EFFECTIVENESS OF FATHOM®-BASED INSTRUCTION IN ENHANCING STATISTICAL REASONING OF FORM FOUR STUDENTS

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ABSTRACT

The goal of Statistics Education is to improve statistical literacy and developing statistical reasoning skills in the classroom. Although learning of statistics begins from preschool to professional level, but many students are not proficient in statistical reasoning. This study aims at investigating the effectiveness of Fathom-based Instruction in Enhancing Statistical Reasoning among Form Four Students. To answer the four research questions of this study, a quasi-experimental non-equivalent pretest-posttest design was employed. One of the International schools in Selangor participated in this study two classes participated with one as the experimental group (N = 34) and the other as the control group (N = 38). The experimental group used the Fathom-based instruction on Statistical Reasoning Learning Environment (SRLE) guidelines, and the control group was taught using the traditional approach without Fathom software. An instrument called Statistical Reasoning Assessment was used to measure students' statistical reasoning ability across the four constructs in Statistical Reasoning namely, Describing Data, Organizing Data, Representing Data and Analyzing and Interpreting Data before and after treatments for the two groups. The result from the non-directional paired-samples t-test revealed the students' statistical reasoning ability in experimental groups improved significantly after the treatment. One-way ANCOVA results indicated that there was a significant difference in statistical reasoning ability between students in the two groups. In addition, the estimated marginal means of posttest score of the students used Fathom-based instruction performed better than students in control group. The paired-samples t-test showed there is a statistically significant mean difference for all the four constructs of Statistical Reasoning (Describing data Organizing Data, Representing Data and Analyzing and Interpreting Data) in experimental group after

the intervention. Also, the results of MANCOVA showed that there was a significant difference across four statistical reasoning constructs between students in control and experimental groups. Furthermore, the results of the analysis emphasized that the students learned statistical reasoning using Fathom-based instruction in the experimental group performed better than students in the control group. In brief, the form four students' statistical reasoning improved after the implementation of Fathom-based instruction. This study also suggested the need for using technology such as Fathom in mathematics classroom to improve students' statistical reasoning. Teachers can provide a variety of technology-based activities in the form of modules or instructional materials as guidance for the teachers.

KEBERKESANAN PENGAJARAN BERASASKAN FATHOM® UNTUK MENINGKATKAN PENAAKULAN STATISTIK PELAJAR TINGKATAN EMPAT

ABSTRAK

Matlamat Pendidikan Statistik adalah untuk memupuk statistik dan membangunkan kemahiran penaakulan statistik dalam bilik darjah. Walaupun pembelajaran statistik bermula dari peringkat prasekolah hingga tahap profesional tetapi masih ramai pelajar tidak menguasai penaakulan statistik. Kajian ini bertujuan untuk menyiasat Keberkesanan Pengajaran berdasarkan Fathom® untuk Meningkatkan Penaakulan Statistik pelajar Tingkatan Empat. Untuk menjawab empat soalan penyelidikan kajian ini, reka bentuk kuasi eksperimen dengan ujian pra dan pasca telah digunakan. Salah satu sekolah Antarabangsa di Selangor telah mengambil bahagian dalam kajian ini dengan dua kelas yang ditugaskan sebagai kumpulan eksperimen (N = 34) dan yang lain sebagai kumpulan kawalan (N = 38). Kumpulan eksperimen telah ditugaskan untuk menjalani rawatan dengan menggunakan pendekatan berasaskan Fathom berdasarkan garis panduan Pembelajaran Penaakulan Statistik (SRLE) manakala kumpulan kawalan diajar menggunakan pendekatan tradisional iaitu tanpa perisian Fathom. Instrumen yang dinamakan Penilaian Pengkajian Statistik digunakan untuk mengukur keupayaan penaakulan statistik pelajar melalui empat konstruk dalam Penaakulan Statistik iaitu, Deskripsi Data, Penyusunan Data, Mewakili dan Menganalisa Data dan Interpretasi Data sebelum dan selepas rawatan untuk kedua-dua kumpulan. Hasil daripada ujian-t sampel berpasangan satu hujung mendedahkan keupayaan penaakulan statistik pelajar dalam kumpulan eksperimen meningkat dengan cara signifikan selepas rawatan. Di samping itu, keputusan dari ANCOVA satu hala menunjukkan bahawa terdapat perbezaan yang signifikan dalam

keupayaan penaakulan statistik antara pelajar dalam kedua-dua kumpulan. Di samping itu, skor min ujian pos pelajar yang mempelajari penaakulan statistik menggunakan Fathom lebih baik daripada pelajar yang belajar tanpa perisian Fathom. Ujian-t sampel yang berpasangan menunjukkan terdapat peningkatan min yang signifikan secara statistik bagi kesemua empat konstruk Penaakulan Statistik (Menggambarkan Data, Penyusunan Data, Mewakili Data dan Menganalisis dan Interpretasi Data) dalam kumpulan eksperimen selepas mengimplementasi teknologi, Fathom. Selain itu, keputusan MANCOVA menunjukkan bahawa terdapat perbezaan yang signifikan di antara empat konstruk penaakulan statistik antara kumpulan kawalan dan eksperimen. Tambahan pula, hasil analisis menekankan bahawa pelajar belajar penaakulan statistik menggunakan Fathom dalam kumpulan eksperimen mencapai keputusan yang lebih baik daripada pelajar dalam kumpulan kawalan. Kesimpulannya, keupayaan penaakulan statistik pelajar meningkat selepas diajar berasaskan Fathom. Kajian ini juga mencadangkan keperluan untuk melaksanakan teknologi seperti Fathom dalam pengajaran dan pembelajaran untuk meningkatkan pemikiran statistik pelajar. Di samping itu, perancang kurikulum harus menyokong kaedah ini dengan memberikan pendedahan dan pengetahuan kepada para guru mengenai metodologi ini. Mereka boleh menyediakan pelbagai aktiviti berasaskan teknologi dalam bentuk modul atau bahan pengajaran sebagai panduan untuk para guru.

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CHAPTER 1

INTRODUCTION

1. 1 Background of Study

In everyday life, people tend to deal with data or observation in which statistics is used. For instance, when viewing record of weights or measurement of heights, weather forecasts or comparison between examination score obtained by different students, people mentally evaluate the various observations or measurements. Sometimes, there are phrases such as average students in a class; pass percentage in a given examination and the range of marks in a given subject. Many decisions in politics, economics, and society are based on data and statistics. To participate as a responsible citizen, we need a solid grounding in reasoning about data (Biehler, Frischemeier, Reading, & Shaughnessy, 2018).

A lot of information nowadays can be expressed in the form of accumulated data. These data are transformed into a variety of different graphical representations, for example bar graphs or histograms (Meletiou & Lee, 2002). Direct visualization of numerical data in production, pollution, alimony and so become a concern in today's society (Bruno & Espinel, 2009). Understanding statistical graphs with the ability to read and interpret graphs are part of learning to be had by every community. Math-related learning statistics focused on data distribution. Good understanding of data distribution in any graph requires mastery of basic concepts of statistical learning. Statistics is a subset or subcomponent of mathematics that specifically teaches us how to collect, organize the data, how to analyze the data and teaches us ways to interpret and to present the data analysis to others (Sorge & Schau, 2002). Statistics as a subject is also important for a future career because it can help to enhance one’s analytical skills, hence increasing one’s marketability.

Hall and Heyde (2014) pointed out that data analysis and interpretations done by statisticians can help to explain a complex business environment and measure the company performance for every quarter of the year. Companies keeping track of their business inventories, employee attendance and their productivity consistently are able to find solutions and improve their management decisions. Besides, the company can use statistical data to compete with other firms by analyzing and comparing data from competitors. Companies can gather information as statistics from customer feedback to improve their product or customer satisfaction and indirectly enhance their competitive advantage. Eventually, learning statistics is not based on computations only but reasoning and thinking skills are major components in describing, evaluating and analyzing a data set. This study helps student decision-making in future careers through learning statistical reasoning.

Statistical reasoning is the method people reason through quantifiable contemplations and understand factual data. Statistical reasoning could include associating one idea to another example mean and boxplot. Reasoning implies understanding and having the capacity to clarify factual procedures, and having the capacity to interpret measurable results (Garfield, 2002). Statistical seen as reasoning the mental representations and connections students have with statistical ideas. During the 1990's there were great demands for more noteworthy statistics education focusing on thinking and reasoning. One of the widespread disagreements developed was that traditional techniques for teaching statistics never lead students to reason statistically.

At the point when students utilize the information to make inferences, they are utilizing their thinking on the grounds that as indicated by Galotti (2008), thinking is the psychological procedures that change given data so as to achieve conclusions.

Students should figure out how to utilize their thinking when they make determinations from the information. Students have to figure out how to make conclusions by structuring the information graphically and to analyze the information. They will utilize the data implanted in these representations and synopses to make inferences about the information.

Even though statistics is one of the important topics taught at primary, secondary and tertiary levels in Malaysia and viewed from the perspective of the larger domain of mathematics education, statistical reasoning is not adequately covered in the Malaysian mathematics curriculum. It is a neglected area, especially compared to statistical literacy. Statistical reasoning should be included in the components of statistics curriculum to foster students' conceptual understanding of statistical concepts. Currently, the components in statistics topic focus on statistical literacy whereby students are required to determine the class intervals, mode, mean, median, construct and interpret the graphs which emphasize on computational skills. Statistical reasoning, in contrast, involves understanding concepts at a deeper level than literacy, such as understanding why the number of class groups decreases as the class width increases. Students should be able to understand, explain statistical processes and be able to interpret particular statistical results (e.g., describe the distribution of the graph in terms of its shape and center) (Garfield, 2002). These provide students opportunities to strengthen their understanding of the statistical method of inquiry and simulations. Statistical reasoning means that students are able to:- formulate statistical questions to be answered using data; design and implement a plan to collect the appropriate data; select suitable graphical and numerical methods for data analysis; and interpret their results to make connections with the initial questions (Accrombessy, 2006). Hence the Malaysia Mathematics curriculum should focus on engaging students with greater emphasis on reasoning, representations, connection and communication. This study aims at bridging these gaps by focusing on statistical reasoning about descriptive statistics.

The study of statistical reasoning provides students with ideas to respond logically to quantitative information around them. Reflecting this need to improve students' ability to think statistically, statistical reasoning is becoming part of the mathematics curriculum (Garfield & Ben-Zvi, 2008). As noted by Ridgway, Nicholson, and McCusker (2008), the need for citizens to be statistically literate is greater now because there is an increased globalization of communication about evidence. Besides that, in today's world, statistics is globally accepted as an analysis tool in various aspects of human growth and advancement, making it necessary for every individual to acquire statistical knowledge and develop statistical competency. Recognizing the importance of statistical education, prominent governmental organizations across the continents such as the National Council of Teachers of Mathematics (NCTM, 2000), the Royal Statistical Society Centre for Statistical Education in the United Kingdom and the Australian Academy of Science in Australia significantly contribute to advocating strong statistical skills among their citizens. The reform movement in statistics education has been especially instrumental in taking this discipline to a higher level of recognition and importance, bringing together various institutions in societies with similar interests in statistics education. Thus, it is essential for the learners to learn statistics from school level.

It is important to teach statistical reasoning from school level as it strengthens students' and teachers' knowledge in statistics. The high school teachers need to deepen their knowledge of statistics so that they develop a deeper knowledge than they will be using to help their students to learn (Shaughnessy, Chance, & Cobb, 2005). Teachers intended to prepare for a new classroom environment, using the Statistical Reasoning Learning Environment (SRLE) rather than lecture notes. The SRLE class will be more on listening and assessing students' answers by reviewing and reflecting on what students are learning by providing useful and timely feedback. When teacher pose good reasoning questions, it will encourage students to speculate and think. Besides that, the questions beginning with "what do you think" or "what would happen if" can lead to good class discussions and require students to explain their reasons and justify their answers. Hence communication will occur between teacher and students when teachers emphasize statistical reasoning. This makes the lesson more becomes more student-centered rather than teacher-centered. Moreover, the subtopics in statistical reasoning involve big ideas, developing statistical reasoning and thinking rather than focusing on basic statistics skills, arithmetic and content. Even though teaching statistical reasoning is more difficult than teaching basic statistics lecture-based lessons, it is interesting from usual statistics classes since teachers will be providing activities based on a suitable model, framework or approach, and technology tools as suggested in the Statistical Reasoning Learning Environment (SRLE) (Cobb & McClain, 2004; Garfield & Ben-Zvi, 2008).

A suitable model or framework is important because it helps teachers to identify students' ability and understanding in statistical reasoning. Similarly, it assist statistics teachers in designing and providing suitable assessment aligned with the students' understanding and learning goals in statistics education (Aishah, Maz, Khatijahhusna, & Safwati, 2018). The researcher used statistical reasoning in four processes developed by Jones et al. and Mooney (describing data, organizing data, representing data & analyzing and interpreting data) to guide the instructional design and assessment.

Jones, Langrall, Mooney, and Thornton (2004) developed four constructs of statistical reasoning as noted by Ulusoy and Altay (2017). The first construct of describing data comprises reading, extracting and generating the data presented in the form of a graph, table or scheme. Moreover, it involves showing awareness regarding graphical representations and determining the units of data values. The second construct of organizing data includes organizing, classifying and summarizing data. Organizing data also involving grouping the relevant data, summarizing the data using central tendency measures, and describing the variation of the data. The third construct of representing data is related to describing the data in form of a graph; representing data are establishment of a style of presentation for the given data set and evaluating the suitability of the selected graphs. The final construct of analyzing and interpreting data includes determination of data set and tendencies in the data and estimation and inference based on the data.

The four constructs of statistical reasoning are helpful in assessing and monitoring student performances over time, as well as in evaluating the effectiveness of statistical reasoning using Fathom-based instruction. As the models provide a coherent picture of students' statistical reasoning, they have implications for curriculum design, instruction, and assessment. Hence, they help teachers to trace students' individual and collective progress in statistical reasoning during instruction. They also provide a knowledge base for teachers in designing and implementing instruction. For example, a teacher who was aware from earlier group work that one student was reasoning about the dimensions of the organizing data construct in an integrated way might use that student's response as a focal point for a formative or summative discussion on the dimensions of organizing data. These directions in teaching and learning using the framework of development in statistical reasoning have a key role in statistical instruction. Because these models or frameworks incorporate domain-specific knowledge of students' statistical reasoning across key statistical concepts and processes, they support teachers with the kind of knowledge that can be used in the design, implementation, and assessment of instruction in statistics and data exploration (Jones et al., 2004). A conducive teaching and learning environment can be created when suitable approaches are used along with technology.

Technological tools are effective in learning statistical reasoning because they helps students to visualize and explore data. Besides that, technology-based instructions appear to help students to learn statistical reasoning concepts by providing different ways to represent the same data set. Students may be able to manipulate different aspects of a particular representation in exploring a data set (Garfield & Ben-Zvi, 2008). Technologies provide new tools and opportunities for teaching statistical reasoning including the use of graphical representations. These new technological tools are designed mainly to enable visualization of statistical concepts, providing a massive potential for making statistical reasoning accessible by all students (Meletiou-Mavrotheris & Stylianou, 2003). This conclusion is supported by Ciancetta (2007) who stated that students are able to understand graphs better with dynamic statistics software. Moreover, when they become comparatively proficient in reading and interpreting graphs, students were approaching problem situations using a combination of visual and arithmetical strategies. Besides that, by using technology in the statistics classroom teachers can provide immediate feedback, increase students' ability to operate quickly and accurately and their ability to link multiple representations, to provide immediate feedback, to enhance students' flexibility in using representations and to facilitate the use of advanced levels of statistical reasoning (Gould et al., 2018).

Statistics teacher at the school noticed that most of the students have a negative attitude towards the subject. Generally, this topic considered boring and difficult to understand because it involves a complicated calculation method along with a lot of numbers. Even smart students find it difficult to apply knowledge gained in the classroom to practical problems (Shu-qin, 2005). Students believe statistics is the same as mathematics; hence they focus on numbers, calculations, formulas and the correct answer in the form of numbers. Rossman, Chance, and Medina (2006) point out key differences between mathematics and statistics, concluding that the two disciplines involve different types of reasoning and intellectual skills. Students of statistics assumed statistical involved analysis of the data without paying attention to the data value (Porter, 1998). Besides that, students are uncomfortable with many data and various possible interpretations of a variety of different assumptions; students realize that in statistics they need writing skills for extensive communication-related statistics. Some teachers felt that the topic was disappointing and not statistically significant to be taught. The main problem for teachers is how to improve student achievement in the subject aligned with helping students to have statistical reasoning in order to apply their knowledge in everyday life.

In Malaysia, teacher-centered practices have often led students to memorize formulae, calculation method and drawing graphs in the learning of Statistics instead of building students' confidence and understanding in Statistics. To complete the syllabus on time, procedural teaching is often employed by teachers as they perceive that it is a faster way of transferring mathematical knowledge to students (Lim & Hwa, 2006). Therefore, teachers have failed to provide opportunities for students to connect statistical questions with a concept and real-life situation that can develop statistical reasoning. Garfield and Ben-Zvi (2004) state that traditional teaching methods that focus on skills, procedures and calculations will not lead students to reasoning or thinking statistically. Besides that, student weaknesses in mathematics that underlie basic statistics such as fractions, decimals and algebraic formula disrupt their learning of statistics. Hence, student's statistical literacy and reasoning became affected and success was difficult to achieve. Teachers therefore have to try all possibilities to minimize the problems students face in learning statistics. In order to make students engage in their work teachers need to develop student curiosity and originality (Noraini, 2006). This depends on how the teachers generate curiosity in their students and provide students with valid data for statistical analysis so that the work is more meaningful to students. Noraini (2004) supported teachers to establish working relationships with their students and to break the traditional barriers to allow students to be creative and express their higher-order thinking. Teachers who have good knowledge of errors likely to be made by students will be able to improve the quality of their statistics teaching (Richard, 2002). Teachers are encouraged to view technology use not just as a way to compute numbers, but also as a way to explore concepts and ideas and enhance student learning (Garfield, Chance, & Snell, 2000).

The statistics teaching at secondary school level deserves attention. Through an interesting approach applying meaningful and active discussion in lessons, it is expected that learning will be more meaningful while incorporating statistical reasoning. Accrombessy (2006) mentions that in this era, given the rapid development of computer science as well as information and communications technology (ICT), it is very useful to introduce the concept of instructional software for teaching statistical reasoning. Students can change their behavior toward statistics and participate actively in the course. The use of ICT should strengthen the teaching and learning of statistical reasoning in secondary schools.

1.2 Statement of Problem

One day statistical reasoning will be compulsory for everyone as it involves the ability to calculate, analyze and make decisions (Mallows, 1998). Over the past decade or so there has been an progressive need for shifting the concentration of basic statistics education from formulae, procedures, and computation skills to statistical reasoning (Garfield & Ben-Zvi, 2004). By drawing on the shift mentioned by Garfield and Ben-Zvi, Bryce (2002) has mentioned students lacking in basic statistical reasoning skill may be unable to meet the needs of future employers or to understand information presented statistically. Even though, statistics classes are compulsory for students, the lessons are more on introductions and basic computations. This made most of statistics scholars question what students were learning in statistics classes.

In Malaysian the statistics curriculum focused more on concepts and computations rather than including reasoning and thinking skills. This can be seen through Sijil Peperiksaan Malaysia (SPM), one of the most important public examinations for Form Five students. Most of questions in SPM organized in a way that was "predictable" by memorizing topics and subtopics. Private and additional classes help students memorize the 'answers' on 'forecasts questions'. Students who can memorize a set of answering method mostly will get better results. Then workshop on "how to answer SPM questions" assist students in memorizing per-determined sets of responses. Our students are not trained to answer questions like those found in Trends in Mathematics and Science Study (TIMSS), in which the level of questions evaluate students' analysis and synthesis skills but SPM questions is more focused on students' understanding and application. This is supported by, General Director of Education, Datuk Dr Amin Senin when he announced the results of SPM 2018, he said mastering of thinking and reasoning skills is important for candidates to ascertain that they are able to face challenges and also to compete at international level. Mastery of these skills he said, needs to be nurtured in school and at home (Bernama, 2019, March 14).

Meanwhile, the Trends in Mathematics and Science Study (TIMSS) assess student knowledge in four content domains: number, algebra, geometry, and data and chance. TIMSS assesses students' mathematical thinking in three cognitive domains: knowing, applying, and reasoning. The report of TIMSS (Mullis, Martin, Foy, & Arora, 2016; TIMSS, 2011, 2015) revealed that Malaysia's score difference in average content domain for data and chance from year 2007 (459), 2011 (429) and 2015 (451) is -13. Even though the average score increased from year 2011 to 2015 yet when comparing to other cognitive domains (e.g., knowing and applying) reasoning domain was lowest in each year, 2007 (466), 2011 (426) and 2015 (453). To be more specific, questions in TIMSS are divided into four levels of benchmark namely, low, intermediate, high and advanced. Based on TIMSS report, only 3% of Malaysian students reached the Advanced international benchmark in mathematics in 2015, 18% reached the High benchmark, 45% reached the Intermediate benchmark, and 76% reached the Low benchmark. At the low-level students are required construct bar graphs and pictographs based on data in tables; since it does not require reasoning skills, most students able to answer correctly. Even at the intermediate-level, the students able to read and interpret data in graphs and tables since they have basic knowledge of data. Questions at high and advanced levels require students to interpret data in a variety of graphs and solve simple problems involving outcomes and probabilities. When students are able to answer correctly that indicated they are able to apply and reason in a variety of problem situations. Hence, reasoning skills are required to score well specifically in data and chance domain.

Many students however struggle to describe data. This is due to difficulties in reading various types of graphs and leads to inability in performing various forms of data analysis (Groth, 2003). Moreover, students also tend to see the data as individual entities rather than as cluster of data (Bakker & Hoffmann, 2005; Ben-Zvi & Arcavi, 2001). Hence, Malaysian students generally are unprepared in today's data-driven world. Based on GAISE report by Franklin et al. (2005) the statistical reform movement argued that it is essential that teachers of statistics focus on teaching underlying process or reasoning skills. Unfortunately, the teaching emphasizes more on computational techniques; as a result, students are unable to see the big picture or develop reasoning skills. Heavily lecturer-based instruction, with a focus on computations and discrete methods, fail to teach adequately statistical reasoning adequately. Meletiou-Mavrotheris and Paparistodemou (2015) conducted an exploratory study in an urban upper elementary school; students' statistical reasoning and sampling were examined through an open-ended written assessment. The pre-test findings indicated that student performance in statistical reasoning was poor. Interestingly, the study found that when students were given the chance to participate in appropriate instructional settings, even young children can exhibit well-established understandings of sampling issues and other fundamental concepts related to statistical reasoning.

