THE EFFECT OF VISUALIZATION TOOLS ON SECONDARY STUDENTS' PROBLEM SOLVING AND COMPUTATIONAL THINKING SKILLS

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ABSTRACT

Education has gone through numerous transformation over the years and with the 21st century learning becoming more prominent, improving students' problem solving and computational skills has become more crucial. This research is aiming to investigate the effect of various visualization tools on secondary school students' problem solving and computational skills. The effect of different visualization tools either, with or without technology, is very important in to enable students to improve their thinking abilities and be prepared to venture into the real world. This research uses qualitative design where 23 students from an international school in Johor Bahru were administered pre-test, post-test and computational thinking test. They were involved in a five weeks intervention process. The findings of the research shows that, there are strong relationship between visualization and students' problem solving. There is significant differences in students problem solving and computational thinking skills after being introduced with different visualization tools. Students have shown improvements in all the problem solving phases as well as all the computational thinking components. Therefore, this research has shown that visualization tools are able to improve students' problem solving and computational thinking skills and it should be implemented in the mathematics classroom.

ABSTRAK

Pendidikan telah melalui banyak transformasi selama bertahun-tahun dan dengan pembelajaran abad ke-21 menjadi lebih menonjol, meningkatkan penyelesaian masalah dan kemahiran komputasional pelajar menjadi lebih penting. Penyelidikan ini bertujuan untuk mengkaji kesan pelbagai alat visualisasi terhadap kemahiran menyelesaikan masalah dan komputasional pelajar sekolah menengah. Kesan alat visualisasi yang berbeza sama ada dengan atau tanpa teknologi sangat penting untuk membolehkan pelajar meningkatkan kemampuan berfikir dan bersedia untuk menceburkan diri dalam dunia sebenar. Penyelidikan ini menggunakan reka bentuk kualitatif di mana 23 pelajar dari sebuah sekolah antarabangsa di Johor Bahru diberi ujian pra, ujian pos dan ujian pemikiran komputasional. Mereka terlibat dalam proses intervensi selama lima minggu. Hasil kajian menunjukkan bahawa terdapat hubungan yang kuat antara visualisasi dan penyelesaian masalah pelajar. Terdapat perbezaan yang signifikan dalam kemahiran penyelesaian masalah pelajar dan kemahiran komputasional setelah diperkenalkan dengan alat visualisasi yang berbeza. Pelajar telah menunjukkan peningkatan dalam semua fasa penyelesaian masalah dan juga semua komponen pemikiran komputasi. Oleh itu, penyelidikan telah menunjukkan bahawa alat visualisasi dapat meningkatkan kemahiran menyelesaikan masalah dan berfikir secara komputasional pelajar dan ia harus dilaksanakan di kelas matematik.

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LIST OF ABBREVIATIONS

PS	-	problem solving
PSS	-	problem solving skills
CT	-	computational thinking
GSP	-	Geometer's Sketchpad
CS	-	computer science
ISTE	-	International Society for Technology in Education
CSTA	-	Computer Science Teachers Association
TIMSS	-	Trends in International Mathematics and Science Study
PISA	-	Programme for International Student Assessment
NCTM	-	National Council of Teachers of Mathematics
CAS	-	Computer Algebra System
DGE	-	Dynamic Geometry Environments
MOE	-	Ministry of Education
PIPP	-	Pelan Induk Pembangunan Pendidikan
CPA	-	concrete-pictorial-abstract

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CHAPTER 1

INTRODUCTION

1.1 Introduction

Education has gone through transformations over the years in terms of curriculum, learning objectives, teaching methods and classroom environment. The curriculum has changed its focus from textbook content-based problem solving (PS) to real world PS. On the other hand, teaching and learning have shifted from teachers-centred where teacher is the predominant knowledge disseminator to student-centred environment where students are involved directly in their own learning and are given more freedom to explore. These changes are aligned with the new vision of education, which is to nurture students with higher order thinking skills, able to venture into the real world and be someone who is analytical, critical and efficient problem solver (Ministry of Education, 2017). In order to achieve these goals, teachers need more than just basic knowledge to produce students who are independent and efficient thinkers. Teachers need to train students to be responsible for their own learning, be a thinker, risk taker, inquirer etc. Teachers on the other hand, need to upgrade themselves with up-to-date knowledge and teaching methods while incorporating different technologies in their classroom to achieve the 21st century education vision.

One of the cornerstones and most desired forms of high order thinking is the skill of problem solving (PS). Problem solving skills (PSS) are considered to be one of the crucial parts in mathematics and it has been a major obstacle for students in performing well in the subject. PS is a dynamic process that involves repetitive problem posing and interpretation with the end goal in mind (Lee & Hollebrands, 2006). PS demands higher order thinking skills, thus it is ranked as the highest skill in Bloom's taxonomy (DeWitt, Alias & Siraj, 2016). PSS is essential as it helps students to reason logically and make connections with their daily lives; however, this skill is also the main reason for anxiety among students. Basic PS process usually follows the popular Polya's Model that outlines four steps: 1) understanding the problem, 2) making a plan, 3) executing the plan and 4) looking back at the solution and the processes. Polya's Model is not a linear model. Instead, students are expected to go back and forth between steps if they are unable to find the solution and they should be able to try different strategies or approaches to find the final answer.

