 8 observed lessons. Finally, the fourth symbol refers to the category that is generated from the qualitative analysis of the comments. For example, CAR-S2-L4-MS refers to the Mathematical Skills category generated from the comments about the Reasoning Cognitive Abilities that were observed in School 2 in Lesson 4.

4.6.6 Teacher's Instructions Comments Data Analysis

Although teachers in both schools were introducing very similar topics during the period of the class observations namely Logical Operators, Conditional Statements, Loops, Classes and Objects, and Introduction to Inheritance. The teachers' instructions varied from one lesson to another based on the topic that was presented. Three categories were generated from the researcher's comments on this section of the observation protocol: Use of Real-life Examples (RL), Problem Solving (PS), and Questioning Techniques (QT). The teachers' instructions seemed to be more focused on real-life examples and linking the introduced knowledge to the students' experiences. This had stimulated the students' memory which revealed their limited capabilities to remember certain details. The teachers used different questioning techniques and props to foster proper students' cognitive behavior. Yet, School 2 teachers seemed to be more competent in asking concrete props. Teachers in both schools exposed students to problems that can be solved using programming in most of the observed lessons. Table 4.79

demonstrates the Inductive Categories and Summary of Results and Examples of the Teacher’s Instructions.

| Section in the observation protocol | Inductive Category | Summary of Results/Examples | | | | | | | | | | | | |
|-------------------------------------|--|--|-------|-------|--------|---|-------|---|-------|---|-------|---|------|---|
| Teacher’s Instructions (TI) | Use of Real-Life Examples (RL) | <p>TI-S1-L2-RL “Write a Java code that assigns a letter grade for a quiz according to the following table as per the given instructions in the comments”</p> <table border="1"> <thead> <tr> <th>Score</th> <th>Grade</th> </tr> </thead> <tbody> <tr> <td>90-100</td> <td>A</td> </tr> <tr> <td>80-89</td> <td>B</td> </tr> <tr> <td>70-79</td> <td>C</td> </tr> <tr> <td>60-69</td> <td>D</td> </tr> <tr> <td>< 60</td> <td>F</td> </tr> </tbody> </table> | Score | Grade | 90-100 | A | 80-89 | B | 70-79 | C | 60-69 | D | < 60 | F |
| | Score | Grade | | | | | | | | | | | | |
| | 90-100 | A | | | | | | | | | | | | |
| 80-89 | B | | | | | | | | | | | | | |
| 70-79 | C | | | | | | | | | | | | | |
| 60-69 | D | | | | | | | | | | | | | |
| < 60 | F | | | | | | | | | | | | | |
| Problem Solving (PS) | <p>TI-S2-L8-PS “There’s a staircase with N steps, and you can climb 1 or 2 steps at a time. Given N, write a function that returns the number of unique ways you can climb the staircase. The order of the steps matters. For example, if N is 4, then there are 5 unique ways:</p> <ul style="list-style-type: none"> • 1, 1, 1, 1 • 2, 1, 1 • 1, 2, 1 • 1, 1, 2 • 2, 2 <p>What if, instead of being able to climb 1 or 2 steps at a time, you could climb any number from a set of positive integers X? For example, if $X = \{1, 3, 5\}$, you could climb 1, 3, or 5 steps at a time. Generalize your function to take in X.”</p> | | | | | | | | | | | | | |
| Questioning Techniques (QT) | <p>TI-S1-L3-QT “How can you apply type casting to convert the interest value to an integer in this code?”</p> <pre>int interestInDollars; double interest = 79.45; interestInDollars”</pre> | | | | | | | | | | | | | |

Table 4.80 Inductive Categories and Summary of Results and Examples of the Teacher’s Instructions

4.6.7 Reasoning Cognitive Activities Comments Data Analysis

Two categories were generated from the comments written on the Reasoning cognitive abilities; Algorithmic Thinking (AT) and Mathematical Skills (MS). Very few examples were captured that require students to use their Induction Reasoning skills. However, in almost all of the observed lesson, teachers used to advise students to follow a step-by-step approach to solve all the problems i.e. algorithmic thinking. In cases where teachers didn’t advise students

to use algorithmic thinking, students were less able to solve the given problem. Additionally, due to the nature of the Java programming course, in most of the classes, student had to demonstrate ability to use their mathematical skills to understand a programming concept or solve a problem. Table 4.80 demonstrated examples on the generated categories.

| Section in the observation form | Inductive Category | Examples |
|---------------------------------|---------------------------|--|
| Reasoning | Algorithmic Thinking (AT) | <i>CAR-S2-L6-AT</i> “the teachers asked students to followed step-by-step approach[Algorithmic Thinking] to solve a given problem” |
| | Mathematical Skills (MS) | <p><i>CAR-S1-L5-MS</i> “The teacher worked out an example that required students to master some mathematical skills, students who didn’t show competence in Mathematics were not able to solve the problem.</p> <p>check if the variable salesAmt is greater than the constant SALES_QUOTA; If true, create a block of statements that will calculate salesAmt * BONUS_PERCENT [Mathematical Skills]and store the result in the variable named bonusPay</p> <ol style="list-style-type: none"> a. In the same block of statements, compute totalPay by adding salesAmt to bonusPay b. Outside of if structure above, add a println statement that will display the totalPay value <pre>public static void main(String args[]) { final double SALES_QUOTA=10000; final double BONUS_PERCENT=0.05; double bonusPay=0.0; double totalPay=0.0; double salesAmt=20000; //complete the code}</pre> |

Table 4.81 Inductive Categories and Summary of Results and Examples of the Reasoning Cognitive Activities

4.6.8 Memory Cognitive Activities Comments Data Analysis

The qualitative analysis of the comments written on the Memory cognitive activities led to two categories: Short Term Memory (STM) and Formative Assessment (FA). Teachers in School 1 were keen to ensure that students can recall the delivered knowledge through proper formative assessment methods and techniques such as a question about the code that was

immediately taught. The Teacher in School 2 did not demonstrate proper use of formative assessment techniques and relied much on a task at the end of the lesson to ensure students’ understanding. Formative assessment appeared to be a key factor in stimulating the students’ short term memory.

| Section in the observation form | Inductive Category | Examples |
|---------------------------------|---------------------------|--|
| Memory | Short Term Memory (STM) | <p>CAM-S2-L1-STM “the teacher has explained how to write a Print statement in Java and the difference between Print and Println, then erased the board. She asked the students to write similar statements using their computers and get a correct output. Some students asked the teacher again about the difference between Print and Println while they were writing their own codes, many others were able to write the code without the teacher’s help [Short Term Memory]”</p> <p>CAM-S1-L5 “the teacher used the projector to display the list of new keywords and explained each one of them and then closed the projector. Students had to answer a ‘Fill in the Blanks’ question that requires them to know and recall the meaning of each keywords”</p> |
| | Formative Assessment (FA) | <p>CAM-S1-L4-FA “in a lesson about the use of conditional statements, students were given a worksheet [Formative Assessment] at the beginning of the class that has 4 questions, each question covers one of the lesson objectives. Students were required to answer each question after explaining each concept/objective. Students show proper understanding and confidence at the end of the lesson toward the learned objectives”</p> |

Table 4.82 Inductive Categories and Summary of Results and Examples of the Memory Cognitive Activities

4.6.9 Sensory Cognitive Activities Comments Data Analysis

Sensory cognitive activities were minimal in the teachers’ instructions during the observed lessons. Teachers did not seem aware of the significance of sensory activities when explaining programming concepts. However, teachers in School 1 and School 2 used visual aids to explain programming concepts and relate them. Accordingly, two categories resulted from the analysis of the comments written on the Sensory cognitive activities: Visual Aids (VA) and Pattern Recognition (PR). One of the concepts that were explained differently between School 1 and School 2 is the “Class Diagram”. The teacher in School 2 started the lesson with a visual

representation of the class diagram and asked students to apply the same concept on their codes. It took students about 15 minutes to get correct results. While in school 1, the teacher spent ample time explaining the class diagram concept and asked students to outline their own class diagrams. Students demonstrated misunderstanding of the class diagram and asked many questions about it before most of them could get it done. Consequently, students in both schools were able to recognize patterns in different problems. Students were trying to utilize the same approach to solve a problem if they recognize a pattern in the problem statement or the what was needed to find.

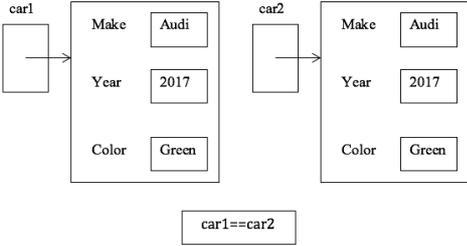
| Section in the observation form | Inductive Category | Examples |
|---------------------------------|--------------------------|--|
| Sensory | Visual Aids (VA) | <p>CAS-S2-L7-VA “the teacher used the class diagram [Visual Aids] shown below to explain the concept of the classes and objects and the identify the relationships between them”</p>  <p>CAS-S1-L8-VA “the teacher started the lesson by giving examples on classes and objects in real-life. One of the examples that were introduced is a School that has 7 branches in 7 different cities. The 7 schools have features that are common and at the same time, they have features that differ from one branch to another, students were then asked to outline a diagram [Visual Aids] that represents their code”</p> |
| | Pattern Recognition (PR) | <p>CAS-S2-L7-PR “students were able to apply [Pattern Recognition] the same concept presented to them to outline their own class diagrams”</p> <p>CAS-S2-L3-PR “the teacher gave students a problem and asked them to look for specific keywords that are common between such problems [Pattern Recognition] in order to be able to figure out a solution.</p> |

Table 4.83 Inductive Categories and Summary of Results and Examples of the Sensory Cognitive Activities

4.6.10 Summary of the Class Observation Data Analysis

The qualitative data analysis of the class observations exposed that teachers could provide moderate anticipation of proper instructions during the computer programming lessons. Teachers need to utilize more visual aids, outlines, and hierarchies in order to facilitate students' understanding of complex programming concepts. Two inductive categories were generated from the notes on the Teacher's Instructions: use of real-life examples, and problem solving.

Reasoning cognitive activities occurred repeatedly during the programming lessons. Quantitative Reasoning activities happened more frequent than Induction and General Sequential Reasoning. Algorithmic thinking and mathematical skills are two categories that were generated from the analysis of the reasoning cognitive activities notes.

Regarding memory cognitive activities, working memory activities did not occur frequently as much as memory span ones. Two categories were generated from the notes written on this section short term memory, and formative assessment.

Lastly, it was evident that the frequency of the sensory cognitive activities was modest. However, visual memory activities occurred the most. Visual aids and pattern recognition are two categories generated from the sensory cognitive activities notes.

4.7 Interviews Data Analysis

This section demonstrates the qualitative data analysis of the interviews that were conducted with students in School 1 and School 2. The main aim from the interviews is to help answer

the first research sub question about the students' perception of their experience when they learn computer programming and to further interpret the questionnaire data analysis results.

The researcher had interviewed all Grade 11 students who are studying computer programming in School 2. However, for School 1, due to the large number of Grade 11 students who were studying Computer programming, the researcher chose to interview three focus groups from three different campuses. Semi-structured in-depth interviews were conducted. 6-8 students in each focus group were nominated by the teachers to attend the interview. According to their teachers, the focus group students were selected based on their own interest, all participating students were given the option to participate or not and were reminded with the research aim and the researcher's intentions from conducting the interviews.

In order to capture what the interviewee actually say (Fraenkel, Wallen, & Hyun 2011), the researcher had voice recorded the interviews and then transcribed them before conducting the qualitative data analysis. All interviews were conducted toward the end of the term i.e. after 14 weeks of studying computer programming also after the researcher had collected the questionnaire data and analyzed them. The duration of each interview was about 40-50 minutes. The number of interviews was based on reaching saturation of data. Though 4 interviews were conducted; 1 interview with the whole group in School 2 and 3 interviews with 3 different focus groups from School 1. The researcher asked the CS teachers to nominate students to attend the focus groups interviews with stress on making the selection voluntary basis. All participating students were introduced to the researcher few days before the interview to explain to them the purpose of the interview and the confidentiality of their responses.

The interview protocol was created based on four themes: Confidence, Usefulness, Attitude, and Motivation. The four themes indicate the four dimensions that were targeted in the questionnaire.

Interviews were audio recorded and transcribed. Qualitative data that was resulted from the transcriptions were cleaned, segmented, coded, and analyzed to generate the categories (Johnson & Christensen 2012). Table 4.83 below presents the interview questions, follow up questions and the targeted dimension.

| Interview Question | Follow up Questions | Dimension |
|---|---|------------------|
| Question 1: What would stand in your mind when you think about yourself as a student learning Java programming? | <ul style="list-style-type: none"> • Can you explain to me more about that? • How can learning Java programming makes you different than other students? • Have you ever thought of dropping the Java programming course? | Confidence |
| Question 2: How can you apply the computational thinking skills you learned in the Java programming class on problems you face in your real-life? | <ul style="list-style-type: none"> • Can you give me example? • How could your computational thinking skills help you in this case? • What other strategies you may use to solve the problem if it is not solved using your computational thinking skills? | Usefulness |
| Question 3: How do you feel when you solve a complex programming problem correctly? | <ul style="list-style-type: none"> • How do you feel if your colleague asks you to help him/her solve a complex programming problem that you are able to solve? | Attitude |
| Questions 4: What would you do if your teacher challenged you to solve a programming problem that none of your colleagues could solve it? | <ul style="list-style-type: none"> • Would you sacrifice a time out with your friend and stay home to study for programming? | Motivation |

Table 4.84 Interview Questions and Follow Up Questions for four dimensions

4.7.1 Thematic Analysis of the Interview Questions

Different inductive categories were revealed from the qualitative data analysis of the interview results including highly paid jobs, programmers' ways of thinking, programming difficulty, real-life problems, problem solving, impact of learning programming, programming complexity and students' life. The themes were identified after collecting the interviews data based on the interviewees responses. Below are the interview questions, their follow up questions, and an elaboration on the students' common responses.

Question 1: What would stand in your mind when you think about yourself as a student learning Java programming?