Along with this, students faced difficulties in organizing data and supported by earlier studies revealed that many students have misconceptions about measures of central tendency, including the mean, median, mode, and measures of variability (Cooper & Shore, 2008). They calculated the average by adding up all the numbers and dividing by the number of data values regardless of outliers. Apart from that, students confuse mean with median. They misinterpret a mean was the same thing as median (Garfield & Chance, 2000). Besides that, Yoclu and Haser (2013) studied eighth grade students concerning their knowledge of average and variability. Students were able to calculate using basic arithmetic computation to the find mean and median. Yet, they found that the students face difficulty in understanding concepts and interpreting the value of a measurement. DelMas (2002) explains that the statistics classroom should focus less on the learning of computations and procedures and more on activities that help students develop a deeper understanding of reasoning and statistical thinking. One way to do that is by using intuition and heuristics to help students develop an understanding of abstract concepts and reasoning. Students also need experience with recognizing implications and drawing conclusions in order to develop statistical reasoning.

Representing data using different mathematical graphics, such as histograms (Meletiou & Lee, 2002), box plots (Bakker, Biehler, & Konold, 2004), and bar graphs (Pfannkuch, Arnold, & Wild, 2015), can be a discouraging task for many students. This supported by, Davis, Pampaka, Williams, and Wo (2006) who conducted research on students' conceptions in bar graphs. They reported errors in scales, lack of identification of patterns, errors in predictions and inappropriate use of information. Meanwhile, Lee and Meletiou (2003) in their study identified students had difficulties to look at the vertical axes and compare differences in the height of the bars when comparing the variation of two histograms. Meanwhile Sharma (2006) undertook research on conceptions in bar graphs. Research indicates that students face difficulties in understanding of graphical representations, leading to poor statistical reasoning.

Students also had difficulties in analyzing and interpreting data. They faced problems when representing several values on a particular interval on a graph. Graphs are graphical representation tool used in the class to get the form for a scatter data. The formation of students' understanding of the concept of data dispersion is visually difficult to describe without the help of a histogram (Meletiou & Lee, 2002). When the students face difficulties in interpreting and understanding the graph, then they face difficulties in their reasoning ability (Gal, 2002). Due to the difficulties, ability to reason in statistics has become a focus of research (Pratt & Ainley, 2008). Several studies have given evidence, which supports that students misinterpret and unable to reason out the result or answer obtained from data (Bergqvist, Lithner, & Sumpter, 2008; Garfield & Chance, 2000; Gundlach, Richards, Nelson, & Levesque-Bristol, 2015).

Traditional statistics classes are unable to provide much information through lectures and questions are asked to get some answers without reasoning or interpreting further on how the answers have been obtained. Such methods are inefficient for developing statistical reasoning because students need to communicate with each other to question and learn to question as well as defend their answers. Cobb and McClain (2004) points out that effective classroom involve statistical arguments and enable students able to engage in sustained exchanges that focus on significant statistical ideas. Unfortunately, traditional approaches to teaching statistics have focused almost entirely on the skills and inadequate procedures in mathematics giving little time for students to reason or think statistically (Garfield & Ben-Zvi, 2004). Implementing Fathom-based instruction in statistical reasoning lessons enable students to learn statistics in different ways; students are able to represent the same data and allowed to make changes in a particular representation or graph to explore the data. In addition, such instruction will improve students' understanding of statistics when they get opportunities to explore, represent statistical models, change assumptions and analyze the data gathered (Biehler, 1991; Jones, Langrall, & Mooney, 2007).

Fathom is now creating new opportunities to build an applicable pedagogy for statistical concept development such as reasoning even at the school level. Fathom is a dynamic classroom statistics package that students can use to explore simulations, create sampling distributions, conduct data analyses, and display the results. Technology such as fathom is useful because student achievement in statistics is still at low levels both in term of quantity and quality (Pusat Perkembangan Kurikulum, 2010). Ben-Zvi (2000) describes how technological tools may be used to help students actively construct knowledge, by "doing" and "seeing" statistics, besides giving students opportunities to reflect on observed phenomena. Fathom is a dynamic classroom statistics package that students can use to explore simulations, create sampling distributions, conduct data analyses, and display the results. Meletiou and Stylianou (2003) conducted an in-depth qualitative analysis of five introductory statistics students using this program to explore whether the use of Fathom in the classroom encouraged the construction of a coherent mental model of key concepts related to statistical inference. She suggested that using Fathom enabled her students to develop a coherent mental model of statistical inference concepts. Mills (2002) provided a review and critical analysis of computer simulation methods used to teach a wide variety of statistical concepts. She concluded that teachers used technology to teach statistical concepts that range from introductory to more advanced procedures. Furthermore, the vast majority of authors suggested that technology-based solutions appeared to facilitate students' understanding of the data.

The statistical reform movement argued that it is essential for teachers of statistics to focus on teaching underlying process or reasoning skills (Franklin et al., 2005), Unfortunately, current teaching emphasizes more on computational techniques; students are unable to see the big picture or develop reasoning skills. Students should able to analyze real data without having to spend hours chained to a bulky mechanical calculator. Scheaffer (2001) suggested that classroom practice should involve a teaching style emphasizing a hands-on approach that engages students to *do* an activity, *see* what happens, *think* about what they just saw, and then *consolidate* the prior learning. He stressed that this could be done in the classroom itself by using appropriate technology. Rumsey (2002) identified three common misconceptions related to the teaching of statistics: (a) “Calculations demonstrate understanding of statistical ideas”, (b) “Formulas help students understand the statistical ideas”; and (c) “Students who can explain things in statistical language demonstrate their understanding of statistical ideas”. Thus, students completing statistics classes founded on such misconceptions may be able to demonstrate some statistical knowledge, but not statistical understanding. Indeed, such rote, formula-based approaches to statistics results in limited transfer of learning (Onwuegbuzie & Leech, 2003). Rote learning does not help students developmentally as they fail to progress in their ability to think and reason statistically (Broers & Imbos, 2005).

Students must develop an effective cognitive scheme in relation to statistical ideas and methods. Students who memorize material may perform well on formula questions but may do poorly on word problems that require deeper levels of learning (Hansen, McCann, & Myres, 1985; Quilici & Mayer, 2002). Students not only need to answer questions correctly but also must be able to explain their underlying thinking and reasoning relevant to the completed problem. Therefore, teachers' teaching methodology is one of the factors contributing to the quality of teaching statistical reasoning (Burgess, 2014; Shaughnessy, 2007). Teachers have responsibilities for creating an effective classroom, guiding the discussion, anticipating misconceptions or difficulties in reasoning, ensuring students are engaged and clearly understand their misconceptions or any difficulties. The focus of these studies was to investigate how students begin to understand these ideas and how their statistical reasoning develops when using well-designed activities assisted by Fathom tool.

1. 3 Conceptual Framework

This study is based on constructivism. Based on this theory, students should be actively constructing their knowledge, rather than simply memorizing ideas taught by teachers (Fosnot, 2013; Larochelle & Désautels, 2009; Phillips, 2000). Constructivists view teachers and learners as collaborators in the learning process and and imply the need for student enthusiasm (Robinson, Molenda, & Rezabek, 2008b). This theory is compatible with the field of statistical reasoning that focuses primarily on the process of creating a classroom where teachers values students thinking, students are encouraged to focus on conceptual understanding rather than mere knowledge of procedures, foster cooperative learning, facilitate authentic assessment and use technology to develop concepts and analyze data (Chaillé, 2008; Payne, 2009). Specifically, this study is concentrated on student achievement using Fathom software to enhance students' statistical reasoning, which focuses on constructing, analyzing and interpreting data, histograms and frequency polygons.

In constructivist theory, it is assumed that students have to construct their own knowledge based on their prior knowledge (Bosman & Schulze, 2018). Each student has a stock of conceptions and skills with which they must construct knowledge to solve problems posed. The role of the teacher and other students is to provide the setting, pose the challenges, and offer the support that will encourage the student to reason and develop their thinking (Chaillé, 2008). Since students lack experience in the field, teachers are great responsibility for guiding student activity and providing examples that will transform lessons into meaningful communication about subject matter (Flynn, 2004).

It is necessary for students to construct knowledge by attempting to make sense of the situations they encounter before arriving at the answer or conclusion (Jonassen, 2000). Hence, educators need to encourage students to use various methods such as asking questions and finding resources to solve a problem. Exploration leads students to more questions and helps them reconsider their conclusions which in turn will develop their reasoning skills. Based on the constructivist perspective, teachers should be aware of what students know and what they are able to do, how students are able to negotiate meaning and build consensus by interacting with one another and with teachers, and how students can put their knowledge to the test and receive feedback on its adequacy. This is supported by Robinson et al. (2008b) who explained that learning is facilitated by giving importance to the learners, their interests and abilities.

Constructivism differs from cognitivism essentially in the subject nature of this knowledge (von Glaserfeld, as cited in Robinson et al., 2008b). The essential constructivist elements are learning in relevant environments, collaboration, the need for multiple perspectives and representations, encouragement of self-learning (Robinson et al., 2008b). Meanwhile, the cognitivists believe that students build knowledge transferred from the environment and not focused on the construction of their own knowledge in the context of social interaction (Solso, Maclin, & Maclin, 2008). Therefore, constructivism more suitable than cognitivism as this helps in the process of collecting data to answer the research question. There are several assumptions for this study (Nik Azis, 1999; Von Glaserfeld, 1995, 2005):

1. Students create statistical reasoning knowledge by relating or connecting it to their previous knowledge.
2. Learning statistical reasoning needed experience and prior understanding.
3. Social interaction plays a role in learning statistical reasoning.
4. Effective learning requires technology, open-ended, challenging problems for the students to solve (Boethel & Dimock, 2000; Fox, 2001)

This assumptions help to narrow the scope of the study so that it can be controlled. Moreover, these assumptions also assist the researcher in collecting, analyzing the data and help to answer the research questions.

1. 4 Objectives of the Study

The purpose of this study is to examine the effectiveness of Fathom in teaching and learning of statistical reasoning, particularly in the secondary school syllabus, which focus in form four statistics topic. In order to achieve that, this study aims at: -

1. Investigate the effectiveness of Fathom-based Instruction on students' statistical reasoning.
2. Investigate the effectiveness in Statistical Reasoning Constructs namely Describing Data, Organizing Data, Representing Data and Analyzing and Interpreting Data of Form Four students after Fathom-based Instruction.

1. 5 Research Questions

This study aimed at addressing the following research questions:

1. Is there any significant difference in the Statistical Reasoning of Form Four students after the Fathom-based Instructions of the experimental group?
2. Is there any significant difference in the Statistical Reasoning of Form Four students in control and experimental groups after controlling for the pre-test?
3. Is there any significant difference in Statistical Reasoning Constructs of Describing Data, Organizing Data, Representing Data and Analyzing and Interpreting Data of Form Four students after the Fathom-based Instructions of the experimental group?
4. Is there any significant difference in Statistical Reasoning Constructs Describing Data, Organizing Data, Representing Data and Analyzing and Interpreting Data of Form Four students after the Fathom-based Instructions of the control and experimental groups after controlling for the pretest?

1. 6 Research Hypotheses

Ho 1: There is no significant difference in the Statistical Reasoning of Form Four students after the Fathom-based Instructions of the experimental group.

H_1 1: There is a significant difference in the Statistical Reasoning of Form Four students after the Fathom-based Instructions of the experimental group.

Ho 2: There is no significant difference in the Statistical Reasoning between Form Four students' in control and experimental groups after controlling for the pre- test.

H_1 2: There is a significant difference in the Statistical Reasoning between Form Four students in control and experimental groups after controlling for the pre-test.

Ho 3: There is no significant difference in Statistical Reasoning Constructs Describing Data, Organizing Data, Representing Data and Analyzing and Interpreting Data of Form Four students after the Fathom-based Instructions of the experimental group.

H_1 3: There is a significant difference in Statistical Reasoning Constructs Describing Data, Organizing Data, Representing Data and Analyzing and Interpreting Data of Form Four students after the Fathom-based Instructions of the experimental group.

Ho 4: There is no significant difference in the Statistical Reasoning Constructs Describing Data, Organizing Data, Representing, Data and Analyzing and Interpreting Data of Form Four students after the Fathom-based Instructions of the control and experimental groups after controlling for the pretest.

H_1 4: There is a significant difference in the Statistical Reasoning Constructs Describing Data, Organizing Data, Representing, Data and Analyzing and Interpreting Data of Form Four students after the Fathom-based Instructions of the control and experimental groups after controlling for the pretest.

1.7 Significance of the study

This study can be beneficial to certain parties such as school mathematics teachers, students, lecturers and curriculum developers. School teachers are expected to use these new teaching techniques, namely the use of software Fathom software in the mathematics classroom. Information from this study will also help teachers to plan appropriate strategies in teaching topics in Statistics as well as encouraging the use of Fathom among students. Teachers can also vary alternative teaching techniques and learning of mathematics, especially for weak students to enhance their enthusiasm and interest in mathematics and improve their mathematics achievement. Therefore, this study is expected to examine the teacher's instructions to follow current developments and changes.

Technology in education supports the mastery and achievement of the desired learning outcomes. Mathematics for secondary schools provides opportunities for pupils to acquire mathematical knowledge and skills, and develop higher order problem solving and decision making skills to enable students to cope with daily life challenges (PPK, 2014). An early exposure to statistics using technology in school would facilitate students when they enter higher education institutions in the future.

This study is important to the curriculum developers as a basis for providing a module or a new syllabus using appropriate computer software to facilitate teachers' classroom teaching. The new policy of secondary school curriculum may be modified and improved by using Fathom learning in mathematics. Thus, the Secondary School Standard Curriculum in Malaysia will be equivalent with the education system in developed countries that have implemented such learning. The Ministry of Education also can make plans and strategies to equip teachers with the skills to teach mathematics effectively. Appropriate courses for teachers in service can be provided to improve pedagogical knowledge and abilities of students in mathematics.

Educational college lecturers can also make this study as a source of perspective to train future teachers to make teaching more innovative. Teachers will be trained to adapt teaching techniques using computer software in advance before working in schools. Then, they will acquire knowledge about the best approach to teach children of this era. Moreover, professional development in education under the Curriculum for Secondary Schools (KBSM) in the era of information technology should be implemented within the context of the efforts to achieve the goal of Vision 2020. Therefore, the results of this study can promote the use of Fathom in all secondary schools in Malaysia.

It is hoped that the findings of this study will be the starting point for future studies to examine in greater detail the impact of using Fathom for learning mathematics among students in Malaysia schools. Hopefully by continuing studies, accurate decisions can be taken immediately in practice the use of Fathom completely in schools in Malaysia. The Curriculum Development Division must also take the initiative in developing activities and materials for using Fathom in mathematics teaching and learning.

1.8 Operational Definitions

The following are definitions of the terms as they are used in this study:

1.8.1 Statistical reasoning

Statistical reasoning is defined as the way individuals reason with measurable thoughts and how they understand factual data. This includes making translations in view of sets of information, representations of information, or statistical summaries of data. Statistical reasoning may include interfacing one idea to another (e.g., center and spread), or it might join thoughts regarding data and chance. Reasoning implies understanding and having the capacity to clarify statistical procedures and having the capacity to completely interpret statistical results (Garfield, Delmas, & Chance, 2003). In this study, Statistical Reasoning had been operationally defined as the overall scores of the Statistical Reasoning Assessment (SRA).

1.8.2 Describing Data

Describing data entails directly reading the data revealed in charts, tables, and other graphical displays (Mooney, 2002). This process involves the explicit reading of raw data or data presented in tables, charts, or graphical representations. Curcio (1987) considers “reading the data” as the initial stage of interpreting and analyzing data. The ability to read a data display becomes the basis for students to begin making predictions and discovering trends. Two sub processes relate to describing data: (a) showing awareness of display features and (b) identifying units of data values. Describing data measured is one of the components used in statistical reasoning assessment. In this study, Describing Data had been operationally defined as the overall mean scores of the Describing Data constructs in the Statistical Reasoning Assessment (SRA).

1.8.3 Organizing Data

Organizing data involves classifying, organizing, or combining data into synopsis form (Mooney, 2002) as well as reducing data using measures of central tendency and variability. This process involves arranging, categorizing, or consolidating data into a summary form. As with the ability to describe data displays, the ability to organize data is vital for learning how to analyze and interpret data. Arranging data in clusters or groups can illuminate patterns or trends in the data. Measures of center and dispersion are useful in making comparisons between sets of data. Three sub processes pertain to organizing data: (a) grouping data, (b) summarizing data in terms of center, and (c) describing the spread of data. In this study, Organizing Data had been operationally defined as the overall mean scores of the Organizing Data constructs in the Statistical Reasoning Assessment (SRA).

1.8.4 Representing Data

Representing data is defined as showing data in graphical form (Mooney, 2002). This process involves displaying data in a graphical form. Friel, Curcio, and Bright (2001) stated that the graphical sense involved in representing data "includes a consideration of what is involved in constructing graphs as tools for structuring data and, more important, what is the optimal choice for a graph in a given situation" (p. 145). Representing data, like the previous two processes, is important in analyzing and interpreting data. The type of display used and how the data are represented will determine the trends and predictions that can be made. Also, different data displays can communicate different ideas about the same data. Two sub processes underlie representing data: (a) completing or constructing a data display for a given data set and (b) evaluating the effectiveness of data displays in representing data. In this study, Representing Data had been operationally defined as the overall mean scores of the Representing Data constructs in the Statistical Reasoning Assessment (SRA).

1.8.5 Analyzing and Interpreting Data

Analyzing and interpreting data involve recognizing trends and making predictions or inferences from a graphical display (Mooney, 2002). This process constitutes the core of statistical reasoning. It involves recognizing patterns and trends in the data and making inferences and predictions from data. It incorporates two sub processes that Curcio (1987) refers to using the following descriptors: (a) *reading between the data* and (b) *reading beyond the data.* The former involves using mathematical operations to combine, integrate, and compare data (interpolative reasoning); the latter requires students to make inferences and predictions from the data by tapping their existing schema for information not explicitly stated in the data (extrapolative reasoning). In this study, Analyzing and Interpreting Data had been operationally defined as the overall mean scores of the Analyzing and Interpreting Data constructs in the Statistical Reasoning Assessment (SRA).

1.8.6 Fathom Dynamic Data Software

Fathom Dynamic Data Software is software for learning and teaching statistics, at the high school and introductory college level. The software was developed by KCP Technologies, Concord Consortium. The software Fathom is a product of Key Curriculum Press (Finzer, 2001). It is exciting and compelling dynamic software for teaching data analysis and statistics, a capable device for secondary schools to use for demonstrating with arithmetic. By helping students comprehend polynomial math, calculus and statistics, Fathom's effective data analysis abilities make it a brilliant device for the physical and natural sciences, and for science courses. Fathom lets students rapidly represent information in an assortment of diagrams, including bar chart, function plots, scatter plots, histograms and more. It provides students with the tools to build simulations that explain probability and statistics concepts. In Fathom, students can plot values and functions on top of bivariate information and shift them powerfully with sliders to demonstrate the impacts of variables. Data analysis and display are currently indispensable parts of secondary school courses. Fathom gives an outwardly convincing environment for students to meet these guidelines as they investigate, dissect and display information. As a dynamic software, Fathom is used as an instructional tool to influence students' performance in statistical reasoning lessons, activities and assessment. This study measures the differences in students' statistical reasoning skills with and without using any intervention (Fathom) using statistical reasoning assessment.

1.9 Limitations of the Study

This study, however, has several limitations. The first limitation of this study was the restricted and non-randomized sample for this study. The population sample of Form Four students from a school in Klang is purposely chosen as the school for the study. The small sample was used in this study. The sample chosen was restricted to Form Four students; a larger sample would provide a stronger conclusion and eventually interpret a detail analysis. Thus, this represents only a very small percentage of the total population of the secondary students in Malaysia.

The second limitation of quasi-experimental approach is that it has considerably more threats to internal validity than the true experimental approach. Because this study does not randomly assign participants to groups, the potential threats of maturation, selection, mortality, and the interaction of selection with other threats are possible. However, the researcher controlled the threats in the experiment by careful selection of participants with the same grade levels. Individual selected do not have extreme scores; nor are they smarter than existing participants to avoid regression. Besides that, a larger sample was chosen to draw conclusions easily even if some participants drop out during the experiment for any reasons.

The third limitation is items in the instrument specifically developed for this study although largely involves the procedures and calculations. Due to the nature of the topic concerned, most of the items if not all by design will require questions and solutions in words particularly because the study is interested in identifying the understanding of the students in statistical reasoning. However, care must be taken in designing the items so that the instrument is indeed assessing students' statistical reasoning and is not assessing other attributes such as students' language proficiency for instance. Therefore, items must not be assessing students' language skills but having said that this factor is quite unavoidable particularly because statistical reasoning mostly involves word problems and solutions. The limitation was overcome by adapting the instrument from previously established and validated constructs.

The next limitation is time factor whereby the study was carried out in approximately eight weeks of teaching and learning. A longitudinal study is preferable under ideal circumstances. Thus, the findings of this study could not be generalized to all schools in Malaysia.

1.10 Delimitations of the Study

This study has several delimitations; three of them are the subjects of mathematics, technology and research participants. The first delimitation related topic selected in Statistics for this study is the frequency tables, histograms and frequency polygons. Many topics in initial statistics are represented by a graphical representation taught in school such as pictographs, bar charts, pie charts and ogive. However, this study only focused on sub topics histogram and frequency polygon, which is in the chapter Statistics for Form Four. This sub topic been option of study because students have difficulties making interpretations and solving problems associated with histogram and frequency polygon. In addition, the two graphs are inter-related. Furthermore, students at this age are just getting exposure on the ungrouped data to be isolated for better understanding and clarity.

The second delimitation is relating to computer software used in the study, Fathom. There are various types of educational software that can be used in the mathematics field as Tinker Plot, GeoGebra, SPSS, Autograph and others. However, Fathom was selected, as a technology tool in learning statistics because the software is designed for high school students for helping students understand Algebra, Pre calculus and Statistics.

The third delimitation is the researcher limits the scope from the aspect of the sample used. The sample chosen was restricted to Form Four students in a secondary school. The content of mathematics is only focused on statistics in the Form Four syllabus of the national curriculum approved by the Ministry of Education. The Form Four students were selected because preliminary statistics topics involving graphic representation learned by high school students began in Form Four.

1.11 Summary

This experimental study aims at exploring in depth the effectiveness of statistical activities based on Fathom statistical reasoning among Form Four students. This study will hopefully help administrators, teachers and other stakeholders at the school level, especially to enrich the teaching of Mathematics technique completely. The connection to that, improvements to existing programs can be created and new programs can be designed to ensure that the school's academic excellence and contribute to the development of future generations.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

The first section contains an explanation of reasoning, mathematical reasoning and statistical reasoning, followed by explanation of constructivism theory. In this part, the justification made about the important aspects of current learning theory and a model of instruction based on the theory used are discussed. The third section discusses Statistical Reasoning Learning Environment and Statistical reasoning assessment. Statistical topics are discussed in the fifth part; followed by Fathom Dynamic Data Software, the discussion on Fathom software practice in learning and teaching of mathematics and statistical reasoning. The last section discusses previous studies involving the learning of mathematics using technology. Finally, chapter two concludes with a summary of the literature review.