Mathematics education is vital in life as it fosters students' thinking to be creative, analytical and critical. As a result, computational thinking (CT) has become a research interest in recent years, as there is still very little research done on CT that focuses specifically on education. The importance of CT can be witnessed when the Programme for International Student Assessment (PISA) recently released their assessment framework, which has placed CT as one of the assessment components (Zahid, 2020). CT is not a new concept but rather it has been around since the nineteenth century, present mostly in science quantitative analysis and later on, it focused more on arithmetic teaching (Child, 2015). During the early years, Computer Science and CT had been used specifically to talk about one's knowledge and fluency in handling computer devices. However, this concept was later modified by Seymour Papert in relation to education and later further described by Jeanette Wing as a skill that is fundamental to everyone beyond the computer scientist. They brought about the idea where CT is not only about mastering the tools or knowledge related to computer science but instead it should be a basic requirement to organise thinking in PS.

CT skills enable students to train their thoughts to work in a systematic process where they are then able to extract information, decompose them into manageable parts and then use their applying and reasoning skills to find the best solution that fits the given situations. In 2014, some countries like Denmark, UK, and Spain and others have made coding compulsory in their basic education. Recently, the computer science (CS) community in education has been considering CS to be part of the school curriculum, thus putting it at the same level as other science subjects. CS related skills such as CT should be developed at younger ages, as early as primary school. Weintrop et al. (2016) claims that the incorporation of CT into mathematics learning can deepen students' understanding, give more realistic views of real world situations outside and prepare them to be ready to venture into the future.

There are different types of PS which ranges from simple to complex, which can include either single or multiple steps. When a problem involves lengthy words with plenty of information and requires multiple steps,students who encounter such problems often face issues. Visualization plays an important role as it helps students to understand different mathematics concepts and their relationship more effectively (Ferdianto & Hartina, 2020). In order to understand the problems better, students need to build suitable representations that help them narrow down the keywords and relevant information to ensure an effective PS process (Krawec, 2014). Students have the tendencies to attempt to use all the information stated in problems and they usually have difficulties in identifying and separating the crucial and non-crucial information. Múñez et al. (2013) in their study found that visualizations help students to build a more concrete mental model of the given problem therefore increasing their abilities to solve the problems at hand. The effect is more prominent in higher levelled problems. Yung and Paas (2015) found that visualization increases the students' performance while reducing their cognitive load as visualization helps students to focus on the important information while building relationships between concepts. Visualization is extremely crucial especially in problems that involve abstract concepts. There are different types of visualization either on paper such as graphs, schematic diagrams, pictorial models etc. or those using technology such as GeoGebra, Geometer's Sketchpad (GSC) etc.

In the fast-paced 21st century, technology has become omnipresent, from alarms used for waking up in the morning to the operation of complex machineries. The use of technology has become a way of life. The evolution of technology can also be observed in the education field through the emergence of tools that simplify and aid the learning process such as cameras, recorders and the Internet. However, technology is not only limited to the simplification of the learning process and improvement of communication. Technology in education has become the game-changer in classroom management and most importantly, the dynamics of the teaching process (Setyaningrum, 2016). The emergence of technology has been the main pushing factor in the transformation of teaching methods and students' learning. New generations of students are more attracted to visual, interactive and collaborative learning compared to pen and pencil tasks that are performed at their desks. As such, their attention spans have shortened with the consistent usage of technology. It is therefore vital that this issue be addressed to improve the new generation students' learning in the classroom. One such method is to incorporate technology into the learning process. Kessler (2010) proposed eight different ways that technology is able to improve students' learning: global learning, storytelling and multimedia, probes and sensors, better simulations and models, epistemic games, e-books, efficient assessments and virtual manipulative. Teachers have to try incorporating such tools and methods into their classrooms as it will add variation to lessons, thus improving students' engagement. This will result in an increase of students' understanding and thus cultivating their students' higher order thinking. Incorporating technology in the mathematics classrooms has been the centre of recent discussion and research in order to encourage the development of PSS. With the surge of technology, CT has become crucial in every field, including mathematics education. CT is an essential skill to students in order to increase their PSS with the use of mathematical software available.

1.2 Background of Study

Mathematics curriculum is still considered as a tough subject and students usually do not have a good relationship with the subject. A study on US education achievements has concluded that by grade 8, only six percent of students were able to reach an advanced level of mathematics, even though they are from the privileged group whose parents have gone through college education (Hanushek et al., 2010). There are two contributing factors to the difficulties in PS: internal and external. Internal factors are those from within the students themselves, such as their preconceived perception of mathematics and the weak foundation in mathematics' concepts and procedures (Tambychika & Meerah, 2010). Research found that students struggle to recall the important facts and struggle to perform procedures in systematic ways (Wahyuni & Dahlan, 2020). Mathematics classroom practices is one of the external factors that affect students' ability in PS. The methods being implemented in PS and the way lessons are being delivered are some issues that need to be looked into, as they are the main factors that affect students' PSS and interests in the subject. Currently, the traditional chalk and talk are still prevalent in many classrooms around the world and teachers still act as the main source of knowledge that imparts all information to students.

Other external factors are non-active learning, textbooks' problems that are not in context with real life situations and absence of variation in teaching and learning strategies. Teachers tend to emphasise heavily on rote learning and memorization without imparting understanding of the concepts involved. This type of teaching is no longer suitable in the 21st century classroom as it diminishes students' ability to think critically. Students are only able to solve problems given in their books but fail to connect skills learnt into real life problems. They do not understand the underlying principles of the concepts they learnt. Problems in the textbook are less contextualised and often not applicable to our daily lives. Students are unable to relate the usage with their daily lives which reduces their ability to reason and make decisions based on given information. Out of context problems makes students feel that the subject is irrelevant to learn. Over time, they lose interest in the subject and feel demotivated in learning, as there is no chance for exploration or active learning.