- Can you explain to me more about that?
- How can learning Java programming makes you different than other students?
- Have you ever thought of dropping the Java programming course?

This question is linked to the 'Confidence' dimension that was investigated in the questionnaire. Students have responded differently to this question. However, most of them expressed their pride to be able to write Java programming codes. Three categories were generated from the students' responses: highly paid jobs, Programmers' ways of thinking, and programming difficulty. Students responses were evolved around their future jobs and how learning programming will help them understand some of the topics they hear about like Artificial Intelligence. Three students have mentioned that they would become well known programmers in the future and get more money from the programmer job than any other job. One student mentioned *"I want to learn programming because I want to make my own company and develop my own programs, one of them may hit the market and then I will become a millionaire"*. Another student added *"I want to learn programming because I want make*

programs that will make students' life easy". Another student stated that "learning how to program will help me learning hacking because I want to work with the Cyber Crimes police".

When the researcher asked about how can learning Java programming makes you different than other students? 2 students have mentioned that "programmers look more sophisticated people than others and this exactly how we want to look like between my friends". School 1 students focused on their participations in the national competition 'Emirates Skills' and learning programming will help them easily nominated to participate and win.

The responses to the third follow up question were contradicting. Almost half of interviewees in each group said that at the beginning of the course wanted to drop the course. Reasons for that intention were basically due to how difficult the course seemed at the beginning. Advises from their teachers and parents were main reasons for not dropping it. Yet, according to interviewed students, "*after 3-4 weeks we found it an interesting subject and we were able to understand the lessons*". One student added "*only when I started to understand the topic, I felt more confident that not only to pass the course but also to get excellent grades*". A sample conversation is shown in the box below.

Student: I wanted to drop, she (the teacher) didn't let me although I didn't understand anything that's why I wanted to drop the course
Interviewer: So you wanted to drop the course at the beginning!
Student: I didn't understand anything at the beginning but now I understand so you see me working.
Student: at the beginning I didn't understand anything but now I understand
Interviewer: so with your friends and your teacher you started to develop kind of excitement.

Figure 4.13 Sample Dialogue about Dropping the Java Programming Course

Overall, during the interviews, even though students could express their interest in studying Java programming, in some cases, few students seemed unhappy of their choice and demonstrated less confidence in their ability to excel the course.

Question 2: How can you apply the computational thinking skills you learned in the Java programming class on problems you face in your real-life?

- How could your computational thinking skills help you in this case?
- What other strategies you may use to solve the problem if it is not solved using your computational thinking skills?
- How would studying Java programming would impact your achievement in other subjects?

This question is linked to the ‘Usefulness’ dimension. The responses to this question varied due to the differences in the students’ understanding of what computational thinking is. Yet, most of the students have related computational thinking to programming and spoke immediately about three categories real-life problems, problem solving, and impact of learning programming. Almost all of the students who responded to this question mentioned real-life examples that could be solved using their understanding of programming. One student mentioned *“I always use the concept of nested if-statements. For example, when I wake up late in the morning I ask myself: what if I couldn’t pick up the school bus, then I will walk to my friend building that will take me around 10 minutes walking and pick up the school from there. Then what if the school bus already passed his building, then I will use the public bus, then I ask, myself again, what if the public bus doesn’t come on time, then I had to pick up a taxi”*. Based on the researcher’s background in programming and CS this is a typical example of the use of the concept of nested if statements. Another student spoke about the concepts of loops

‘iterations’ when playing computer games. Many other students seemed to have very good understanding of how game scores are saved as variables in the game program.

Then they were asked about other strategies they may use to solve the problem if it is not solved using your computational thinking skills. Most students took time to think about the other strategies. Only few of them could answer. One of the common answers was the use of trial and error concept. They would try a solution that they are not really sure about its accuracy or effectiveness. Three students confirmed that will just ignore the problem “*forget about it*” and focus on something else.

When asked to explain how studying Java programming would impact their achievement in other subjects than CS, few students could answer the question with examples and evidence and many others were unable to identify how studying Java programming would affect their performance in other subjects such as Math and Sciences.

Generally, almost all students showed great interest when asked about how studying Java programming would affect their ways of thinking about real life problems. Many students had given examples from their daily life and tried to apply computational thinking skills to solve them.

Question 3: How do you feel when you solve a complex programming problem correctly?

- How do you feel if your colleague asks you to help him/her solve a complex programming problem that you are able to solve?

This question was linked primarily to the ‘Attitude’ dimension of the questionnaire questions. Two categories were generated from the students’ responses; pride and being a well-known

programmer. Almost all students expressed their self-satisfaction and pride if they were able to solve complex programming questions. Students seemed passionate about learning more advanced programming concepts because it had a very positive impact about their own self esteem. One student said *“when I solve a complex problem I feel like a smart guy that everyone recognizes”*. Another student added *“when I solve complex programming problems will tell my teacher that I am excellent in her class and I like to be known as the programming geek in the school”*. Additionally, students, in general, showed good intention to help their colleagues solve complex programming problems. They have confirmed their feeling of being proud of themselves if they were asked to help especially if they could get the answer correctly. A student said *“no doubt I feel a bit confused if my friend believes in my abilities to solve such problems. However, if I was able to help her, I would be very happy”*.

Questions 4: What would you do if your teacher challenged you to solve a programming problem that none of your colleagues could solve it?

- Would you sacrifice a time out with your friend and stay home to study for programming?

This interview question was linked to the ‘Motivation’ dimension in the questionnaire. programming complexity and students’ life were main categories generated from the responses. Most of the students who opted to answer this question said that they will ‘Google’ the answer. That was the easiest way to get any answer for any question. However, four students confirmed that they can research the and check the textbook to find answer even if that takes them time. Other students said that they will ask help from another teacher, a friend, a brother, a cousin, or any other relative. One student said *“honestly, if the teacher will not add marks if I solve the problem, then I will not bother myself and waste my time just to get an answer”*. When they were asked about if they would sacrifice a time out with a friend and stay home to study for

programming, almost half of them prefer to go out with their friends and later they could manage their time and study. Very few were willing to stay home and study for programming. Few others expressed no willingness to stay home and study if there had an option to go out with a friend.

4.7.2 Summary of the Interviews Data Analysis

The key responses to the interview questions are presented in table 4.84.

| Interview Questions | Key Responses [Categories] |
|--|--|
| <p>Question 1: What would stand in your mind when you think about yourself as a student learning Java programming?</p> <ul style="list-style-type: none"> • Can you explain to me more about that? • How can learning Java programming makes you different than other students? • Have you ever thought of dropping the Java programming course? | <ul style="list-style-type: none"> • programming will students get good jobs and earn more money [highly paid jobs] • Programmers have different ways of thinking than others [programmers' ways of thinking] • programming is difficult in the beginning of the course but it gets much more interesting by time. Particularly when students start to write codes and see outputs [programming difficulty] |
| <p>Question 2: How can you apply the computational thinking skills you learned in the Java programming class on problems you face in your real-life?</p> <ul style="list-style-type: none"> • How could your computational thinking skills help you in this case? • What other strategies you may use to solve the problem if it is not solved using your computational thinking skills? • How would studying Java programming would impact your achievement in other subjects? | <ul style="list-style-type: none"> • Computational thinking applies to many real-life situations [real-life problems] • Trial and error is a common strategy to solve problems [problem solving] • Students are not fully aware of how understanding programming would impact their achievement in other subjects [impact of learning programming] |
| <p>Question 3: How do you feel when you solve a complex programming problem correctly?</p> <ul style="list-style-type: none"> • How do you feel if your colleague asks you to help him/her solve a complex programming problem that you are able to solve? | <ul style="list-style-type: none"> • Students are proud to be good programmers [pride] • Students are willing to help their colleagues in programming because they want to be known as good programmers [being a well know programmer] |
| <p>Questions 4: What would you do if your teacher challenged you to solve a programming problem that none of your colleagues could solve it?</p> <ul style="list-style-type: none"> • Would you sacrifice a time out with your friend and stay home to study for programming? | <ul style="list-style-type: none"> • Not all students are willing to accept a challenge to solve a complex problem [programming complexity] • Many students prefer to go out with friends rather than studying for programming [students' life] |

Table 4.85 Participants' Key Responses to the Interview Questions

4.8 Summary

Chapter 4 presented the results of the quantitative and the qualitative data analyses. The selection of the data analysis techniques was based on what kind of data were collected from each instrument and the targeted question or sub question. The demographic data was analyzed through descriptive and inferential statistical techniques to answer sub question 4 and revealed discrepant results between School 1 and School 2 regarding students' choices.

The Cognitive Styles Index questionnaire data analysis shows that students who chose to study computer programming demonstrated more quasi-analytical and analytical cognitive styles. While students who do not study computer programming were more quasi intuitive and intuitive, and the difference was significant, which answers sub question 3. Additionally, male students were more analytical. This could help answer sub question 4.

To answer the research main question, the analysis of the CT Cognitive Abilities Measure results shows that students in both School 1 and School 2 demonstrated a significant improvement in their Induction, Quantitative Reasoning, Closure Speed, Visual Memory, and Serial Perceptual Integration abilities. However, only students in School 1 have achieved a significant improvement in Memory Span and Working Memory Abilities. Quantitative data collected from students' responses to the questionnaire exposed that students demonstrated confidence while learning computer programming. Yet, Male students are more confident. Similarly, positive attitudes were captured. However, no significant difference between males and females was evident. On another hand, students were not enough aware of the usefulness of studying computer programming. Though they were highly motivated. These results would help in answering sub question 1 and partially answers sub question 4.

Nonetheless, class observation qualitative data analysis clearly shows that teachers are not fully aware of the students cognitive needs. Yet, regarding the cognitive activities, the researcher could capture more occurrences of quantitative reasoning, working memory, and visual memory activities happening during the programming lessons which supports the results obtained from the CT Cognitive Abilities Measure in response to the main research question. Also, the cognitive activities that are mostly happening were recorded to answer sub question 2. Finally, the interview qualitative data analysis supported the questionnaire results regarding students' confidence, attitudes, usefulness, and motivation.

Chapter 5 Discussion of Findings

The previous chapter presented the analysis of data and results. Both quantitative and qualitative data analyses were conducted in order to achieve the aim of this research study and to answer the research questions. This research sought to investigate the impact of learning computer programming on the cognitive abilities development of high school students in the UAE. The aim will be achieved by answering the following main research question and the sub-questions:

Main research question: To what extent does learning computer programming impact the development of high school students' cognitive abilities in the UAE?

- Sub-question 1: What are the students' perceptions of their experience when they learn computer programming?
- Sub-question 2: What cognitive activities and practices may occur in the classroom during a computer programming lesson?
- Sub-question 3: How the Cognitive Style may affect students' choice of studying computer programming?
- Sub-question 4: How gender differences may affect students' choices, cognitive styles, and perceptions when they learn computer programming?

The study is based on a well-established theoretical framework that incorporates Piaget theory, Cattell-Horn-Carroll theory, Vygotsky theory, Dewey theory, Executive Function theory, Fuzzy Trace theory, and Cognitive Load theory. Each of these theories is linked to key concepts that are solely related to the main aim of this research as demonstrated in table 5.1.

| theory | Key Concepts |
|-----------------------------|---|
| Piaget theory | Deductive Reasoning Skills, Abstraction Skills (Slavin 2014) |
| Cattell-Horn-Carroll theory | Fluid Intelligence Reasoning, Short-Term Memory, Visual Processing (Flanagan & Dixon 2014) |
| Vygotsky theory | Experience, Social Interaction, Cooperative Learning (Slavin 2014) |
| Dewey theory | Problem Solving, Reflective Thinking (Dewey, 1910) |
| Executive Function theory | Working Memory (Short-Term Memory), Cognitive Flexibility, Inhibitory Control (Zelazo 2015) |
| Fuzzy Trace theory | Verbatim, Gist, Memory (Barrouillet 2015) |
| Cognitive Load theory | Working Memory / Short-Term Memory (Plass, Moreno, & Brünken 2010) |

Table 5.1 Key Concepts in the Theoretical Framework

Schunk (2012) stated that the integration of cognition, emotion, and behavior proposed by the Neuroscience is essential in order to consolidate the learning process and achieve the desired outcomes. Therefore, the researcher has studied the three elements. The cognitive abilities were rightly linked to the students' perceptions and attitudes that reflect their emotions as well as their classroom behaviors.

The researcher focused on the research problem and the situation of learning computer programming as well as the actions and behaviors of both students and teachers. Hence, the research approach was conceptualized from the pragmatism paradigm with an emphasis on the research problem rather than the antecedent conditions. Mixed method research design was followed which integrated both quantitative and qualitative data collection and analyses. According to Guba (1990), the methods can be thoughtfully mixed in a single research study. Therefore, the researcher had decided on the use of mixed methods to generate appropriate data that are needed to answer the research questions.

Accordingly, as mentioned earlier, demographic data, Cognitive Style Index questionnaire results, CT Cognitive Abilities Measure (CT-CAM) results, as well as the data collected from

the questionnaire, class observation, and interviews were analyzed seeking to find answers for the aforementioned research questions.

This chapter discusses the findings of the data analyses' results and relates it to the research questions in different sections. Each section will discuss the background information of the issue, testifying the results of the pertinent data analysis, stating the major findings, referencing the findings to previous research studies that either supports or contradicts with them, if any, explaining the results, and concluding the implications of the results. The last section will summarize the discussion that was carried throughout the chapter.

5.1 Main Research Question

This section aims to discuss the findings of the data analyses that answer the main research question i.e. To what extent does learning computer programming impact high school students' cognitive abilities development in the UAE? In order to answer to this question, the researcher had analyzed the data collected through both CT Cognitive Abilities Measure and Class Observation protocol and then integrate the analyses for further understanding and interpretation of the answer.

Rapid changes in the world around us pushes toward a fast progress in the educational paradigms. One of the major characteristics of the new paradigm is the integration of Computational Thinking (CT) and Computer Science (CS) within the K-12 school curriculum. Shute, Sun, and Asbell-Clarke (2017) examined the relationship between CS, programing, and computational thinking and confirmed that programming and computational thinking are closely related. While computational thinking is broader than CS, CS is also a broader domain

than programming. It is evident that the development of the computational thinking skills has a positive impact on the problem solving skills (Popat & Starkey 2019). Shute, Sun, and Asbell-Clarke (2017) had reviewed the literature about different programming tools that leverages teaching computational thinking in different contexts ranges from kindergarten up to undergraduate levels and found that there were programming languages, robotics programs, and games/simulations that were used to teach computational thinking.