2.2 Reasoning

"Reasoning" develops lines of thinking or argument, which serve a number of purposes, for example, to convince others or ourselves of a particular claim, to solve a problem, or to integrate a number of ideas into a more coherent whole. Bergqvist and Lithner (2012) defined reasoning as the line of thought adopted to produce assertions and reach conclusions when solving tasks. Reasoning is not necessarily based on formal logic and is therefore not restricted to proof; it may even be incorrect as long as there are some sensible reasons supporting it. Meanwhile, Shaughnessy, Ciancetta and Canada (2004) defined reasoning as an understanding of aspects of everyday life through the application of common sense logic as a locus of an action and its impact on life. Reasoning skills are also known as the process of obtaining information and making inferences based on individual responses (Lyn, 2004; Osborne, 2013). Therefore, based on these skills, reasoning in education is a stepping stone for students to sharpen their thinking.

As education moves toward the 21st century, reasoning skill is employed more and more in learning because it enables students to state causal and rational ideas based on the problems that arise. Students are encouraged to estimate, predict and make intelligent guesses in the process of seeking solutions. Students at all levels have to be trained to investigate their predictions or guesses by using concrete materials. Reasoning has to be absorbed in the teaching of mathematics so that students can recognize, construct and evaluate predictions and mathematical arguments (Pusat Perkembangan Kurikulum (PPK), 2010). These acquired skills enhance students, encouraging them to explore and generate new ideas as well as prepare themselves to face any upcoming hardships (Thompson, Senk, & Johnson, 2012).

2.3 Mathematical Reasoning

"Students must learn mathematics with understanding, actively building new knowledge from experience and prior knowledge" (NCTM, 2000). This principle is based on two ideas. First, learning mathematics with understanding is essential. Mathematics today requires not only computational skills but also the ability to think and reason mathematically in order to solve new problems and learn the new ideas that students will face in the future. Secondly, the principle states quite clearly that students can learn mathematics with understanding. Learning is enhanced in the classroom when students are required to evaluate their own ideas and those of others, are encouraged to make mathematical conjectures and test them, and develop their reasoning skills.

Brousseau and Gibel (2005) points out that reasoning is only considered to be reasonable when they relate to the constraints of the problem or the knowledge under consideration. An appeal to authority, for example to what a teacher or textbook says, does not count as a reason for a productive argument. The product of a reasoning process is a text, either spoken or written (Douek, 2005), which presents deserves for a conclusion that is acceptable within the community producing the argument. An individual can reason, or a group of people can reason together, co-producing the line of argument. Mathematical reasoning assumes mathematical communication and "basic skill" of mathematics and it is necessary for a number of purposes such as to understand mathematical concepts, to use mathematical ideas and procedures flexibly and to reconstruct once understood (Ball & Bass, 2003; Bergqvist et al., 2008; Lithner, 2000).

In a mathematical situation, any time students might ask, "why?" "how do we know that?", "what would happen if…?", "would it ever be true that….?" they are asking questions that involve reasoning skills. The pursuit of the question "why" in the mathematics classroom is critical. Students want to know, for example, why fractions are divided by inverting the last fraction and multiplying, why the formula for the area of a circle is $A = \pi r^2$, why the value of the constant e is irrational, and why the first derivative of the sine function is the cosine function. As they study mathematics, students should become inquisitive and inclined to seek proof and verification of conjectures raised in the classroom. And this is most likely to occur in classrooms where mathematical reasoning is valued (Brahier, 2016; Lithner, 2000)

Reasoning is the logical thinking that helps students decide if and why their answers make sense. Students need to develop the habit of providing an argument or a rationale as an integral part of every answer. Students can and do learn that the reasons for their answers are at least as important as the answers themselves. Requiring students to explain or defend their responses has a positive effect on how students view mathematics and their own mathematical abilities. Doing so also promotes confidence and self-worth. Justification of responses force students to think reflectively; they learn to defend their ideas, eliminate guessing or reject responses based on rote learning. Thus having students explain their answers is another excellent mechanism for getting the same benefits as from discourse and writing (Van de Walle, 2007).

2.4 Statistical Reasoning

Statistics is an interpretive science (Kelly, Sloane, & Whittaker, 1997). DelMas (2002) described statistical reasoning as the examination of the underlying process of statistical procedures and research, the why, how and explanation of the process. It is not enough for someone to be able to compute a probability but they should be able to apply that reasoning to everyday life and situations involving probabilistic thinking in the real world. Garfield and Chance (2000) defined statistical reasoning as:

> *The way people reason with statistical ideas and make sense of statistical information. This involves making interpretation based on sets of data, the representation of the data, or statistical summaries of the data. Students need to be able to combine ideas about data and chance, which leads to making inferences and interpreting statistical results* (p.101).

On the other hand, Lovett (2001) claimed statistical reasoning involves the use of statistical ideas and tools to summarize the situation and draw assumptions and make conclusions from the data. Martin (2009) defined statistical reasoning as forming conclusions and judgments according to the data from observation studies, experiments or sample surveys.

As mentioned in Chapter One, there are three types of statistical reasoning, namely reasoning about center, spread, and distribution. Reasoning about center concerns data analysis that involves mean, mode, and median. Reasoning about spread involves range, interquartile range, variance, and standard deviation. Reasoning about distribution entails interpreting a compound structure comprised of reasoning about features such as center, spread, skewness, density, and outliers as well as other concepts such as causality, chance, and sampling (Pfannkuch & Reading, 2006).

Statistical reasoning is a primary learning outcome for any introductory statistics course (Gal & Garfield, 1997). Students need to develop an understanding of the underlying processes involved in research methods and statistics and learn to ask questions that challenge their reasoning about processes. Based on Galotti (2008), when students use the data to make conclusions, they are using their reasoning skills. Reasoning is the cognitive processes that transforms given information in order to reach conclusions. Students will need to learn to use their reasoning when they draw conclusions from the data. In statistics, students will learn to represent the data in tabular form and graphically and also, they learn to summarize the data. They will be using the information embedded in these representations and summaries to draw conclusions about the data.

In general, statistical reasoning, thinking, and literacy are unique areas; however two instructional perspectives have been formed to describe how these three outcomes are interconnected to each other (Garfield & Ben-Zvi, 2004). Some instructional activities, if viewed from different instructional perspectives, may enhance students' understanding in two or more domains. The first perspective is that statistical literacy provides the foundation to develop the basic knowledge and skills needed to foster statistical thinking and reasoning. Some content of statistical reasoning, thinking, and literacy overlap, but some are independent (DelMas, 2002). Another instructional perspective suggests that statistical literacy contains all the learning outcomes. It implies that statistical reasoning and thinking are subsets of statistical literacy and thus do not have their own independent content (DelMas, 2002).

One of the goals of the GAISE Report was that teachers should stress conceptual understanding rather than mere knowledge of procedures. Without an understanding of the underlying concepts related to statistical procedures, students will not be able to apply reason effectively or engage efficiently in statistical problems and solutions (Schau & Mattern, 1997). It is important to recognize that statistical reasoning is not only a learning outcome but also a necessary process used by students to learn statistics (Tempelaar, Gijselaers, & van der Loeff, 2006). As such, teachers should apply statistical reasoning in the classroom. Additionally, assignments and assessment practices should have a reasoning component. Unless they learn statistical reasoning properly, students who complete statistics class can describe but not justify their answers, do not understand the concepts underlying their statistical solutions and cannot recognize their own mistakes or understand why they come up with an ineffective statistical solution (Kelly et al., 1997).

Jones et al. (2004) argued that statistical reasoning is not a skill but rather undergoes levels of development to an understanding of statistical reasoning. They stated that teachers could apply several models of cognitive development to an understanding of statistical reasoning. Therefore, researchers have grounded their models on the results of clinic studies, structured interviews and classroom studies involving primarily elementary and middle schoolchildren (Jones et al., 2001). Similar models of statistical reasoning presented by Jones et al. (2000) and Mooney (2002) place students' abilities at one of four levels; Idiosyncratic, Transitional, Quantitative and Analytic. If teachers plan to facilitate the development of statistical reasoning skills, they need to be aware of each student's developmental reasoning level. Teaching the more advanced levels of statistical reasoning is unreasonable for students operating at the lower levels of reasoning abilities. Hence, teachers need to be aware of students' level of statistical reasoning as it influences not only the student but also the classroom as a learning community (Moore & Cobb, 2000).

In order to develop statistical reasoning, simulations, simple handouts emphasizing the role of selection skills related to the use of appropriate statistical procedures and concept maps can help students form cognitive schemata necessary for conceptual understanding of statistics (Broers & Imbos, 2005; Garfield et al., 2003; Quilici & Mayer, 2002). Teachers can post question different from normal routine to the students such as how or for what valid reason the discoveries are created. Meanwhile, to promote statistical reasoning, students can be required to apply their knowledge to real questions. This enables students to analyze and evaluate the design to make a conclusion or summarize the information from the classroom to new situations. Through implementing statistical reasoning in teaching, students' statistical thinking skills also can be improved. Achievements in statistical reasoning appear to be long-term and levels of reasoning remain high upon retesting (Cobb, McClain, & Gravemeijer, 2003).

2.5 Four Constructs of Statistical Reasoning

The four constructs of statistical reasoning framework by Jones (2000) provided the directions with the kind of knowledge could be used in designing teaching, learning and assessment to investigate students' statistical reasoning ability. Based on Simon (2000, p.133) the knowledge required involves "the reflexive relationship between the teacher's design of activities and consideration of the reasoning that students might engage in as they participate in those activities". Hence, Jones (2002) framework that consists of describing data, organizing data, representing data and analyzing data highlighted the need for researcher to understand and use the reasoning to improve student's statistical knowledge. In particular, each construct helps to frame questions and written tasks that accommodate the diversity of reasoning.

2.5.1 Describing Data

The first construct, describing data, helped the study to focus on student's awareness of the display attributes of the graphical representation. In addition, guide researcher to prepare activities that sees the ideas and recognize the characteristics of graphical representations and measures of central tendency as a whole unit. In accord with these key elements, researcher generated questions like the following to assess students' reasoning on this construct:

- What does this picture tell you?
- Why you think these pictures represent the same data?

The open-ended questions used to access the limits of students' reasoning skills in relation to describing data and used follow-up questions to probe their statistical reasoning.

2.5.2 Organizing Data

The second construct of statistical reasoning is organizing data students were required to organize the data in the computer system for experimental group and manually for control group. Based on our definition of organizing data, the key elements of this construct as follows: (a) grouping and ordering data, (b) recognizing that information may be "lost" in a reorganization of data, (c) describing data in terms of representativeness or typicality, and (d) describing data in terms of spread. In accord with these key elements, researcher generated clusters of questions or tasks like the following to assess students' reasoning on this construct:

- How would you organize this data in another way?
- Complete the frequency table
- What is the mean value?

Note that, in determining students' understanding of mean for instance, researcher asked two variations of the same question: (a) one that asked, "find the value of mean?" and (b) one that used the term "measure of tendency". Students' knowledge of mean revealed the full extend through this different variation of questions.

2.5.3 Representing Data

Constructing representations and visual displays that exhibit different organizations of a data set is central to this construct in Jones framework. It also involves certain elemental conventions that are associated with the presentation of visual displays.

The key elements of representing data: (a) completing a partially constructed data display and (b) constructing displays to represent different organizations of a data set. In accord with these key elements, researcher generated questions or tasks like the following to identify students' reasoning on this construct:

- Organize and present this data in another way.
- Which graph do you think represents the data better?

Moreover, when students were required to identify different graphical representations for the same set of data it allows not only evaluating the process of creating graphs but also making sense of the graphs in order to develop more sophisticated reasoning in representing data. In order to determine the limits of students' reasoning ability in representing data and, in particular, to ascertain whether they would show any tendencies to represent different organizations of the data, the construct is importance as it helps to evaluate students' success in designing a graph to visually support a certain claim about a trend in the data.

2.5.4 Analyzing Data

This construct last construct, analyzing data incorporates recognizing patterns, trends, and exceptions in data and making inferences and predictions from the data. Predicting the allowance for a student presented on a graph, most students at this grade were unsuccessful because they considered the graphs to be complete. Based on definition of analyzing and interpreting data the key elements for this construct were (a) comparing data and (b) extrapolating and predicting from the data. Consistent with these key elements, we generated clusters of questions or tasks like the following to assess children's thinking on this construct:

- Which measure of tendency is most affected?
- Do you think Janine will lose her job?

This extrapolation questions do not just assess the process of constructing graphs but tries to make sense of the created graph to enhance sophisticated reasoning about analyzing data. Students were required to think beyond the given data set or display.

2.6 Problems Encountered by Students in Learning Statistical Reasoning

Many statistical ideas and rules are complex, hence creating difficulties in understanding the terms and procedures. Many students struggle with the basic mathematics (such as fractions, decimals and algebraic formulas), and that interferes with learning the related statistical content. The context in numerous statistical problems may mislead the students, causing them to rely on their experiences and often-faulty perceptions to produce an answer, rather than select an appropriate statistical procedure. Students link statistics with mathematics and expect the focus to be on numbers, computations, formulas and one right answer. They are uncomfortable with the messiness of data; the different possible interpretations based on different assumptions, and the extensive use of interpreting data and communication skills.

Many studies show that students encounter problems in interpreting the histogram. DelMas, Garfield, and Ooms (2005) stated that the students are confused by the terms of "horizontal" and "vertical" which led to difficulties to plot or interpret data. Students are also confused between histograms and bar graphs that leads to the interpretation to each square represents an observation on the vertical axis reflects the values of variables. Finally, students are unable to read information from histograms correctly that led to the wrong response when answering the question about the value of a specific frequency.

Besides that, making data interpretation wrongly was found among university students. This was shown by Lee and Meletiou (2003) where they developed four test items specifically designed to investigate students' reasoning about histograms and analyzed 162 respondents from an Introductory Statistics course in a Midwestern University. Based on their analysis, they have identified four main types of student difficulties in constructing, interpreting and applying histogram in different real world contexts:

a. Perceiving histogram as displays of raw data with each bar standing for an individual observation rather than as presenting grouped sets of data.
b. Interpreting histograms as two-variable scatterplots or as time sequence plots.
c. Tending to look at the vertical axes and compare differences in the heights of the bars when comparing the variation of two histograms.
d. Wrongly assumed when interpreting the distribution in the context of the real world.

Poor performance in statistical reasoning has many causes, such as lack of attention, lazy to think, memory overload or inability or misconception in statistics (Saldanha & Thompson, 2002). Students already have the assumption that statistics is one of the most difficult topics with many computations and plotting graphs. Sorge and Schau (2002) who studied students' attitudes toward statistics subject believed that attitudes have great influence on academic performance, willingness to learn and that they would pass the course with flying colors. The conclusion by Sorge and Schau was supported by studies done by Mahanta (2014) as well as Singh, Granville, and Dika (2002). Changing in attitude is due to several circumstances for example increasing in difficulty of the subject being taught. Brown, Brown, and Bibby (2008) found a trend of increasing disinterest in statistics among students. They note that students were not interested in statistics because of lack of confidence, boredom and anxiety, and also due to failure to understand the subject. This type of factor is closely related to teachers' role as an educator and facilitator.

Teachers who have creative skills and those who really enjoy implementing new methods in teaching statistics can change students' attitude in the classroom and facilitate learning. Some researchers (e.g., Lazarides & Ittel, 2012; Lesser & Pearl, 2008) suggested that teachers who try to create interesting, enjoyable and fun learning environment would help to increase students' interest and positive thinking towards statistics.

2.7 Constructivism Theory

Statistical is a complex subject as it requires deeper understanding and proper teaching approaches. When an initial confusion occurs, it will lead to failure to receive sufficient explanations or assistance from the teacher, followed by lack of confidence to learn statistics. Eventually, students will be uninterested and disengaged from the lesson. This circumstance will decrease students' ability to handle quantitative problems and make them develop negative perception on statistical skills (Tobias, 1994). Gal and Ginsburg (1994) stated that a parallel situation happening in statistical reasoning classes. It is crucial for statistics educators to be sensitive to students' learning environment as it gives impact on students learning process in statistical reasoning. On the other hand, teaching is known as "telling" and learning is labeled as "remembering" (Charles & Zeuli, 1999). This assumes that the students are absorbing and transmitting the knowledge without understanding. This study concentrated on creating a conducive learning environment by using technology to create active learning student-centered teaching and learning, and self-directed students. To achieve this goal, teacher has to encourage students by provoking deeper understanding of the material learned. However, deeper understanding cannot be developed in a traditional teacher-centered classroom. This study implemented statistical reasoning lessons using Fathom-based instructions by integrating constructivism theory in teaching practice. Since constructivism theory describes learning as something quite different than the telling and remembering sequence hence constructivism was used as the theory in this study. Different versions of constructivism exist, but the basic idea is that students learn by constructing knowledge, rather than by receiving knowledge. Based on constructivism theory, teaching should be more learner centered and teacher should facilitate learning. Moreover, constructivism emphasizes on teaching that make students understand the topic and not simply memorizing facts or procedures. As this theory aligns with the needs of this study, hence it is suitable to use constructivism as a guideline and to understand the connection between the variables.

In order to investigate the effectiveness of students' statistical reasoning on Fathom-based instruction, there is a need to use proper learning environment guidelines and measures of statistical reasoning. As recommended by Ben - Zvi and Garfield (2008), the Statistical Reasoning Learning Environment (SRLE) helps to develop students statistical reasoning by teaching students how to reason with the statistical concepts and information. SRLE model is developed based on the constructivist approach of learning as well as Cobb and McClain's six principles of instructional design (Garfield & Ben-Zvi, 2008). The Jones et al. (2000) framework describes the development of students' statistical reasoning across the four constructs namely; describing data, organizing data, representing data and analyzing and interpreting data. These four constructs of statistical reasoning describe students' learning, with specific descriptors of reasoning at each level; while the SRLE emphasizes on the design of the learning environment, they are both designed to enhance students' statistical reasoning embedded with constructivism theory.

In this study, the lessons and activities were developed to incorporate the constructivist approach in the Fathom-based lessons. During the lesson, the students are able to develop habits of questioning, representing, concluding, communicating and reasoning statistically. Based on constructivist teaching, students are encouraged to engage willingly in activities, share thoughts in dialogs, or other ways to pursue topics in depth. Meanwhile, teachers can incrementally substitute constructivist practices for traditional practices and construct knowledge based on the student-teacher interaction as well as student-student interaction as suggested by the SRLE guidelines. Besides that, statistical reasoning lessons in this study focused upon understanding instead of the statistical computation; even students with low mathematical level should be able to learn statistics. To develop statistical reasoning, the learner has to work and communicate with the educator to carry out the rules in realistic problems as stated in constructivism theory. Constructivism is considered as a philosophical framework or theory of learning, which argues that humans construct meaning from current knowledge structures. Hence, students 'construct' their own meaning by building on their previous knowledge and experience. New ideas and experiences are matched against existing knowledge, and the learner constructs new or adapted rules to make sense of the world. In such an environment the teacher cannot be in charge of the students' learning, since everyone's view of reality will be so different, and students will come to learning already possessing their own constructs of the world. Teaching styles based on this approach mark a conscious effort to move from traditional (Cannella & Reiff, 1994) to a more student-centered approach as applied in this study.

The implementation of constructivism learning approach in this study helped to focus on constructing student understanding and not only reflecting what had been taught or read. Students had the chance to look for meaning and discuss their findings with others and thus develop shared understandings. The instructional activities in statistical reasoning lessons required students to actively participate to create survey questions, collect data and present their findings statistically, while they reconsider their prior knowledge in the presence of the new information. Thus, students had more practice in discussing and comparing their answers or findings with peers. In this way, they gained more experiences in reasoning skills and developed deep understanding of the new knowledge. In constructivist theory, students learn best when actively engaged in the learning process by connecting their prior knowledge to new knowledge and making meaning in real world experience. This study represents such instructional lessons whereby a dynamic software, Fathom and particular elements of constructivism are incorporated in statistical reasoning lessons to improve students' learning outcome and deepen their understanding in statistical reasoning.

The researcher will discuss in general the technology-assisted teaching in this study influenced by constructivism. The relationship between technology utilization and constructivism is expected to complement each other (Nanjappa & Grant, 2003). A connection normally occurs between what students already know and what they are expected to learn (Gagnon & Collay, 2005). The constructivist classroom requires different views of learning. Students are active constructors of their own conceptual understanding and urged to be actively involved in their own learning process (Piaget, 1976), whereby, students are encouraged in inquiry methods to ask questions, investigate statistical questions, and use a variety of resources to find solutions and answers. As students explore the statistical data, they draw conclusions and as exploration continues, they revisit those conclusions. Exploration of questions leads to more questions. Meanwhile, technology refers to the design and environment that helps in its learning. Therefore the focus of both constructivism and technology is to create an effective learning environment (Januszewski & Molenda, 2013). Educational technology empowers learners and teachers, through focusing more on student-centered learning (Robinson, Molenda, & Rezabek, 2008a). As technology becomes integrated into the teaching and learning process, the role of the classroom teacher changes noticeably. Classroom teachers become facilitators who assist students in constructing their own understandings and capabilities in carrying out tasks on computer technologies. The shift occurs from routine lecturing, which often still occurs in the secondary classrooms, to constructing knowledge, which supports a constructivist approach in learning (Collins, 2001; Hannafin & Hill, 2002).

In this study, the lessons, exercises and assessments were developed to integrate the constructivist approach in the Fathom-based instruction. During the lesson, the student connects past knowledge about the data and statistical concepts while carrying out lessons using Fathom educational software; students are able to reconstruct new knowledge as they interact and discuss with each other. The hands-on and real data will also assist in the deeper understanding in statistical reasoning. Moreover, the information learned can be retained and transferred to the subsequent class or be applied to the real world (Garfield & Ben-Zvi, 2008; Lovett & Greenhouse, 2000). Constructivism helped the researcher to uncover how teachers teach and learn to teach enormously. If the efforts in reforming education for all students are to succeed, then it must focus on students. Up to the present time, a focus on student-centered learning may well be the most important contribution of constructivism. Constructivism had provided service to education by alerting teachers to the function of prior learning and available concepts and by making educators aware of the human dimension in subjects such as science and statistics.

2.8 Statistical Reasoning Learning Environment (SRLE)

Learning is a necessary measure when evaluating the appropriateness of instructional design. Learning is student-centered for the constructivist, an activity that the individual must perform. As an active processor of information, the learner creates meaning and once given information, the learner must be able to interpret and often elaborate on it. This is the situation that occurs in an integrated learning curriculum-based classroom. For this reason, the teacher must accept that students are not coming to them as blank slates. The students have already discovered viable ways of dealing with the environment, and to have maximum impact, new information is best related to the current topics the individual accepts (Jonassen & Duffy, 1992).

The teaching and learning of statistics is becoming increasingly challenging due to the change in the perspective of the number of calculations and procedures emphasized in developing statistical reasoning (Garfield & Ben ‑ Zvi, 2007). DelMas (2002) put statistical reasoning as an explicit goal when he nurtured and developed in the classroom. He urged that the experience while learning statistics can have a big impact not only in understanding the statistical emphasis in the calculation process and the procedures to be followed (Garfield & Ben ‑ Zvi, 2007). Therefore, the model Statistical Reasoning Learning Environment (SRLE) was introduced which was based on constructivist learning theory. This approach is used as an interactive learning environment due to a combination of print materials, activities in class, culture and life, discussion, technology, and evaluation of technology used.