Malaysian mathematics teachers generally still practice a conventional teaching style that heavily emphasises procedural methods, fact-memorisation and basic computational skills (Singh, 2003). In PS, students practice rote learning to master the methods and procedures. Teaching is mainly tailored to exam needs rather than focusing on students' higher order thinking skills. Teachers are constantly trying to finish the syllabus fast, so that they will have enough time to do more practices to prepare students for the exam. Classrooms are highly teacher-centred with minimal involvement from students where knowledge transmission is the main teaching model. Behavioural learning approaches are prevalent in the Malaysian mathematics classroom. Teaching usually revolves around introducing surface concepts, which then lead to learning specific PS procedures, which are enhanced by repetitive practices. The effects of this can be seen in the results of both PISA and TIMSS where Malaysia has been performing below the international average. There are a few factors that cause these issues, for example, time constraint, pressure to perform well in the examination and teachers' lack of experience in teaching higher order thinking. Teachers have no freedom to explore different learning strategies as they have limited time to complete the extensive syllabus while being pressured by the exam demands. Furthermore, many teachers do not have the necessary knowledge and experience to teach higher order thinking problems due to limited experience and professional development opportunities.

Malaysian students have been performing below average in TIMSS and PISA compared to other countries. Compared to other Asian countries, Malaysia has experienced a significant dropped in the TIMSS results since our first participation in 1999. Other countries like Singapore, Japan and Korea can be seen as progressing yearly, have more stable achievement and were able to maintain their standards throughout the years. From TIMSS report 2015, it can be observed that Malaysian Mathematics achievements have dropped significantly from 1999 to 2011 and increases towards 2015. The summary is shown in Figure1.1. In terms of content domain, Malaysian students score below average in both geometry and data and chances. Our students scored below average in both applying and reasoning domains. According to the same report, Malaysian students' score was 465, which puts our students in the zone of only "having knowledge of the whole number and basic graphs". Our students are not able to apply their understanding or reason in different problem situations and unable to either solve linear equations or make generalisations. Malaysia's students scored only 463 in the applying domain and 453 in the reasoning domain while Singapore scored 619 and 616 respectively.

There exists a very big gap in standards when compared to our neighbouring country. Only 3% of our students are in the advanced benchmark where students have the capacity to apply concepts, make reasoning and generalisation while Singapore has 54% of students who are able to do so. This shows that our students are significantly lacking in terms of their higher order thinking skills especially in the ability to apply concepts, reasoning with given information and making decisions and generalisation. Applying and reasoning are crucial skills required in PS and these statistics show us that our students are lacking in their PSS. They are unable to break down problems into manageable parts that will enable them to decide the concept that is involved and make decisions on the best solution and this is where CT skill is deemed necessary.