According to Sáez-López et al. (2016), the growing interest in teaching programming was driven by future job opportunities as well as other benefits related to the overall educational system advantages. In a different context, in a recent study done by Popat and Starkey (2019), the researchers confirmed that learning to program influences the educational outcomes that are classified as higher order thinking, lower order thinking, and personal skills. They incorporated the conclusions of their study in an “overarching model”. Computer programming students use a range of skills beyond programming skills, one of them is problem solving, that is considered a higher order thinking skill or sometimes called complex cognitive skill.

The demonstration of programming skills is a manifestation of computational thinking competencies, a fundamental skill of computational science and an essential tool to support the cognitive tasks included in computational thinking (Sáez-López et al. 2016).

Ambrósio, Xavier, and Georges (2014) cited in Román-González et al. (2017) stated that computational thinking is linked to the following three abilities factors from Cattell-Horn-Carroll model of intelligence: Fluid Reasoning (G_f), Visual Processing (G_v), and Short Term Memory (G_{sm}). Román-González et al. (2017) had developed the Computational Thinking test (CTt) to measure the above mentioned cognitive abilities. The test included programming

components such as sequences, loops, conditionals, abstraction, modularization, and events. The test reliability was measured against the Primary Mental Abilities (PMA) battery and researchers concluded that Reasoning, Spatial Ability, and Working Memory are cognitive abilities related to programming and computational thinking. The researchers found moderate correlation between computational thinking and the three out of the four Primary Mental Abilities of Intelligence Verbal Factor PMA-V, Special Factor PMA-S, Reasoning Factor PMA-R. While the correlation was weak with the Numerical Factor PMA-N. In conclusion, they found high correlation between computational thinking and problem solving ability.

Ambrósio, Xavier, and Georges, (2014) referred to cognitive testing as the quantitative and qualitative evaluation of the subject's intellectual abilities. They stated that "tests for evaluating cognitive components are based on submitting the subject to a given task and then assessing performance according to an established set of reference parameters". Yet, they have recommended further investigation of the relationship between fluid intelligence and computational thinking. Johnson et al. (2014) cited Sáez-López et al. (2016) confirmed that computational thinking practices such as modeling and abstractions enable students understand the world around them and provide them with the essential skills needed for complex problem solving.

Hence, the researcher has expanded her understanding of how learning computer programming may impact the different cognitive abilities through theory-driven investigation and the development of the CT Cognitive Abilities Measure as well as the class observation protocol.

The quantitative data that was collected from the CT Cognitive Abilities Measure responses were analyzed. Both descriptive and inferential data analyses led to interesting findings. Three

reasoning abilities were defined in the CHC theory and measured for the purpose of this research; Induction, General Sequential Reasoning, and Quantitative Reasoning.

Table 5.3 summarizes the t-test results of CT Cognitive Abilities Measure data obtained from the comparison between the scores of students who study Java OOP and students who do not study Java OOP in the posttest.

| | Site | t-test | df | p |
|--|----------|--------|---------|--------|
| Induction (I) General Sequential Reasoning (RG) | School 1 | 6.354 | 151.271 | <0.05 |
| | School 2 | 2.519 | 27 | <0.05 |
| Quantitative Reasoning (RQ) Induction (I) | School 1 | 0.870 | 197.934 | p>0.05 |
| | School 2 | 1.041 | 27 | p>0.05 |
| General Sequential Reasoning (RG) | School 1 | 6.889 | 154.423 | p<0.05 |
| | School 2 | 2.831 | 27 | p<0.05 |
| Working Memory (MW) | School 1 | 3.108 | 741 | < 0.05 |
| | School 2 | 1.373 | 27 | >0.05 |
| Working Memory (MW) | School 1 | 2.946 | 163.091 | <0.05 |
| | School 2 | 0.674 | 27 | >0.05 |
| Visualization (Vz) | School 1 | 1.058 | 179.931 | >0.05 |
| | School 2 | 764 | 27 | >0.05 |
| Speeded Rotation(Spatial Relations; SR) | School 1 | 0.401 | 750 | >0.05 |
| | School 2 | 1.273 | 27 | >0.05 |
| Closure Speed (CS) | School 1 | 10.769 | 753 | <0.05 |
| | School 2 | 2.977 | 27 | <0.05 |
| Flexibility of Closure (CF) | School 1 | 0.122 | 759 | >0.05 |
| | School 2 | 0.459 | 26.334 | >0.05 |
| Visual Memory (MV) | School 1 | 4.268 | 149.186 | <0.05 |
| | School 2 | 3.071 | 27 | <0.05 |
| Spatial Scanning (SS) | School 1 | 1.636 | 207.200 | >0.05 |
| | School 2 | 0.061 | 27 | >0.05 |
| Serial Perceptual Integration (PI) | School 1 | 11.709 | 753 | <0.05 |
| | School 2 | 3.017 | 8.328 | <0.05 |

Table 5.2 t-Test Results' Analysis of the Cognitive Abilities Development Test

Students in both School 1 and School 2 demonstrated a significant improvement in their Induction, Quantitative Reasoning, Closure Speed, Visual Memory, and Serial Perceptual Integration abilities. However, only students in School 1 have achieved a significant improvement in Memory Span and Working Memory Abilities.

According to Sneider et al. (2014), problem solving, modeling, data analysis and interpretation, and statistics and probabilities are common skills between Mathematics and computational

thinking. Which may explain the significant difference in induction and quantitative reasoning abilities. While general sequential reasoning is concerned with the subject's ability to follow a step-by-step approach. The insignificant difference in the latter ability indicates a deficit in the teacher's instructions which is confirmed by the analysis of the teachers' instructions data analysis of class observation. Further elaboration will be demonstrated in section 5.3.

Psycharis and Kallia (2017) conducted a quasi experiment to investigate the impact of learning computer programming on students' reasoning skills and unsurprisingly found that learning computer programming has improved the reasoning skills. This claim was advocated by many researchers before; Gorman and Bourne (1983), Tu and Johnson's (1990), Degelman et al. (1986) supported the aforementioned results. Fox and Farmer (2011) have also pointed out the same results with significant difference between the control group and the experiment group.

Overall, this study pointed out a significant improvement in the high school students' cognitive abilities. A claim that adds to and supports the results of the study that was conducted by Hayes and Stewart (2016), when they indicated a significant progress in middle school students' intellectual performance when they learned computer programming.

On another hand, as mentioned earlier, the class observation data also supported the answer to the main research question. Four dimensions were considered during the class observations, teacher's instructions, reasoning cognitive activities, memory cognitive activities, and sensory cognitive activities. The main purpose of collecting this data was to triangulate it with the data collected from the CT Cognitive Abilities Measure and to further investigate the impact of the teachers' instructions on the different cognitive activities that were happening during the programming classes.

Pihlgren (2013) investigated the criteria of the teachers' instructions that might improve students' cognitive development. He stated that the teachers' instructions must be carefully planned and chosen to nurture students' mental activities. He called the classroom that is rich with such mental activities a "Thinking Classroom".

Observing the teacher's instructions was aiming to collect data about:

- Provision of concrete props
- Provision of visual aids, such as models and/or time line
- Use of familiar examples to facilitate learning more complex ideas, such as story problems in math
- Allowance for opportunities to classify and group information with increasing complexity
- Use of outlines and hierarchies to facilitate assimilating new information with previous knowledge
- Present problems that require logical analytic thinking

The frequency analysis of the teachers' instructions revealed lack of proper instructions provision that includes concrete probes and different visual aids such as models and/or timelines. However, School 1 teachers were able to provide slightly better instructions than teachers in School 2 with consistency between the different teachers. This indicates that teachers in School 1 had received training, instructions, and/or professional development sessions about that.

Vandenbroucke et al. (2018) studied the relationship between teacher-student interaction and the Executive Function (EF) i.e. “cognitive processes that enable goal directed behavior”. They concluded that the interaction between the teacher and the students in the classroom has an impact in the executive functioning and the students working memory. Yet, there was no evidence on that the teacher’s instructions may affect the students’ cognitive flexibility. According to Vandenbroucke et al. (2018), teachers’ instructions can promote students’ cognitive processes which will consequently stimulate the cognitive activities in the classroom environment. Similarly, Abenavoli and Greenberg (2014) pointed out that teacher’s-child interaction impacts the students’ working memory. Yet, age and gender are predictors of the teacher’s instructions effect size on the students’ cognitive process (Vandenbroucke et al. 2018). Nir-Gal and Klein (2004) confirmed that teachers’ mediation improves children’s cognitive performance in the computer learning environment. This confirms the vital role of the teachers’ instructions on students’ cognitive development when they learn computer programming. In a different context, Kim and Lundberg (2016), the researchers confirmed that more interaction between teachers and students leads to higher level of classroom engagement which will improve their cognitive skills development.

The Reasoning cognitive activities that were observed are:

- Students’ ability to realize the characteristics, rules, and concepts when solving problems
- Students’ ability to generate rules and follow guidance in a step-by-step approach to find a solution for a problem
- Students’ ability to use mathematical relationships and properties for inductive and deductive reasoning

The results show that teachers were not able to provide adequate amount of cognitive activities that require students to realize the characteristics and rules needed for problem solving. However, the use of mathematical relationships activities was significantly higher. Denning (2009) and Grover and Pea (2013) confirmed that computational thinking and programing encompass a range of problem solving skills; reasoning is one of them. Considering problem solving as a complex cognitive ability that requires reasoning, Psycharis and Kallia (2017) failed to prove that computer programming improves students' problem solving skills. Aukrust (2011) stated that problem solving and the development of the students' reasoning skills is at the top priorities of the curriculum development of many systems these days. This claim was also supported by English and Halford (2012).

One of the interesting lessons that were observed, was introduced by one teacher in School 1. The teacher explained the concept of the 'while loop' by linking it to another concept that was learned before i.e. the 'for loop'. Such approach indicates how students could utilize deductive reasoning and abstraction skills in their programming lesson according to Piaget's theory. A week before the observed lesson, students learned that a for-loop iterates through a block of code and executes a specific number of times using a counter. When students examined the while loop, students noticed that a loop is also executed to iterate through a block of code. A skill that reflects Assimilation. However, they noticed a discrepancy between the new experience and the old scheme/structure. The loop starts with the condition rather than the counter which reflects cognitive disequilibrium. Then, the new structure for understanding the while loop was constructed which led to adaptation or cognitive equilibrium. By then, students were able to differentiate between the for-loop and the while-loop using new structures reaching the cognitive equilibrium. Figure 4. Demonstrates the example used by the teacher.

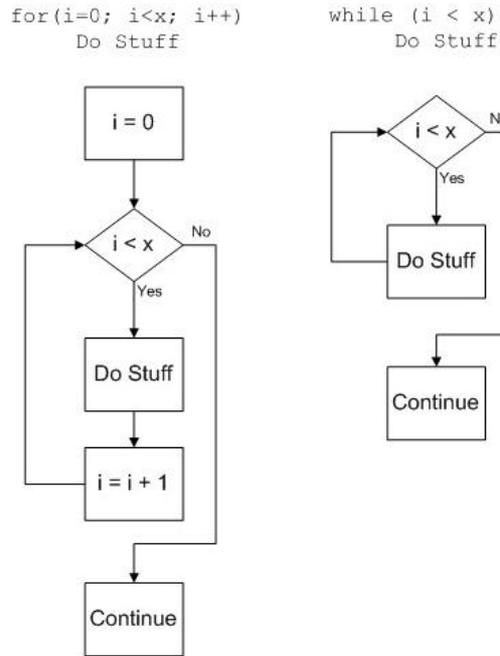


Figure 5.1 for-loop and while loop examples used in the observed class

Memory cognitive activities that were observed include:

- Students' ability to recall provisionally ordered elements after they are presented once to the subject
- Students' ability to manage the capacity of the short term memory and perform different cognitive operations on a temporarily stored information

The results show a significant difference between School 1 and School 2. School 2 teachers have demonstrated more frequent occurrences of memory cognitive activities. Vandembroucke et al. (2018) stated that classroom instructions affect the working memory of students in the classroom. Therefore, in order to achieve improvement in students' cognitive abilities, classroom instructions must include adequate amount of working memory activities that can stimulate students' cognitive processes particularly during the computer programming lessons. In his study about declarative memory and implicit memory, Sprenger (2018), cognitive processes that comprise higher level thinking skills can be addressed through the rehearsal step

of memory building as well as review and retrieve steps. Hence, the existence of the memory stimulation activities within classroom instructions seemed to be essential for developing cognitive processes.

Observing sensory cognitive activities in the programming class was meant to capture information about:

- Students' ability to mentally simulate complex objects and patterns when they are rotated, changed in size, and partially hidden
- Students' ability to simulate mental rotation of simple objects
- Students' ability to formulate and identify a whole object when given its disconnected or partially hidden parts with no previous knowledge of the object
- Students' ability to formulate and identify an object or a pattern within a complex visual array with previous knowledge of the pattern
- Students' ability to recognize and recall an image or a visual stimulus
- Students' ability to scan a spatial visual field and then accurately identify a path or a pattern on it
- Students' ability to identify a symbolic or visual pattern when parts of the pattern are presented in a continuous order

The results show that modest number of sensory activities were being conducted during the programming classes. Visual memory activities were slightly higher. Vinogradov and Nagarajan (2017) have related sensory input with cognition and executive functioning. Hence the researcher was keen to identify how frequent sensory activities can appear in the computer programming classroom and then study its effectiveness. Computer programming teachers seemed to be not adequately aware of the importance of having those sensory activities or they are not aware of the different approaches to integrate them within their lessons.

The results of the CT Cognitive Abilities Measure align with the results of the class observation to a high extent. The CT Cognitive Abilities Measure results reveals a significant improvement in the students' Induction, Quantitative Reasoning, Closure Speed, Visual Memory, and Serial Perceptual Integration abilities. Yet, improvement in Memory Span and Working Memory was evident in School 1 only.