The SRLE model consists of six principles of instructional design as described by Cobb and McClain (2004):

1. Focuses on the development of ideas centered not only showed statistical procedures alone.
2. Using actual data in encouraging students to make a hypothesis.
3. Promote activities in the classroom to develop reasoning skills among students.
4. Integrate the use of appropriate technological tools that allow students to explore and analyze data and develop their statistical reasoning.
5. Encourage students to make a statistical argument and explain reasoning done by focusing on the idea of statistically significant.
6. Use the assessments to evaluate teaching plans and progress in developing statistical reasoning.

Teaching and learning process oriented SRLE can help enhance understanding of statistical reasoning skills. Combined use of printed materials, the classroom activities, discussion, use of technology, teaching and assessment approaches can facilitate learning of statistics. Curriculum of statistics should always be updated in learning content, pedagogy and technology used (Moore, 1997).

Garfield and Ben-Zvi (2008) assert that technology plays a very important role in improving student achievement and teacher professional development in statistics. Chance, Ben-Zvi, Garfield, and Medina (2007) argue that technology has changed the method of data analysis. Ben - Zvi and Garfield (2008) showed that students who are using technology create graphs quickly and easily. Technology use in Statistics is said to sharpen the mind to reason and think about the content and concepts of statistics based on statistical ideas (Chance & Rossman, 2001; Garfield, 2002; Zieffler, Garfield, Delmas, & Gould, 2007). Fathom was used in this study to enable students to produce graphs and visualize the multiple representations of data that develop their statistical reasoning. The following Table 2.1 displays the SRLE aspects and instructional activity.

Table 2.1
Statistical Reasoning Learning Environment (SRLE) Aspects

SRLE Aspects	**Instructional Activity Questions**
Focuses on the development of ideas centered not only showed statistical procedures alone.	If the number of classes required is (a) 5 and (b) 8, determine the suitable class intervals that can include all the above data.
Using actual data in encouraging students to make a hypothesis.	Suppose that one battery included in the set of data for brand Y is defective and its lifespan is 0.5 years instead of 5.9 years. Discuss how this would or would not affect Paulo's decision.
Promote activities in the classroom to develop reasoning skills among students.	Survey Project
Integrates the use of appropriate technological tools that allow students to explore and analyze data and develop their statistical reasoning.	1. The number of calories per serving for selected ready-to-eat cereals is listed here. Using Fathom, draw a histogram for the data. 2. Which measure of center is the most suitable to be used to represent the number of children in each family? Explain why.
Encourage students to make a statistical argument and explain reasoning done by focusing on the idea statistically significant.	State, with a reason, whether your answer to part (b) is likely to be high or low.
Use the assessments to evaluate teaching plans and progress in developing statistical reasoning.	Paired quiz (Comparison between graphs)

2.9 Statistical Reasoning Assessment

Assessments are used for many different purposes. These include informing students of their progress, informing teachers of individual student proficiency, and providing feedback on how effectively students are learning the desired material in order to modify instruction. In addition, student assessment data may be used to help instructors learn about and improve their courses, and to provide information to evaluate curriculum and programs.

Jones et al. (2000) and Mooney (2002) mentioned four constructs in their studies: a) describing data, b) organizing data, c) representing data, and d) analyzing and interpreting data. These four constructs of statistical reasoning were adopted from the work of Chan, Ismail, and Sumintono (2016) to identify student understanding in statistical reasoning. Many students face difficulties to reading, analysizing and interpreting data. Besides that, students have misconceptions about measures of central tendency. This continues with difficulties to represent task into mathematical graphs, which leads to incapability in comparing graphs and distributions (Ciancetta, 2007; Clark, Kraut, Mathews, & Wimbish, 2007; Cooper & Shore, 2008; Mevarech, 1983; Pollatsek, Lima, & Well, 1981). Therefore, the framework designed by the researchers to overcome this tendency is more suitable as the framework for this study as this helps in the process of collecting data to answer the research questions. The framework described in table 2.2 developed by the researcher consists of sub-processes for each construct.

Table 2.2
Model of Four Constructs

Construct	Sub-processes
Describing data	i. Extracting and generating information from the data or graph. ii. Showing awareness of the display attributes of the graphical representation. iii. Recognizing the general features of the graphical representation.
Organizing data	i. Organizing data into a computer system. ii. Reducing data using measures of central tendency, either by calculation or aided by technology. iii. Reducing data using measures of spread, either by calculation or aided by technology.
Representing data	i. Demonstrating data sets graphically using a computer. ii. Identifying different representations for the same data set. iii. Judging the effectiveness of two different representations for the same data.
Analyzing and interpreting data	i. Making comparisons within the same data set. ii. Making comparisons between two different data sets. iii. Making a prediction, inference or conclusion among the data or graphs.

2.10 Fathom Dynamic Data Software.

Chief designer Bill Finzer developed Fathom in the mid-1990s. Fathom software enables students to get into the flow of working with and understanding data. Finzer situated the importance of the software in a broader context “all significant problems that we face in the world require people who understand about how to work with data to reach solutions”. The educational software Fathom differs from conventional statistical packages in that it is a pedagogical tool designed for concept development (Finzer, 2001), rather than software designed for professional data analysis. Fathom targets secondary and higher education students. The software was specifically designed to enhance learning and making statistical thinking accessible to students. Its design drew on current studying and several years of academic research about the way students learn and process statistical concepts and the main difficulties they face (Habre, 2013).

Fathom belongs to the new family of educational software in the teaching of statistics that came to be known as dynamic software, which offers an environment that permits the construction and flexible usage of multiple data representations. All of the software’s objects are continuously connected and thus selection of data in one representation means the same data are selected in all representations. Therefore, students can interact with the data and see the immediate impact that their actions will have on the different representations of the data on the screen (Finzer, Erickson, Swenson, & Litwin, 2007).

Meletiou and Stylianou (2003) developed a course, which has its main component a technological tool, Fathom. This study was designed to investigate the effects of a technology-based course on students’ understanding of graphical representations of data. Specifically, they examined how technology affected students' perception of data presented graphically and their approaches to problems involving a strong graphical element. The findings showed that technology integration in the classroom brought about important changes in students' ways of learning statistics. Moreover, using Fathom as a learning tool had increased students' interest in actively pursuing problems involving a difficult graphical element.

Lane-Getaz (2006) researched the progressive integration of Fathom into a senior high school statistics program and provided an example of a teaching professional's use of the software. In the second year of the program, two of five topics, bi-variate data and inference, were delivered in Fathom. In the third year of the study, Fathom was used throughout the course including in the final assessment research project. Lane-Getaz concluded that students, as part of this course, showed improvement in statistical thinking, used statistics more appropriately and accurately, and their interpretations and conclusions showed measurable improvement. The improved student performance was attributed to a number of contributing factors that included Fathom, the use of investigative projects, process oriented software, engaging activities employing the big statistical ideas, formative assessment and the teacher's ability to interweave topics into a conceptual whole. Doerr and Jacob (2011) reported that the choices in representational capabilities in Fathom allowed students to visualize their understanding of sampling distributions. In addition, they found significant improvements in teachers' overall statistical reasoning and in their understanding of graphical representations.

2.11 The Effectiveness of Technology in Mathematics Education

Technological developments have provided many more alternatives to traditional approaches in mathematics teaching and learning. With the availability of technology in the classroom, students have more opportunities to visualize, analyze and investigate important mathematical concepts besides making connections between mathematical ideas and real life. Instead of the traditional deductive approach to learning mathematics, technology can empower teachers and students to learn mathematics through dynamic manipulation of objects that is only possible to learn through computer software. The National Standards Council of Teachers of Mathematics (NCTM, 2000) points out that, technology in teaching and learning mathematics is essential and useful. Even though computer use in teaching and learning processes involve multiple applications, the process of creating mathematics should be given more emphasis than the algorithms and solutions (Noraini, 2006). Technology is absorbed into the school curriculum as a step towards instilling and fostering an interest and a positive attitude towards learning. Researchers have investigated, explored and explained about the technology in teaching and learning of mathematics.

Based on Abdullah and Zakaria (2013) in their quasi-experimental research design investigating the effectiveness of van Hiele's phases of learning geometry using the Geometer's Sketchpad among Form Two students showed that the students' levels of geometric thinking in the treatment group improved compared to the control group. The findings suggest that instruction using van Hiele's phases of learning geometry with GSP had significantly improved students' geometrical thinking. Besides that, a combination of technological tools such as the GSP and graphing calculator in teaching quadratic function contributed to learning (Teoh & Fong, 2005). The study found that visualization using both the technological tools could facilitate learning and increase students' understanding of quadratic functions. Using traditional method of teaching, the ability of visualization is very minimal.

Therefore, teachers are encouraged to practice the technology in teaching and learning statistics.

Arganbright (2005), employed fundamental techniques using Excel to create animated graphical display for teaching mathematics and the result showed improvement after teaching using Excel. The main three criteria looked by the researcher in his study are: (a) should be apt with the mathematics teaching and learning process; (b) fixed time to use the software effectively during the lesson; (c) the software should be effective after lesson and for long-term. Based on the findings, the author stated that technology as Excel meets the criteria well and confront two main benefits from using Excel as a teaching tool. Firstly, Excel is a suitable tool for teaching since it is readily available on computer that is also needed in future employment. Second, students can discuss, demonstrate and share their ideas, techniques, animations, data table and more using Excel.

Dogan and Icel (2011) conducted an experimental study investigating effect of GeoGebra on triangle among eighth-grade students' achievement. The study with pre-post test conducted for two weeks involve a twelve-hour period. Based on the outcome, they concluded that a computer-based lesson is efficient and suitable to be used in the teaching and learning process. Moreover, students achieve high-level thinking skills after implementing GeoGebra in lessons. Technology created positive impact on student learning by motivating students and enhancing their long term memory.

Furinghetti, Morselli, and Paola (2005) explored the phenomenon of covariance by using Cabri for drawing geometric figures, measuring, and sketching graphs. Students involved in the study have difficulties in understand and solve problems when they are not using the Cabri software. After the students used the

Cabri software, however, they were able to understand the lesson well that had been difficult previously. The researchers highlight the need of Cabri by stating, without Cabri the students would have missed the exploration of the role of dependent and independent variables that emerged in the experiment and would have not had the deep insight into linear dependence. Teaching and learning had become fun and students could solve the problem easily with Cabri. Students also believed that indeed the Cabri software facilitated their mathematics learning; teachers too had positive perceptions after using the software. Dahan (2010) who carried out a training session for ten teachers on using Cabri software software found that teachers who use the Cabri software were able to solve all kinds of problems in geometrical shapes more quickly. Not only that, teachers who consider Cabri software as difficult to use had changed their perception and stated that it is fun and easy to use in teaching and learning mathematics.

In order to improve the level of education in our country, the government has provided all the necessary equipment for computer-aided teaching that is believed to fulfill the aspirations of the government to ensure quality education for every student. Therefore, government encourages technology use in teaching and learning. Hardware and software technology can benefit the students by increasing their understanding of a concept, providing visuals and simplifying complex calculations. The uses of software that can help create a visualization of mathematical concepts can facilitate learning of abstract concepts. The software can also help students explore their modeling problems more effectively (Pusat Perkembangan Kurikulum (PPK), 2010).

2.12 The Effectiveness of Technology in Statistical Reasoning

Garfield and Ben‑Zvi (2007) believes that technology can be an effective tool in teaching statistics. Technology such as the visualization software Fathom and TinkerPlots assists students in exploring data and reasoning statistically. Technology has an extraordinary potential to improve student's accomplishment and educators skill development, and keep on impacting the training and the teaching of statistics in numerous ways. This is aligned with a study done by Doerr and Jacob (2011) investigating the understanding in sampling distribution using Fathom. The findings reveal that Fathom had representation capabilities that enable students and teachers to understand the topic in depth. There was a significant improvement in students' statistical reasoning and graphical representations. This proves that using dynamic statistical software in the classroom is able to develop students understanding on statistics. For instance, NCTM principles and standards for school mathematics states that "the existence, versatility, and power of technology make it possible and necessary to reexamine what mathematics students should learn as well as how they can best learn it" (p. 3). This is aligned with the Guidelines for Assessment and Instruction in Statistics Education (GAISE) curriculum framework for PreK-12 stating that "advances in technology and in modern methods of data analysis of the 1980s, coupled with the data richness of society in the information age, led to the development of curriculum materials geared toward introducing statistical concepts into the school curriculum as early as the elementary grades" (p.3) (Franklin & Garfield, 2006).

Konold (2007) examined technology use in the data management. He found data can be entered into the computer using a technology such as TinkerPlots, namely the replacement of directly using data cards or table or import it from a worksheet or website. In Thailand, TinkerPlot software was used in class to calculate statistics mean and standard deviation through problem-based learning approach. In the study Khairiree and Kurusatian (2009), students and teachers are required to complete a task involving data collection by themselves in respect of heavy backpacks. The study found that they could build the plot to explore and analyze the data. Students use the TinkerPlot software to deepen their understanding of data analysis and provide a variety of solutions described or represented in four forms of graphs. TinkerPlot allows teachers and students to use the tool to draw over the plot and show the trend of the graph.

Data modeling through the formulation of a graph and making its interpretation has been the main characteristic of statistics education in Australia and presented by using ICT (Ben-Zvi, 2000). Ben-Zvi conducted a study on the changes that emphasize three main subtopics frequency dispersion data in table form, the basic size as the range, mode, mean and median, and graphic representations such as bar charts. The activities created a platform for students to consider data as a distribution and provided the opportunity to see, recognize and describe the changes. Spreadsheet package (Excel) is used during the execution of this experimental study. According to Ben-Zvi, even if Excel is not the appropriate tool for the analysis of data this software provides direct access for students to see and explore data in various forms, such as manipulation of the model differences in the scatter plot. After all, this package is used daily in many fields, as well as in other areas of the mathematics curriculum, and can be found in the school computer.

The emphasis should be on how students are able to learn statistics effectively as *The Standards* has deemphasized the traditional way of learning statistics (NCTM, 2000). Students are called to restrain from using memorization techniques and viewing statistics as complete deductive systems. Instead, open exploration, conjecturing and increased attention on mathematical reasoning are encouraged in the teaching and learning of mathematics through technology. Technology such as Fathom can revolutionize the way statistics is taught so that students learn statistics with understanding instead of just relying on the procedural methods for obtaining the right answer. Moore (1997) notified statisticians to remember that “we are teaching our subject and not the tool” (p. 135), and to decide applicable technology for student learning, rather than use the software that statisticians use, which may not be pedagogical in nature.

Ben-Zvi (2000) describes technology in statistical design to support learning in the following ways:

i. The students develop knowledge actively by "doing" and "observing" the statistics.
ii. Create opportunity for students to reflect on the observed experiences.
iii. The development of students' metacognitive ability, which is the knowledge about their learning, thinking process, a sense of responsibility and self-control to make the learning.

Furthermore, hardware and software technologies make teaching and learning statistics more meaningful and interesting. Teachers can give examples from problems in real-life situations. Technology became a platform and a tool to enhance learning besides giving teachers and students more opportunities to get feedback, reflection and revision. Technology provides a wide and easy method for students to create graphs and other visual techniques. This creates a powerful new way of helping students to explore and analyze data, think of the idea of statistics and allows them to focus on interpretation the findings and understanding the concept rather than the mechanism of calculating the statistics.

Each day more choices of technology used are increasing. Students in this era are more likely and able to use this hardware and software. Therefore, it is more important for educators to focus on how best to use existing technology to get optimal benefits from using technology with students. Among the technology that can help in teaching-learning are statistical software packages such as SPSS and Minitab statistics. The education software such as Fathom, TinkerPlots and InspireData can also be used. On the other hand, there are online applications such as Applets, Graphing Calculator and Microsoft Excel. For the scope of this study, teaching technology refers to a well-planned methodology using of Fathom software for teaching and learning statistics in Form Four.

2.13 The Functions of Fathom in Statistical Reasoning

Fathom Dynamic Data Software used in this study is one of the software components available in the market. Fathom software is required to be purchased but there is a trial version for educators to test the software in their teaching. Although this software has to be purchased but its highly effective for teaching and learning of mathematics, particularly statistics topics. Biehler, Ben-Zvi, Bakker, and Makar (2012) state that among the advantages of using software such as Fathom are as follows:

1. Quickly drag-and-drop variables into a graph to visualize distributions and relationships between variables;
2. Through dragging, visualize how dynamically changing data and parameters affect related measures and representations in real time;

3. Link multiple representations of data to informally observe statistical tendencies;
4. Create simulations to investigate and test relationships in the data.

One element of Fathom that makes it simple to learn and beneficial is the capacity to drag-and-drop variables into a graph. This gives a simple way, through synchronous collaboration, to check the circulation of a variable or its relationship with another variable rapidly. This activity of moving is commonplace to most computer users, even young learners (Agudo, Sánchez, & Rico, 2010), making it easier to understand than menu-driven frameworks. This allows students to use the data from the real world to understand the statistics besides making data meaningful for student learning.

This interactive technology use in the classroom makes the teacher as facilitator. It is consistent with the cognitivist theory which states role of teachers is not to drill information into students through repetition, or to spur them into learning through precisely utilized prizes and disciplines. Thus, the instructor's role is to encourage revelation by giving the important resources and by managing learners as they endeavor to learn new information to integrate with the old and to alter the old to oblige the new. Instructors should be responsible for checking the prior knowledge that the learner has when choosing how to construct the curriculum and to present, arrange, and structure new material.

Piaget (1976) has distinguished four essential phases of advancement: sensorimotor, preoperational, concrete operational, and formal operational. The student at formal operational stage (Ojose, 2008) is fit for shaping speculations and concluding conceivable results, permitting the student to develop his or her own mathematics. Moreover, the student regularly starts to create abstract thought patterns where reasoning is executed using pure symbols without the necessity of perceptive data. Reasoning skills at this stage represent to the mental procedure required in the assessing of intelligent incorporate with clarification, inference, evaluation, and application (Anderson, 1990).

It is difficult to envision these days a statistics class that does not use technology in a few ways. With the availability of computers and calculators, students no longer need to spend more time and energy performing dull computations. After seeing how a formula functions, they can mechanize the procedure using technology. This permits students to concentrate on analyze information, allowing them to focus on interpreting the results and testing of conditions as different to the computational mechanics.

2.14 Conceptual Framework

Figure 2.1 illustrates the conceptual framework for the study. It shows how the student statistical reasoning ability is affected by SRLE and by instructions without interventions.

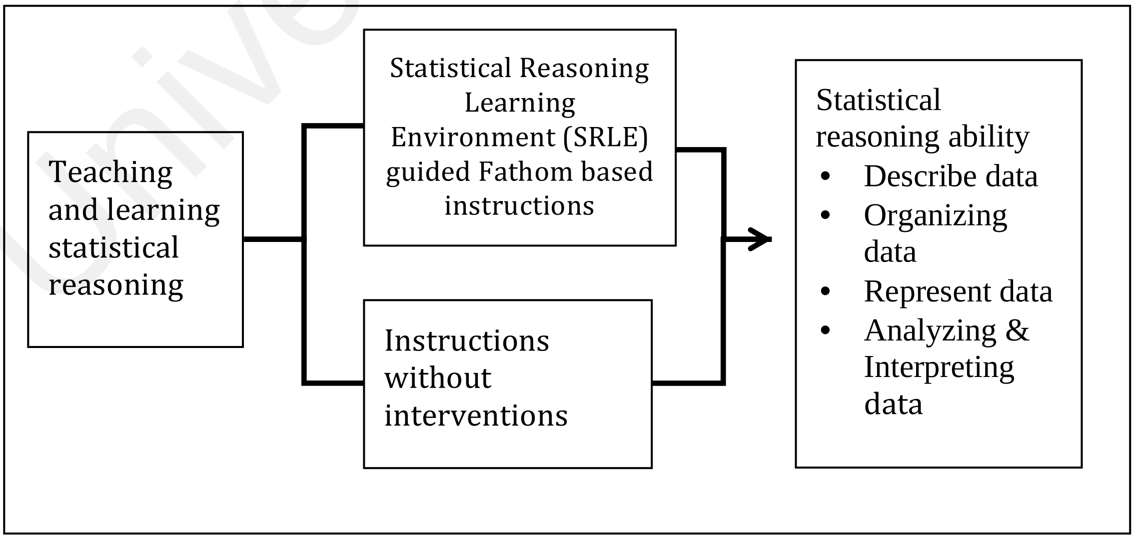

Figure 2.1. Adapted from Cross-sectional model by Richey, Klein, and Nelson (2004). Development Research: Studies of Instructional Design and Development

The process shown in Figure 2.1 represents how the study was carried out to determine the research outcome. The two variables are related with each other such as independent variables and dependent variables. In this study, the independent variable is teaching approach as shown in the first column. Based on the figure, there are two teaching approaches. One of the teaching approaches is using Fathom-based instruction guided by Statistical Reasoning Learning Environment (SRLE). This approach is for students assigned to the experimental group. Students learned statistical reasoning using Fathom dynamic software, and instructional activities based on SRLE and Four Constructs of Statistical Reasoning. Students who learned under this approach receive the treatment through this intervention for eight weeks.

The other teaching approach is instruction without intervention or traditional approach. This approach is for students assigned in the control group. Students in the control group learned statistical reasoning with only textbook and exercises. Teacher delivered knowledge in the traditional method and students did the exercises in the book.

The dependent variable in this study is the subject that is measured, namely the four constructs of statistical reasoning of Form Four students. The students from both groups, experimental and control group were tested in pre and posttest after the interventions for the experimental group.

Based on the review of literature and need of study, the conceptual framework was constructed. This conceptual framework is a combination of Constructivism Theory, as a learning theory that helps describe learning as an active process whereby interaction and collaboration between students and teachers are fundamental to learning. This approach was selected for better understanding the effectiveness of teaching and learning approach on students' statistical reasoning ability.

Additionally, Garfield and Ben-Zvi (2008, 2007) have summarized, that teaching practices that incorporate technology foster students' statistical reasoning ability. This continues with their description of a constructivist approach for instruction called the Statistical Reasoning Learning Environment (SRLE). Instruction with use of the SRLE is in close alignment with NCTM (2000) teaching principles that teachers and students have regular access to technologies that support and advance statistical reasoning, problem solving, and communication. Effective teachers optimize the potential of technology to develop students' understanding, stimulate their interest, and increase their proficiency in statistical reasoning. When teachers use Fathom dynamic software strategically they can provide greater access to statistics for all students (Gadanidis & Geiger, 2010; Nelson, Christopher, & Mims, 2009; Pierce & Stacey, 2010; Roschelle et al., 2010). Besides that, fosters student engagement and classroom discussion between teacher and students (Jansen & Middleton, 2011; Shaughnessy et al., 2005; Smith & Stein, 2011). As a result, Fathom may play a role in enhancing students' statistical reasoning ability.