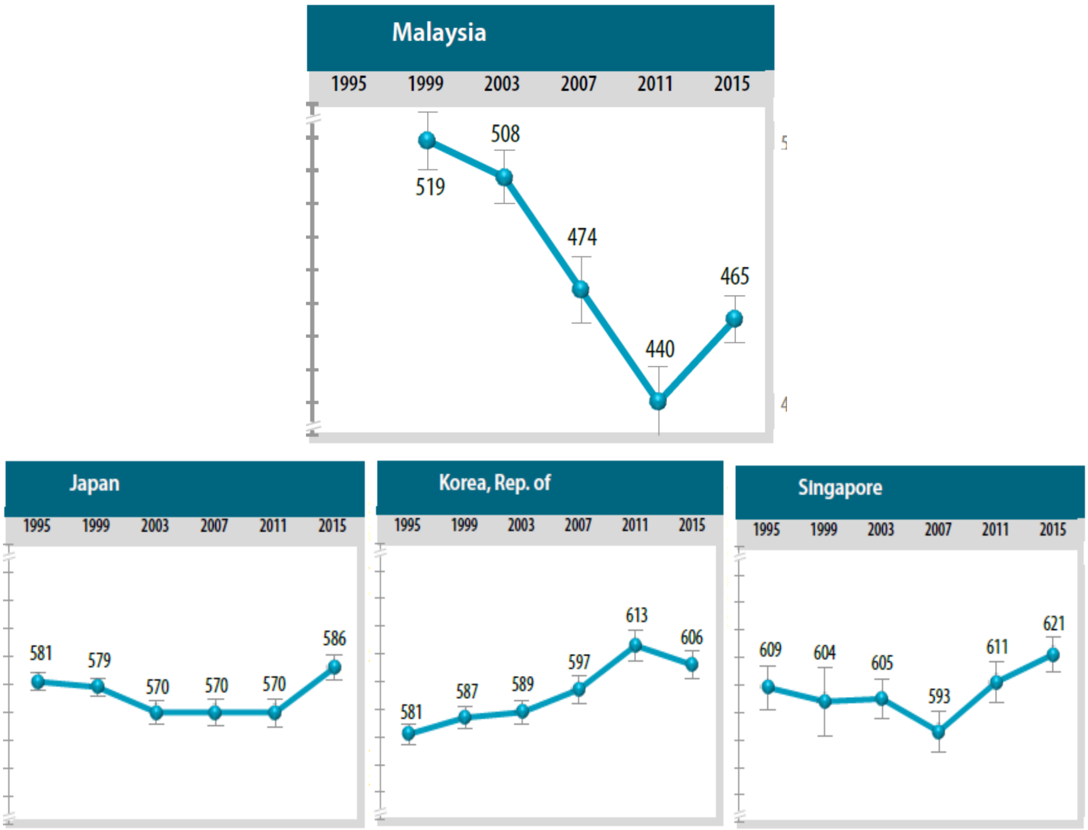

Figure 1.1 Malaysia and neighbouring countries achievements in TIMSS

In mathematics, the ability to visualise in topics like geometry, volume and functions is extremely important as these topics involve abstract thinking and reasoning skills. The ability to visualise is even more crucial in word PS as the problems usually contain extensive amounts of information that often confuses students. However, due to the extensive exposure with social media, animation, various media and easy accessibility to the internet, the new generation's students are more inclined to this particular type of visualisation compared to a 2D paper visual representation (Majerek,2014). When lessons are not presented in interactive ways, students seem to be easily discouraged and lose interest in the subject, which later affects their overall performance. Majerek (2014) outlined three major challenges in mathematical teaching: 1) learning concepts with no suitable visualisation, 2) the static nature of graphs or visuals and 3) inability to generalise using static objects. Thus, the ability to break down problems using tools that are supported by visual representation is very important in providing students with deeper understanding of a concept.

TIMSS 2003		
Rank	Country	Score
1	Singapore	605
2	Korea	589
3	Hong Kong	586
4	Chinese Taipei	585
5	Japan	570
	- -	
10	Malaysia	508
	- - -	
26	Romania	475
International Average		
27	Norway	461

TIMSS 2007		
Rank	Country	Score
1	Chinese Taipei	598
2	Korea	597
3	Singapore	593
4	Hong Kong	572
5	Japan	570
	- - -	
20	Malaysia	474
	- -	
27	Bosnia	456
International Average		
28	Lebanon	449
29	Thailand	441

TIMSS 2011		
Rank	Country	Score
1	Korea	613
2	Singapore	611
3	Chinese Taipei	609
4	Hong Kong	586
5	Japan	570
	- - -	
20	Norway	475
International Average		
21	Armenia	467
	- -	
26	Malaysia	440
27	Thailand	427

TIMSS 2015		
Rank	Country	Score
1	Singapore	621
2	Korea	606
3	Chinese Taipei	599
4	Hong Kong	594
5	Japan	586
	- -	
18	Sweden	501
International Average		
19	Italy	494
	-	
22	Malaysia	465

Figure 1.2 Malaysian TIMSS scores from 2003 - 2015

The National Council of Teachers of Mathematics (NCTM) has outlined six principles in mathematics teaching in school and one of them is technology. Technology has become an important tool in mathematics teaching, especially with topics that involve abstract concepts. The use of technology helps students explore deeper into a problem presented to them, increase their ability to break down complex information and form understanding the process of inquiring, visualising, PS and reflection (Barak et al., 2011). The use of technology also enhances students' collaboration skills and more importantly, it improves their critical thinking and reasoning skills. Technology also transforms the learning process into student-centred thus reducing students' reliance on the teachers and encouraging them into taking more responsibility over their own learning. As students take more responsibilities over their learning, they will have more freedom which allows them to explore different concepts and solutions in creative ways. This will foster students' motivation that will lead to increasing confidence in dealing with mathematical PS. The increasing confidence will reduce students' anxiety towards mathematics and develop their higher order thinking further.

Regardless of the type of visualization teachers choose, with or without technology, they will definitely ease students into the process of abstraction and decomposition of problems that improves conceptual understanding and lead to better PSS. There are various forms of software available in the market now and the two main categories are Computer Algebra System (CAS) or Dynamic Geometry Environments (DGE). One of the most popular examples would be GeoGebra, which has become one of the softwares that is widely used in education, as it is a free, open source software. GeoGebra combines both CAS and DGE in one package and can be used for different topics. GeoGebra allows students to generate graphic visualization while changing different parameters thus allowing students to observe how each parameter affects different functions. It also helps students to visualize complex graphical representation in 3D with simple click options. All these promote students' conceptual understanding thus improving their motivation in mathematical PS.

The Malaysian Ministry of Education (MOE) has also been putting emphasis on the importance of integrating technology into the classroom. Under the Pelan Induk

Pembangunan Pendidikan (PIPP) 2006 – 2010, MOE has introduced several programmes such as computer literacy classes, smart school, providing schools with different infrastructure such as internet connection, laptops, LCDs to support the use of technology and even teachers' training in technological use (Andin & Ali, 2010). In 2004, MOE made a drastic choice by subscribing to the GSC in order to improve student's abstract PS skill. GC is used mainly in algebraic function, where it helps teachers to produce sketches that are not static and distorted but more dynamic (Teoh & Fong, 2005). The process of drawing graphs is usually tedious and time consuming thus the usage of GC can significantly reduce time use in drawing, so students will be able to put more time in understanding and solving the problem instead. Technology can change the dynamic of a classroom from chalk and talk to an interactive environment by allowing students to engage in activities that involve investigation and experimentation, which will train them not to only solve questions, but simultaneously cultivate their abilities to pose questions (Setyaningrum et al., 2018). Different software has been made available for mathematical learning focusing on visualisation such as GSC, Cabri Geometry, Scratch and GeoGebra etc. These software help in terms of visualising the abstract nature of certain topics and linking between geometry and algebra. They allow students to visualize different perspectives and observe the connections between different properties and parameters by doing modelling or simulations.