Overall, triangulating the results of the data analyses from both instruments; CT Cognitive Abilities Measure and Class Observation, one can find that the improvement in the Induction ability can be explained by the results obtained from the class observation that show that although teachers were not able to provide adequate amount of reasoning activities in general, having problems to solve, at heart of the computer programming curriculum, expose students to experience reasoning skills at a high level. Additionally, the significant number of Quantitative Reasoning activities can also be related to the improvement in their Quantitative Reasoning ability. Hence, the higher number of cognitive activities, the more improvement that can be achieved. This also applies to the high number of Visual Memory activities that were also associated with the significant improvement of the Visual Memory ability in both schools.

It is also obvious that the number of memory activities that were conducted in School 2 was considerably higher than those in School 2 which may explain the significant improvement in Memory Span and Working Memory abilities in School 1. Yet, the number of Closure Speed activities was low. Yet students achieved a significant improvement in the Closure Speed ability. Further investigation need to be conducted.

5.2 Sub question 1

This section aims to discuss the findings of the data analyses that answers the first sub question: What are the students' perceptions of their experience when they learn computer programming? The answer of this question could be obtained from the quantitative data analysis of the questionnaire responses in addition to the qualitative data analysis of the interviews field notes.

Students' perceptions of their experience when they learn computer programming were looked at from four dimensions: students' confidence when learning computer programming, students' attitude toward learning computer programming, students' awareness of the usefulness of learning computer programming, and students' motivation to learn computer programming. The same dimensions were examined through interview questions to validate the data collected from the questionnaire and triangulate the results.

Cognitive theories emphasize the role of learners' thoughts, beliefs, attitudes, and values (Schunk 2012). Gomes et al. (2012) stated that there is a strong correlation between students' perception about learning computer programming and their achievements in the course. As found in the literature, programming is a difficult subject for students particularly when they have no prior knowledge and skills about it (Krpan, Mladenović, & Rosić 2015). On another hand, research about introductory programming courses is mostly concealed within research about 'Computer Science' (Radenski, 2006). Less research was found about computer programming in particular. Yet, in a study conducted by Eckerdal, Thun, and Berglund (2005), they found that students struggle in abstract thinking and they were unable to understand what computer programming is all about which had affected their perceptions of their learning experience.

Very little was found in the literature about the perceptions of high school students about their computer programming experience. On the contrary, many studies were conducted about college and university students. Though, Krpan, Mladenović, and Rosić (2015) have studied undergraduate students' perceptions about their computer programming learning experience and they concluded that "Sometimes students have too high expectations, but sometimes exam assignments might be inappropriate".

The following sub sections will present the discussion of the results obtained for each of the previously mentioned dimensions including Confidence, Attitudes, Awareness of usefulness of learning programming, and Motivation.

5.2.1 Confidence

The findings of the current study revealed that, generally, students in both schools were confident when they were learning computer programming. That was evident from their responses to the confidence questionnaire elements. It is interesting to note that the percentage of students who agree or strongly agree with the most of the confidence statements was more than 50%.

Students' responses to the interview questions about confidence align with the questionnaire data analysis. Many students expressed their interest and confidence in studying Java programming, in some cases, few students seemed unhappy of their choice and demonstrated less confidence in their ability to excel the course. As mentioned in the previous chapter, three categories were generated from the students' responses: highly paid jobs, programmers' ways of thinking, and programming difficulty. Future jobs and how learning programming will help them understand some of the topics they hear about like Artificial Intelligence. According to

Clark and Jenkins (1999), highly paid jobs is one of the main motivators for students studying computer programming which aligns with the research results.

There are different possible explanations for the results. one of them was elaborated in a recent study conducted by Tsai (2019). Tsai (2019) referred to confidence as the self-efficacy. Students may not have enough confidence when learning programming due to their belief that it is a complex subject that requires high cognitive abilities (Chao 2016). According to Jenkins (2001), students struggle in their first programming course due to little confidence in their ability to excel the course. Difficulty in learning computer programming is common, particularly in introductory programming courses. Students confidence can be boosted up by practicing computer programming which in turn, will increase the students' self-confidence. More experienced students demonstrated more confidence. Hence, practicing programming could to be a major factor in the students' high confidence and therefore, students in both schools seem to have enough practice for the programming concepts they were learning that could impact their confidence while studying the course. Another possible explanation for the results is that the selection of studying the course was up to the student's choice. Hence, students who chose to study computer programming must have confidence in their abilities and enjoy their learning experiences. However, in a similar context, Kalelioğlu and Gülbahar (2014) pointed out that learning programming has a non-significant impact on students' confidence in their problem solving ability. According to Gopu (2016), confidence leads to excellence. This can be an interesting topic for further research.

5.2.2 Attitudes

The results of the study revealed that students' attitude toward learning computer programming was positive. Most of the students agree or strongly agree with the questionnaire attitude statements except for the seventh statement: programming is my favorite subject. Students

seemed to enjoy other subjects rather than computer programming. Yet, the results were promising.

When asked the interview questions that might unveil their attitudes toward programming, students' responses were evolved around two main categories; pride and being well known programmers. Almost all students expressed their self-satisfaction and pride when they were able to solve complex programming questions. Also, students seemed passionate about learning more advanced programming concepts because it had a very positive impact on their own self esteem.

Negative attitude toward programming may affect the students' attitude toward the whole programming field (Ismail, Ngah, & Umar 2010). Furthermore, research shows that attitudes and achievements are positively correlated a claim that was proven by Baser (2013) who found a positive correlation between students' attitudes and their achievements. Hence, it is crucial to ensure that students' have positive attitudes toward programming in their introductory courses in order to improve their achievement. However, Gopu (2016) confirmed that the school environment does not affect students' attitudes toward the study of programming. Therefore, there must be other reasons for the positive attitudes that students, who participated in this study, had demonstrated. It could be, again, due to the fact that programming is an elective course in both schools where students, who were involved in the study, had full control of their choices. Additionally, to their motivation that was evident as shown in the previous chapter.

These findings support previous research conducted by Özden and Tezer (2018) when they found that students taking the coding course exhibited a positive attitude toward the subject.

They have justified that with the fact that, while coding, students practice high level of metacognitive thinking and exhibit advanced social skills which will consequently impact the students' "self-efficacy perceptions". Hence, students' attitudes seem to be related to their confidence as mentioned in the previous sub section. Similarly, Kalelioğlu (2015) confirmed that students demonstrated positive attitude toward programming. In another study about students' attitudes when learning basic programming concepts "Game Maker", Johnson (2017) also confirmed that students exhibited positive attitudes toward their work particularly when the problems they solved were relevant to their personal and cultural backgrounds.

However, in a similar context, Baser (2013) studied the attitudes and gender of students studying computer programming and how it was related to their achievements. Overall, he found that students have moderate attitude toward studying computer programming. Yet, it was found that male students have more positive attitudes than females. The discussion about gender differences are going to be elaborated further in section 5.5

5.2.3 Awareness of Usefulness of Learning Programming

The results of the usefulness statements in the questionnaire were analyzed and showed that, in general, students are not aware of the usefulness of learning computer programming. The results of the third statement of this dimension: Learning programming is necessary to everyone these days and the fourth statement: I don't think everyone must learn programming reflect a huge need to aware students of the importance of learning programming. This can be achieved by making them aware of how programming contributes to the development of their own cognitive abilities.

The second interview question and sub questions were linked to the ‘Usefulness’ dimension. The responses to this question varied due to the differences in the students’ understanding of what computational thinking is. Yet, most of the students have related computational thinking to programming and spoke immediately about three main ideas which were identified as categories during the analysis process; real-life problems, problem solving, and impact of learning programming. Almost all of the students, who responded to this question, mentioned real-life examples that could be solved using their understanding of programming. Hence, students could demonstrate slightly better awareness of the usefulness of learning computer programming during the interview rather than the questionnaire.

Unfortunately, the researcher could not find literature that supports or contradicts with the results found about the students’ awareness of the usefulness of learning computer programming. However, a few studies had included some related information. Rubio et al. (2015) studied the perceived usefulness of the programming course and found that students are not highly aware of the usefulness of the programming course. He stated that the perceived usefulness of the programming course leads to behavioral intentions, which was obvious to the researcher of this study, during the interviews.

This also accords with the results of the research done by Kong, Chiu, and Lai (2018) when they found that senior grades’ students find programming less meaningful than junior grades. Researchers had defined the term “meaningfulness” as “a person's perceived value of a task's purpose based on his or her ideals or standards” (Hur 2016, Kong, Chiu, & Lai 2018). Kong, Chiu, and Lai (2018) had viewed programming meaningfulness perception as one of four programming empowerment components.

5.2.4 Motivation

Regarding Motivation, the results showed that students are not highly motivated to learn computer programming. That was evident from the students' responses to the third statement of the motivation dimension of the questionnaire: If I have a programming problem, I insist to solve it even if it takes me long time, the fourth statement: I wonder how people may spend long hours to learn programming, and the fifth statement: I usually solve programming problems at home even if they are not required for my class. Most of the students' responses were either neutral, disagree, or strongly disagree.

The interview question that was linked to the 'Motivation' dimension is the fourth. Two categories were generated from the students' responses; programming complexity and students' life. Many students who opted to respond to this question preferred the easy way to find an answer for a given problem i.e. "Google it". Additionally, almost half of the students who responded to this question did not demonstrate motivation to learn programming.

What explains this might be the complexity level of the course. Previous research show that students may lose their motivation to learn a subject if they find it difficult. Ball (1977) pointed out that there is no specific definition for motivation. Hence, the difficulty in measuring it. However, in essence, motivation is a key aspect to learn. This applies not only to programming but also to all other subjects. Jenkins (2001) stated that students seem to appreciate the value of the programming course. Yet, they lose their motivation once they start facing the course difficulties and believing that they will not succeed. Hence students need not only to value the outcomes of the course but also to believe in their abilities to succeed. Nevertheless, reasons for motivation might be different from one student to another. Further research seems to be crucial to understand and explain the results.

5.3 Sub question 2

This sections aims to discuss the findings of the data analyses that answers the second sub question: What cognitive activities and practices may occur in the classroom during a computer programming lesson? The class observation quantitative and qualitative data were analyzed and an answer for this sub question was obtained.

Tomprowski, McCullick, and Pesce (2015) stated that according to Piaget formal operational stage, children must be able to perform deductive reasoning logic activities at this period which requires capacity to foster and use knowledge in an abstracted form. This allows children to view the world around them from multiple perspectives. Day (1981) pointed out that an individual who thinks in an operational manner will not necessarily continue to do so. She confirmed that only 50% of those who are theoretically in a formal operation stage think in a formal operation manner which applied to adolescents and college students. Similarly, it is not also necessary that people think in an operational manner for all tasks. One may think operationally in one situation but not another.

Therefore, the researcher found necessity to examine students' cognitive activities and practices in the classroom in different aspects. As stated earlier, teacher's instructions, reasoning activities, memory activities, and sensory activities were observed and results were analyzed. Yet, it is commendable to keep in mind that students may demonstrate the relevant cognitive abilities with different competency levels. The following sub sections discuss the findings of the class observation and how do they contribute to answer the second sub question.

5.3.1 Teacher's Instructions

Generally, the teachers' influence on the students' skills and competencies is long-term and its impact can be recognized in different life stages. According to Sharma (2015), the teacher's instructions need to be reformed based on the students' cognitive styles. In an interesting study done by Song et al. (2005) on African-American Grades 10 and 11 students, they considered the cognitive style, which was referred to as 'learning style', as an important aspect when designing any educational program. They confirmed that intuitive learners need more visual representations and graphics while analytical learners prefer formulations and sequenced forms of knowledge. Hence, the students' learning styles must be considered when designing any educational program as well as choosing the course content to accommodate for intuitive and analytical learners' needs.

As mentioned previously in Chapter 4, the results also show that teachers were not able to provide sufficient number of visual aids such as models and timelines that are associated with the students' ability to problem solving (Swanson 2016). This means that intuitive programming learners will not have proper cognitive support. The use of formulations and sequences was slightly better than the use of visual aids. Yet, it did not seem enough for analytical learners to learn programming in its best way. Therefore, there was no evidence of incorporating the learners' cognitive styles, any accommodations in the course design, nor the lesson planning.

The use of such high-stakes accommodations is not only effective for students' cognitive development, its impact extends to other transferrable skills, students should master in a programming class, such as problem solving skills. This aligns with what Hargrove and Nietfeld (2015) have found in their study about the "The Impact of Metacognitive Instruction

on Creative Problem Solving”. Additionally, Kraft (2019) from Brown University, studied the impact of the teachers’ instructions on the students’ complex cognitive skills, which directly relate to the cognitive skills studied within the context of this research, and concluded that the impact of the teachers’ instructions is multidimensional. An adequate attention of the students’ cognitive skills need to be considered in order to ensure students’ earnings of proper long-term skills. This conclusion aligns with the qualitative data analysis of the teachers’ instructions in the class observation. The three categories that were extorted from the field notes are: Use of Real-life Examples (RL), Problem Solving (PS), and Questioning Techniques (QT). During the observed lessons, teachers had exposed students to various real-life examples and problems to solve using different programming concepts. Yet, the recorded data could not provide any evidence of differentiation based on students’ cognitive style nor cognitive ability. Another evidence is the random use of the questioning techniques that was supposed to enhance the students’ cognitive behavior. Yet, the cognitive activities that the teachers had used could not improve the number of the cognitive activities students could demonstrate.

5.3.2 Reasoning Cognitive Activities

The results of the reasoning cognitive activities demonstrated another evidence that the teachers’ instructions lack what programming students need. Although there was an adequate number of activities were learners could demonstrate quantitative reasoning ability to use mathematical relationships and properties for inductive and deductive reasoning, the induction activities and the general sequential reasoning activities were minimal. This shows obliviousness of cognitive learning and what different students need to achieve cognitive development while studying programming.