Jones et al. (2004) and Mooney (2002) mentioned four constructs in their studies: describing data, organizing data, representing data, and analyzing and interpreting data which provides specific descriptors of students' reasoning at each level. Their model was used in this study as guidance to prepare and evaluate statistical reasoning assessment. The models of development in statistical reasoning can be helpful in assessing and monitoring students' performances over time, besides evaluating the effectiveness of classroom instruction. The SRLE also involves components of assessment that include students in the assessment process and use assessment to advance student reasoning. By assessing and observing changes in students' reasoning according to the model, able to identify weaknesses in the teaching methodology and technology, have further refined and monitored changes, and then reassessed the students' reasoning. This cycle of assessment and refinement has great potential in evaluating the pedagogical effectiveness of teaching methodology and use of Fathom.

The conceptual framework in this study serves as the proposed research model of the study to examine whether Fathom-based instruction is able to improve statistical reasoning among Form Four students. Moreover, the statistical reasoning skills were measured across four constructs namely Describing Data, Organizing Data, Representing Data and Analyzing and Interpreting Data.

2.15 Summary

In conclusion, literature review discussed in this chapter support the needs for technology use in learning and teaching statistical reasoning. Various studies have attempted to explain technology use in mathematics and statistics teaching and learning. Past studies provide some basic information as references for conducting this study. Among them is the theory underlying this study, the difficulty of students in the exploration of statistics and technology use in learning statistics. Technology advancement in mathematics and statistics teaching around the world also reflects the need for using technology in mathematics learning in Malaysia. Although technology use in the mathematics curriculum in Malaysia has been introduced and developed since 2001, its use is still at a minimum and statistical reasoning among secondary school students is still limited. Based on the literature, we need to study how Fathom can be used by students for developing statistical reasoning. The study on how to identify the Form Four students' understanding and reasoning skills about statistical problems using Fathom software is suitable to be conducted to get more information from the perspective of the students themselves

CHAPTER 3

RESEARCH METHODOLOGY

3.1 Introduction

This chapter presents the research methods to be carried out, which is an experimental study using the statistical activities to improve the performance and effectiveness of statistical reasoning in students. The chapter discusses the research design, subject of study, and contents of teaching, research instruments, instrument reliability and validity, where the study was carried out, and analysis procedures for research.

3.2 Research Design

To address the research questions, the researcher used quantitative research. Quantitative study is more suitable compared to qualitative because of the measurements of the variables are through inferential statistical. Besides that, in quantitative research the sample selected is numerous based on the research objectives and questions that align with the study objectives. The instrument used in this study is formal which focused on specific topic, form four statistics and had a rubric-marking scheme with measurement scale, which makes this study a quantitative research.

A quasi-experimental non-equivalent pretest and posttest design was study carried out for eight weeks using statistical activities using the Fathom software to improve the performance and effectiveness of statistical reasoning among Form Four students. This design enables the researcher to compare intact groups when random assignment is not possible (Campbell & Stanley, 1963). Although random assignment would strengthen internal validity, it is often unethical or impossible to do when conducting research in educational settings where classes and schedules have been previously established (Glatthorn & Joyner, 2005). A quasi-experimental design is deemed the strongest research design when a true experimental design is not possible. Quasi-experimental design allows the researcher to use existing groups; thus it is more convenient than a true experimental design. Moreover, quasi-experimental design is commonly used to assess the effectiveness of a program if the respondents cannot be distributed randomly (Chua, 2012). In order to determine the causality of an intervention with the target population experimental design was used. An experimental design is more suitable as the research design for this study compared to the correlation design as this helps in the process of testing the significant differences between control and treatment groups which enable to answer this study's research hypothesis. This design consists of two groups of respondents, one as an experimental group and the other as the control group. Meanwhile, a pretest provides a measure on some attribute or characteristic assessed for students in both groups before they receive an intervention. A posttest is a measure on some attribute or characteristic that is assessed for students after an intervention. This study assessed student achievement in statistical reasoning after using Fathom software. A pretest–posttest comparison of students' achievement in statistical reasoning provided accurate data (Campbell & Stanley, 1963). The following Table 3.1 illustrates the research design for this study.

Table 3.1
Quasi-experimental pretest-posttest design

Experimental Group	O_1	X_1	O_2
Control Group	O_1	X_2	O_2

Adapted from Campbell and Stanley (1963). Experimental and Quasi-Experimental Designs for Research.

O_1: Pretest X_1: Teaching using Fathom

O_2: Posttest X_2: Teaching without Fathom

For this study, before the teaching lessons take place, a pretest was given to both groups. Their scores in the test will serve as a major aspect of the data in this study. These two groups were given the same kind of mathematics instruction and the teaching activities presented to both groups were identical. The difference between the two groups is, the treatment group utilized Fathom to learn statistics while the control group was learning without utilizing any Fathom application. After the sample experienced the instruction program, a posttest was given to both groups to measure their achievement in statistics and improvement in statistical reasoning.

The research treatment was based on constructivism theory. The theory has been applied as a guideline and to improve the quality of statistical reasoning learning. Constructivism formulates to be specific when designing an invention by focusing on clear course goals and comprehension objectives that students should accomplish by the end of a lesson. Besides that, helped to emphasize the ways students construct their knowledge, and encourages students to interact with each other as much as possible.

Subsequent to this research instrument, constructivists' encouraged on students' argumentation and the ways they arrive at their responses, and open questions provide an excellent way for students to communicate their thoughts to instructors (Jonassen, 2003). As discussed in previous chapters, constructivist teaching, learning, and assessment methodology all depend on high levels of student activity and is much more subjective. In short, constructivist educational put forth student-centered methodologies, foster open, challenging learning environments, and integrates students' prior experience in the learning process. Overall, constructivism helped this study to plan, design and execute the intervention efficiently and effectively.

3.3 Sample of the Study

The sample of study was selected by convenience sampling; it consisted of seventy-two Form Four students from a secondary school. Convenience sampling was used in this study since not all members of the population could be selected to participate in this study. Besides that, convenience sampling is the most helpful for exploratory stages of studies such as a pilot study. The researcher used a nonequivalent groups design but ensured that both groups are as similar as possible. The researcher selects two classes at the same school, where the students in the two classes have similar scores on a standardized math test. This increased the validity of the study by eliminating some of the most important confounding variables.

Thirty-four students are in experimental group (taught using Fathom) meanwhile the remaining thirty-eight students are in control group. Since all the sample is mix abilities students therefore researcher randomly assigned samples into two groups. According to Fraenkel, Wallen, and Hyun (1993), a sample size needs to be more than thirty units because of the assumption that the normal distribution is usually met when the subject number more than thirty units. In KSSR and KBSM mathematics, students are exposed to statistical topics ranging from Year Three to Form Five. However, the study participants were selected from Form Four because the scope of study is limited to descriptive statistics, which were only taught in Form Four. These students are16 years old, they take the mathematics as a compulsory subject.

Student selection is made on the recommendation of the school head of mathematics and meets the following criteria such as willingness to participate in the study and was actively involved. In this study, the sample were students who passed mathematics with minimum grade of D in the "Pentaksiran Tingkatan Tiga (PT3)" examination. Students involved consisted of the Chinese as the majority, followed by the Indians, Malays and foreigners. Mastery of English as the medium used for mathematics was satisfactory and did not become an obstacle to the process of teaching and learning during the research process.

The study was conducted in a secondary school in the Klang district. The choice of location is based on practical grounds. The school has a computer lab with a sufficient number of computers and facilities to conduct teaching and learning activities smoothly. In addition, the school principal is very cooperative and supports the use of technology to improve student academic achievement. This school

3.4 Instrument of the Study

The statistical reasoning instrument used in this study, namely, Fathom Dynamic Data Software Workshop Guide, pre-test, technology-based statistical reasoning tasks, and post-test. The Fathom Dynamic Data Software Workshop Guide was adopted from Finzer and Erickson (2014). The tutorial was used as guideline to introduce students to the technology, Fathom. The topic covered in these instruments is descriptive statistics, which involves the measures of central tendency and graph distribution. The tasks in the instrument based on technology align with statistical reasoning. It was utilized in the SRLE instruction to develop the students' statistical reasoning ability. This study's instrument was adapted from "Developing Statistical Reasoning Assessment Instrument for High School Students in Descriptive Statistics" (Chan et al., 2016). The original assessment was designed based on the initial statistical reasoning framework to evaluate students' statistical reasoning levels across the four constructs developed by Jones et al. (2000), which fulfill the needs of this study's instrument. Initially, the topics of descriptive statistics covered in original assessment tool measures of central tendency and measures of variability.

The statistical reasoning assessment used in this study was slight modified and eliminated items to fit the Fathom based instructions and to be aligned with syllabus. Items such as measuring of variability were eliminated because Form Four level focuses on measures of central tendency, histogram and frequency polygons. Besides that, number of items in the original instrument was 51. After the validity and reliability performed to ensure the items are suitable for students hence the items were reducing to 13. Besides that, the scoring of the instrument based on rubric was adapted from "Developing Statistical Reasoning Assessment Instrument for High School Students in Descriptive Statistics" (Chan et al., 2016). Rubric of selected items from original assessment were chosen and modified to fit the Fathom based answers. For instance, answer for constructing graph question had been changed from GeoGebra software to Fathom software output. The table 3.2 shows questions selected for this study from the original instrument aligned with four constructs. The assessment attached in Appendix 4.

Table 3.2
Four Key Constructs

Key constructs	**Initial Items**	**Items**
Describing data	2a) Do you know how many fish had a length of 22 centimeters? Why or why not? 2b) Why do you think the scientists were concerned about what they saw in the histogram of the lengths of yellow perch? 2c) Use the histogram to complete the following table.	2a) Do you know how many fish had a length of 22 centimeters? Why or why not? 2b) Why do you think the scientists were concerned about what they saw in the histogram of the lengths of yellow perch? 2c) Use the histogram to complete the following table.
Organizing data	1a) Organize the data into GeoGebra spreadsheet. 1c) What is the mean of the graph? Explain how. 1f) Record the values of the	1a) Organize the data in table form using Fathom. 1c) Find the values of the mean and median. 1f) Record the values of the

	mean, median and standard deviation from the computer.	mean and median.
Representing data	1b) Construct a frequency polygon using GeoGebra spreadsheet. 1d) Represent the data in another way. 1e) Which graphs do you think represents the data better, the histogram or the box plot? Explain why.	1b) Construct a histogram using Fathom with five classes based on the table in (a). 1d) Represent the data in another way using Fathom. 1e) Which graphs do you think represents the data better? Explain why.
Analyzing and interpreting data	1g) Compare the values in question (c) and question (f) which measure of tendency is most affected? Explain your answer. 2d) Sketch a histogram representing a sample of 100 yellow perch lengths that you think would indicate the perch are not in danger of dying out. 2e) If the length of a yellow perch is an indicator of its age, how does this second sample differ from the sample you investigated in the exercises? Explain your answer. 3) Janine has 20 minutes to get to her after-school job. Despite her best efforts, she is frequently late. Her employer says that unless she arrives to work on time consistently, she will lose her job. She has recorded her travel times (in minutes) for the past 7 shifts: 18, 20, 22, 27, 19, 23, and 25. Over the next 7 shifts, she continues to record her travel times: 20, 22, 19, 20, 23, 16, and 25. Do you think Janine will lose her job? Use mean, median and range to justify your answer.	1g) Compare the values in question (c) and question (f) which measure of tendency is most affected? Explain your answer. 2d) Sketch a histogram representing a sample of 100 yellow perch lengths that you think would indicate the perch are not in danger of dying out. 2e) If the length of a yellow perch is an indicator of its age, how does this second sample differ from the sample you investigated in the exercises? Explain your answer. 3) Janine has 20 minutes to get to her after-school job. Despite her best efforts, she is frequently late. Her employer says that unless she arrives to work on time consistently, she will lose her job. She has recorded her travel times (in minutes) for the past 7 shifts: 18, 20, 22, 27, 19, 23, and 25. Over the next 7 shifts, she continues to record her travel times: 20, 22, 19, 20, 23, 16, and 25. Do you think Janine will lose her job? Use mean, median and range to justify your answer.

3.5 Reliability and Validity of Instrument

The instrument used to assess effectiveness of Fathom based instructs in enhancing students' statistical reasoning had undergone evaluation before it could be administered. This had been done through content validation and pilot study. It is very important to check the validity, reliability and practicality of an instrument to draw warranted and conclusions about the achievement score of the sample in this study. An instrument is valid when it is accurately measuring what is supposed to measure (Campbell & Stanley, 1963).

Content validity refers to whether the content of items, whether the scores from the instrument show that the test's content relates to what the test is intended to measure (Creswell, 2002). The researcher had made an extensive search of the literature from theories, previous instruments, frameworks and past research findings for the statistical reasoning instrument. In accomplishing content validity of an instrument, two extensive experienced teachers validated the Statistics Reasoning Assessment. One of the teachers is head of mathematics and had been teaching for 15 years. Meanwhile, another teacher has been teaching for 10 years and has extensive experience in setting mathematics exam questions for upper secondary students. Both teachers were informed of the purpose of the study and they were requested to assess the concept and skills, difficulty level and clarity of the problems as well as whether the language and terms were suitable for Form Four students. Besides that, the researcher had sent the instrument to professors who are experts in this area for validation.

On the other hand, reliability is defined as 'the extent to which test scores are stable and consistent' (Creswell, 2002). Internal consistency reliability is looking at the connection between all items that make up the constructs to ensure that the items are measuring the same concept. The pilot study was intended to investigate any weakness in the research design. It was conducted under the same conditions using similar respondents and the same instrument planned for the study. The pilot study was also intended to test how well the design can be applied in the field, to find errors in the data collection instrument and to locate errors in the interpretation of the data collected. This pilot study was conducted at the secondary schools in Klang. It is not the place of the actual research but it has a similar background to the actual study. Internal consistency reliability was used to check the reliability of the instrument as this study involves only one instrument and it is administered once to all the respondents. Since this study lacks in test-retest reliability aspect as test is administered only once, in terms of instrument practicality, when pilot study was conducted, the respondents were asked to comment on the wording, timing and their understanding of the items. There were 30 subjects in the sample (N = 30) and the Statistical Reasoning Assessment instrument obtained Cronbach alpha of .82; hence the coefficient indicated that the instrument was reliable.

After the pilot test inter-rater reliability was assessed with two different raters to examine the consistency of the statistical reasoning assessment rubric. Inter-rater reliability helps to identify whether the rubric of the instrument considered relatively subjective and precise scoring (Creswell, 2002; Jackson, 2003). The Pearson correlation was used in this study to measure how consistent the raters were in marking the Statistical Reasoning Assessment. Correlation coefficient was used in this study, as it is excellent for measuring the association between two independent raters. One rater was a school mathematics teacher with 10 years of experience teaching secondary school mathematics. Results of the Pearson correlation coefficient indicated a very strong and positive correlation between the two raters' scoring, r (30) = .981, $p < .01$. This indicated strong positive consistency between both raters in scoring, suggesting that the statistical reasoning assessment is reliable.

3.6 Discriminant Index and Index of Difficulty of the Statistical Reasoning Assessment

To determine the validity and reliability of the statistical reasoning assessments questions, the difficulty index and discrimination index were searched based on a pilot study involving a total of 30 students. The analysis to determine the discriminant index and the difficulty index was carried out using the ANATES software. The analysis results from the validity of the instruments are given in Table 3.3 below.

Based on Table 3.3, the discriminant index and index of difficulty of the statistical reasoning assessment questions are at moderate level. Therefore, the difficulty of the question is balanced and almost perfect. The discrimination index value of the test is between 31.25% and 62.50%. This shows the discriminant index of each item of statistical reasoning assessment questions are at a good and very good level. While, for the index value of the difficulty, the subject matter of the statistical reasoning assessment question items is between 36.46 and 68.75. Each item in the question of statistical reasoning assessment has a discriminant index at a moderate level with Cronbach alpha value of .87.

This shows that the reliability of the statistical reasoning assessment questions is at a good level. Therefore, each item in the question for the topic statistical reasoning are used in real studies.

Table 3.3
The Discriminant Index and Index of Difficulty of the Statistical Reasoning Assessment Questions

Question	T	ID	IK	Interpretation of IK	Correlation	Alpha Cronbach
1	3.12	50.00	68.75	Sedang	.671	
2	3.47	37.50	64.58	Sedang	.618	
3	5.00	62.50	56.25	Sedang	.513	
4	3.74	50.00	50.00	Sedang	.678	
5	3.42	37.50	59.38	Sedang	.659	
6	3.12	50.00	68.75	Sedang	.618	
7	3.90	41.67	66.67	Sedang	.616	.87
8	3.42	41.67	45.83	Sedang	.513	
9	4.58	56.25	59.38	Sedang	.503	
10	3.12	33.33	54.11	Sedang	.532	
11	3.86	50.00	68.75	Sedang	.616	
12	3.62	56.25	59.38	Sedang	.603	
13	4.85	31.25	36.46	Sedang	.655	

3.7 Instructional Activities

The researcher was aware of the importance of knowing the fundamentals of selecting the appropriate assessment tools and then constructively plan and conduct classroom environment to make students engage in raw data or primary sources, aiming to develop student's statistical reasoning. Constructivist theory is of great value in this study in efforts to help students be engaged in making and testing estimations using data, discussing and explaining statistical reasoning, and focusing on the importance of statistical reasoning. This study implemented the SRLE's six components that also embedded with constructivist-learning environment. Hence, the constructivist theory is suitable for this study with regard to statistical reasoning and habits of questioning, representing, concluding, and communicating.

These are activities used by the students in learning the topic on Statistics with the Fathom software. The researcher prepared one activity to introduce students to the tools and structures of the Fathom software. Another six activities were prepared for the lessons on Statistical Reasoning aligned with the Statistical Reasoning Learning Environment (SRLE). Students from the treatment group used the Fathom software while students from the control group were not given the experimental treatment. The same teacher taught the two groups and the materials were provided. The activities were planned to help students investigate, construct and reflect on the concept of statistical reasoning. The objectives of each activity are listed in Table 3.4. Two mathematics teachers who had 12 years' experience and 9 years' experience reviewed the instructional activities. They were requested to assess whether the activities and the difficulty levels were suitable for the Form Four students and in line with the Mathematics Syllabus. The instructional activities for the experimental group are attached in Appendix 3 while the control group the lesson plan is in Appendix 1.

Table 3.4
Content of Instructional Activities

Week	Activity	Objectives
1	Introduction to the Fathom (Appendix 2)	i. To construct histogram. ii. To construct plot graph. iii. To draw table from data.
2	Understand the concept of class interval.	i. Complete the class interval for a set of data. ii. Determine the upper limit and lower limit, the upper boundary, lower boundary and size of class interval of a class in a grouped data. iii. Determine suitable class interval iv. Construct a frequency table for

		a given set of data.
3	Understand and use the concept of mode and mean of grouped data.	i. Determine the modal class from the frequency table of grouped data. ii. Calculate the midpoint of a class. iii. Calculate the mean from the frequency table of grouped data. iv. Discuss the effect of the size of class interval on the accuracy of the mean for a specific set of grouped data.
4	Draw a histogram based on the frequency table of a grouped data.	i. Draw a histogram based on the frequency table of a grouped data.
5	Interpret information and solve problems from a given histogram.	i. Interpret information from a given histogram. ii. Solve problems involving histograms.
6	Draw the frequency polygon.	i. Draw the frequency polygon based on: a) a histogram, b) a frequency tables.
7	Interpret information and solve problems from a given frequency polygon.	i. Interpret information from a given frequency polygon. ii. Solve problems involving frequency polygon.

3.8 Procedure

After carrying out the pilot test to ensure the reliability and validity of the instrument the researcher obtained permission from a school to carry out the actual research. The experimental group received the intervention outside classroom time. The objectives of the research project were explained to the students and they were told to give their best cooperation. In the beginning, students from the control and treatment group were given a pre-test. Pre-test was conducted to ensure that two groups were equal in understanding of statistics. Students were instructed to show all the steps involved in their solutions.

In addition, they were told that the tests that they sat for in this study would not affect their own school’s test score. All the questions in the tests were subjective and based on the topics in Statistics. The summary of the data collection procedure is presented in Table 3.5.

Table 3.5
Data Collection Table

Week	Day	Lesson/Activities/Test	Time	Sample Group	Content/ Topic
1	Day 1	Statistics Test	1 hour	Treatment Control	All that covered in form four syllabus
	Day 2	Fathom Basic Workshop (Aishah et al.)	1 hour and 20 minutes	Treatment	-
2	Day 3	Lesson 1 (L1) Activity 1 (A1) Guide (E1)	1 hour and 20 minutes	Treatment	Understand the concept of class interval
3	Day 4	Lesson 2 (L2) Activity 2 (A1) Guide (E2)	1 hour and 20 minutes	Treatment	Understand and use the concept of mode and mean of grouped data.
4	Day 5	Lesson 3 (L3) Activity 3 (A3) Guide (E3)	1 hour and 20 minutes	Treatment	Use Fathom to draw a histogram based on the frequency table of a grouped data.
5	Day 6	Lesson 4 (L4) Activity 4 (A4) Guide (E4)	1 hour and 20 minutes	Treatment	Use Fathom to interpret information and solve problems from a given histogram.
6	Day 7	Lesson 5 (L5) Activity 5 (A5) Guide (E5)	1 hour and 20 minutes	Treatment	Use Fathom to draw the frequency polygon based on: a) a histogram, b) a frequency table.
7	Day 8	Lesson 6 (L6) Activity 6 (A6) Guide (E6)	1 hour and 20 minutes	Treatment	Use Fathom to interpret information and solve problems from a given frequency polygon.
8	Day 9	Statistics Test	1 hour	Treatment Control	All covered in form four syllabus

3.9 Data Analysis

The quantitative data were analyzed with the Statistical Packages for the Social Sciences Personal Computer (SPSS). In order to answer the first research question, one-tailed paired-samples *t*-test was carried out to determine the significance of the mean difference between pre-posttest in the experimental group. Next, ANCOVA test was carried out to determine the significance of the mean difference between the control and experimental group on the statistical reasoning performance outcome. ANCOVA statistic was selected for a number of reasons. ANCOVA test is the best instrument for analysis that is based on adjusted pretest mean scores using posttest measures. ANCOVA can test the significance of differences among means of final experimental data. It also removes the effects of any environmental source as such variation that could inflate the environment error. Thus the researcher in this study used ANCOVA statistic to ensure that the results were not attributed to other teaching approaches during the experiment.

Moving on to the third research question, a one-tailed paired-samples *t*-test was done to analyze the differences in pre-posttest score means of four statistical reasoning constructs in the experimental group. For answering the last research question, MANCOVA was used to analyze whether the learning method has any differences between the four constructs. MANCOVA was chosen because it involves the use of covariance that serves as a measure. Another reason is that MANCOVA will control the control variable (covariate), which is a factor that does not want to be studied, but it affects the dependent variables. This allows seeing the exact effect of independent variables on dependent variables without unwanted interference.