GeoGebra is currently one of the most widely used mathematical dynamic software in the classroom as it is open source and it also has a virtual community that offers support in terms of lesson ideas and materials. GeoGebra is commonly used to teach algebra, calculus, functions and geometry, however, there are other topics that can be integrated in the software and it enhances learning through multiple representations. Findings from researcher such as Moeller, Reitzes and Velichova, show that integration of GeoGebra in the mathematics lesson improves students' satisfaction, provides interactive learning and equips students with essential skills for the future workforce (Wassie & Zergaw, 2018). Mathematics representation includes both mathematical reasoning products such as algebraic expression, graphs and diagrams and cognitive processes. Multiple representations are very important in mathematical PS as recent studies have shown an increasing emphasis on students' ability to use it. Nevertheless, in order to prepare effective mathematics instructions, multiple representations should be accompanied by students' ability to view complex problems holistically. Mathematics learning has to be planned with increasing scaffold complexity along with progression from concrete to abstract representations and manipulations. Even though using GeoGebra in teaching is beneficial, there are still challenges in integrating it into the curriculum and lessons.

Lack of resources such as computers still poses one of the major problems in integrating technology in the classroom. Teachers' limited pedagogical knowledge in using software and fluency are also the obstacles for a successful technological integration. By only having the software does not guarantee successful lessons, as teachers need to be able to produce comprehensive lesson plans and materials that can ensure a smooth integration of the technology. Although efforts have been made to integrate technologies in different areas of education, students have not shown tremendous improvements in their mathematics performance. This is largely contributed by the factor that technology has not been accommodated into the curriculum but rather only assimilated. Some teachers only use technology to produce electronic worksheets in place of paper, while classes are still being conducted in the traditional method. The learning environment stays the same with no changes towards active learning, which provides students with opportunities to explore (Olive et al., 2009).

Even though the incorporation of technology is very crucial, nonetheless, we cannot deny that visualization method on paper is still a crucial skill to nurture in students, as technology may not be accessible at certain times, such as during the exam period. Furthermore, not all the problems can be depicted through software. One of the simplest ways to integrate visualization with low cost is the Bar Model method. The Bar Model is one of the mathematics visualization strategies introduced by Singapore's education system. The Bar Model acts as a tool to solve problems as it helps students to visualize the relationship of all the information present in the problem using a schematic diagram. There are two types of models: the part whole model and comparison model. Comparison models can be divided further into different types, such as the before and after model, depending on the processes that are involved in the problem presented. Bar Models help students to visualize the information presented in the problems based on their own understanding and this is a strategy that is in line with the constructivism theory whereby students need to construct their own knowledge. This method also fosters students' creative and critical thinking as it involves drawing and trains students to think in systematic ways (Osman et al, 2018).

1.3 Problem Statement

From different data related to Malaysian students' achievements, it can be said that our students are lacking in terms of their PSS and higher order thinking abilities. Many students struggle to perform effective PS due to different factors and by integrating appropriate visualization tools, it will improve students conceptual understanding thus improving their PSS. This is in line with the MOE initiatives to produce students with higher order thinking skills who are better prepared to venture into the high-tech future as a competent workforce. On the other hand, CT is a another important skill that is required for the new generation of students. CT will not only enhance students' understanding of mathematics concepts but also increase students' engagement in class and increase their interest in learning different subjects. It will also increase students' ability to engage in higher order thinking tasks, thus improving their ability to solve real life problems.

Both Bar Model and GeoGebra are great visualization tools to explore as they are easily accessible and do not incur any cost. Bar Model and GeoGebra enhance students' ability to visualise abstract concepts and simultaneously train their CT skills. There is some research in Malaysian context on the effects of the Bar Model and GeoGebra on students' mathematics skills. However, there has not been much research on the effectiveness of the Bar Model and GeoGebra in students' PSS, especially in terms of CT skills. Therefore, the researcher will like to incorporate both the Bar Model and GeoGebra as visualization tools for mathematics lessons in order to see the effect of these tools on secondary students' PSS and CT skills. The researcher will also like to expose teachers to the usage of different visualization tools in the hope that it will give teachers confidence in implementing them in their teaching process.

1.4 Research Objectives

The objectives of the study are to investigate

i. The relationship between CT and PSS in visualization learning environment

ii. The effect of visualization tools integration on secondary school students' problem solving (PS) phases.

iii. The effect of visualization tools integration on secondary school students' overall Problem Solving skills (PSS).

iv. The effect of visualization tools integration on secondary school students' computational thinking (CT) skills.

1.5 Research Questions

Based on the research objectives that have been identified, following research questions have been generated:

RQ 1: Does visualization effect students' overall PSS skills?

RQ 2: What is the effect of visualization on each of the PS phases?

RQ 3: Are there any significant differences in the students' PSS before and after the interventions?

RQ 4: What is the CT skill level in the samples after the intervention?