Many researchers discussed the “Cognitive Learning theory” highlighting its importance in identifying how learners acquire understanding of how knowledge can be digested in the human brain. They also explained that the digest can happen through incorporating reasoning to solve problems. The National Academies of Sciences, Engineering, and Medicine (2000) published a book about how people learn, looking at learners’ approaches to learn from different perspectives. It indicated that research generally supports the benefits of using abstractions that extends the focus from a particular context to a more general overview. Computer languages, analogical reasoning and visual learning were some examples on this claim.

Most of the previous research, which focus was the ‘reasoning skills’, were studied in Mathematics or related context. A study was conducted about primary school students’ math reasoning skills by Casey et al. (2015), they stated that students’ math reasoning skills are predictors of later performance and achievement. Hence, the importance of stimulating those reasoning skills seems to be evident. Mix and Cheng (2012) pointed out a short-term relationship between space and math reasoning skills. They particularly discussed the relationship between mental rotation and spatial visualization and students’ achievement in Mathematics. They also pointed out a strong relationship between them, confirming the importance of the spatial skills as an early predictor of the Mathematics reasoning skills in upper grades for girls in particular.

Psycharis and Kallia (2017) studied the impact of computer programing on the students reasoning skills, problem solving and self-efficacy in Mathematics. Unsurprisingly, the researchers found a strong correlation between studying programming and the development of the reasoning skills. The importance of this finding lies in two folds. First, the finding supports

the findings of this research that states that studying programming impacts reasoning as a cognitive ability. Second, the findings also highlight the importance of enhancing students' reasoning skills through different reasoning activities.

The inclusion of the students' mathematical way of thinking should be closely examined when developing the computer programming curriculum (Krpan, Mladenović, & Rosić 2015). This claim is aligned with the qualitative data analysis of the class observation items related to reasoning cognitive abilities. The two categories that were generated Algorithmic Thinking (AT) and Mathematical Skills (MS) were relevant to the nature of the programming subject. As mentioned earlier, in most of the observed lessons, teachers advised students to use algorithmic thinking in order to be able to solve problems. Although students tried to utilize their mathematical abilities, yet, they could not demonstrate noticeable aptitude when they were trying to solve the given problems.

5.3.3 Memory Cognitive Activities

As mentioned before, the results of the frequency analysis show that the number of memory cognitive activities was moderate in favor of school 1 students who were exposed to, significantly, more memory activities. The results also show a relationship between working memory and memory span. Redick (2016) studied memory span as a measure of working memory and confirmed that working memory is a predictor of multitasking above other cognitive abilities. He also pointed out a relationship between the working memory and memory span which aligns with the current research results.

Research about the working memory suggests that rehearsal can positively impact the working memory. Oberauer (2019) confirmed the importance of rehearsal on the working memory and

the ability to maintain elements in the short-term memory. He had provided an “evidence for a causal role of rehearsal that relies primarily on correlations which are open to alternative interpretations”. Hence, programming teachers must be aware of this fact and make use of it when planning their lessons. Short Term Memory (STM) and Formative Assessment (FA) were two categories generated from the qualitative data analysis of the class observation. This finding supports the relationship between the working memory and the short-term memory which was also supported by Oberauer (2019).

Memory, particularly the working memory, is strongly associated with the individuals’ problem solving ability as complex cognitive ability. Swanson (2016) confirmed that the working memory is an essential component in the children’s ability to solve problems as well as real-life attainment (Wout, O’Donnell, & Jarrold 2019). Therefore, it should be a priority for programming teachers to consider the rehearsal of the working memory that will support the students’ problem solving ability.

On another hand, Kristof, Molenaarb, and Conway (2019) recently studied the relationship between the working memory capacity and other cognitive abilities including Fluid reasoning (G_f), Crystallized (G_c) and Spatial (G_v) ability and found that “there was no significant moderation by crystallized (G_c) and spatial (G_v) ability and G_f only moderated differentiation in WMC but not in short-term memory”.

5.3.4 Sensory Cognitive Activities

The frequency analysis of the observation results’ analysis, it has been shown that modest number of sensory activities were captured during programming classes including Visualization, Speeded Rotation, Closure Speed, Flexibility of Closure, Spatial Scanning, and Serial Perceptual Integration in both Schools. Although visual Memory activities were more

frequent than other, it cannot be a sufficient reason to reject the assumption about teachers' unawareness of how students could cognitively develop when learning computer programming. It is again another evidence that teachers are not aware of the students' cognitive needs and hence, the need for professional development on this subject, seem to be necessary.

Very limited literature was found about sensory cognitive activities in the same context of this research study. One study was done by Casey et al. (2015), where researchers linked spatial skills to the reasoning skills. They stated that spatial skills are long-term predictors for spatial math reasoning skills indicating a strong relationship between spatial skills and reasoning skills.

The field notes that were taken about the sensory cognitive activities also generated two themes, Visual Aids (VA) and Pattern Recognition (PR). Both are related to the visual representation of objects; which intuitive learners need to maximize their cognitive potential. None of the sensory cognitive activities was tackled appropriately except for visual memory activities. The "Class Diagram" was an example explained by teachers in both schools. Students behavior against their misunderstanding of the concept particularly in School 2, indicated a need to use visual representations of objects to facilitate students' learning of the various programming concepts. When given problems that have the same pattern, students were able to solve them. This is an evidence of the importance of cognitive rehearsal and practice when solving programming problems.

5.4 Sub question 3

This sections aims to discuss the findings of the data analyses that answers the third sub question: How the Cognitive Style may affect students' choice of studying computer

programming? The quantitative data collected from the Cognitive Style Index questionnaire helped in finding the answer for this sub question.

Interestingly, the results of this study revealed that more than 50% of the students who chose to study computer programming possess quasi-analytic or analytic cognitive style index in both school 1 and school 2. There was a significant difference between the cognitive style index of students who chose to study Java OOP and students who did not choose to study Java OOP. This also indicates an impact of the students' cognitive style on their decisions.

Mughal (2016) pointed out that the cognitive style concept has been a precious "source of information science research and has crossed line of psychology and educational theory". In his paper about "the impact of approaches to learning and cognition on academic performance in business and management", Spicer (2004) stated that the learner's cognitive style impacts his/her performance. He defined the cognitive style as the "consistent individual differences in preferred ways of organising and processing information and experience". It describes the person's mode of thinking (Sharma 2017).

The characteristics of the individuals vary as their cognitive style ranges from intuitive to analytic. According to Woestenen (2011), the workload can be optimized according to the cognitive styles developed by Allinson and Hayes (2012). Woestenen (2011) listed the characteristics of intuitivists as they have intuitive way of processing information, use random ways of thinking, have holistic views of things and problems, and synthesize problems. While analytics have more logical ways of thinking, appreciate sequential order of tasks, seek for rationale, use analytical techniques of thinking, are objective, and look at the details of things and problems. Such description helps in explaining why students who chose to study Java OOP

are more analytic than intuitive. Though, learners must be aware of their cognitive style and the fact that it influences their learning and consequently they can optimize their study requirements in different ways.

5.5 Sub question 4

This sections aims to discuss the findings of the data analyses that answers the fourth sub question: How gender differences may affect students' choices, cognitive styles, and perceptions when they learn computer programming? The quantitative data collected from the students' demographics, Cognitive Style Index test, and the questionnaire were main resources to obtain an answer for this sub question. The sub question includes three parts, gender differences and students' choices, gender differences and cognitive styles, and gender differences and perceptions. The following sections discuss each part separately.

5.5.1 Gender Differences and Students' Choices

Compared to the expected number of male and female students in the population of both schools, the number of male students who chose to study computer programming was greater than the expected number while female students were less. This indicates that computer programming is not alluring for female students in School 2. However, in School 1, the situation was different, male students who chose to study computer programming was less than females. This difference can be explained by the fact that School 2 offers many other options for male and female students such as the engineering subjects that might be more attractive for male students. Further investigation of the school system may help in finding more possible interpretations.

School 2 results corroborates the findings of Du and Wimmer (2019) research about the gender gap in the field of computer programming. The researchers confirmed that although females have achieved higher aptitudes in different programming tasks, males are significantly more interested in pursuing computer programming studies and females are significantly underrepresented. Hence, more work need to be done to attract more females to study computer programming in order to help fill the gap in CS studies and the job market.

No literature was found to support the results found in School 1. However, in their study about the gender gap in an introductory programming course, Rubio et al. (2015) found no significant difference between males and females.

5.5.2 Gender Differences and Cognitive Style

Due to the Cognitive Style Index questionnaire concurrent validity, it could be used to discriminate between groups (Allinson & Hayes 2012). This claim aligns with results found by Sharma (2017). He indicated that the difference in cognitive styles of secondary students is by virtue of differences in their gender. Hence, the researcher had used it to compare between male and female Cognitive Style Indices. The results show that the percentage of male students who are analytic or quasi-analytic was slightly higher than female students. Allinson and Hayes (2012) have listed the CSI scores by gender in different studies, which showed that the difference between male and female university students is diluted at the studying stage and gets more obvious when they start joining the work place, when women appear to be more analytic while men appear to be more intuitive. Song et al. (2005) studied the Cognitive Style Index of male and female high school students and also found that males tend to be more intuitive than analytical while intuitive female students were as much as analytical ones.

5.5.3 Gender Differences and Students' Perceptions

Unsurprisingly, female students were less confident about their computer programming learning experience. The results show significant differences between males and females in School 1 for all confidence statements in favor of males. However, for School 2, the difference was significant only in AC2: I think at the end of the programming course; I will be able to solve complex programming problems and AC5: I feel secure when I am asked to solve problems in programming. The reason for this difference between School 1 and School 2 can be due to the difference in the sample size.

The findings of this research study are in agreement with Sullivan and Bers (2016) research that has demonstrated that females struggle more with computer programming than males, which leads to low confidence. However, they confirmed that the improvement in the females' confidence through the programming course was higher than the improvement that males had achieved. Furthermore, in other studies, researchers pointed out that females are less attracted to programming which results in low confidence in their abilities to program (Baser 2013). Hoegh and Moskal (2009) stated that females are underrepresented in the field of CS and programming which might be affected by their less confidence in learning them. Additionally, Chang et al. (2012) stated that women's attitudes are generally more negative toward computers.

Contrary to expectations, there was no significant difference in attitudes nor the awareness of the usefulness of learning computer programming between males and females in both schools. Most of the literature reviewed about gender differences in programming attitudes were studies about undergraduate and post graduate students. Very few studies were found on high school students' attitudes. Literature has no agreed upon perspective about the difference in attitudes toward computing and programming between males and females. However, the findings

support what Bakr (2011) and Rubio et al. (2015) have found. They stated that there is no difference between the attitudes of males and females toward programming. While Jennings and Onwuegbuzie (2011) found females are more positive than males. Also, Kay (2008) studied gender differences in three different areas, computer attitudes, ability and use of computers. He found that both males and females have almost the same attitudes. Yet, males reported slightly more positive affective attitudes.

Contrarily, Baser (2013) found that males' attitudes toward programming was significantly higher than females. He also found a significant difference in the students' perceptions about the usefulness of studying computer programming. In contrast to the findings of both Yildirim and Kaban (2010) cited in Baser (2013), they claimed that females' attitudes are meaningfully higher.

While contradicting results were found in this research between school 1 and school 2 in the students' motivation to learn computer programming. The difference in school 1 was more significant. Males were more motivated than females. According to Rubio et al (2015), the results of their research indicate that "male and female students have different perceptions and learning outcomes: male students find programming easier, have a higher intention to program in the future and show higher learning outcomes than female students". That was justified by higher motivation in male students than females.

Woestenen (2011) described the concept of "need for cognition" as the individuals' tendency to enjoy thinking and engage in thinking about different topics. According to her, motivation takes into account the "need for cognition" where learners are motivated to apply their thinking skills in various aspects. An interesting topic that is worthy for further research.

5.6 Summary

Chapter 5 presented the discussion of findings of the current research study. It started with a brief about the research paradigm, research design and an explanation of the mixed method used followed by separate section allocated for the discussion of research results according to the research questions. To answer the main research question that serves the aim of conducting this research, the researcher discussed the findings of the CT Cognitive Abilities Measure and the class observation and concluded that after studying the programming course, students could demonstrate a significant improvement in their Induction, Quantitative Reasoning, Closure Speed, Visual Memory, and Serial Perceptual Integration abilities. However, only students in School 1 have achieved a significant improvement in Memory Span and Working Memory Abilities. There was evidence on the improvement of the other cognitive abilities. The results of the CT Cognitive Abilities Measure and the observations were triangulated to strengthen the findings. Those results were also endorsed by previous research.

The next section discussed the findings of the questionnaire and interviews that could answer the first sub question. The researcher had determined the perceptions of the students who were studying the programming course through the analysis of the results of both instruments. Students confidence and attitudes were evidenced and supported by research in the same field of study. The discussions of the four dimensions were obviously interrelated. The alignment between the results obtained from the questionnaire and the interviews was clearly recognized.

Then, the findings of the observation were also discussed in the following section to answer the second sub question about students' cognitive activities during the programming class. The significance of the teachers' instructions was discussed in details to justify the need for professional development plans for teachers regarding the identifications of the students'

cognitive needs and the action plans that has to be put in place. Also, the captured reasoning, memory, and sensory activities were also used to support the findings of the CT Cognitive Abilities Measure results.

The discussion of the third sub question was focused on how the Cognitive Style Index may affect students' choices. The discussion was basically focused in the characteristics of the intuitive and analytic learners and linking it to the nature of computer programming.

Subsequently, a discussion of how gender may affect students' choices, cognitive style, and perceptions was demonstrated in details. The researcher could support the findings with previous research studies that either agree or disagree with the research findings. In brief, gender has no significant impact on students' choices although males seem to be more attracted to the CS studies and programming in particular. Male students were more analytic. A claim that was debatable by many researchers. Gender and students perceptions were also discussed showing the contradicting results between school 1 and school 2 in favor of male students in school 1 who were more motivated to study computer programming.

Chapter 6 Conclusions and Recommendations

The previous chapter discussed the findings that were obtained from the quantitative and qualitative data analyses. The discussion was right linked to the research questions and answers were elaborated clearly and supported with proper data triangulation. The researcher endeavored to investigate the impact of learning computer programming on the cognitive abilities development of high school students in the UAE by answering the following questions:

Main research question: To what extent does learning computer programming impact the development of high school students' cognitive abilities in the UAE?