3.10 Summary

The study used quasi-experimental design as it is intended to collect data to verify the assumptions in the research questions. The students in the experimental group used the Fathom-based instructional activities while the students in control group learn the same material without any intervention. Both groups learned the same learning topics and were provided the same instructional activities. Statistical Reasoning Assessment was given to both groups to answer the research questions.

CHAPTER 4

FINDINGS

4.1 Introduction

This chapter presents the data analysis of the results based on the data collected. The data were obtained from the statistical reasoning achievement test on the use of dynamic software Fathom in learning statistical reasoning from 72 Form Four students. The findings were able to provide insight into the effects of Fathom dynamic software in developing students' statistical reasoning.

The aim of this research is to examine the effectiveness of Fathom based instruction in enhancing statistical reasoning of Form Four students. The statistical reasoning achievement test was administered as a pretest before the intervention was carried out. Then, test was again administered at the end of the intervention as posttest. The statistical tool used to analyze the data in this study is SPSS (Statistical Packages for the Social Sciences). Results of achievement test were analyzed using paired-sample *t*-test, Analysis of Covariance (ANCOVA) and MANCOVA, in order to investigate the research hypothesis.

4.2 Findings of First Research Question

RQ 1: Is there any significant difference in the Statistical Reasoning of Form Four students after the Fathom-based Instructions of the experimental group?

H_o 1: There is no significant difference in the Statistical Reasoning of Form Four students after the Fathom-based Instructions of the experimental group.

H_1 1: There is a significant difference in the Statistical Reasoning of Form Four students after the Fathom-based Instructions of the experimental group.

Assumptions of Paired *t*-Test

Table 4.1 shows that data were normally distributed for experimental group, as assessed by Shapiro-Wilk test ($p_{pretest}$ = .34 and $p_{posttest}$ = .77).

Table 4.1
Shapiro-Wilk Test of Pre-Posttest Scores for Experimental Group

Teaching approach		*Shapiro-Wilk*		
		Statistic	*df*	*p*
Experimental group (Fathom-based)	Pretest	.965	34	.340
	Posttest	.980	34	.770

This study used skewness and kurtosis to check the normality of the data. Table 4.2 shows the results of normality testing. Based on Chua (2013), for data to be normally distributed, the skewness and kurtosis values should be in the range of -1.96 to +1.96. Normal distribution of the pre-test means score and post-test mean score indicates no violation of normality assumption for all the dependent measures. Hence, the pre-test and post-test for the statistical reasoning were analyzed for normality of distribution for the experimental group. In this study, the distribution of data is normal because the skewness and kurtosis values are within the normal distribution range. Therefore, the assumption is met.

Table 4.2
Skewness & Kurtosis of Pre-Posttests Scores for Experimental Group

			N	*Skewness*		*Kurtosis*	
	Mean	*SD*	*Statistics*	*Statistics*	*Std. Error*	*Statistics*	*Std. Error*
Pretest	14.97	5.713	34	-.220	.403	-.840	.788
Posttest	21.24	5.571	34	.124	.403	-.487	.788

Result of Paired *t*-test

A one-tailed paired-sample *t*-test was conducted to evaluate whether a significant mean difference existed in Statistical Reasoning between form four students before and after using Fathom-based instruction in the experimental group. The effect size was calculated using the mean differences and standard error, (21.24 - 14.97) ⁄ 5.63 = 1.11. As table 4.3 shows, a statistically significant mean increases of 6.265, 95% CI [9.042, 3.488], t (33) = 4.589, $p < .05$ with a large effect size d = 1.11.

Table 4.3
Paired Samples Test for Experimental Group

		Paired difference							
					95% Confidence Interval of the Difference				
		Mean	SD	Std Error	Lower	Upper	*t*	df	Sig.
Experimental Group	Posttest Pretest	6.265	7.959	1.365	9.042	3.488	4.589	33	.000

Based on the result, the null hypothesis stating the mean of the pretest and posttest scores of form four students in statistical reasoning are different in the experimental group at significant level of .05. The effect size for post-test is 1.11. These results indicate that learning Statistical Reasoning using dynamic software, Fathom do differ in students' achievement. The effect size indicates that use of Fathom-based instruction has a large effect on students' achievement in Statistical Reasoning. Thus, the data provide sufficient evidence to conclude that the Form Four students' statistical reasoning abilities in the experimental group improved significantly after using Fathom-based instruction.

4.3 Findings of Second Research Question

RQ 2: Is there any significant difference in the Statistical Reasoning of Form Four students in control and experimental groups after controlling the pre-test?

H_0 2: There is no significant difference in the Statistical Reasoning between Form Four students in control and experimental groups after controlling the pre-test

H_1 2: There is a significant difference in the Statistical Reasoning between Form Four students in control and experimental groups after controlling the pre-test

Assumptions of ANCOVA

ANCOVA statistical analysis was computed to answer whether there is any significant effect on the statistical reasoning assessment score of the dependent variable. The research design is quasi-experimental pretest-posttest design with non-equivalent group. The design is needed when the researcher strongly suspects that the pretest measurement will affect the posttest responses in a way that could easily lead to incorrect inferences about the cause (Cook & Reichardt, 1979; Field, 2013). Therefore, analysis of covariance (ANCOVA) is used to test the main and interaction effects of categorical variables on a continuous dependent variable, controlling for the effects of selected other continuous variables, which co-vary with the dependent. To run the ANCOVA statistical analysis there a few assumptions need to be met. Figure 4.1 illustrated evidence of independence; the points fell relatively randomly above and below the horizontal reference line at zero. Therefore, the assumption of independence has been met.

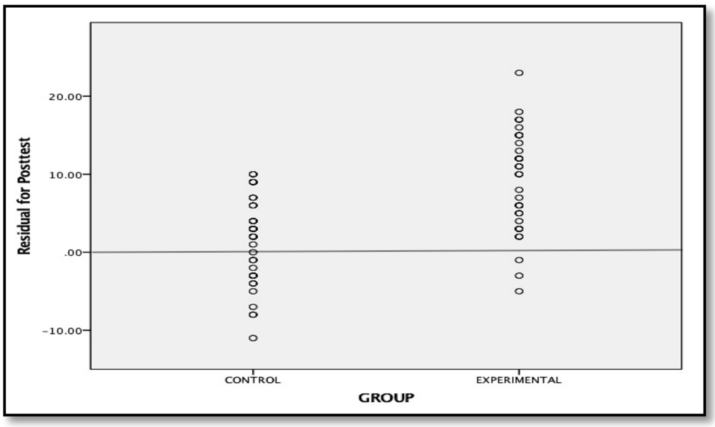

Figure 4.1. Assumption of Independence

Furthermore, the scatterplot assessed to measure the assumptions of linearity was fulfilled, as there was a linear relationship between the posttest scores and pretest score as a covariate for control and experimental groups. Moreover, the boxplot shows there are no outliers in data.

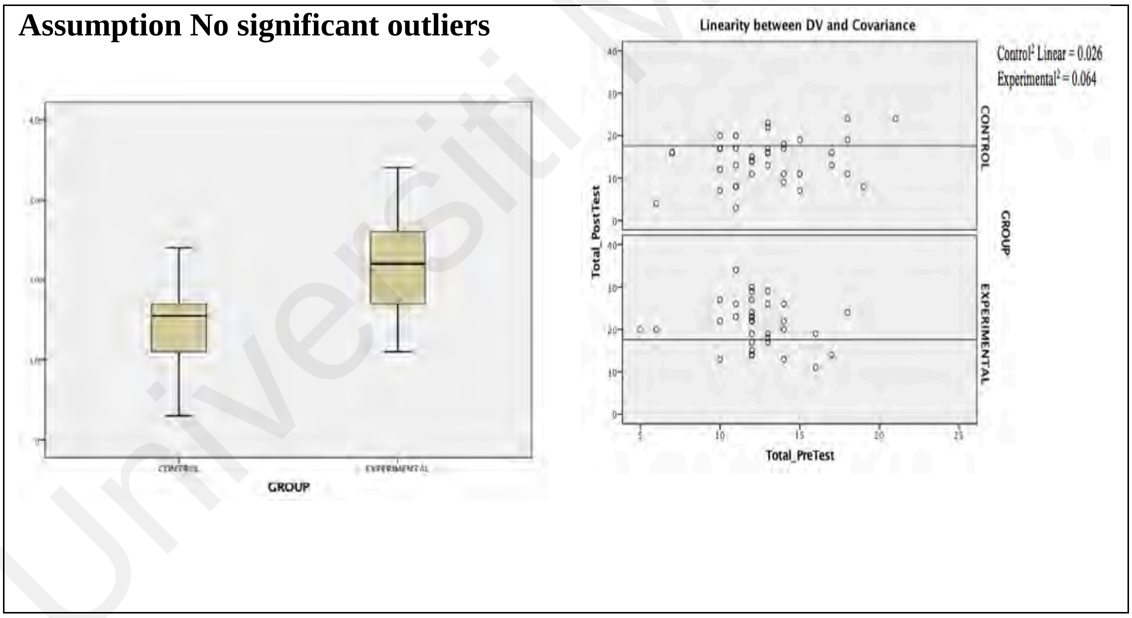

Figure 4.2. Assumptions of outliers and linearity

Table 4.4 shows that there was homogeneity of regression slopes as the interaction term was not statistically significant, F (1, 68) = 2.74, p = .102.

Table 4.4
Assumptions of Homogeneity of Regression Slopes

Source	*Type of Sum of Square*	*df*	*Mean Square*	*F*	*p*
Corrected Model	939.347[a]	3	313.116	10.809	.000
Intercept	1030.179	1	1030.179	35.564	.000
Group	228.805	1	228.805	7.899	.006
Pretest	.332	1	.332	.001	.915
Group*Pretest	79.493	1	79.493	2.744	.102
Error	1969.764	68	28.967		
Total	25240.000	72			
Correlated Total	2909.111	71			

a. *R* Squared = .323 (Adjusted *R* Squared = .293)

The homogeneity of variance-covariance is assessed by Levene's test of homogeneity of variance. The test result as shown in Table 4.5 reveals there is no significant difference between the experimental group and the control group (F = .086, p = .771). This result indicates that the assumption of homogeneity of variance was not violated. Therefore, the two groups are equal before the treatment. Thus, the scores of students in the experimental and control groups were analyzed using ANCOVA analysis.

Table 4.5
Levene's Test of Homogeneity of Variances

F	*df1*	*df2*	*P*
.086	1	70	.771

Tests the null hypothesis that the error variance of the dependent variable is equal across groups.

In addition, Table 4.6 shows the standardized residuals for posttest were normally distributed as assessed by Shapiro-Wilk's test for control group (SW = .99, df = 38, p = .61) and experimental group (SW = .98, df = 34, p = .77).

Table 4.6
Standardized Residual for Posttest for Control and Experimental Groups

	Groups	*Shapiro-Wilk Statistics*	*df*	*p*
Standardized Residual for Posttest	Control	.997	38	.607
	Experimental	.980	34	.770

Results of ANCOVA

As the required assumptions were met the descriptive and inferential analyses on scores were conducted. The adjusted mean of posttest score of statistical reasoning for control group were 14.48 (*SE* = .893, 95% CI [12.70, 16.26]) and for the experimental group it was 21.11 (*SE* = .946, 95% CI [19.22, 23.0]) respectively as shown in table 4.7.

Table 4.7
Adjusted Means of Posttest of Statistical Reasoning Score for Control and Experimental Groups

Group	Mean	Std. Error	95% Confidence Interval	
			Lower Bound	Upper Bound
Control	14.480[a]	.893	12.698	16.262
Experimental	21.110[a]	.946	19.224	22.997

a. Covariates appearing in the model are evaluated at the following values: Pretest= 12.63

Additionally, Figure 4.3 shows the estimated marginal means of posttest score where the adjusted mean of posttest for the experimental group was higher than the adjusted mean of posttest of the control group after the intervention.

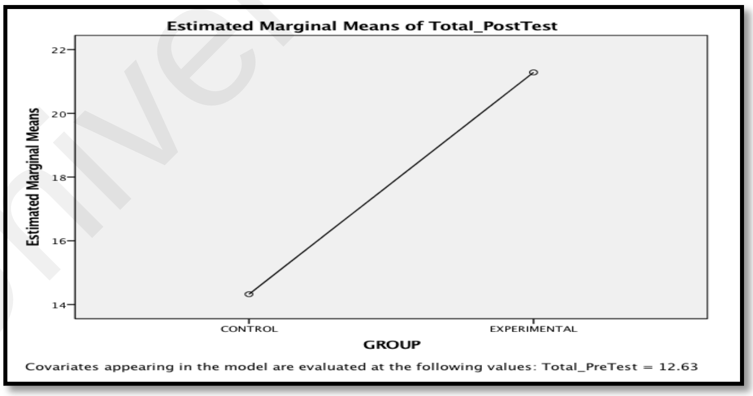

Figure 4.3. Adjusted Means of posttest score for control and experimental groups

Table 4.8 shows the Test of Between-Subjects Effects result conducted to determine a statistically significant difference between Statistical Reasoning test score between Form Four students in experimental and control groups when controlling for the pretest. The results reveal that there is a statistically significant difference in the mean of the posttest score in Statistical Reasoning assessment between control and experimental group after controlling for the pre-test, F (1,69) =25.36, p< .05, with a large effect size (partial η^2 = .93). The effect size suggested that about 93% of the variance in posttest scores could be accounted for by the treatments in the experimental group. Moreover, the observed power = 1 indicates maximum power; the probability of rejecting the null hypothesis if it is really false is 1. Thus, the null hypotheses stating the mean of Statistical Reasoning test score had no differences between Form Four students' in experimental group and control group when controlling for pretest, is rejected at the .05 significance level. Post hoc analysis was not performed as this study has two groups only. The data provided is sufficient evidence to conclude that there is a significant difference in statistical reasoning score between Form Four students learning with Fathom-based and students who learned without any intervention.

Table 4.8
Tests of Between-Subjects Effects

Source	Type of Sum of Square	df	Mean Square	F	Sig.	Partial Eta Squared	Observed Power[b]
Corrected Model	866.035[a]	2	433.018	14.624	.000	.298	1.000
Intercept	1819.210	1	1819.210	61.439	.000	.417	1.000
Pretest	19.884	1	19.884	.672	.415	.007	1.000
GROUP	750.983	1	750.983	25.363	.000	.927	1.000
Error	2043.076	69	29.610				
Total	25240.000	72					
Correlated Total	2909.111	71					

a. R Squared = .296 (Adjusted R^2 = .275) b. Computed using alpha = .05

4.4 Findings of Third Research Question:

RQ 3: Is there any significant difference in Statistical Reasoning Constructs Describing Data, Organizing Data, Representing Data and Analyzing and Interpreting Data of Form Four students after the Fathom-based Instructions of the experimental group?

Ho 3: There is no significant difference in Statistical Reasoning Constructs Describing Data, Organizing Data, Representing Data and Analyzing and Interpreting Data of Form Four students after the Fathom-based Instructions of the experimental group.

H_1 3: There is a significant difference in Statistical Reasoning Constructs Describing Data, Organizing Data, Representing Data and Analyzing and Interpreting Data of Form Four students after the Fathom-based Instructions of the experimental group.

Descriptive Statistics

Table 4.9 shows descriptive statistics of statistical reasoning constructs of experimental group for both pre-post tests

Table 4.9
Descriptive Statistics Pre-Posttest Scores for Statistical Reasoning Constructs in Experimental Group

	Test	Constructs	Mean	N	Std. Deviation
Pair 1	Pretest	Describing	5.91	34	.244
	Posttest	Describing	5.00	34	.267
Pair 2	Pretest	Organizing	5.56	34	.271
	Posttest	Organizing	3.97	34	.241
Pair 3	Pretest	Representing	4.94	34	.283
	Posttest	Representing	3.00	34	.296
Pair 4	Pretest	Analyzing	4.82	34	.265
	Posttest	Analyzing	3.00	34	.267

Assumptions of Paired *t*-Test

Table 4.10 shows that data were normally distributed for all the statistical reasoning constructs in the experimental group for both pre-post tests as assessed by Shapiro-Wilk test.

Table 4.10
Shapiro-Wilk Test of Pre-Posttest Scores for Statistical Reasoning Constructs in Experimental Group

Teaching Approach	Constructs	*Shapiro-Wilk*		
		Statistic	*df*	*p*
Experimental Group (Fathom-based)	Pretest Describing data	.957	34	.198
	Pretest Organizing Data	.948	34	.103
	Pretest Representing Data	.952	34	.139
	Pretest Analyzing and interpreting Data	.957	34	.198
	Posttest Describing data	.955	34	.171
	Posttest Organizing Data	.951	34	.136
	Posttest Representing Data	.954	34	.166
	Posttest Analyzing and interpreting Data	.954	34	.157

Skewness and kurtosis were used to check the normality of the data. Table 4.11 shows the results of normality testing. According to Chua Yan Piaw (2013), for data to be normally distributed, the skewness and kurtosis values should be in the range of -1.96 to +1.96. Normal distribution of the pre-test mean score and post-test mean score indicates no violation of normality assumption for all the dependent measures. Hence, the pre-test and post-test for the statistical reasoning were analyzed for normality of distribution for the experimental group. In this study, the distribution of data is normal because the skewness and kurtosis values are within the normal distribution range. Therefore, the assumption is met.

Table 4.11

Skewness & Kurtosis of Pre-Posttest of Statistical Reasoning Constructs for Experimental Group

Test	Constructs	*N*	*Skewness*		*Kurtosis*	
		Statistic	*Statistics*	*SE*	*Statistics*	*SE*
Pretest	Describing Data	34	.010	.403	.493	.788
	Organizing Data	34	.364	.403	.880	.788
	Representing Data	34	.010	.403	.713	.788
	Analyzing and interpreting Data	34	.010	.403	.423	.788
Posttest	Describing Data	34	.097	.403	.458	.788
	Organizing Data	34	.106	.403	.550	.788
	Representing Data	34	.073	.403	.639	.788
	Analyzing and interpreting Data	34	.209	.403	.332	.788

The result of testing the assumption revealed that there were no outliers, as assessed by the boxplot in Figure 4.4.

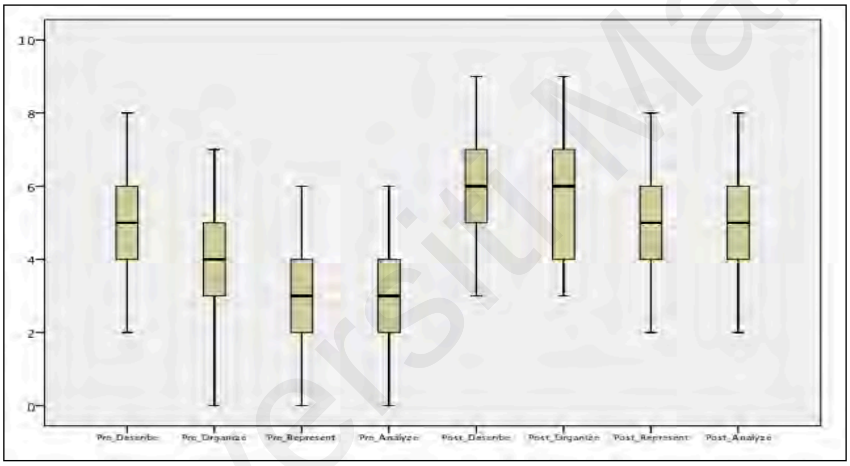

Figure 4.4. Assumption of no Outlier

Result of Paired *t*-Test

The third research question was analyzed by paired-samples *t*-test; the findings showed a statistically significant mean increase for all the four constructs, namely Describing data

.912, 95% CI [.267, 1.557], *t* (33) = 2.876, Organizing Data 1.588, 95% CI [.829, 2.347], *t* (33) = 4.256, Representing Data 1.941, 95% CI [1.082, 2.800], *t* (33) = 4.599 and Analyzing and Interpreting Data 1.824, 95% CI [1.048, 2.599], *t* (33) = 4.785, $p < .05$.

Table 4.12
Paired Sample Test

Teaching Approach		Constructs	M	95% CL LL	UL	*t* (33)	*p*
Experimental Group	Pair 1	Post_Describing-Pre_Describing	.912	.267	1.557	2.876	.000
	Pair 2	Post_Organizing-Pre_Organizing	1.588	.829	2.347	4.256	.000
	Pair 3	Post_Representing-Pre_Representing	1.941	1.082	2.800	4.599	.000
	Pair 4	Post_Analyzing-Pre_Analyzing	1.824	1.048	2.599	4.785	.000

Based on the result, the hypothesis stating the mean of the pretest and posttest scores of Form Four students in statistical reasoning are different in the experimental group at significant level of .05 is accepted. Thus, the data provide sufficient evidence to conclude that the Form Four students' statistical reasoning abilities in experimental group improved significantly after using Fathom-based instruction.

4.5 Findings of Fourth Research Question

RQ 4: Is there any significant difference in Statistical Reasoning Constructs Describing Data, Organizing Data, Representing Data and Analyzing and Interpreting Data of Form Four students after the Fathom-based Instructions of the control and experimental groups after controlling for the pretest?

H_0 4: There is no significant difference in the Statistical Reasoning Constructs Describing Data, Organizing Data, Representing, Data and Analyzing and Interpreting Data of Form Four students after the Fathom-based Instructions of the control and experimental groups after controlling for the pretest.

H_1 4: There is a significant difference in the Statistical Reasoning Constructs Describing Data, Organizing Data, Representing, Data and Analyzing and

Interpreting Data of Form Four students after the Fathom-based Instructions of the control and experimental groups after controlling for the pretest.

Assumptions of MANCOVA

To answer research question four, Multivariate analysis of covariance (MANCOVA) statistics was used. A few assumptions of MANCOVA statistics analysis need to be met before we can run the test. Figure 4.4 shows the results of testing assumptions indicated that there were no univariate or multivariate outliers as assessed by boxplot.

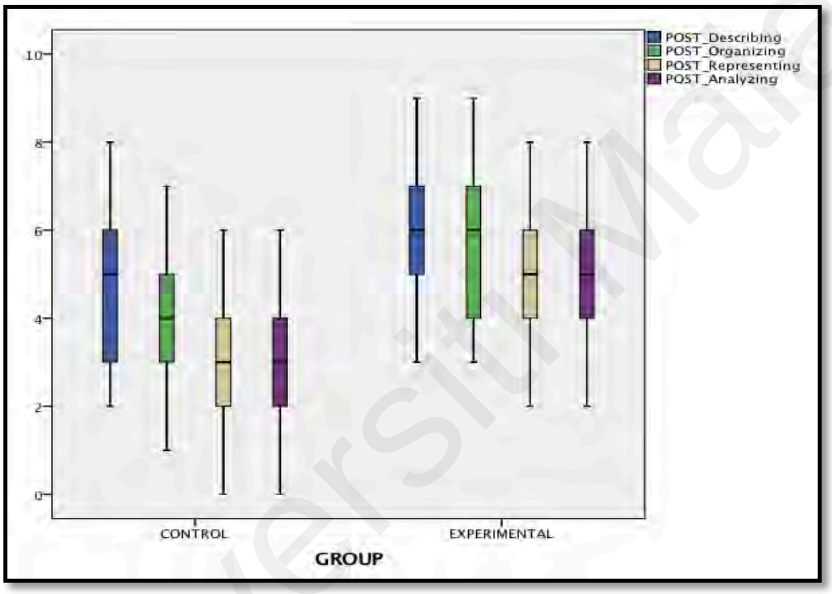

Figure 4.5. Assumptions of no univariate

Moreover, the data were normally distributed for statistical reasoning constructs namely, Describing Data, Organizing Data, Representing Data and Analyzing and Interpreting Data for both groups. Table 4.13 shows the Shapiro-Wilk test (p > .05) for checking the assumption of normality.