1.6 Conceptual Framework

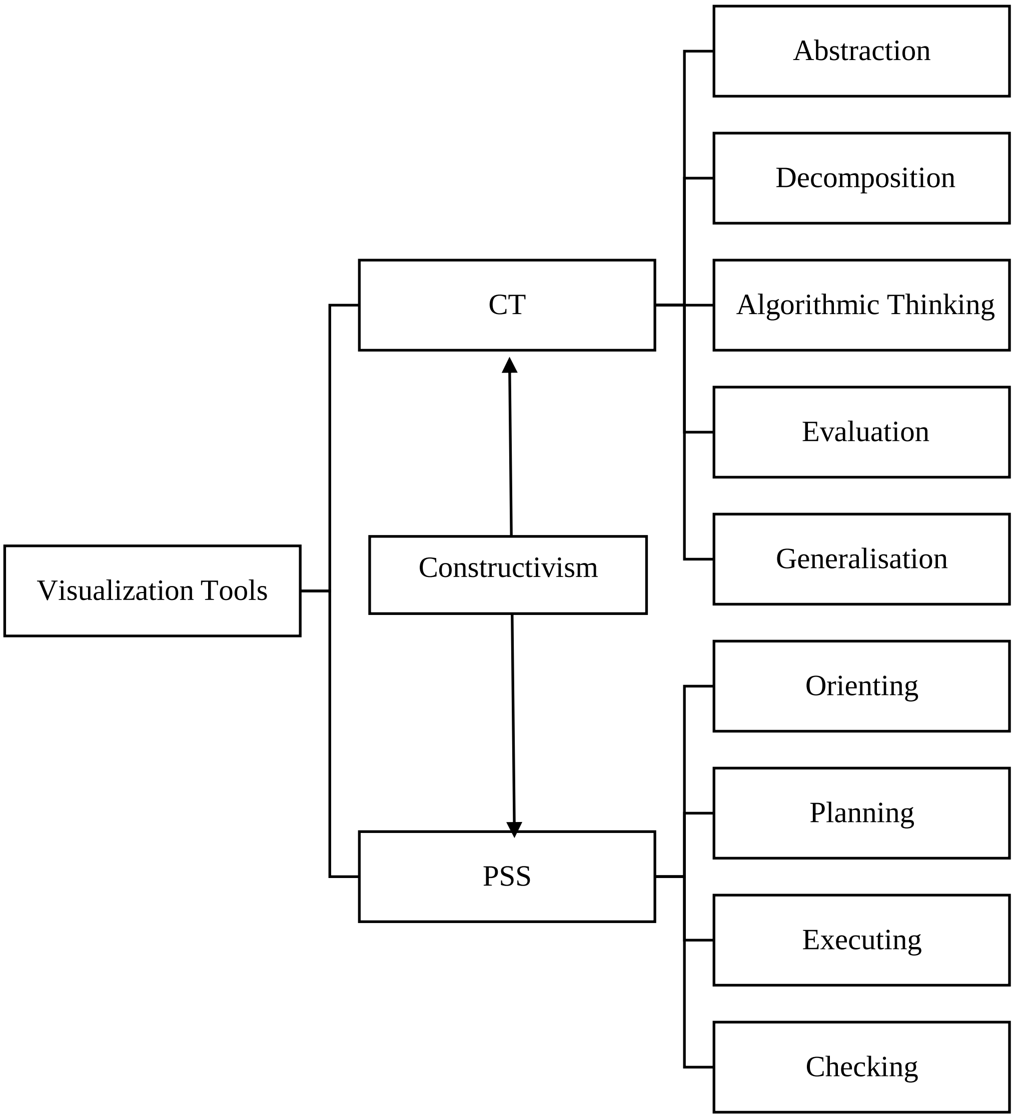

Figure 1.3 Conceptual Framework

Figure 3 illustrates the conceptual framework of this research study. This research applies constructivism theory as this theory emphasizes the need for students to construct their own knowledge through exploration and experience instead of becoming a passive receiver of knowledge. In constructivism, engaging actively during the learning process that is relevant to the students themselves will increase curiosity and improve critical thinking skills. Teachers are supposed to act as a facilitator who poses relevant problems to incite students' curiosity, provide suitable tools and give students the opportunity to explore. Seymour Papert introduced the theory of constructivism where he made an extension to Piaget constructivism theory but focused on children constructing meaning during the interaction of experience and ideas. Papert believes that learning occurs only when students are engaged in constructing a public entity. This theory emphasises the technology fluency of students and learning through collaborative environments. Papert put focus on how individual learners form ideas in their own way using different mediums that they prefer. He emphasises that the ability of learners to express their ideas is the key to learning where the learner is able to make an idea tangible and share it with others. His idea talks about self-directed learning where the learner is able to externalise their ideas and develop their thoughts using other objects, media or tools.

In mathematical PS, this research uses Carlson & Bloom's Multidimensional Problem Solving Model (MPS). The four phases outlined by them are the orienting phase, planning phase, executing phase and checking phase. Even though understanding a problem seems very basic, this is the main obstacle for students as they often fail to understand a problem, thus leading to their inability to solve the problem (Melvin, 2007). According to Melvin (2007), students need to have different strategies at hand in order to devise a plan and constant practice in PS will make the process of choosing suitable strategies easier. Carrying out the devised plan is usually the easier part followed by looking back, which involves reflection but this step is often neglected by students. Students always stop the moment they find a solution and find it a waste of time to do a reflection but Polya stated that reflection would help students in terms of choosing appropriate strategy when faced with a problem in the future. Pretz et al. (2003) described the PS processes in seven stages: problem identification, problem definition and mental representation, strategy development, organizing knowledge related to the problem, resources allocation, progress monitoring towards goal and the solution accuracy evaluation. They describe the processes as a descriptive cycle and do not need to be performed in order, as they believe that being flexible is one of the criteria for a successful problem solver.

In this research, different visualization tools will be used to push students to think more systematically, therefore, directly improving their PSS and CT skills. In order to make a visual representation, students need to be able to extract crucial information from the problems given and break that information into smaller parts so that they can use them to make a step-by-step plan that can be used to generate suitable visuals. These processes comprise the first three components of CT skills. Lastly, students need to use their prior knowledge to make an evaluation and generalisation on their choices and answers obtained. When students use the CT skill steps, they will automatically work in a more systematic way and those processes will indirectly push students to follow the PS model.

1.7 Importance of Research

This research will be useful to those who are involved in the planning of Malaysian education system, such as the MOE and those who are involved in the execution, such as teachers and most importantly the students.

1.7.1 Ministry of Education

In light of this research, the researcher hopes that the MOE will see the importance of nurturing CT among students. In TIMSS 2015 report, only 3% of our students are in the advanced benchmark compared to Singapore (53%), Korean (43%) and Japan (34%). Students in this phase are able to apply their knowledge and reason in various situations, solve equations and are able to generalise. Students are able to solve problems related to fraction, percentage, geometric figures and justify their conclusions. Only 18% of our students are in the high benchmark, which refers to their ability to apply knowledge and understanding in various relatively complex situations. Unfortunately, 76% of our students are in the low benchmark category. This shows that our students are only capable of doing basic math concept problems and are still lacking in higher order thinking from applying phase to creating phase. The researcher would like to show that CT skills can be the key to improving our students' PS abilities. CT skills will train students' ability to break down and find the 'best fit' solution for a problem. Visualization tools such as GeoGebra and Bar Model can be used as tools to support this process and enhance students' deeper thinking of concepts and knowledge learnt. Through the research finding, it is hoped that MOE will see the importance of introducing these tools in schools. However, in order to introduce methods related to these tools to schools, MOE will still need to provide teachers with the necessary training and infrastructure.

1.7.2 Teacher Training Institute

The teaching in Malaysia's classroom is still very traditional and teacher centred, thus in order to improve this situation, changes should begin with the teachers' training institute. The modules in the institutes should be transformed and altered, based on the 21st century demands. Pre-service teachers need to be introduced to different PS strategies that encourage higher order thinking skills. They should be exposed to more advanced, modern PS strategies and taught how to implement them effectively in an actual classroom. These pre-service teachers need to be trained in order to have the capacity to create lessons that promote higher order thinking. They need to be trained in how to assess students' PSS in alternative ways instead of using exams. Through this research, the researcher would like to show the importance of computational skill and its relationship with the PSS. Pre-service teachers should be taught and trained on CT-related skills and strategies to ensure successful implementation. They need to familiarize themselves with the skills and be competent in them before implementing it in their classroom. Courses related to relevant technology usage such as GeoGebra, GSC etc. should also be introduced so that teachers will be competent in teaching and implementing technology in their classroom. Technological training for in-service teachers should also be created and introduced. The findings from this research will show the importance of PS, CT and technology in the mathematics education. The researcher hopes that the findings can be used to modify courses currently available in order to equip future teachers with the knowledge to execute lessons that will foster students' CT and PSS.

1.7.3 Mathematics Teacher

The research findings will help teachers to realize the importance of practicing CT in Mathematics classroom. They will also be able to see how CT skills will help students to be efficient problem solvers thus improving their analytical and critical thinking skills. This will lead to better reasoning skills that will increase their overall higher order thinking skills. This research will also help teachers to evaluate the benefits of using different visualization tools in their lessons and give them a variety of options to implement in their lessons. The researcher hopes that Mathematics teachers will be motivated to integrate visualization tools both plugged and unplugged in their lessons. Teachers should be open to changes and be prepared to transform their teaching and students learning towards building a more challenging and interactive classroom that pushes students towards higher thinking ability.

1.7.4 Students

Students will greatly benefit from this study as this study opens up opportunities for students to have more freedom and variation in their learning. Students will have more chances to explore new ideas, build on their new knowledge and learn things differently than before. Students will be exposed to better working methods to improve their PSS and CT. Integration of visualization tools will increase students’ understanding on abstract concepts and directly affect their CT and PSS. Technology in classrooms will appeal more to the new generations of students as they are more attracted towards visually rich and interactive lessons. Through the implementation of visualization tools, students will be able to obtain a deeper understanding in their learning, which will result in students who are self-motivated and have high analytical and critical thinking.

1.8 Limitation of Research

This research sample is very small and limited to students from one school and one grade from the Johor Bahru area. The research also focuses only on secondary school students’ CT skills in PS; therefore, it does not portray the whole students’ population in Malaysia. The sample used in this study involves students from an international school, which means these students come from more privileged families, thus, they have a better financial background as well as a support system. The school also has more resources available in terms of technology and internet connectivity compared to standard public schools. In order to get results that are more comprehensive, larger number schools that comprise students from different areas and backgrounds.