- Sub-question 1: What are the students' perceptions of their experience when they learn computer programming?
- Sub-question 2: What cognitive activities and practices may occur in the classroom during a computer programming lesson?
- Sub-question 3: How the Cognitive Style may affect students' choice of studying computer programming?
- Sub-question 4: How gender differences may affect students' choices and perceptions when they learn computer programming?

This chapter will wind up this research. A summary of the key findings will be presented and its implications in education. Besides, recommendations of necessary actions and further research will be proposed to enlighten scopes for interested researchers to support the CS and programming education field. The concluding remarks will bring the research to the end.

6.1 Key Findings

The theoretical framework of this mixed-method research was based on Piaget theory, Cattell-Horn-Carroll theory, Vygotsky theory, Dewey theory, Executive Function theory, Fuzzy Trace theory, and Cognitive Load theory. A thorough study of the aforementioned theories provided the researcher with an insight to choose and develop instruments that helped in collecting quantitative and qualitative data. Thoughtful selection of the analysis techniques led to the key findings which were evolved around the research questions.

For the main research question: To what extent does learning Computer programming impact high school students' cognitive abilities development in the UAE? Based on previous research and the reviewed literature, the researcher had identified twelve cognitive abilities that might have been affected by studying computer programming. The twelve cognitive abilities are: Induction (I), General Sequential Reasoning (RG), Quantitative Reasoning (RQ), Memory Span (MS), Working Memory (MW), Visualization (Vz), Speeded Rotation (SR), Closure Speed (CS), Flexibility of Closure (CF), Visual Memory (MV), Spatial Scanning (SS), and Serial Perceptual Integration (PI).

The main research question was answered by analyzing the data of the CT Cognitive Abilities Measure, as well as the class observations. The quasi experiment was conducted considering two groups of grade 11 students. The control group are grade 11 students who do not study Java OOP while the experiment group are students who study Java OOP. Up to her best, the researcher tried to control other variables that might have influenced the results. The CT Cognitive Abilities Measure (CT-CAM) was used as a pre test and a posttest. The tests were done by the two groups to identify the impact of studying the Java OOP course on the students' cognitive abilities development.

The t-test inferential statistical technique was used to compare between the mean scores of the two groups and results revealed that students who studied Java OOP have achieved improvement in their Induction, Quantitative Reasoning, Closure Speed, Visual Memory, Serial Perceptual Integration abilities, Memory Span and Working Memory cognitive abilities.

The results of the quasi experiment were supported by the class observation data that demonstrated adequate provision of activities that are associated with the most of the developed cognitive abilities. However, the class observations' data analysis also revealed the teachers' unawareness of the students' cognitive needs and how their instructions would impact students' cognitive abilities development. The absence or less provision of certain cognitive activities led to less improvement.

Regarding the first sub question: What are the students' perceptions of their experience when they learn computer programming? The researcher used a questionnaire and interviews to study the students' perception in four dimensions; confidence when learning programming, attitudes toward learning programming, awareness of the usefulness of learning programming, and motivation to learn programming. The results disclose the students' confidence when they were learning computer programming. It was also evident that students demonstrated a positive attitude toward learning programming. However, the usefulness of learning programming was not fully acquired by students although they were aware of the relationship between programming and problem solving especially when it comes to real-life problems. Correspondingly, motivation to learn programming was not also manifested in their responses.

The second sub questions: What cognitive activities and practices may occur in the classroom during a computer programming lesson? Was investigated through class observation. The

results revealed that teachers' instructions reflected lack of awareness of the students' cognitive needs. Also, the reasoning cognitive activities that were provided could somehow justify the students' responses of the reasoning questions in the CT Cognitive Abilities Measure. Memory cognitive activities and sensory cognitive activities also validate the students' responses to the relevant questions of the CT Cognitive Abilities Measure in addition to an explanation of the difference between the two schools.

Regarding the third sub question: How the Cognitive Style may affect students' choice of studying computer programming? The results show that more than 50% of the students who chose to study computer programming possess quasi-analytic or analytic cognitive style index in both school 1 and school 2. While students who do not study computer programming were more of an intuitive cognitive style. The cognitive style seems to have an impact on the students' decisions.

Finally, for the fourth sub question: How gender differences may affect students' choices and perceptions when they learn computer programming? The data analysis revealed contradicting results between school 1 and school 2 regarding students' choices when compared to their gender. Further research would help in explaining such differences. Considering gender when studying students' perceptions; generally, male students were more confident and more motivated when they learn computer programming. No significant difference was found in their attitudes and awareness of the usefulness of studying computer programming.

6.2 Implications

Although computer programming is a difficult subject to teach, new paradigms of many educational systems worldwide, tend to include it in their curriculum due to its positive impact on the students' higher order thinking skills (Kalelioğlu 2015). Provided that problem solving is a higher order thinking skill that requires complex cognitive activity, students who study computer programming develop more problem solving skills than those who do not (Zhang et. al. 2014). Román-González, Pérez-González, and Jiménez-Fernández (2017) studied specific cognitive abilities underlie computational thinking linking computational thinking to programming as a major approach to teach it. Yet, their focus was about Broad Stratum II abilities including Fluid Reasoning (G_f), Visual Processing (G_v), and Short Term Memory (G_{sm}). Yet, research about specific cognitive abilities that could be impacted by learning computer programming is found limited particularly in the middle east and gulf area. Therefore, the researcher is eager to fulfil this gap by studying the impact of teaching computer programming on the students' cognitive abilities development in the UAE.

Therefore, after completing this research, the researcher found several implications can be inferred from the results that were obtained:

First, the research will draw the educators and curriculum developers' attention to the fact that the impact of learning computer programming is not limited to CS domain skills. It, by the same token, impact the students' cognitive abilities including Induction, Quantitative Reasoning, Memory Span, Working Memory, Closure Speed, Visual Memory, and Serial Perceptual Integration. Correspondingly the impact on these cognitive abilities will extend to influence students' achievement in other subjects such as Mathematics and Sciences that require higher order thinking skills and complex cognitive abilities e.g. problem solving. The

attention to teaching computer programming shall encourage decision makers, leading the new paradigms in the education field, to consider teaching computer programming as a core course for K-12 students. Computer programming courses can be aligned and integrated with the curriculum international as well as the 21st century skills. Yet, forms and strategies to teaching computer programming vary and worth further discussion.

Second, students' confidence, attitudes, and motivation can be boosted up if the teachers try to simplify the programming concepts they are teaching. Hence, teachers should have profound subject knowledge that allows them to abridge the burden of studying such difficult topics. On another hand, students' awareness of the usefulness of studying computer programming can be easily addressed by linking programming and computational thinking to everyday problems. Thinking about how to solve real-life problems can be driven by computational thinking when reasoning, memory, and sensory cognitive abilities can be utilized.

Third, teachers currently teaching computer programming in schools can consider the cognitive needs of their students which starts with proper identification of their cognitive styles. Such activity would help teachers teaching, not only CS or programming, but also all other subjects, to accommodate their instructions and lessons plans to meet the learners' cognitive styles and needs. Furthermore, the inclusion of various cognitive activities within classroom instructions will help in achieving proper differentiation at different levels to meet the learners' needs.

Fourth, many schools offer different elective courses at the high school level. Students selection of courses will impact their graduation outcomes and the skills they develop before they move for to further education. Therefore, by accurate identification of their own cognitive styles, students will be able to recognize their areas of interest and hence have proper course

choices. This will increase the possibility of having highly motivated students in the computer programming courses that will consequently impact their further achievements.

The fifth and the last implication of this study states that while there were no consistent results between the two schools regarding the differences between the choices of males and females, female students seem to be less attracted to study computer programming due to reasons that might be related to the norm cognitive style and career opportunities. Hence, females can be motivated to join the programming courses by considering their cognitive styles and the provision of various differentiation prospects. As mentioned earlier, motivating female students to study computer programming will not accordingly impact their performance and attitudes while studying the programming course.

6.3 Recommendations

After completing this research study, the researcher would like to set a list of recommendations for educators and policy makers that, if considered, the revolution in computational thinking, CS education and computer programming in particular, would be justified and supported with research based evidence. The recommendations include:

- Encourage educators and decision makers to give more attention to teaching computational thinking and programming particularly in the UAE and consider programming as a set of core skills that all students, within the K-12 educational systems, can and should learn. The influence of programming will expand to all other subjects due to its impact on students' cognitive abilities.

- Identify the students' cognitive styles prior to teaching the programming courses. Such identification would inform the curriculum development process and guide developers to write proper learning outcomes based on students' differentiated cognitive abilities.
- Develop the programming teachers' instructional strategies to ensure the inclusion of various classroom activities that would cater for the students' cognitive styles. Teachers should be able to tailor their instructions to meet the students' cognitive needs.
- Integrate programming with other subjects such as Mathematics and Sciences to foster students higher thinking skills including problem solving skills and help them utilize computational thinking when solving problems.
- Motivate students to learn computational thinking and programming at all school levels as it would help them develop their cognitive abilities e.g. reasoning skills, memory skills, and sensory skills. Hence, better opportunities for higher achievement.
- Set plans to involve more female students in programming activities that may include, but not limited to, competitions and entrepreneurship programs. This would increase the females' representativeness in the programming domain.

6.4 Limitations

Following the discussion of the findings of this research, it is also necessary to state the limitations that the researcher was aware of as listed below:

- The study was conducted in two different settings, the first is a private school in Abu Dhabi that has a reasonable population. Hence, the number of Grade 11 student who opt to take the Java OOP course were only 10. While the other setting is a school system that consists of fourteen schools across the UAE. Including the two schools in one study could expose the validity of the results to threats. Hence, the data of each school was analyzed separately and results were also elaborated differently.
- It was difficult to schedule interviews with individual student due to the limitations of the school schedule, and in the rare cases when it was possible, it was difficult to the researcher due to her long working hours and far distance from the two sites. Hence, the researcher had to arrange for a whole group interview in School 1 and focus groups in School 2.
- The development of the CT Cognitive Abilities Measure was based on the CHC theory and the questions were based on the literature reviewed carefully by the researcher. Yet, there might be other aspects that the researcher could not capture from the reviewed literature. Yet, to avoid such limitation, the internal consistency reliability, split half reliability, as well as construct, content, and face validity were carefully studied and confirmed.
- The researcher aimed to investigate the impact of learning computer programming on the students' cognitive abilities development based on her long experience in supervising the subject in one of the largest Ministry of Education streams in the UAE. The stance of the

researcher may lead to bias, particularly in the discussion of the results. Therefore, the researcher tried her best to stand at a mid-point considering all perspectives based on the collected data.

- The mixed-method research was conducted in a multiphase design that required sophisticated planning which required extra time and effort that needed to be managed by the researcher. However, the researcher had developed a monthly plan across the period of the research that specifies the tasks that need to be conducted, the material and tools that need to be used, as well as the stakeholders that need to be involved. The researcher had shared the plan with the Director of Studies (DoS) and the management of the two schools. Upon their approval, the researcher went through all phases and could achieve the set targets within the timeframe. In some situations, the plan had to be altered slightly particularly in cases of public holidays and unexpected school events. Yet, a back up plan was immediately set and hence targets were achieved.
- The mixed-method multiphase design also led to some contradictory findings. This include contradicting results between the different instruments and contradicting results between the schools. Therefore, the researcher paid attention to those results and tried to explain them. In case of unavailability of any reasonable convincing explanation, the researcher had recommended further research.
- The students joining the Java OOP course are also studying other courses that might also impacted their cognitive development. Hence, the researcher selected the sample based on its characteristics and ensured that all participants in the sample study the same other courses to bound the influence of studying the other courses. Additionally, if a course

would have impact any of the student's cognitive abilities, which is definitely the case, then it would be most probably of a similar impact on the other students in the same group.

- Finally, the last limitation that worth mentioning is the demographics of each school. As mentioned earlier, School 2 is a private multi-nationality school with diverse population. It is a well-known school in Abu Dhabi Emirate and scored relatively high in ADEK school rating. On another hand, School 1 represents a well-reputed public school system that offers quality education for Emirati students. This specialty of the context for the two schools may alter the generalizability of the results and may also cause unfair comparison between the two Schools. So, as mentioned before, the researcher had studied the data obtained from the schools separately. Though comparison between the two results was necessary for triangulation purposes.

6.5 Scope of Further Research

Throughout the research, the researcher had identified few aspects that worth further research including:

- Guzdial (2011) stated that identifying the cognitive skills associated with CT, how can they be taught, and how can we evaluate them is crucial and worth further research. Yet, although the researcher had studies particular cognitive skills, similar research can be conducted in other places around the world to support the generalizability of the results.
- Previous research identified certain cognitive processes related to teaching CT skills and programming such as spatial reasoning and general intelligence (Ambrosio et al. 2014). Román-González, Pérez-González, and Jiménez-Fernández (2017) also determined Fluid reasoning (Gf), Visual processing (Gv), and Short-term memory

(Gsm) as cognitive abilities underlie CT. the current study was based on these findings in their relationship with the CHC theory. Hence, further research is recommended to investigate if other cognitive abilities can also be impacted by learning computational thinking and programming or not.

- On of the CT Cognitive Abilities Measure results was that the number of Closure Speed activities was low. Yet students achieved a significant improvement in the Closure Speed ability. A research about closure speed cognitive ability and its relationship to programming might be worthy.
- During the discussion of this study, students' perceptions were linked to their achievement. Specifically, motivation and attitudes. However, the researcher was not concerned with the students' performance or achievement due to the scope of the research problem. According to Gopu (2016), confidence leads to excellence. So, it is worth considering students' achievements in programming courses for further interpretation of their perceptions. Reasons for motivation can also me studied.
- Woestenen (2011) described the concept of "need for cognition" as the individuals' tendency to enjoy thinking and engage in thinking about different topics. The use of the concept "need for cognition" can be invested in programming classes. A case study would help identify how students can enjoy the programming class.