Table 4.13
Assumption of Multivariate Normality

	Group	Shapiro-Wilk Statistics	df	*p*
Posttest Total Average Describing Data	Control	.952	38	.104
	Experimental	.955	34	.171
Posttest Total Average Organizing Data	Control	.954	38	.121
	Experimental	.951	34	.136
Posttest Total Average Representing Data	Control	.954	38	.119
	Experimental	.954	34	.166
Posttest Total Average Analyzing and Interpreting Data	Control	.956	38	.138
	Experimental	.954	34	.157

Table 4.14 shows there was homogeneity of variance matrices, as assessed by Box's M test (*M* = 14.08, *F* = 1.32, *p* = .212).

Table 4.14
Box's Test of Equality of Covariance Matrices

Box's M	14.080
F	1.321
df1	10
df2	22750.965
P	.212

Table 4.15 shows that the assumption of homogeneity of variance-covariance was met, as assessed by Levene's test of homogeneity of variances for four constructs, namely: Describing Data (*F* = 1.103, *p* = .303), second construct Organizing Data (*F* = .245, *p* = .550), followed by third construct Representing Data (*F* = .320, *p* = .481) and lastly Analyzing and Interpreting Data (*F* = 1.020, *p* = .919).

Table 4.15
Assumption of Homogeneity of Variances

	F	*df1*	*df2*	*p*
Posttest Total Average Describing Data	1.103	1	70	.303
Posttest Total Average Organizing Data	.245	1	70	.550
Posttest Total Average Representing Data	.320	1	70	.481
Posttest Total Average Analyzing and Interpreting Data	1.020	1	70	.919

The shape of the scatterplot shows linearity of variable was oval shaped hence the relationships between variables were linear as shown in Figure 4.5.

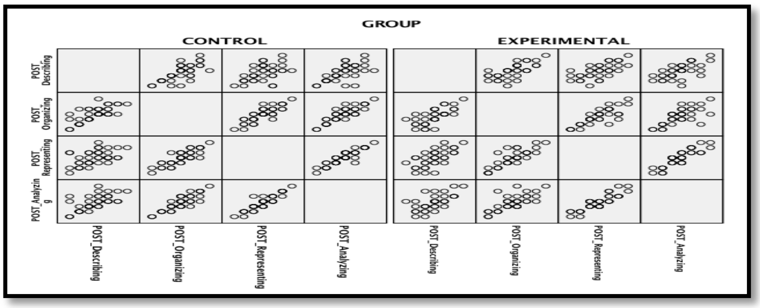

Figure 4.6. Linearity between DV and Covariate for constructs of IV

The next assumption homogeneity of regression slope was met since the interaction term while controlling the pretest score was not statistically significant for all the four constructs as shown in Table 4.16. The first construct Describing Data *F* (2,64) = .87, *p* = .43 was not statistically significant, Organizing Data *F* (2,64) = 3.81 was not statistically significant, *p* = .30, Representing Data *F* (2,64) = 1.39 was not statistically significant, *p* = .26 and lastly Analyzing and Interpreting Data *F* (2,64) = 1.81, *p* = .18 was not statistically significant.

Table 4.16
Homogeneity of Regression Slop
Tests of Between-Subjects Effects

Source	Dependent Variable	*df*	*F*	*P*
Group*Pre_Describing*Pre_Organizing*Pre_Representing*Pre_Anlayzing	Posttest Total Average Describing Data	2	.87	.43
	Posttest Total Average Organizing Data	2	3.81	.30
	Posttest Total Average Representing Data	2	1.39	.26
	Posttest Total Average Analyzing and Interpreting Data	2	1.81	.18

Result of MANCOVA

The result of adjusted means of post-test score for four constructs is presented in Table 4.17. The post-test score of Describing Data while controlling for pretest for control group (*M* = 4.668, *SE* = .279, 95% CI [4.111, 5.224]) was different than for the experimental group (*M* = 5.812, *SE* = .299, 95% CI [5.216, 6.409]). The adjusted mean of posttest score of Organizing Data was different between control (*M* = 3.881, *SE* = .285, 95% CI [3.312, 4.449]) and experimental (*M* = 5.692, *SE* = .305, 95% CI [5.083, 6.301]) groups. Posttest score of Representing Data for control (*M* = 2.936, *SE* = .291, 95% CI [2.354, 3.517]) and experimental (*M* = 5.013, *SE* = .312, 95% CI [4.390, 5.636]) was also different; and also, the total average score of posttest of Analyzing and Interpreting Data was different between the control (*M* = 2.787, *SE* = .287, 95% CI [2.213, 3.360]) and experimental (*M* = 4.826, *SE* = .308, 95% CI [4.212, 5.441]) groups.

Table 4.17
Adjusted Mean of Posttest Scores for Each Statistical Reasoning Construct in Control and Experimental Groups

Dependent Variable	Group	Mean	Std. Error	95% Confidence Interval	
				Lower Bound	Upper Bound
Posttest Describing	Control	4.668[a]	.279	4.111	5.224
	Experimental	5.812[a]	.299	5.216	6.409
Posttest Organizing	Control	3.881[a]	.285	3.312	4.449
	Experimental	5.692[a]	.305	5.083	6.301
Posttest Representing	Control	2.936[a]	.291	2.354	3.517
	Experimental	5.013[a]	.312	4.390	5.636
Posttest Analyzing	Control	2.787[a]	.287	2.213	3.360
	Experimental	4.826[a]	.308	4.212	5.441

a. Covariates appearing in the model are evaluated at the following values: Pre_Describing = 4.94, Pre_Organizing = 3.97, Pre_Representing = 2.97, Pre_Analyzing = 2.01.

These differences visualized by the generated plots of estimated marginal means of posttest scores in terms of Describe Data, Organizing Data, Representing Data and Analyzing and Interpreting Data as shown in Figure 4.6.

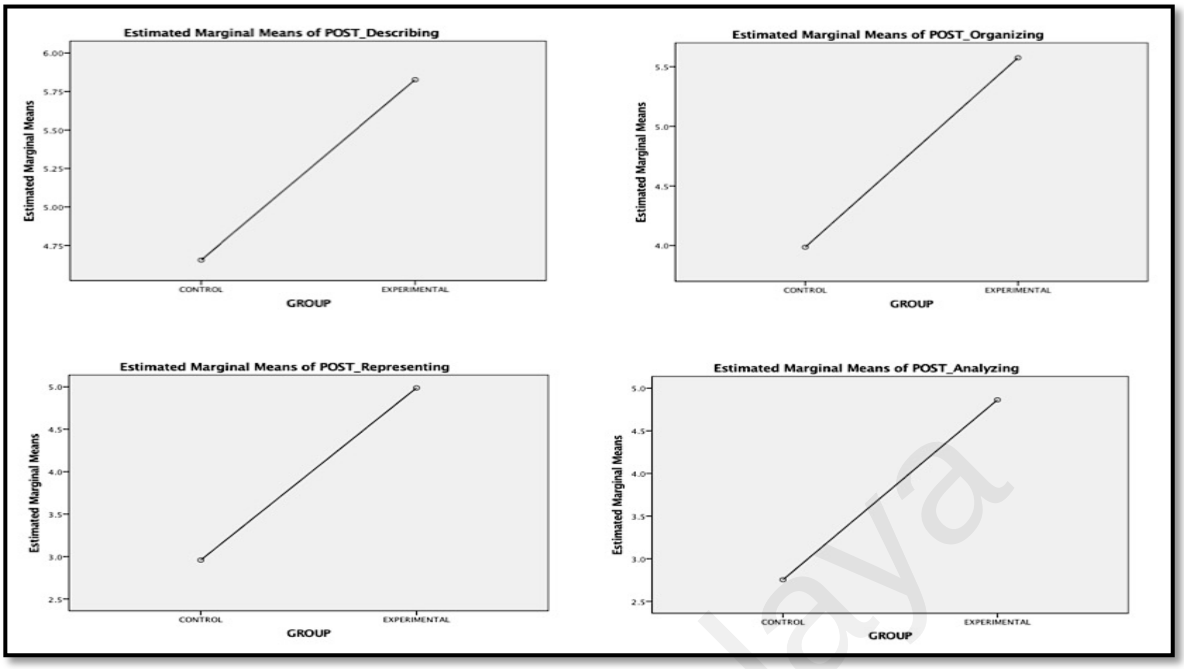

Figure 4.7. Estimated Marginal Means of Posttest Scores for Each Construct

The multivariate tests in table 4.18 shows that the differences between the control and experimental groups on the statistical reasoning constructs was statistically significant, F (4, 63) = 4.852, p < .005; Wilks' Λ = .60, with large effect size and observed power (partial η^2 = .236, observed power = 1). Thus, this study rejects the null hypothesis stating the mean of the posttest score of Describe Data, Organizing & Reducing Data, Represent Data and Analyzing and Interpreting Data of Form Four students showed no significant different between experimental and control groups after controlling pretest scores. The data provided evidence to conclude that there is a significant difference in term of Describing Data, Organizing Data, Representing Data and Analyzing and Interpreting Data between form four students in control and experimental groups while controlling for pretest scores.

Table 4.18

Adjusted Mean of Posttest Scores for Each Statistical Reasoning Constructs in Control and Experimental Groups

Multivariate Tests

	Value	*F*	*Hypothesis df*	*Error df*	*p*	*Partial Eta Squared*	*Observed Power*
Wilks' Lambda	.764	4.852[b]	4.000	63.00	.000	.236	1.000

The Tests of Between-Subject Effects presented in table 4.19 had adjustment for pretest scores and showed a statistically significant difference in the mean of the posttest score in Statistical Reasoning Constructs for experimental and control group, Describing Data posttest score F (1,64) = 6.286, $p < .005$, partial $\eta^2 = .09$; Organizing Data posttest score F (1,64) = 15.10, $p < .005$, partial $\eta^2 = .19$; Representing Data posttest score F (1,64) = 18.97, $p < .005$, partial $\eta^2 = .22$ and Analyzing and Interpreting posttest score F (1,64) = 18.80, $p < .005$, partial $\eta^2 = .22$ were statistically significantly different between the control and experimental groups after controlling for the pretest scores. Post hoc analysis was not performed as this study has two groups only. The data provided sufficient evidence to conclude that there is a significant difference in Statistical Reasoning Constructs namely, Describing Data, Organizing Data, Representing Data and Analyzing and Interpreting Data between Form Four students in control and experimental groups while controlling for pretest scores.

Table 4.19
Test of Between-Subjects Effects

Source	Dependent Variable	Type III Sum of Square	df	Mean Square	F	Sig.	Partial Eta Squared
GROUP	Posttest Describing data	14.128	1	14.128	6.286	.000	.087
	Posttest Organizing Data	35.386	1	35.386	15.100	.000	.186
	Posttest Representing Data	46.546	1	46.546	18.970	.000	.223
	Posttest Analyzing and interpreting Data	44.861	1	44.861	18.802	.000	.222

4.6 Summary

Results of the achievement test analyzed using paired-samples *t*-test showed a significant difference between pretest and posttest scores in the experimental group. Meanwhile, analysis of covariance (ANCOVA) used to investigate the research hypothesis showed that students in the experimental group that learned statistical reasoning using Fathom performed significantly better than students in the control group that learned statistical reasoning without any intervention. Furthermore, the paired-samples *t*-test analysis reveals the experimental group performance was better across the four constructs of statistical reasoning compared to the control group. The fourth research hypothesis was analyzed using MANCOVA test. The data analysis showed there is a statistically significant difference across four constructs between Form Four students in the experimental group when controlling for the pre-test.

CHAPTER FIVE

DISCUSSION AND CONCLUSION

5.1 Introduction

This study investigated the effect of Fathom-based instructions to enhance Form Four students' statistical reasoning. This quasi-experimental research was conducted in a school located in Klang, Selangor. Participants consisted of 38 mixed ability students in the control group and 34 students in the experimental group. Data were collected quantitatively and analyzed statistically using paired *t*-test, ANCOVA and MANCOVA tests. This section of the study presents the summary of findings, discussion, implications and recommendations for further studies.

5.2 Summary of Findings

First Research Question

Is there any significant difference in the Statistical Reasoning of Form Four students after the Fathom-based Instructions of the experimental group?

The first research question was analyzed by paired-samples *t*-test; the findings showed a statistically significant mean differences of 6.265, 95% CI [9.042, 3.488], $t(33) = 4.589$, $p < .05$ with a large effect size $d = 1.11$. Based on the result, the null hypothesis stating the mean of the pretest and posttest scores of form four students in statistical reasoning are different in the experimental group at significant level of .05. Thus, the data provide sufficient evidence to conclude that the statistical reasoning ability of Form Four students in the experimental group improved significantly after using Fathom-based instruction.

Second Research Question

Is there any significant difference in the Statistical Reasoning of Form Four students in control and experimental groups after controlling for the pre-test?

The second research hypothesis was analyzed by ANCOVA; analysis showed the adjusted mean of posttest score for statistical reasoning in the control group was 14.48 (*SE* = .893, 95% CI [12.70, 16.26]) and in the experimental group it was 21.11 (*SE* = .946, 95% CI [19.22, 23.00]). The results of ANCOVA reveal that there is a statistically significant difference in the mean of the posttest score in Statistical Reasoning assessment between control and experimental group after controlling for the pre-test, F (1,69) = 25.36, $p < .05$, partial $\eta^2 = .93$ at the significance level of .05.

Hence, there is a statistically significant difference in statistical reasoning scores between Form Four students in the control and experimental groups. Based on the estimated marginal means of posttest score the students who learned statistical reasoning using Fathom performed better than students who learned without any intervention.

Third Research Question

Is there any significant difference in Statistical Reasoning Constructs Describing Data, Organizing Data, Representing Data and Analyzing and Interpreting Data of Form Four students after the Fathom-based Instructions of the experimental group?

The third research question was analyzed by paired-samples *t*-test; the findings showed a statistically significant mean increase for all the four constructs, namely Describing data .912, 95% CI [.267, 1.156], t (33) = 2.876, Organizing Data 1.588, 95% CI [.829, 2.347], t (33) = 4.256, Representing Data 1.941, 95% CI [1.082, 2.800], t (33) = 4.599 and Analyzing and Interpreting Data 1.824, 95% CI [1.048, 2.599], t (33) = 4.785, $p < .05$.

Based on the result, the null hypothesis stating the mean of the pretest and posttest scores of Form Four students in statistical reasoning are different in the experimental group at significant level of .05. Thus, the data provide sufficient evidence to conclude that the Form Four students' statistical reasoning abilities in experimental group improved significantly after using Fathom-based instruction.

Fourth Research Question

Is there any significant difference in Statistical Reasoning Constructs Describing Data, Organizing Data, Representing Data and Analyzing and Interpreting Data of Form Four students after the Fathom-based Instructions of the control and experimental groups after controlling for the pretest?

The fourth research question was analyzed by MANCOVA and showed that the result of adjusted means of post-test score of Describing Data while controlling pretest for the control group (M = 4.668, SE = .279, 95% CI [4.111, 5.224]) was different than for the experimental group (M = 5.812, SE = .299, 95% CI [5.216, 6.409]). The adjusted mean of posttest score of Organizing Data was different between control (M = 3.881, SE = .285, 95% CI [3.312, 4.449]) and experimental (M = 5.692, SE = .305, 95% CI [5.083, 6.301]) groups. The adjusted mean for posttest of Representing Data for the control (M = 2.936, SE = .291, 95% CI [2.354, 3.517]) and the experimental (M = 5.013, SE = .312, 95% CI [4.390, 5.636]) group was also different; and also, the total average score of posttest of Analyzing and Interpreting Data was different between the control (M = 2.787, SE = .287, 95% CI [2.213, 3.360]) and experimental (M = 4.826, SE = .308, 95% CI [4.212, 5.441]) groups. Moreover, the Multivariate Tests show that the differences between the control and experimental groups on the statistical reasoning constructs were statistically significant, F (4, 63) = 4.852, p < .005; Wilks' Λ = .60, with large effect size, partial η^2 = .236 and observed power (observed power = 1). Thus, this study rejects the null hypothesis stating the mean of the posttest score of Describe Data, Organizing &

Reducing Data, Represent Data and Analyzing and Interpreting Data of Form Four students was not significantly different between experimental and control groups after controlling for pretest scores. Besides that, the plots of estimated marginal means of posttest scores showed students learned statistical reasoning using Fathom scored better than students who learned without any intervention in each construct of statistical reasoning namely, Describing Data, Organizing Data, Representing Data and Analyzing and Interpreting Data.

5.3 Discussion of the Findings

In this section, the discussion of the results in chapter four is presented. The discussion is divided into two parts based on the two objectives of the study. The first part discusses the effectiveness of Fathom teaching approach on students' statistical reasoning, while the second section deals with the effectiveness of the Fathom teaching approach on students across four constructs in statistical reasoning as well as the effectiveness of Fathom teaching approach in comparison to the traditional teaching approach without intervention.

5.3.1 Effectiveness of Fathom-based Instruction in Statistical Reasoning

Review of literature has shown that students with low statistical reasoning skills will have difficulties interpreting and understanding statistical data and graphs (Ben-Zvi, Gravemeijer, & Ainley, 2018; DelMas et al., 2005; Gal, 2004). This can leave students unprepared in today's data-driven world and unable to think statistically. Therefore, it is crucial to introduce and expose students to statistical reasoning from school level. Statistical reasoning is able to develop students' reasoning skills and made them question the context of the data. Students experienced the process of data collections, data exploration, analyzing data, how conclusions can be drawn and investigate statistical interpretations in a virtual world.

However, chalk-and-talk approach was unable to provide much information as it focused more on computations and students were unable to engage in sustained exchanges that focus on significant ideas (Cobb & McClain, 2004; Dogan & Icel, 2011; Garfield & Ben-Zvi, 2004; Zieffler, delMas, Garfield, & Brown, 2014). Hence, there is a need to change instructional practices and tools employed in the classroom to teach statistical reasoning differently to help students to improve statistical reasoning by using the technology as a tool for making comparisons, predictions and generalization (Burrill & Biehler, 2011; Rubin, 2007). Therefore, this study employed technology to investigate "Effectiveness of Fathom based Instruction in Enhancing Statistical Reasoning of Form Four Students". The findings of the study reported that there were statistically significant differences in students' statistical reasoning between students who learned using dynamic software, Fathom in the experimental group compared to students who learned without any intervention in the control group. Based on the findings, it can be concluded that students who learned statistical reasoning using Fathom-based instructions showed improvement compared to students who learned without any intervention.

The use of Fathom software helped students to visualize the representations of data. Students can select different graphical representations by choosing from the menu at the corner of the graph object as shown in figure 5.1.

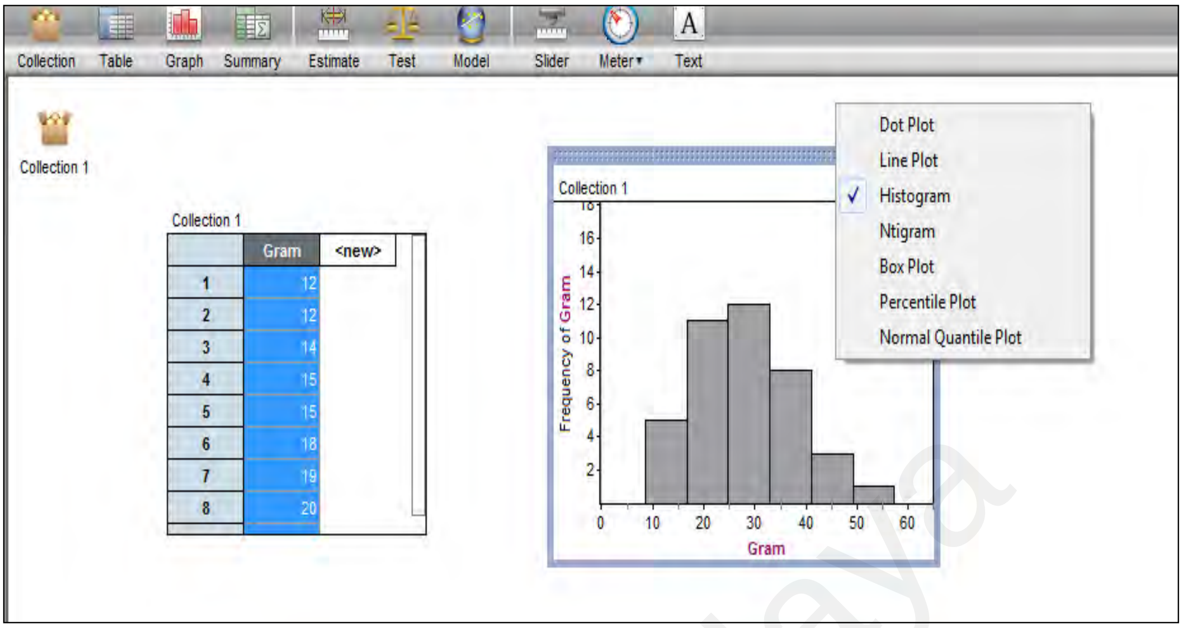

Figure 5.1. Feature of Fathom

Students actively construct their own knowledge with the provided tool (Fathom) rather than copying knowledge transmitted to them. Besides that, students had the chance to change graphs from histogram to frequency polygons and vice versa in the shortest time that enable them to compare the graphs. Doerr and Jacob (2011) studied the representational capabilities using Fathom and found it allowed students to visualize their understanding of sampling distributions and significantly improved students' statistical reasoning and their understanding of graphical representations. Additionally, findings of Meletiou-Mavrotheris and Paparistodemou (2015) stated that learning using technology had an effective impact on students' responsiveness of representativeness and of the ways to ensure representativeness.

Students also learn better by 'doing' or 'hands-on' activities. Fathom-based instruction encouraged students to learn by experiencing the lesson through seeing and doing. The instructional activities used in the experimental group involving Fathom made students experiment or test the statistics data compared to control group that learned in chalk-and-talk. For instance, students are required to change the width of a histogram to see what happens to the number of class groups (Figure

5.2). Based on the outcome, students were able to understand the relationship between class width and number of classes. In the activity, the technology provided students with opportunity to compare different type of representation of histogram that would be impossible to create in the shortest time without the use of Fathom.

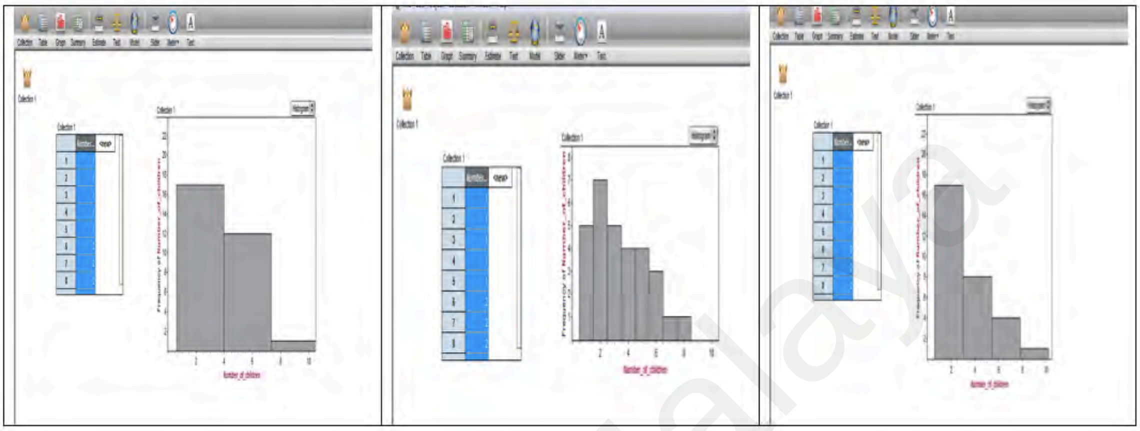

Figure 5.2. Sample answer from student when changing the width of histogram

Therefore, hands-on activities encourage students to experiment with their ideas and doubts to learn better, think critically, analyze information, communicate ideas and make arguments (Scheaffer, 2001). When students are encouraged to do those things over and over in many different contexts, their performance improves. Merely repeating and reassessing tasks improved skills or deeper understanding unlike in the control group. This is supported by Finzer (2001) who stated that the software will allow students to investigate relationships in the data because Fathom allows easy creation of graphs through a drag-and-drop process; students can examine data directly and create simulations to test conjectures.

Based on the findings, communication enables students to think together about the ideas and problems. Fathom provided opportunity for students to communicate effectively during the instructional activities using the statistical terms to solve statistical problems, draw conclusions, and justify conclusions by explaining the reasons behind them. Since the experimental group used Fathom software to perform basic computations, students had many chances to discuss their exploration of a variety of information from the data. Meanwhile, the control group had to spend more time to construct and perform basic computations rather than discussing the important aspects in statistical reasoning; thus, this limits the communication and spontaneous feedback during the lesson (Ben-Zvi, 2007). Fathom provided a focus around which the students discussed with one another and their teacher about the data and graphs on the screen. Eventually, students challenged each other's ideas and sought clarification and further explanation. Therefore, this encouraged students to think deeply about the answers given in order to justify or explain them.

The SRLE approach focuses students learning environment with constructivism learning. The activities organized for students integrated the use of technology as a tool that allows students to actively participate in order to develop their statistical reasoning. A variety of assessment methods involving Fathom were used to capture the full participation of students (e.g., written and oral presentation on answers, paired quiz and survey) compared to the control group that primarily used textbooks and workbooks. With Fathom, the teacher used actual data in encouraging students to make a conclusion. Recent studies have proposed that technology-based learning with well-planned lessons will help students learn statistical concepts (Ben-Zvi et al., 2018; Brahier, 2016; Eichler & Zapata-Cardona, 2016). The findings supported by Loveland and Schneiter (2014) stated that both constructivist methodology and technology play a significant role in enhancing students' statistical reasoning ability and statistical concepts by providing them competent access to view and design simulations.

The results of this study align with the results of some prior studies that examined two different instruction methods such as utilized technology and traditional method. These two methods were implemented in a class to determine the best instructional technique that was able to improve students' scores. The results showed that students who learned with technology performed better because the technology tool engaged them in the statistical reasoning activities which focused on promoting higher standards of reasoning skills by enabling them to make comparisons, predictions and generalization of the data (Burrill & Biehler, 2011; Rubin, 2007).

5.3.2 Effectiveness of Fathom-based Instruction across Four Constructs of Statistical Reasoning

This study continued to analyze the difference in Statistical Reasoning Constructs namely, Describing Data, Organizing Data, Representing Data and Analyzing and Interpreting Data between Form Four students in the experimental group after controlling for the pre-test. The four statistical reasoning constructs by Jones et al. (2004) were able to identify whether students' statistical reasoning have been improved. The questions in the statistical reasoning assessment were adopted based on the four constructs. Students in both control and experimental group answered the questions in the pre- and posttest.

Based on the findings, for the first statistical reasoning construct, "Describing Data" the experimental group performed well compared to the control group ($M_{Experimental}$ = 5.81 and $M_{Control}$ = 4.67). Describing data is a fundamental step to begin extracting and developing awareness of graphical representation. When students see each data provides meaning, they are able to generate information from data. Students face difficulties in describing data because most traditional classrooms focused on computations and constructing graphs without paying attention to the meaning behind the data and graphs (Kleanthous & Meletiou-Mavrotheris, 2018;

Shaughnessy et al., 2005). Therefore, this study emphasized statistical reasoning by asking students "why" questions to make them think and reason why an event or situation took place. The instructional activities questions involved technology as suggested in the SRLE and constructivism theory where students construct knowledge when confronting new and unfamiliar questions or environments.

The findings of the second construct "Organizing Data" showed that students in the experimental group scored better than those in the control group ($M_{Experimental}$ = 5.69 and $M_{Control}$ = 3.88). Organizing data enable students to arrange or classify data into particular graphical forms to illustrate data trends. Through this, students were able to identify and measure the central tendency such as mean, median, mode and range. However, misconceptions in data, measure of central tendency and graph always happen among the students (Garfield & Chance, 2000; Rumsey, 2002; Yoclu & Haser, 2013). Recent studies have proposed technology-based learning for helping students to learn statistics (Ben-Zvi et al., 2018; Brahier, 2016; Eichler & Zapata-Cardona, 2016). This study gives priority for students to understand the concepts rather than memorizing the computation steps. By embedding constructivism in learning, this study encourages students to practice by themselves while engaging in activities, so that students will adapt the knowledge they receive with existing knowledge to build new knowledge.

During classroom activities, students are required to collect and organize data by themselves. After organizing the data, students made interpretations and discussed among peers and their teacher. Based on feedback, students were able to understand that statistics has different interpretations for the same data. There is no one correct answer in statistical reasoning as projected in the traditional statistics classroom. With help from Fathom, the teacher was able to show clearly and precisely the arrangement of data in the frequency table and the measure of central tendency located (mean, median and mode). Students had been taught to compare, predict and justify the conclusion made from the measure of central tendency. Overall, students in the experimental group showed better performance than those in the control group after being provided with worksheets with effective activities, and using Fathom to explore the data and arguing their answers among peers.

The next or third construct is "Representing Data." This study used Fathom as a tool to construct graphs that made students focus on reasoning and prevented them from misconceptions on constructing graphs. Students face difficulties to identify and justify the correct graph as the traditional teaching method focused on constructing graphs without reasoning the idea of selecting a particular statistical representation (Gal, 2002). Hence this study used Fathom to construct graphs to help students to reason and visualize the different graphical representation for the same data. The findings showed that the experimental group with Fathom instruction performed well with higher mean score (M = 5.01) than the control group (M = 2.94). As technology has the ability to show the outcome immediately it does not require more time to construct different graphs at one time especially during teaching. Hence, students had opportunity to actively engage in discussions as they did presentation and discussions of their graphs with peers. Moreover, students were aware of what was needed to construct graphs and presented suitable graphs according to situational requirements. When teacher posts a question such as 'How does your line graph help you see changes in number of births differently than the table does?' even though most of the students were able to identify and judge the correct graphical representation they could not explain using statistical terms for their answers. For instance, when a question from statistical reasoning assessment asked, ‘which graphs do you think represents the data better? Explain’. Students were able to identify the better representation but somehow their explanation are not precisely related on how the features of graph helped to identify the pattern, as displayed in Figure 5.3.

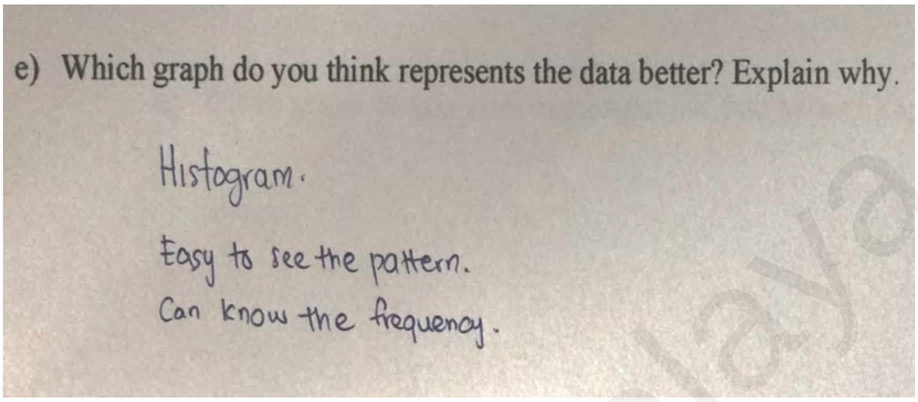

Figure 5.3. One of solution from experimental group student

The final construct is “Analyzing and Interpreting Data”, considered the most difficult construct in statistical reasoning. Fostering analyzing and interpreting skills is one of the core challenges faced by teachers especially in statistics. Students generally think that statistics involves numerous numbers and boring topics (Saldanha & Thompson, 2002). One reason for this is that teachers use the same approaches when teaching students and struggle to engage them in reasoning with and about statistics knowledge. The urge to complete the syllabus may cause teachers to lead in a teacher-centered way. Studies show that students continue performing poorly in statistical reasoning even though the aspects of statistics in the form of basic and integrated process skills were introduced from the primary school level (Mullis et al., 2016; TIMSS, 2011). This study highlighted teaching and learning would involve reasoning skills that increase students’ interest and challenge their imagination. A constructivist-learning environment was created using Fathom that piques the curiosity of the students and encourages them to explore the topic in depth. Thus, students will not fear statistics and willingly investigate, reflect and converse. The findings showed students in the experimental group outperformed those in the control group. The experimental group obtained mean score of 4.83 that is higher than the control group mean score of 2.79. When compared to other constructs the mean score of experimental group for analyzing and interpreting data is lowest. However students had used their own words to interpret their explanation correctly as shown in Figure 5.2.

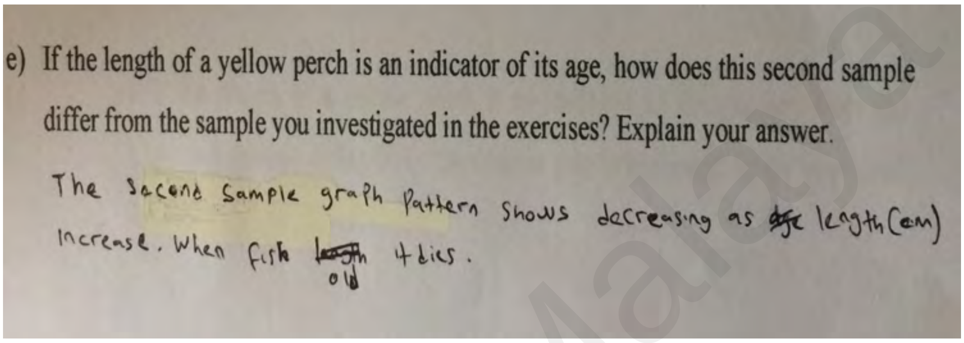

Figure 5.4. One of solution from experimental group student

The use of key terms or concepts of statistical reasoning was still lacking and students tend to explain their answers in informal ways. However, the findings showed improvement in the experimental group after being taught using Fathom. Continued application of teaching and learning strategies enable students to further improve their analyzing and interpreting skills

Effectiveness of statistical reasoning of students using Fathom had been evaluated and identified using the Jones et al. (2004) four constructs aligned with the statistical reasoning learning environment (SRLE) which was developed using constructivism. The constructivism theory helped this study to see students as "active learning seekers" in the learning process. The learning process in this study took place after students actively participated in understanding and interpreting what they had learned. Fathom-based instructions do not isolate students from peers and teachers. Teacher's role changed based on constructivist learning where the teacher is a facilitator rather than an instructor who transmits knowledge. Communication between students was more prominent when conducting the activities and the students are confident to explore even when at times they are out of topic in the assignment. Overall, Fathom has provided an effective learning environment for students.

5.4 Contributions of the Study

The Fathom-based instruction places students in a hands-on situation where their statistical reasoning was developed. Constructivism aspects of active learning, construction of own knowledge, self-regulated and self-directed learning were combined with Fathom technology to provide a meaningful experience for the students. Therefore, the students who learned statistical reasoning with Fathom-based Instruction performed better than students who learned without any intervention. The findings of this study make significant contributions to the literature on students' statistical reasoning and how this affects further on statistics and data. Besides that, this study provides real-time activities and application where students work with discrete and continuous quantities interchangeably. Based on this, future researchers and teachers are able to get insight into using real-time instructional activities in the classroom as well as being supportive of several curricular strategies. On the other hand, it provides teachers with an alternative curriculum that addresses not only prerequisite knowledge and skills that support the acquisition of statistical reasoning. Lastly, the inquiry method used during the tasks will foster an important transformation in the students' understanding of statistical reasoning. This study encourages teachers and educators to implement technology in teaching and learning to develop student reasoning.

5.5 Implications of Research Findings

Two main implications of research findings are discussed under this section: a) Implication for Statistical Reasoning teaching and learning; b) Implication for Curriculum Development.

a) Implication for Statistical Reasoning Teaching and Learning

This study has important implications for improving students' statistical reasoning. The result of the study indicated that the groups of students who use Fathom demonstrate a higher gain in their post-test score compared to the pre-test scores within the group. Meanwhile, the group of students who do not use Fathom only showed slight improvement after being taught without using any intervention. Moreover the four constructs of Statistical Reasoning by Jones helped to identify the students' statistical reasoning abilities. The results of this study showed students from the experimental group performed better than those in the control group for each construct, namely, describing data, organizing data, representing data and analyzing and interpreting data. These findings show this teaching approach provided positive outcome and was useful for students as well as for teachers. When teachers implement Fathom-based statistical activities, students are taught how to explore, analyze, conclude and investigate data by providing suitable statistical interpretations. Moreover, Fathom provided opportunities and supported students to explore the data by retrieving and applying their prior knowledge during the statistical reasoning learning process and creating new knowledge. Hence, findings of this research are able to provide information for teachers on how to create better teaching methods for improving students' statistical reasoning and increasing their interest through Fathom-based instruction.

Based on the theoretical aspects, the findings of this study are in congruence with the statistical reasoning-learning environment. Students learn statistical reasoning by developing central statistical ideas, using real data, activities focusing on developing statistical reasoning, integrating technology (Fathom), discussion and communication and appropriate assessments. This learning environment will help students to engage in constructing and testing inferences using data, involve in discussions, explanations and reasoning the solution or prediction made which enables development of their statistical reasoning skills. Teachers can implement the statistical reasoning learning environment (SRLE) aligned with various meaningful tasks to be explored by students within the Fathom environment. Interaction between students and the computer tasks generates many useful insights into learning. Instructions with use of the SRLE foster student's engagement and classroom discussion between students and the teacher. Elements in the SRLE are extremely applicable and useful for monitoring the statistical classrooms. Garfield and Ben-Zvi (2009) assumed that the SRLE approach to statistical instruction could promote student interest in statistical reasoning with the presence of technology. Thus, teachers should be able to provide students with opportunities to explore the world of statistics by doing it joyfully while learning. The results of this study establish that statistical reasoning skills were developed after using technology (Fathom) approaches in the classroom. Hence, teachers should give importance to creating an innovative approach to provide instruction according to student needs.

Besides that, based on the result, it is found that students in the control group learned without any intervention concentrated on basic computations and graph constructions; they did not focus on deeper understanding of data. Therefore, the traditional teaching approach did not allow them the opportunity to explore data and graphs to make decisions. They do not have the experience to argue on the inferences and conclusions made based on the data. Hence, the findings of this study will be of interest to educators who wish to use Fathom approach to enhance students' statistical reasoning. Using technology (in this case, Fathom) created an effective classroom environment able to provoke students' interest, enthusiasm to learn and eventually deepen their understanding (Ben-Zvi et al., 2018; Garfield & Ben-Zvi, 2008; Shaughnessy, Chance, Kranendonk, & Mathematics, 2009; Wilson, 2018). The theory utilized in this study can explain the result because students' ability to reason using the data improved, which shows they became better at generating information from data, comparing data, predicting and justifying the conclusions made. Besides that, students were able to reason out their answers after being taught by using Fathom. In short, students' statistical reasoning improved in the experimental group.

From this study, it is known that educational technology serves as an alternative teaching method that can help students to excel in statistics learning. Educational technologists can provide a variety of technology-based activities in the form of modules or instructional materials as guidance for the teachers. Moreover, the educational technologists may take the initiative to suggest activities that match students of all abilities. They may provide special training for teachers on how to teach using technology. The results of this study show the dynamic software Fathom assisted Form Four students in developing their new knowledge aided by existing knowledge in meaningful ways during the intervention. The interaction between Fathom and students strengthened the reasoning ability of students, who were able to utilize the Fathom features especially the quick drag-and-drop variable into graphs and plotting different graphs simultaneously. Students were able to observe the changes made in data and plots and check their predictions fast. Through this, students' mental construction was reinforced by using Fathom.

b) Implication for Curriculum Development

From this study, it is known that the dynamic software Fathom method serves as an alternative teaching method that can help students to excel in statistical reasoning. Nevertheless, teachers need time to plan such activities in the classroom. Curriculum planners can promote this method by giving the teachers exposure and knowledge of this new method. They can provide a variety of technology-based activities in the form of modules or instructional materials as guidance for the teachers. Curriculum planners may take the initiative to suggest activities that cater to the needs of students whatever their ability. They may provide special training for teachers on how to teach using technology such as Fathom. Curriculum planners can also use the SRLE approaches in teaching and learning statistical reasoning as well as other topics. This will prepare a platform for the teacher to choose the appropriate approach according to student achievement level and abilities.

Thus, curriculum planners play an important role in creating a conducive environment encouraging excellence. In this respect, headmasters and teachers need to understand and internalize the integrated approach of the curriculum. Student success depends on the curriculum in assisting the school to develop students' qualities and to participate actively in matters relating to education. Meticulous planning is necessary to ensure effective curriculum implementation (Wilson, 2018).

Overall, the results of this study showed there is a positive influence of Fathom-based teaching approach on secondary school students' statistical reasoning as the lessons were well planned to match student needs and abilities. Educators and school management can provide training, workshops and seminars that focus on Fathom and its utilities in the statistics classroom.

5.6 Recommendations for Future Research

Researchers believe that statistical reasoning can be constructed using the activities provided if sufficient time is available and if the ideas that have been used are improved and modified by future researchers. Fathom-based statistical activity in this study was based solely on the Form Four mathematics syllabus; hence the findings only apply to Form Four students. Even though this technique was effective in improving the quality of student achievement in statistical reasoning, some aspects need to be addressed by future researchers in order to advance this method. Further research recommendations are as stated hereafter.

a. Future researchers can investigate the effectiveness of using Fathom-based activities in other statistics subtopics especially variance, stem and leaf, probability and distributions which are included in additional mathematics. Next the researchers expected to perceive the technique used in statistical reasoning activities as a technique that can enable the students to attain in-depth understanding.

b. This study has focused on four statistical reasoning constructs; describing data, organizing data, representing data and analyzing data. In future, studies could be done to investigate other crucial thinking skills such as putting forward hypothesis, understanding how data are produced to estimate probabilities, understanding and utilizing the context of a problem, planning and evaluating investigations and others (Chance & Rossman, 2001).

c. Future researchers are suggested to expand the number of respondents to more than 72 people who have been studied. This is important in order to gain a high degree of validity. Besides that, respondents from different backgrounds and abilities can be included; researchers are able to get more comprehensive response such as the difference in achievement between male and female students. Future researchers are suggested to conduct research on primary and secondary school respondents. In the meantime, studies on the effectiveness of techniques using Fathom-based statistical reasoning are to be compared between urban and rural students.

d. In order to get more details, the researcher feels that it is necessary to study the effectiveness of using Fathom-based statistical reasoning activities conducted by quantitative and qualitative (mixed) methods. The researcher assumed that the qualitative study would add a realistic picture of the students' thinking process when using Fathom-based statistical activities since this study never measured students' perception. Future researchers will be able to see the acceptance of students or teachers in the statistical reasoning teaching and learning process before using Fathom and after the technique is taught. Research reports will definitely be more interesting; thus comparisons can be made to see how far this technique is effective in increasing student statistical reasoning skills. Case study incorporating field notes, observations, video recording and structured-interviews can be conducted to examine how teachers use Fathom in statistical reasoning lessons. Thus a qualitative study may reveal many in-depth findings that cannot be examined in a quantitative study.

Even though plenty of research stated that technology serves as a facilitator on teaching and learning statistics it seems to be not focused on software such as Fathom in other mathematics topics (Eichler & Zapata-Cardona, 2016). It will be interesting to find out if the use of the same software can be applied to other topics in mathematics such as geometry, algebra, probability and so forth. Besides that, special teaching activities similar to the study have to be designed to integrate the technology in statistical reasoning. The effectiveness of the software can be explored within the subjects and results may vary comparatively.

5.7 Conclusion

In this study, the Fathom-based method was carried out to investigate its effect on Form Four students' statistical reasoning across four constructs namely describing data, organizing data, representing data and analyzing and interpreting data. The students showed a remarkable improvement in these skills through this new intervention. Although the findings showed low improvement in analyzing data students had more understanding in describing data, organizing data, data representing and analyzing data after using Fathom dynamic software. Students knew more clearly the use of software as well as how to analyze the data accurately. Moreover, students were able to present reasoning skills based on questions that provoke arguments and build statistical ideas. The dynamic software Fathom had helped the students to interpret their findings.

From the theoretical aspect, the findings of this study are in congruence with constructivism learning theory. This suggested that if teachers perceive students as "active learning seekers" in the learning process, they are able to synthesize information to construct knowledge and understanding from prior knowledge. Furthermore, the results of this study are also in accordance with the Garfield and Ben-Zvi (2008) instruments and statistical reasoning learning environment (SRLE), where the tools encouraged students to make and test inferences using data, involve in discussions and explain ideas. The learning process in this study made students actively participate in understanding and reflecting back what they had learned with the help of technology. Fathom-based instructions do not isolate students from peers and teachers. Communication between students was more prominent when conducting the activities and the students are confident to explore even when at times they are out of the topic of the assignment given to them. This aspect has provided an enjoyable and meaningful learning environment for students.

This study has provided an alternative approach for enhancing students' statistical reasoning skills. Therefore, mathematics educators may consider applying this method to encourage students to learn statistical reasoning in a meaningful way.

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