1.9 Operational Definition

1.9.1 Computational Thinking (CT)

CT was commonly used in the computer science field where it refers to the knowledge of programming. However, Seymour Papert was the first to propose that CT is more than just computer literacy. He referred to CT as procedural thinking which a powerful tool is for children. Later, Jeanette Wing (2006) became the first person to relate CT with K-12 education where she believed that CT is a basic skill that is needed by everyone and not only for computer scientists. She first presented the concept using various examples from CS application but later created reference curricula for CS in basic education to reflect skills associated with CT. She described CT as:

> "*solving problems, designing systems and understanding human behaviour by drawing on the concepts fundamental to computer science*".
>
> (Wing, 2006)

She stated that CT involves unfamiliar ideas such as recursion, parallelization and binary search along with more common ideas like data representation, problem decomposition and modelling. CT is described as the process of using computational resources along with algorithmic strategies to solve problems by using a cognitive process that is related to abstraction and decomposition skill. There are different components stated by different researchers, Wing (2006) outlined four main components of CT as shown in the figure below. Decomposition is a process where a complex problem is broken down into smaller manageable parts and followed by finding the similarities or differences as a pattern recognition process. Once a pattern has been identified, an abstraction process will take place where the mind will create general principles and lastly followed by algorithm design where step-by-step instructions are created and executed (Google School, 2016). There are some similarities between CT components with Polya's model (Barcelos et al., 2018). Polya pointed out that to be successful in mathematical PS, abstraction and decomposition skills are crucial.

CT skills comprises of different components that vary depending on the researchers' preferences. Nevertheless, for the purpose of this study, the researcher chose the following five components: abstraction, decomposition, algorithmic thinking, evaluation and generalisation. Abstraction is the process of extracting important information from large data while decomposition involves the process of breaking those large chunks of information into smaller manageable parts. Algorithmic thinking is a thinking process where the problem solver develops systematic steps in solving the given problem. Evaluation is the process of making judgement by the problem solver. The solver engage in evaluation process by making judgement based on different factors such as information presented in the problem, prior knowledge and past experiences. The analysing and application processes can be done repetitively until the most accurate answer is obtained and this process can be done either mentally or with the help of technology. Lastly, the generalisation process is the highest level of thinking where one can produce a working procedure that will be applicable for any similar situations faced in the future. In the context of this research, the researcher refers to CT as specific skills that are needed by a problem solver to solve a given authentic problem in a systematic manner and to obtain the most accurate solutions with the help of appropriate visualization tools.

1.9.2 Problem Solving (PS)

PS is the main objective of Mathematics education as students are always given different problems to solve with increasing complexity. Different people have different perspectives of PS. For people in Mathematical fields, PS includes different tasks such as creating patterns, doing word problems, developing geometric construction, interpreting figures, etc. while for those who are not in the field PS can be any mathematics activity (Wilson & Fernandez, 1993). Reitman defined a problem as a given situation where nothing satisfies the description while Henderson and Pingry defined the problem as having a goal, blocks towards the goal and the acceptance of the goal by the solver. Schoenfeld (2013) states that problem definitions depend on the individual, what is the problem for one person might not be a problem for someone else. In the context of this study, the researcher defines PS as a process that involves multiple phases that sometimes needs to be repeated in a cycle until the most accurate answer is obtained. The working definition in this study is built based on the MPS framework proposed by Carlson and Bloom (2005). There are four main phases in the MPS framework namely orienting, planning, executing and checking where the last three phases are a cycle that can be repeated until the most satisfactory answer is obtained.

1.9.3 Bar Model

The Bar Model is a PS method introdyced in the Singapore education system in the 1980s a measure to improve students PSS in the country. The Bar Model is partly based on the Greeno's pictorial form and uses the *concrete-pictorial-abstract* (CPA) concept. The Bar Model is divided into two main types, which are the part-whole model and comparison model. These two models were originally created for addition and subtraction concepts and later further developed to include other operations and concepts such as multiplication, division, ratio, fraction etc. the part-whole model is made up of at least three variables consisting of two parts that make up a whole. Comparison models are similar to the part-whole where it has at least three variables; however instead of the whole, this model has differences and the sum can also be included. For multiplication and division the models will consist of few equal parts that will make up the whole and each part is called 1 unit (1 u).

1.9.4 GeoGebra

GeoGebra is a dynamic software that is applicable for the use of topics such as geometry, algebra, calculus and statistics. It can be used to model and simulate abstract mathematical concepts that involve representation and act as an interactive tool in Mathematics teaching. The software is suitable for mathematics teaching from primary to university level. This software aids the students in making representation for abstract concepts and enables them to observe the effect of parameters changes that occur. In this study, the researcher will use GeoGebra classic 6 as it is the latest version that is released in July 2020.

1.10 Conclusion

The researcher has defined aspects from the background of study, problem statements, research objectives, research questions, the importance of research, the conceptual framework, limitations of the research and lastly the operational definition of the study. All these elements are being described to give an overview of the research. Through the introduction, we can see the importance of CT and PSS especially in the context of Malaysia education. If we aim to produce students with strong reasoning and critical thinking, our students' ability in CT and PSS definitely needs to be upgraded. With the integration of technology, teachers will be able to enhance students' understanding and increase their participation and engagement in classrooms. Students will have more opportunities to explore ideas and construct their own knowledge by problem posing and PS. Students will have deeper understanding through their active participation in the learning process. Software like GeoGebra will enhance students' understanding by providing a richer and interactive visualization, thus increasing their interest in learning the subject. Students will be more motivated in their learning process. Technology integration will increase students' CT thus fostering higher order thinking in them.

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