6.6 Contribution of This Research

The contribution of this research to the literature is in two folds: First, the literature reviewed to achieve the purpose of this research evolved around the research problem which relates to CS and programming, cognition and cognitive development. Through this, the research has developed a conceptual framework shown in figure 2.4 that links learning programming to the cognitive and noncognitive functions. Such a conceptual framework can be used by other

researchers to further study the same or similar topics in similar contexts. Second, the research has contributed to the literature that deals with testing to measure the Cognitive Abilities pertinent to learning computer programming based on the CHC theory. As mentioned earlier, a test was developed by the researcher to measure the reasoning, memory, and sensory abilities based on a thorough study of the CHC theory and following the approaches used in “Woodcock-Johnson IV Tests of Cognitive Abilities (WJ IV)”, and “Wechsler Adult Intelligence Scale-Fourth Edition (WAIS IV)”. The test’s validity and reliability were confirmed. Though, researchers can make use of the test as it is or adapt it to develop similar tools.

The theoretical contribution of this research in its theoretical framework that integrates the key concepts of cognition and learning including; Piaget, Cattell-Horn-Carroll (CHC), Vygotsky and Dewey theories. Other supporting theories were also used to consolidate the understanding and the interpretation of the research results including; Fuzzy Trace theory (FTT), Executive Function theory (EFT), and Cognitive Load theory (CLT). Researchers can utilize the same approach in similar studies relating to the study of cognitive and noncognitive behaviors in any learning context.

Finally, the methodological contribution of the study scaffolds on the conceptual and the theoretical frameworks that helped in developing a methodological approach that other researchers, undertaking similar research, in similar contexts, can employ. The methodological approach is characterized by its thoughtful integration of methods and instruments including the use of quasi experiment as well as quantitative and qualitative methods. The methodology starts with a classification of learners based on their Cognitive Style Index followed by a pre-test to identify a baseline for the development of the learners’ cognitive abilities. Students’

progress is then monitored and observed throughout the study until they conduct the posttest. Similarly, the noncognitive behaviors i.e. perceptions were also captured through the questionnaire and the interviews. This sequence of methods allowed for profound understanding of the research problem and analysis of results. Therefore, the approach forms a foundation for other researchers and paves the way for further studies relating to computer programming to cognition and cognitive development.

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Appendices

Appendix 1 Approval from School 1 Director


www.buid.ac.ae

4/8/2018

To whom it may concern

This is to certify that Ms.Heba Daraghmeh with Student ID number 2016152103 is a registered part-time student in the Doctor of Education offered by The British University in Dubai since September 2016.

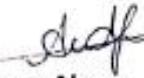
Ms. Daraghmeh is currently collecting data for her research (The Impact of Learning Computational Thinking Through Computer Programming on High School Student Cognitive Skill Development).

She is required to gather data through conducting tests, class observation, survey, and interviews that will help her in writing the final research. Your permission to conduct her research in your organisation is hereby requested. Further support provided to her in this regard will be highly appreciated.

Any information given will be used solely for academic purposes.

This letter is issued on Ms.Daraghmeh's request.

Yours sincerely,



Dr. Amer Alaya
Head of Academic and Student Administration

PO Box 345015 - Block 11 Dubai International Academic City Dubai U.A.E - T +971 4
 FB.com/BUIDTeam  BUID_Team  youtube.com/BUIDAdmin

Appendix 2 Approval from School 2 Principal



4/8/2018

To whom it may concern

This is to certify that Ms.Heba Daraghmeh with Student ID number 2016152103 is a registered part-time student in the Doctor of Education offered by The British University in Dubai since September 2016.

Ms. Daraghmeh is currently collecting data for her research (The Impact of Learning Computational Thinking Through Computer Programming on High School Student Cognitive Skill Development).

She is required to gather data through conducting tests, class observation, survey, and interviews that will help her in writing the final research. Your permission to conduct her research in your organisation is hereby requested. Further support provided to her in this regard will be highly appreciated.

Any information given will be used solely for academic purposes.

This letter is issued on Ms.Daraghmeh's request.

Yours sincerely,




Dr. Amer Alaya
Head of Academic and Student Administration

PO Box 345015 - Block 11 Dubai International Academic City Dubai U A E - T +971 4 279 1400 - F +971 4 279 1490
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Appendix 3 Cognitive Style Index Test

Cognitive Style Index

| |
|---------------------|
| Name: |
| Gender: Male/Female |
| Grade:10/11/12 |

People differ in the way they think about problems. Below are 38 statements designed to identify your own approach. If you believe that a statement is *true* about you, tick **True**. If you believe that it is *false* about you, tick **False**. If you are *uncertain/not sure* whether it is true or false, answer tick **Not Sure**.

This is not a test of your ability, and there are no right or wrong answers. Simply choose the one response, which comes closest to your own opinion. Work quickly, giving your first reaction in each case, and make sure that you respond to every statement.

| No. | Item | True | Not Sure | False |
|-----|---|------|----------|-------|
| 1 | In my experience, logical thought is the only realistic basis for making decisions | | | |
| 2 | To solve a problem, I have to study each part of it in detail | | | |
| 3 | I am most effective when my work involves a clear sequence of tasks to be performed | | | |
| 4 | I have difficulty working with people who 'dive in at the deep end' without considering the bigger aspects of the problem | | | |
| 5 | I am careful to follow rules and regulations at any task | | | |
| 6 | I avoid taking a course of action if chances of success are low | | | |
| 7 | I tend to scan through reports rather than read them in detail | | | |
| 8 | My understanding of a problem tends to come more from thorough analysis than flashes of insight | | | |
| 9 | I try to keep to a regular routine in my studies and homework | | | |
| 10 | The kind of work I like best is that which requires a logical, step-by-step approach | | | |
| 11 | I rarely make 'off the top of the head' decisions (quick decisions) | | | |
| 12 | I prefer chaotic action to consistent inaction | | | |
| 13 | Given enough time, I would consider every situation from all angles | | | |
| 14 | To be successful in my studies, I find that it is important to avoid hurting other people's feelings | | | |
| 15 | The best way for me to understand a problem is to break it down into its basic parts | | | |
| 16 | I find that to adopt a careful, analytical approach to making decisions takes too long | | | |
| 17 | I make most progress when I take calculated risks | | | |
| 18 | I find that it is possible to be too organised when performing certain kinds of task | | | |
| 19 | I always pay attention to detail before I reach a conclusion | | | |
| 20 | I make many of my decisions on the basis of feeling | | | |
| 21 | My philosophy is that it is better to be safe than risk being sorry | | | |

| No. | Item | True | Not Sure | False |
|-----|---|------|----------|-------|
| 22 | When making a decision, I take my time and thoroughly consider all relevant factors | | | |
| 23 | I get on best with quiet, thoughtful people | | | |
| 24 | I would rather that my life was unpredictable than that it followed a regular pattern | | | |
| 25 | Most people consider me as a logical thinker. | | | |
| 26 | To fully understand the facts I need a good theory | | | |
| 27 | I work best with people who are spontaneous/natural | | | |
| 28 | I find detailed, systematic work satisfying | | | |
| 29 | My approach to solving a problem is to focus on one part at a time | | | |
| 30 | I am constantly on the lookout for new experiences | | | |
| 31 | In gatherings with colleagues and friends, I have more to say than most | | | |
| 32 | My 'feeling' is just as good a basis for decision making as careful analysis | | | |
| 33 | I am the kind of person who pays attention and caution to the wind | | | |
| 34 | I make decisions and get on with things rather than analyse every last detail | | | |
| 35 | I am always prepared to take a risk | | | |
| 36 | Formal plans are more of an interruption/limitation than a help in my work | | | |
| 37 | I am more at home with ideas rather than facts and figures | | | |
| 38 | I find that too much analysis results in stopping my work to finish | | | |

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Heba DARAGHMEH <heba.daraghmeh@gmail.com>

Cognitive Style Index-Help Needed

John Hayes <J.Hayes@lubs.leeds.ac.uk>
To: Heba DARAGHMEH <heba.daraghmeh@gmail.com>
Cc: "cw.allinson@yahoo.com" <cw.allinson@yahoo.com>

Mon, Jul 9, 2018 at 8:56 PM

Dear Heba

Thank you for your recent enquiry. Professor Chris Allinson and I are pleased for you to use the Cognitive Style Index (CSI) in your study, subject to the following conditions:

1. It is used purely for academic research and not in any commercial application.
2. It is not passed on to anyone other than your research subjects. If you know of anyone else who wishes to use it in research, please ask them to contact us directly.

I attach files containing:

- (a) a copy of the CSI (csi.doc)
- (b) a scoring key (csiscore.doc)
- (c) a form titled Use of the CSI (csiuse.doc) to assist us in monitoring applications of the instrument; please complete it and return it to us when you are in a position to do so
- (g) a copy of the CSI Manual and Users' Guide.

You are welcome to retype the CSI and incorporate it into a larger questionnaire if you wish, but, in all other respects, please abide by the copyright statement at the foot of the inventory. You may reproduce no more than 5 items for illustrative purposes in any dissertation, research paper or report, but you should not, under any circumstances, reproduce more than 5 items in any form of printing or by any other means, electronic or mechanical. We should be grateful for a copy of any report or paper resulting from work in which you have used the CSI, or any statistics emerging from your analysis which you feel may be of interest to us. If there is any way in which we can be of further assistance, please do not hesitate to contact us.

For the time being, we have decided to supply the instrument free of charge for applications in academic research studies so no payment needs to be made in your case.

Yours sincerely

John Hayes

Appendix 5 CT Cognitive Abilities Measure

1 Which shape comes next in the pattern?

A B C D

2 Which figure comes next in the pattern?

A B C D

3 Which figure comes next in the pattern?

A B C D

4 Which row comes next in the pattern?

| | | | | | | |
|---|---|---|---|---|---|---|
| A | F | J | B | R | F | A |
| F | A | A | F | J | B | R |
| B | R | F | A | A | F | J |
| F | J | B | R | F | A | A |

Row A F A A F J R F B
 Row B A A A F J B R F
 Row C F A A F J B R
 Row D F J B R F F A A

5 Choose the best answer.

If some students are talented and some talented are piano players. Which statement is correct?

A. Some students are piano players
 B. All students are piano players
 C. Some piano players are talented
 D. All talented are piano players

6 Choose the best answer.

Khalid, twelve years old, is three times as old as his brother. How old will Khalid be when he is twice as old as his brother?

A. 15
 B. 16
 C. 18
 D. 20

7 Choose the best answer.

The price of a mobile phone was cut 60% for a sale. By what percent must the phone be increased to, again sell the mobile phone at the original price?

A. 50%
 B. 100%
 C. 150%
 D. 250%

8 Choose the best answer.

Maryam had a number of cookies. After eating 2, she gave half the remainder to her sister. After eating another 2 cookies, she gave half of what was left to her brother. Maryam now had only 10 cookies left. How many cookies did she start with?

A. 11
 B. 24
 C. 36
 D. 44

9 Compare two quantities - Quantity A and Quantity B - and then determine which of four statements describes the comparison.

- Quantity A: $x^2 + 1$
- Quantity B: $2x - 1$

A. Quantity A is greater
 B. Quantity B is greater
 C. The two quantities are equal
 D. The relationship cannot be determined from the information given

10 Rashid is older than Hamda, and Maryam is younger than Rashid. Which of the following statements would be most accurate?

A. Maryam is older than Hamda
 B. Maryam is younger than Hamda
 C. Maryam is as old as Hamda
 D. It is impossible to tell

13 Choose the best answer.

g is to 6 as R is to?

| | | | |
|---|---|---|---|
| A | B | C | D |
| g | R | g | R |

14 If the transparent piece of paper is folded along the middle dotted line, which of the following illustrations will result?

A B C D

11 Mohammad and Nasir each saved AED 5,000 in 2018. In 2019 Mohammad saved 10 percent more than in 2018, and together he and Nasir saved a total of AED 10,000. Approximately what percent less did Nasir save in 2019 than in 2018?

A. 5%
 B. 8%
 C. 10%
 D. 15%

12 Rashid is training for a race. He runs at 8 Kilometer per Hour and completed the track in 120 minutes. His Friend Salim, completes the same track in 2.5 Hours. How much faster was Rashid running?

A. 1.6
 B. 1.8
 C. 2.0
 D. 2.2

15 Which is a mirror image of the below image? Assume that the dotted line is the mirror.

A B C D

16 Which of the following shows a reflection of the image below? Assume that the dotted line is the line of reflection.

| | | | |
|------------------|------------------|------------------|------------------|
| A | B | C | D |
| circle, triangle | circle, triangle | circle, triangle | circle, triangle |

17 Which figure is NOT identical to the figure below?

A B C D

18 Which one is different than the others?

| | |
|---|---|
| A | B |
| C | D |

21 Which of the following, when folded will give the cube below?

A B C D

22 Which cube will result if the following template was folded?

A B C D

19 Which of the following is a rotation for the following shape?

A B C D

20 If wheel A moves anticlockwise, how many wheels will also move anticlockwise other than A?

A. 2
 B. 3
 C. 4
 D. 5

23 Which shape will result if the following template was folded?

A B C D

24 What shape will result if the following template was folded on the dotted lines?

A B C D

Appendix 6 Observation Protocol

Observation Protocol

| | | | |
|-------------|--|----------------------------------|--|
| Observer | | Grade Level/Cluster | |
| Date & Time | | Number of Students (Male/Female) | |
| Location | | Lesson Title | |

| Teachers' Instructions | | | | | | | | | | | |
|--|--|------|-------|-------|-------|-------|-------|-------|-------|----------------------|--|
| <i>Limited to the time when the teacher is explaining a concept or giving instructions</i> | | | | | | | | | | | |
| Indicate the occurrences of each item/activity by X | | | | | | | | | | | |
| Item/Activity <i>(Two or more items/activities may happen concurrently)</i> | Time slots (minutes) | | | | | | | | | Evidences / Comments | |
| | 1-5 | 6-10 | 11-15 | 16-20 | 21-25 | 26-30 | 31-35 | 36-40 | 41-45 | | |
| 1 | Provision of concrete props | | | | | | | | | | |
| 2 | Provision of visual aids, such as models and/or time line | | | | | | | | | | |
| 3 | Use of familiar examples to facilitate learning more complex ideas, such as story problems in math | | | | | | | | | | |
| 4 | Allowance for opportunities to classify and group information with increasing complexity | | | | | | | | | | |
| 5 | Use of outlines and hierarchies to facilitate assimilating new information with previous knowledge | | | | | | | | | | |
| 6 | Present problems that require logical analytic thinking | | | | | | | | | | |

| Reasoning | | | | | | | | | | | |
|--|---|------|-------|-------|-------|-------|-------|-------|-------|----------------------|--|
| <i>The use of both deductive and inductive approaches about a topic</i> | | | | | | | | | | | |
| Indicate the occurrences of each item/activity by X | | | | | | | | | | | |
| Item/Activity <i>(Two or more items/activities may happen concurrently)</i> | Time slots (minutes) | | | | | | | | | Evidences / Comments | |
| | 1-5 | 6-10 | 11-15 | 16-20 | 21-25 | 26-30 | 31-35 | 36-40 | 41-45 | | |
| 1 | Ability to realize the characteristics, rules, and concepts when solving problems (Induction) | | | | | | | | | | |
| 2 | Ability to generate rules and follow guidance in a step-by-step approach to find a solution for a problem. (General Sequential Reasoning) | | | | | | | | | | |
| 3 | Ability to use mathematical relationships and properties for inductive and deductive reasoning. (Quantitative Reasoning) | | | | | | | | | | |

| Memory | | | | | | | | | | | |
|---|--|------|-------|-------|-------|-------|-------|-------|-------|----------------------|--|
| <i>The use of the memory to recall a topic and perform tasks based on the capacity of the short term memory</i> | | | | | | | | | | | |
| Indicate the occurrences of each item/activity by X | | | | | | | | | | | |
| Item/Activity <i>(Two or more items/activities may happen concurrently)</i> | Time slots (minutes) | | | | | | | | | Evidences / Comments | |
| | 1-5 | 6-10 | 11-15 | 16-20 | 21-25 | 26-30 | 31-35 | 36-40 | 41-45 | | |
| 1 | Ability to recall provisionally ordered elements after they are presented once to the subject. (Memory Span) | | | | | | | | | | |
| 2 | Ability to manage the capacity of the short term memory and perform different cognitive operations on a temporarily stored information. (Working Memory) | | | | | | | | | | |

| Sensory | | | | | | | | | | |
|---|--|----------------------|------|-------|-------|-------|-------|-------|-------|----------------------|
| The use of visual stimuli to solve problems | | | | | | | | | | |
| Indicate the occurrences of each item/activity by X | | | | | | | | | | |
| Item/Activity (Two or more items/activities may happen concurrently) | | Time slots (minutes) | | | | | | | | Evidences / Comments |
| | | 1-5 | 6-10 | 11-15 | 16-20 | 21-25 | 26-30 | 31-35 | 36-40 | |
| 1 | The ability to mentally simulate complex objects and patterns when they are rotated, changed in size, and partially hidden. (Visualization) | | | | | | | | | |
| 2 | The ability to simulate mental rotation of simple objects. (Speeded Rotation) | | | | | | | | | |
| 3 | Ability to formulate and identify a whole object when given its disconnected or partially hidden parts with no previous knowledge of the object. (Closure Speed) | | | | | | | | | |
| 4 | Ability to formulate and identify an object or a pattern within a complex visual array with previous knowledge of the pattern. (Flexibility of Closure) | | | | | | | | | |
| 5 | Ability to recognize and recall an image or a visual stimulus. (Visual Memory) | | | | | | | | | |
| 6 | Ability to scan a spatial visual field and then accurately identify a path or a pattern on it. (Spatial Scanning) | | | | | | | | | |
| 7 | Ability to identify a symbolic or visual pattern when parts of the pattern are presented in a continuous order. (Serial Perceptual Integration) | | | | | | | | | |

Appendix 7 Questionnaire

| | | Strongly Agree | Agree | Neutral | Disagree | Strongly Disagree |
|---|---|----------------|-------|---------|----------|-------------------|
| | Confidence | | | | | |
| 1 | I am sure I can learn programming | | | | | |
| 2 | I think at the end of the course, I will be able to solve complex programming problems | | | | | |
| 3 | Programming is the worst subject for me | | | | | |
| 4 | I can get excellent grades in this programming course | | | | | |
| 5 | I feel secure when solving problems using programming | | | | | |
| 6 | If given the choice, I will not take the advanced level of the programming course | | | | | |
| 7 | I plan to study programming or any other related discipline in the college | | | | | |
| | Attitude | | | | | |
| 1 | Mastering programming will help me excel in other subjects | | | | | |
| 2 | Being recognized as a smart programmer would make me feel happy | | | | | |
| 3 | I think being good in programming is not something to be proud of | | | | | |
| 4 | I feel proud when I solve programming questions | | | | | |
| 5 | I don't like people to know I am good in programming | | | | | |
| 6 | I wish I can participate in a programming competition and win | | | | | |
| 7 | Programming is my favorite subject | | | | | |
| | Usefulness | | | | | |
| 1 | I think programming is useful for me | | | | | |
| 2 | Learning programming will help me get a well-paid job in the future | | | | | |
| 3 | Learning programming is necessary to everyone these days | | | | | |
| 4 | I don't think everyone must learn programming | | | | | |
| 5 | Learning programming will help me solve daily problems | | | | | |
| 6 | It is important for me to learn programming before I go to college | | | | | |
| 7 | Programming is not related to any of the real-life problems | | | | | |
| | Motivation | | | | | |
| 1 | I enjoy studying programming | | | | | |
| 2 | I explore resources to learn programming other than the textbook | | | | | |
| 3 | If I have a programming problem, I insist to solve it even if it takes me long time | | | | | |
| 4 | I wonder how people may spend long hours to learn programming | | | | | |
| 5 | I usually solve programming problems at home even if they are not required for my class | | | | | |
| 6 | Programming lessons are usually boring | | | | | |
| 7 | I pay good efforts to understand programming | | | | | |

Appendix 8 Interview Protocol

Interview Protocol

Question 1: [Confidence] What would stand in your mind when you think about yourself as a student learning Java programming?

- Can you explain to me more about that?
- How can learning Java Programming makes you different than other students?
- Have you ever thought of dropping the Java Programming course?

Question 2: [Usefulness] How can you apply the computational thinking skills you learned in the Java Programming class on problems you face in your real-life?

- Can you give me example?
- How could your computational thinking skills help you in this case?
- What other strategies you may use to solve the problem if it is not solved using your computational thinking skills?

Question 3: [Attitude] How do you feel when you solve a complex programming problem correctly?

- How do you feel if your colleague asks you to help him/her solve a complex programming problem that you are able to solve?

Questions 4: [Motivation] What would you do if your teacher challenged you to solve a programming problem that none of your colleagues could solve it?

- Would you sacrifice a time out with your friend and stay home to study for Programming?

Consent Form – Students Interviews

Title: The Impact of Learning Computational Thinking through Computer Programming on High School Student Cognitive Skill Development

Principal Investigator: Heba Daraghmeh

Mobile Number: 00971 50 368 44 66

Your son/daughter is invited to participate in a research study that aims primarily to investigate the impact of learning Computer Programming on high school students' cognitive abilities development in the UAE.

If you agree, the researcher will interview your son/daughter with a group of students. The interview will be audio recorded for the purpose of this research only. Attached a copy of the interview questions. You should always remember that you can withdraw and stop participating in the study at any time you wish.

All data that will be collected in this study will be kept strictly confidential. Anonymity is guaranteed. Names and any identifying information will not be revealed.

There are no risks from participating in this study. The results of this study can be shared with you and the school management once the research is completed.

Agreement to participate in the research

I have read, the above and have the opportunity to ask questions which have been answered to my satisfaction. I agree voluntarily for my son/daughter to participate in the study as described.

Date: Parent/Caregiver: Signature:

Date: Researcher: Heba Daraghmeh Signature:

Appendix 10 BUiD Research Ethics Form



Research Ethics Form (Low Risk Research)

To be completed by the researcher and submitted to the Dean's nominated faculty representative on the Research Ethics Committee

i. Applicants/Researcher's information:

| | |
|-----------------------------|-------------------------------|
| Name of Researcher /student | Heba Abdel Rahman DaraghmeH |
| Contact telephone No. | 0503684466 |
| Email address | 2016152103@student.buid.ac.ae |
| Date | 19/3/2018 |

ii. Summary of Proposed Research:

| | |
|--|--|
| <p>BRIEF OUTLINE OF PROJECT (100-250 words; this may be attached separately. You may prefer to use the abstract from the original bid):</p> | <p>This research aims to fulfil the gap and to support the CS education research with evidences on the need to teach CT and programming and its impact on the students' cognitive skill development; this research aims primarily to investigate the impact of learning Computational Thinking (CT) through Computer Programming (CP) on the cognitive skill development of high school students by answering the following research questions:</p> <ol style="list-style-type: none"> 1. To what extent does learning Computational Thinking through Computer Programming impact student core cognitive skill development? 2. How do high school students reflect on their experience when learning Computational Thinking through Computer Programming? 3. What cognitive behaviours/classroom practices do students demonstrate when learning Computational Thinking through Computer Programming? |
|--|--|

| | |
|--|--|
| | <p>4. What is the relationship between students' cognitive styles and their cognitive skill development when they learn Computational Thinking through Computer Programming?</p> <p>5. How do demographic factors affect students' cognitive development when they are taught Computational Thinking through Computer Programming?</p> |
| <p>MAIN ETHICAL CONSIDERATION(S) OF THE PROJECT (e.g. working with vulnerable adults; children with disabilities; photographs of participants; material that could give offence etc...):</p> | <ul style="list-style-type: none"> - Conduct a pre-test and post-test - Observe Computer Programming classes - Survey students who will attend the Computer Programming lessons - Interview a sample of the students who will attend the Computer Programming lessons |
| <p>DURATION OF PROPOSED PROJECT (please provide dates as month/year):</p> | <p>Four months-September 2018-December 2018</p> |
| <p>Date you wish to start Data Collection:</p> | <p>September 2018</p> |
| <p>Date for issue of consent forms:</p> | <p>April 2018</p> |

iii. Declaration by the Researcher:

I have read the University's policies for Research and the information contained herein, to the best of my knowledge and belief, accurate.

I am satisfied that I have attempted to identify all risks related to the research that may arise in conducting this research and acknowledge my obligations as researcher and the rights of participants. I am satisfied that members of staff (including myself) working on the project have the appropriate qualifications, experience and facilities to conduct the research set out in the attached document and that I, as researcher take full responsibility for the ethical conduct of the research in accordance with subject-specific and University Research Policy (9.3 Policies and Procedures Manual), as well as any other condition laid down by the BUId Ethics Committee. I am fully aware of the timelines and content for participant's information and consent.

Print name: Heba Daraghmeh

Signature: 

Date: 19/3/2018

If the research is confirmed as not medium or high risk, it is endorsed HERE by the Faculty's Research Ethics Committee member (following discussion and clarification of any issues or concerns) John McKenny and forwarded to the Research Office to be recorded.*

I confirm that this project fits within the University's Research Policy (9.3 Policies and Procedures Manual) and I approve the proposal on behalf of BUiD's Research Ethics Committee.

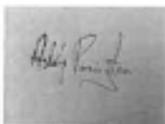
Name and signature of nominated Faculty Representative: JOHN MCKENNY

Signature: John McKenny Date: 4/4/18

- iv. If the Faculty's Research Ethics Committee member or the Vice Chancellor considers the research of medium or high risk, it is forwarded to the Research Ethics Officer to follow the higher-level procedures.

* *If the Faculty representative is the DoS, the form needs the approval of the Chair of the Research Ethics Committee.*

In addition to this application, I have read and am satisfied with the content of the draft research proposal and appendices, and the consent letter for access to school students.



1st April 2018.

Appendix 11 Letter from BUiD to Schools



4/8/2018

To whom it may concern

This is to certify that Ms. Heba Daraghmeh with Student ID number 2016152103 is a registered part-time student in the Doctor of Education offered by The British University in Dubai since September 2016.

Ms. Daraghmeh is currently collecting data for her research (The Impact of Learning Computational Thinking Through Computer Programming on High School Student Cognitive Skill Development).

She is required to gather data through conducting tests, class observation, survey, and interviews that will help her in writing the final research. Your permission to conduct her research in your organisation is hereby requested. Further support provided to her in this regard will be highly appreciated.

Any information given will be used solely for academic purposes.

This letter is issued on Ms. Daraghmeh's request.

Yours sincerely,

Dr. Amer Alaya
Head of Academic and Student Administration

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FB.com/BUiD.Team BUiD_Team youtube.com/BUiDAdmin @BUiD_Team BUiD

Appendix 12 Sample Teacher Signed Consent

Consent Form

Title: The Impact of Learning Computational Thinking through Computer Programming on High School Student Cognitive Skill Development

Principal Investigator: Heba Daraghmeb

Mobile Number: 00971 50 368 44 66

You are invited to participate in a research study that aims primarily to investigate the impact of learning Computational Thinking (CT) through Computer Programming (CP) on the cognitive skill development of high school students

If you volunteer to participate in this research study, the researcher will observe 8 of your "Java Programming" lessons over the next three months. The teacher's instructions as well as the students' cognitive activities will be observed and recorded. Attached a copy of the class observation form. Additionally, an interview will be conducted with you and the students at the end of the course to collect data about their reflections on their Java programming learning experience. You should always remember that you can withdraw and stop participating in the study at any time you wish.

All data that will be collected in this study will be kept strictly confidential. Anonymity is guaranteed. Names and any identifying information will not be revealed.

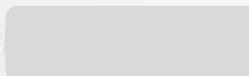
There are no risks from participating in this study. The results of this study will be shared with you and the school management once the research is completed.

Agreement to participate in the research

I have read, the above and have the opportunity to ask questions which have been answered to my satisfaction. I agree voluntarily to participate in the study as described.

Date:

Participant:



Signature:

Date:

Researcher: Heba Daraghmeb

Signature: