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Early Undergraduate Emirati Female Students' Beliefs about Learning Mathematics Using Technology

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Abstract: Covid-19 has accelerated the speed of technocratic transformation in teaching and learning. Previous researches on whether technology enhances students' motivation towards learning or burdens them with additional layer of anxiety in learning the nitty gritty of technology itself have mixed results. The purpose of this study was to explore early undergraduate students' beliefs about learning mathematics with technology. These research participants were first-year female undergraduate students in a public university in the United Arab Emirates (UAE). The study comprised of phase one with qualitative task-based interviews with four female first-year undergraduate students. Phase two included a quantitative belief survey with a sample of 62 students from the same institution. I constructed four major belief categories from the iterative process of interview data analysis– technology for computing and graphing, technology for speed and accuracy, technology for a short-cut but not for meaning, and affective aspects of beliefs. The quantitative survey result demonstrated that a majority of participants (about 75.8%) were found to be using some kinds of technological tools while learning mathematics. About 90% of them reported using a calculator while learning mathematics. A majority of participants (54.9%) believed that technology helps them in learning mathematics, and about 50% of them also believed that the use of technology improves their learning of mathematics.

Keywords: *Student beliefs, technology integration, radical constructivist grounded theory (RCGT), learning mathematics.*

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Introduction

Since belief is an abstract idea it may be defined in various ways. For example, Schoenfeld (1985) defines mathematics related belief as an individual's personal worldview. For Lester, Garofalo and Kroll (1989), belief means an individual's subjective knowledge of the belief object that may be a physical object or mathematical object or another thing. Similarly, Hart (1989) considers belief as a personal judgment of something (see Belbase, 2019). A similar definition of belief has been proposed by Pajares (1992). This paper focuses on a group of undergraduate students' belief about learning mathematics using technology.

Scholars have provided some categories of beliefs about mathematics, mathematics teaching-learning, and technology integration in mathematics (Bennison & Goos, 2010; Li, 2007; National Council of Teachers of Mathematics [NCTM], 2000). For example, Op't Ende, de Corte, and Verschaffel (2002) have categorized in terms of social, conceptual, functional, psychological, relational, and contradictory beliefs. Furinghetti and Pehkonen (2002) discussed beliefs as some kinds of attitudes, affects, cognitive processes, levels of consciousness, propositions, subjectivities, personal logic and convictions, and individual psychology. Similarly, Goldin (2002) have highlighted mathematical beliefs in terms of correspondence of mathematics to the physical world, misconceptions about mathematics, and various aspects associated with it such as historical, philosophical, sociopsychological, aesthetics, cultural, and pedagogical. Likewise, Gijsbers, Putter-Smits and Pepin (2020) recently reported that teaching advanced mathematics such as differential equations by the application of small-group oriented tasks helped to changed students' beliefs about mathematics.

Some additional studies pertinent to the use of technology include Belbase (2017), Erens & Eichler (2016) Gomez-Chacon (2015) and Leatham (2002). Some of these studies have related affective variables to mathematics learning with technology in terms of mathematical confidence, technological confidence, attitudes toward technology, and engagement in mathematics learning. There is less attention to student beliefs about learning mathematics using

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technology although there are some recent efforts to link students' self-efficacy beliefs toward the use of online tools for learning (LaFrance & Beck, 2018) and students' computer self-efficacy and beliefs about the computer-related task in the classroom (Santoso et al., 2018).

Kloosterman (2002) examined students' personal, environmental, and conceptual beliefs about mathematics. Their personal beliefs about mathematics are associated with their cognitive ability and their preferences for mathematics. Such beliefs have a strong effect on students' motivation and attitude toward mathematics. The environmental beliefs associated with mathematics and learning mathematics are concerned with classroom, peers and groups, school, and home environment. The conceptual beliefs are associated with the contents of mathematics and the learning of these contents through memorization, imagination, logical thinking, and problem-solving tasks and activities.

Technological advancement has influenced every sector including education hence K-12 and postsecondary institutions increasingly used technology in teaching. The effective use of a technological tool for teaching-learning of any discipline in general and mathematics, in particular, may depend on the beliefs held by the users of the tools. Past studies on teacher beliefs about teaching-learning mathematics using technology established a relationship between teacher beliefs and their pedagogical practices with the tools (Shifflet & Weilbacher, 2015). It has been claimed that "students' beliefs about mathematics are likely to influence how they approach new mathematical experiences" (Spangler, 1992, p. 19). The mathematical disposition of students can be influenced by using technological tools that may help them develop a positive belief about using the tools for learning mathematics. Their beliefs may have a powerful influence on their own ability to solve mathematical problems effectively and efficiently with a greater interest in mathematical activities and tasks (NCTM, 1989).

Technology integration in education in general and mathematics education, in particular, has been an emphasis in schools at the local level and the governments at the central level. The integration has been done through the revision of educational plans, policies, infrastructures, and learning outcomes. Such reforms may help in enhancing student participation and active engagement in learning mathematics by constructing meaning with advanced mathematical thinking (Kul, 2018). The review of literature presented above shows that students' views and beliefs toward learning mathematics with technology may have a decisive role in the success of such a reform approach. Their beliefs, in the long run, may develop an attitude toward technology application for learning mathematics based on the perceived usefulness of the tools and ease of their uses; for example, the use of computers in teaching mathematics (Teo, 2012).

However, there is almost no literature on students' beliefs about learning mathematics by using technology. What effects do the uses of computers and other technology will have on students' learning of mathematics or other subjects and how their beliefs influence practice has been largely unknown (Havelka, 2003). The use of technology for learning mathematics may affect students' beliefs depending on the extent of use and their ability to use the tools for independent learning. If they have positive learning experiences, then they might develop positive beliefs. Otherwise, they may think that technology brings more distraction in learning (Beckman, 2015). Students' belief may also depend on what kind of images they form about learning mathematics in a technological environment and how those images corroborate with their attitudes and anxieties to the subject and the tools they use in learning (Belbase, 2013). Those students who have experience of using laptops or other technological tools in the classroom may have positive beliefs and attitudes toward learning mathematics or other disciplines with technology, which also indicates that one's beliefs about technological tools for learning mathematics are associated with their self-efficacy toward the use of the tools in the long term (Gudek, 2019).

The group of students who participated in this study had some experience of using Microsoft Excel spreadsheets in their basic statistics course in the first year. In the course work, they were engaged in basic computations of statistical values, such as average, median, mode, standard deviation, and construction of charts, such as pie-chart, bar-chart, line-chart, and histogram. This study aims to explore the beliefs of those students about learning mathematics by using technology and how their learning experiences may affect their beliefs. However, their beliefs could be different in different contexts of studying mathematics with different technology, or no technology at all. According to Grootenboer and Marshman (2016), "the contextual and clustered nature of beliefs may well mean that individuals can express different beliefs in different situations or contexts. In terms of individuals' behavior, thinking and learning, beliefs are seen as playing a filtering role for new experiences and information, and as such, they moderate what and how children learn mathematics" (p. 16). In this sense, a study on students' beliefs about learning mathematics using technology may evolve and change through their experiences.

Students' beliefs about the use of technology may affect their choice and application of tools for mathematics problem-solving, construction, representation, and demonstration (Belbase, 2015; Polanco et al., 2013). Suratno and Aydawati (2016) consider that technology, such as multimedia facilities, may facilitate and mediate student learning. If we intend to transform mathematics education, we should pay attention to meaningful uses of technological tools for teaching, learning, and assessment in mathematics. The purpose of this study was to explore the early undergraduate students' beliefs about learning mathematics with technology. I am particularly interested in exploring the following research question: What beliefs do early undergraduate Emirati female students hold about learning mathematics using technology? I applied radical constructivist grounded theory (RCGT) as a theory, which is discussed below. This study is significant because it is a new initiative in the region in terms of female early undergraduate students' beliefs about learning mathematics with technological tools. The Ministry of Education (MoE) in the UAE and Abu Dhabi Education Council (ADEC) also highly emphasized technology integration in schools and classrooms to develop 21st-century skills among students (Alsaleh, 2014). The paper has three main sections: first, I discuss the theoretical frame; second, I explain the method of study; and in the third section, I presented the results in terms of key categories of students' beliefs about learning mathematics using technology. The paper concludes with some implications of the belief categories in teaching-learning mathematics.

Radical Constructivist Grounded Theory (RCGT)

To use RCGT as a theory I outline its five key assumptions by integrating basic tenets of radical constructivism (Von Glasersfeld, 1995) and grounded theory (Charmaz, 2006) . In this respect, I would argue that RCGT has been built upon two premises: (a) the premise of radical constructivism entails that knowledge is constructed by an individual or a group by actively building upon prior experiences, and the function of knowing is an iterative and adaptive process with the new experiences (Von Glasersfeld, 1995); (b) the second premise drawn from the grounded theory entails that the meaning out of data can be constructed actively through constant comparison, theoretical sampling, coding, integrating codes into thematic categories, and modification of the categories with the emerging codes and concepts in the data (Charmaz, 2006). While these two premises are integrated we find five key assumptions of RCGT: are symbiosis, voice, cognition, adaptation, and praxis (see Belbase, 2018). Below I provide brief explanations of each assumption.

Symbiosis: The research participants (students and teachers) and researchers have a symbiotic relationship, which is based on mutualism that benefits both the research participants and the researchers. In light of this assumption, in this study, the researcher considered the research process as a collaborative endeavor between the researcher (myself) and my participants (Belbase, 2015).

Voice: A research outcome reflects participants' and researchers' voices through various forms of data, analyses, and interpretations, for example, life stories, narratives, excerpts, reflections, and vignettes. I maintained the participants' voices in their authentic views, opinions, and beliefs by constructing narrative excerpts (Belbase, 2015).

Cognition: Research participants and researchers go through different levels of cognitive processes in educational research that focuses on teaching-learning and development. While undertaking in-depth interviews, the very process of data construction as per this assumption, both the participants and the researchers involved in coding, recoding, categorizing the major concepts or ideas from the data, implementing several steps of theoretical and pedagogical sampling, and comparing codes, meanings, and categories (Belbase, 2015).

Adaptation: The educational research process is an adaptive function because the collaboration between the research participants and the researcher go through various emerging pedagogical processes in which they adapt to the new contexts, experiences, and challenges (Belbase, 2015).

Praxis: The research participants and the researcher together contribute to the various stages of data construction, analysis, and interpretation informing the relevant theories and practices, and making a connection between them (Belbase, 2017, 2015). The praxis of fit helps the researcher reconstruct the narrative vignettes or excerpts to fit the context or the categories. The praxis of viability explains the usefulness of the participant belief categories about learning mathematics with technology by interpreting their experiences in the context of using the technological tools, such as Excel spreadsheets, to learn central tendency (mean, median, and mode) (Belbase, 2015).

Methodology

In light of the RCGT as a theoretical framework this study was undertaken by combining qualitative interviews (first phase) and a quantitative survey (second phase) to conceptualize the research design and analysis (Belbase, 2015).

Phase 1: This phase comprised of four one-on-one task-based interviews (one at a time) with fresh undergraduate female students in a public university in the United Arab Emirates (UAE). I invited the participants for interviews based on their interest to participate in the study after informing them about the research in four sections of general mathematics, where I was an instructor. There was no influence from my side as an instructor on their participation except using the classroom as a context to seek a voluntary contribution of the students to the study. Ethical clearance from the Office of Research was obtained from the public institution where the author was conducting this study. An interview guideline (see Interview Protocol in Appendix) was designed with some initial questions, and additional prompts were applied to clarify the participants' views on the topic of discussion during the interviews.

Four female undergraduate students agreed to participate in the study voluntarily. They were all first-year students of the undergraduate general education program in a public university in the United Arab Emirates (UAE). The interviews were conducted in the spring of 2018. I tried my best not to influence the participant selection process. I communicated to 96 students about the study and requested for about ten volunteers to participate. However, only four students committed to volunteer in the interviews. Each interview lasted for 20-22 minutes. Each interview had a task to find the mean, median, and mode of a given set of numbers. I asked the first few questions related to students' prior mathematics learning experiences with or without using technology. Then, I presented to them a situation with a few numbers like 10, 12, 14, 12, 12, 18, 15, 9, and asked them to find the mean, median, and mode values without using any technology at first on paper. After doing calculations of mean, median, and mode values with paper and pencil work, I further asked the participants to find the same values using Microsoft Excel on a computer. After completing both tasks on the paper and computer, I interviewed them further to know their beliefs about learning mathematics using technology in the context of using a paper-pencil approach and a computer program (in Excel). The purpose of using the paper-pencil and computer tasks for mathematical calculations were aligned to help them make sense of what they were doing, how they were performing, and thinking in the context. This helped us to build a *symbiotic relationship* based on mutualism for learning and helping each other through the process of generating meaning from the data at the same time.

The research participants were in a General Mathematics course that focused on basic statistics integrated with the construction of graphs and charts from data sets. Therefore, the interview went beyond what was done during interview time on paper-pencil and Excel calculations of mean, median, and mode values, but it also linked to their beliefs of using technological tools in the classroom practice related to computing, graphing, and making sense of data. Each interview was audio recorded with the permission of the research participants while seeking their informed consent to participate in the study.

I transcribed the first interview data verbatim. Then, I used the interview transcript to generate codes to determine meaningful units. Each meaningful unit or conceptual unit in the transcript was selected and coded in the form of a primary code. The primary codes were organized into a matrix by grouping them into initial thematic categories. After coding the data from the first interview, I constructed themes from the key ideas about students' beliefs related to learning mathematics with technology in terms of functional, conceptual, and psychological beliefs. This iterative process helped in bringing the *participant voice* in interview excerpts and *researcher's voice* in his interpretive accounts.

I focused on the belief categories as provisional themes in the subsequent interviews to explore other participants' beliefs about the use of technology for learning mathematics. Therefore, the subsequent interviews were more focused on already constructed themes in order to saturate the data around those themes. Then, I analyzed the consecutive interview data until he did not find any new significant concepts in terms of their beliefs after the fourth interview. I organized all the codes related to technology in alphabetical order in a matrix to see if the codes were closely related. Then, I re-organized the codes into groups in the matrix based on the related thematic meanings associated with participants' beliefs about learning mathematics using technology. The grouping and re-grouping continued until I came up with the four major groups as the categories of the participants' beliefs. This was an iterative *adaptive function* to construct the final thematic categories.

The four thematic categories constructed from the interview data were – technology for computing and graphing, technology for speed and accuracy, technology for a short-cut but not for meaning, and psychological aspects of technology. Each thematic category has been explicated with narrative excerpts to discuss the concepts related to them by connecting the main concepts with the relevant literature.

Phase 2: The second phase of the study utilized a quantitative survey with ten multiple-choice or Likert-scale questions designed by the researcher (myself) based on the main categories from the phase 1 study. The population of the study was all fresh undergraduate students in a public university in the United Arab Emirates (UAE). I selected four sections with around 96 students altogether as a sample for the study out of about more than 1000 (1160 enrolled in 2018, and some might have dropped out) first-year undergraduate female students' population. I used a purposive sampling method based on the convenience to collect the data from the four sections where I was an instructor. The survey questionnaire was constructed in an online platform, surveymonkey.com, which allowed a maximum of ten questions in the survey without any cost. The questions for the survey were based on the thematic categories in the first phase (Table 1).

Table 1. Student online survey questionnaire (in surveymonkey.com)

Item No.	Question	Response Choices				
1	How often do you use technology for learning mathematics?	Most Often	Sometimes	Very Few Times	Rarely	Never
2	Which of the following technological tools have you used for learning maths?	Calculator	Computer	Online App	Online Videos	iPad and Phones
3	I believe that technology helps in learning mathematics because it helps in computing and graphing easily.	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
4	I believe that using technology in learning mathematics helps me to solve mathematics problems with greater speed (fast) and more accurately than without using it.	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
5	Technology helps me to learn mathematics because it makes my learning shortcut and easy.	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
6	I understand mathematical concepts on paper-pencil activity more easily than on a computer by using Excel or other programs.	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
7	I believe that the use of technology in learning mathematics helps me to understand the meaning of mathematical concepts better than without using it.	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
8	I think using technology in learning mathematics makes it more interesting.	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
9	I believe that using technology in learning mathematics is a time-consuming process.	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
10	I believe that the use of technology improves my learning of mathematics.	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree

The survey link (https://www.surveymonkey.com/r/WHCTR6T) was sent to the students in their emails requesting them to respond to the survey with prior informed consent. Out of 96 students who received the survey links, 62 of them responded to the survey questionnaire within 3 days. The survey data was analyzed using percent distribution across different categories for each question. The percent distribution of each category of responses was plotted in bar charts or pie-chart. The quantitative data helped in elaborating the qualitative thematic categories by linking theoretical categories into practical belief functions of several students. This also helped the searcher to broaden the thematic categories in a classroom context as a *praxis of technology integration* in mathematics teaching.

Both the qualitative thematic categories and findings from the quantitative data were interpreted by describing the major concepts and data elements related to each question with the most and least significant variables in the data. These findings were discussed by relating them to the relevant literature to make sense of them in a broader theoretical and practical context extending the *praxis of fit and viability* of the constructed thematic categories in the classroom context. The two-stage data collection and analyses provided methodological and analytical triangulation of the study.

Findings and Discussion

I constructed four major categories from the grouping and re-grouping of the primary codes of interview data and presented them in Figure 1. Then he discussed each category at three layers—first, I constructed the narrative excerpts from the interviews to portray the participant's voice. Second, I discussed the major concepts from each category related to the participants' beliefs. Each categorical belief has been elaborated with quantitative survey results.

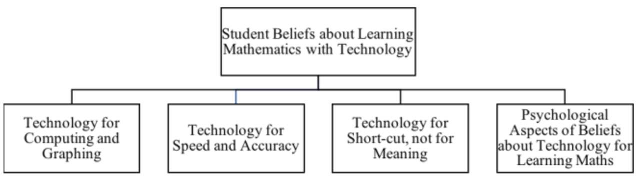

Figure 1. Early Undergraduate Students' Beliefs about Learning Mathematics with Technology

I presented the survey data in charts and explained them in terms of the most significant beliefs about the use of technology in learning mathematics. Third, I integrated and connected these concepts to relevant literature to interpret them by connecting theory to practice and vice-versa.

Students' use of technology: The participants were asked how often they used technological tools such as calculators, computer programs or applications, and online tools for learning mathematics and what technology did they use. The results have been presented in Figures 2 and 3.

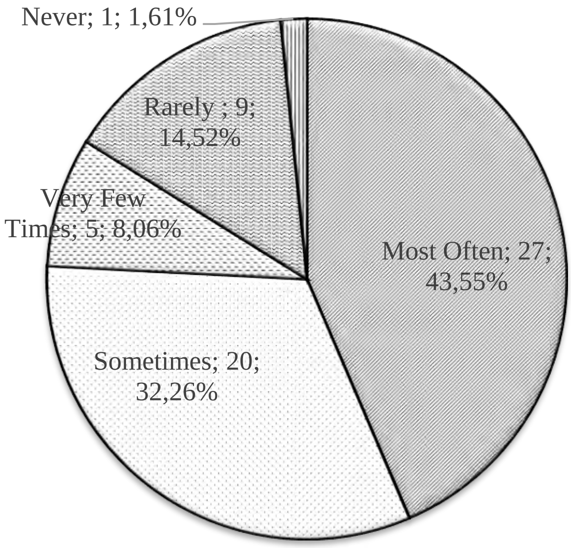

Figure 2. Percent of students who used technology for learning mathematics

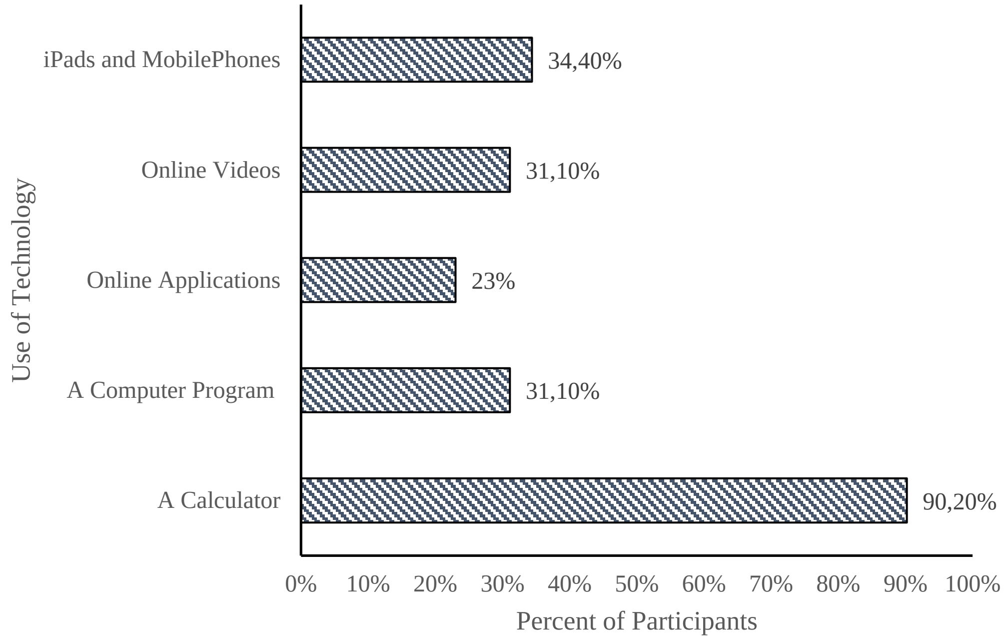

Figure 3. Percent of students who used different technological tools for learning mathematics

The information in Figure 2 shows that 43.5% of students expressed that they used technology most often while learning mathematics, whereas 32.3% expressed that they used technology for learning mathematics sometimes. However, 1.6% of students mentioned that they never used technology for learning mathematics. The graph in Figure 3 shows that the majority of students (90.2%) used a calculator while learning mathematics. Some of them (34.4%) reported that they used iPads and mobile phones while learning mathematics. The percent of students who used computers and online videos is 31%, and only 23% of participants have used other online apps for learning mathematics. The data clearly indicated that a calculator was the most common technological tools used by the participants in mathematics classrooms.

Technology for computing and graphing: The participants had limited experience of using technology, except the calculator, in their school mathematics. They used Microsoft Excel in mathematics class for the first time in their college. The participants believed that technology, such as MS Excel, is good for computing mean, median, mode, and other mathematical values. They also believed using the MS Excel for graphing would be better than just doing it on paper-pencil. The interview Excerpt-1 is an example of how the participants expressed their beliefs about the use of technology for computing and graphing while doing and learning mathematics.

Interview Excerpt-1. Narrative Excerpt of Students' Beliefs about Technology for Computing and Graphing

R: Suppose we have a data. Think of any set of numbers, let's say 9, 12, 14, 12, 12, 16, 18, 15. How do you find the mean of this data (these numbers)?

S1: I add them and divide by 8.

R: Yes, you add them and divide by the number.

S1: Yeh.

R: Do you want to do it mentally, or do you want to do it with a calculator or computer?

S1: I will use a calculator if I don't know how to do it on my own. But, I want to do it myself.

R: Okay, you want to write it yourself?

S1: Yes.

R: That means you want to use a calculator only when you don't know calculations?

S1: Yeh.

R: In what way a graph is better? With or without technology?

S1: It depends on the question.

R: We did column chart, line chart, and histogram both ways, on paper and pencil, and using Excel. Which way do you think is better for students?

S1: I understand better if I do it on paper.

R: Which function is more relevant to technology—demonstration, calculation, and understanding of meaning in mathematics?

S1: Calculation.

S4: Demonstration and calculation. Yah, it gives us more accurate graphs.

R: Can we be more creative by using technology for learning math?

S1: Sometimes. But, we should not depend too much on it.

[R=Researcher, S1= Student 1, S2 = Student 2, S3 = Student 3, and S4 = Student 4.]

The major concepts from the Excerpt-1 are – the procedure to compute the central tendency value (e.g., mean), a choice to do it mentally or with technology, contextual belief about graphing with technology, the relevance of technology for computing and graphing, and less dependency on technology. While concerning the first point about technology versus paper-pencil work for computing the central tendency, the participants preferred to compute with paper and pencil at first and then practice more computing problems with technology by using a calculator or Excel on a computer. This concern sounds valid because learning mostly takes place when they solve any problem by doing themselves without using any technology. While they work on paper and pencil activity, then they can utilize their brains for thinking, reasoning, and mental calculation, which obviously helps them understand the problem better than just using the tools.

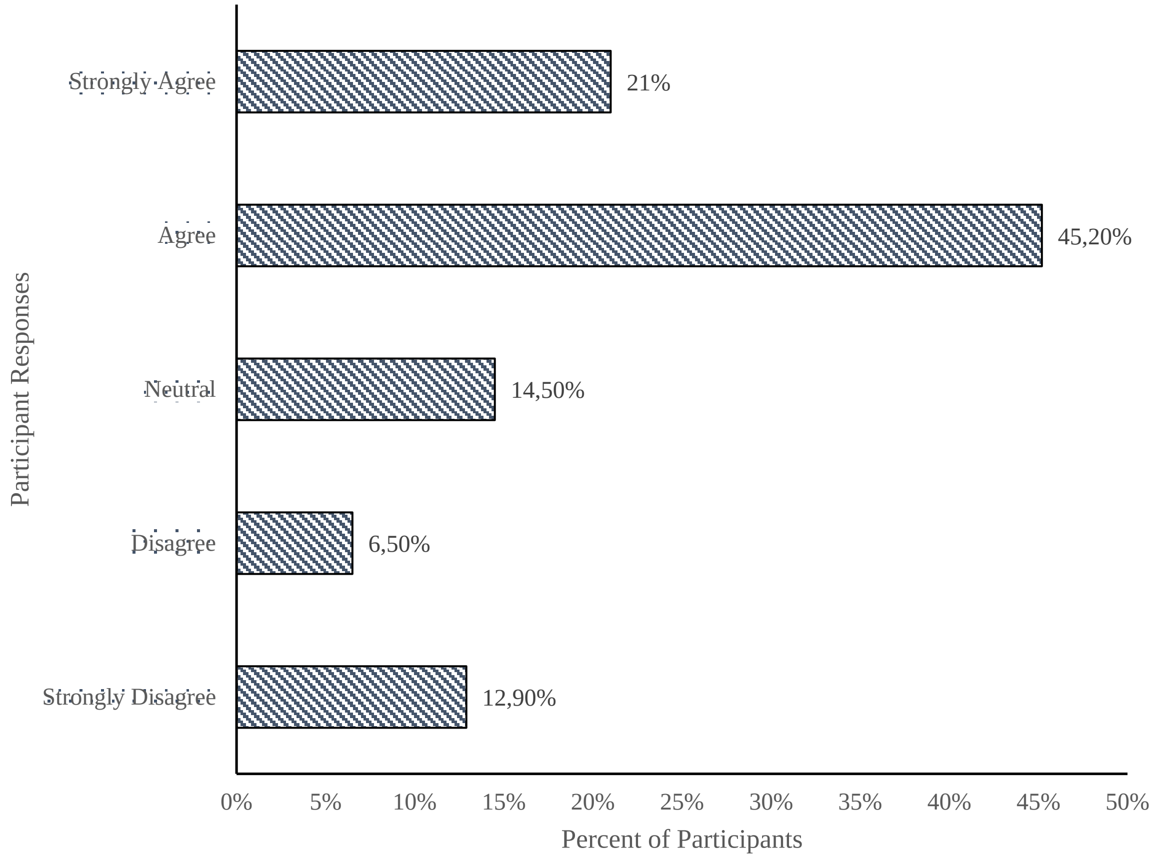

Figure 4. Percent of students who believed technology for computing and graphing

Whereas, the quantitative data in Figure 4 shows students' opinions on the statement, "I believe that technology helps in learning mathematics because it helps in computing and graphing easily." In this opinion, a majority of the participants in this study (66.2%) believed that technology helps in computing and graphing of mathematical values and structures procedurally. Whereas, 19.4% did not believe it, and 14.5% were in a neutral position. That means many student participants considered that the use of technology might help them in computing and graphing of mathematical problems.

Past studies on the application of technology for learning mathematics shows that students' ability to use the technology depended on their mathematical understanding (Burrill, 2002). That means the effective use of technological tools for learning mathematics is influenced by students' mathematical ability to manipulate the tool. Burrill (2002) claims, "given supporting conditions, the evidence indicates that handheld graphing technology can be an important factor in helping students develop a better understanding of mathematical concepts, score higher on performance measures, and raise the level of their problem-solving skills" (p. i). However, students' beliefs about learning mathematics with technology might be a necessary condition for them to apply the tool effective way to computing or graphing or conceptualizing mathematics, but it may not be sufficient one (Hawkins, 1997). This view is supported by Coley, Cradler, and Engel (1997) that most of the time, computers and other technology might be useful for writing, drawing, computing, and graphing. Similarly, one of the research participants in a study by Drijvers et al. (2015) stated that "the calculators are mainly needed for performing an algorithm or computing an approximate value, and it seems to be a kind of mechanical use of a calculator" (p. 76). It is a practice tool for many students while using technology during the learning of mathematics (Yang & Leung, 2015). MS Excel spreadsheet is especially useful in exploring mathematical concepts, including "numerical and graphical methods to solve problems" (Drier, 2001, p. 170). Drier (2001) further claims that Excel spreadsheets help students to explore mathematics, providing them the depth of understanding of the mathematical concepts in "numerical, graphical and algebraic representations" (p. 170). Despite having many features in Excel, most of them are underutilized in mathematics teaching, especially in teaching mathematical concepts.

Technology for accuracy and speed: Technological tools such as computers and calculators are mostly used by students as a servant that replaces paper-pencil work to evaluate the output it generates (Goos, 2010). Hence, in this context, technology serves as a tool for accuracy and speed in mathematics teaching-learning. The sample interview Excerpt-2 demonstrates some examples of how the participants expressed their beliefs about learning mathematics with technology focusing on accuracy and speed.

Interview Excerpt-2. Narrative Excerpt of Students' Beliefs about Technology for Accuracy and Speed

R: You did them two ways: one on paper-pencil and the other on the computer. Can you talk more about your experience of learning mean, median, and mode in this context?

S1: I really like to work in Excel. We didn't do it on Excel in school. It is a shortcut. It is easier and faster on Excel.

R: We moved from paperwork to Excel in the class. Would you prefer to go directly to technology, or you prefer paperwork first?

S3: This (paperwork) first. If you use technology from the beginning, then there will be many questions from students. They will ask, "How is it, sir?"

R: We don't see the details, right?

S3: Yes, only we see the answers.

R: Should I move from paperwork and then go to technology? Or should I directly go to technology?

S3: Use paper first, then use technology. We cannot see if it is correct or not, then you can check it in Excel. Also, use Excel to make charts. It is difficult on paper.

R: When we learn mathematics, we can use technology, or we don't use it. Which way do you think it is easier?

S2: Without technology.

R: Tell me, what is the advantage of doing this way (with paper) and what is the advantage of doing this (on a computer)?

S2: You will learn how to do it (from a paper-pencil). The Excel helps you to do it fast.

R: Without technology? What might be the reason?

S2: Because it does fast. I have not used it in my whole life. So, it is difficult with technology.

R: When we use technology for learning mathematics, does it help in a demonstration, or calculation or understanding meaning?

S4: It helps in quick calculation.

R: What else do you think about using technology for learning math?

S2: It never goes wrong.

R: Finally, tell me more about learning mathematics with technology?

S1: It is good. It is easier and faster. Sometimes we should use paper-pencil and using our brain than a calculator.

[R=Researcher, S1= Student 1, S2 = Student 2, S3 = Student 3, and S4 = Student 4.]

The major concepts from the Excerpt-2 are – preference of technology and paper-pencil work for computing the central tendency value (e.g., mean), a choice to do paper-pencil work first and then use technology, using brain instead of technology, technology makes computing and graphing faster and more accurate, paper-pencil is easier to understand, and understanding is difficult with technology. The participants believed that it is better to learn computing on paper-pencil first, and then do the more complicated ones on a computer or calculator. Only the positive thing with technology for computing and graphing, according to the research participants, is that it makes the process faster and more accurate than doing it on paper. Some participants thought that using one's brain is better than using technology for learning of mathematics. Although a computer makes calculations accurate and faster, it is not easier due to the complexity of technological operations and functions with different tools. Also, there is a chance that some students feel it more complex due to divided attention to technological factors and mathematics itself. Hence, using technology saves our time and effort in computing and graphing, but it is not easy to understand the concepts and processes with it compared to paper-pencil.

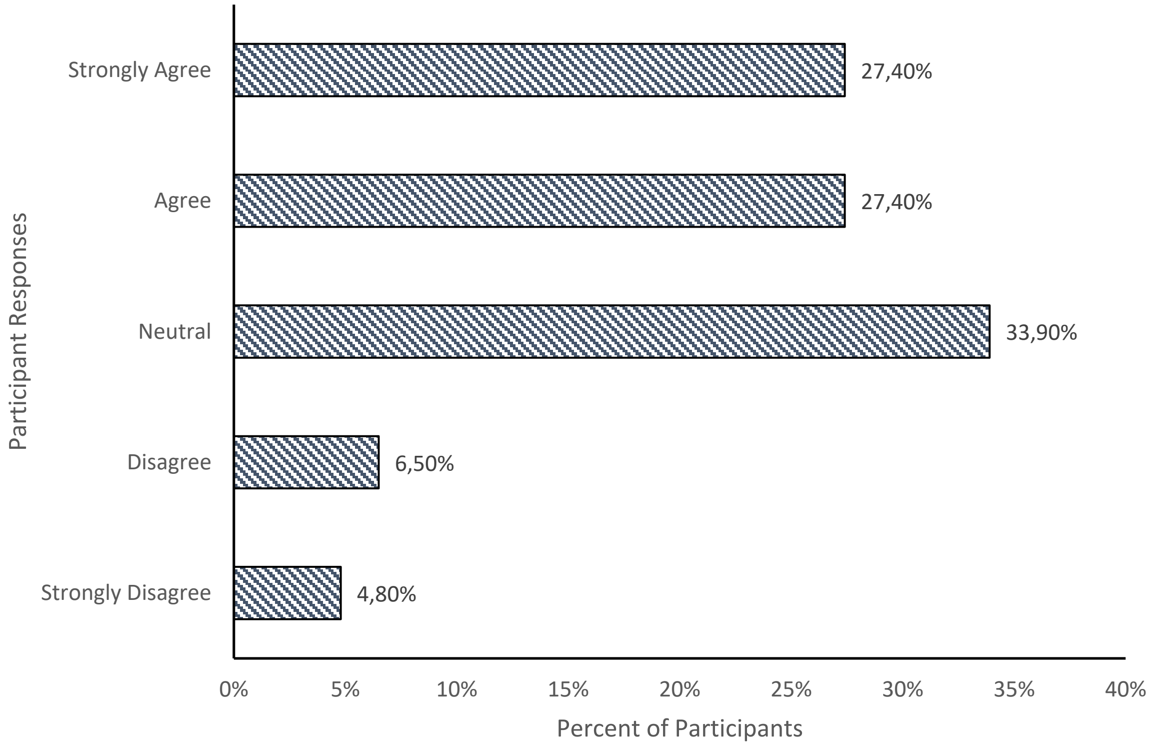

Figure 5. Percent of students who believe the use of technology for speed and accuracy

The graph in Figure 5 presents the percent distribution of students across a range of beliefs about using technological tools for mathematics problem-solving with speed and accuracy. A majority of students (54.8%) believed that technology, in fact, ensures speed and accuracy in mathematics learning, whereas only 11.3% did not believe it. An interesting fact from Figure 5 is that 33.9% were neutral in this regard. That means some students still were not sure whether they considered that technology is important for speed and accuracy while learning mathematics.

However, some of the past study results do not show that the use of technology always increases the speed and accuracy of mathematical tasks of students (Letwinsky & Berry, 2017). It has been accepted that one of the major advantages of using computer technology in graphing and computing is "their dynamic nature, their speed and the increasingly comprehensive range of software that they support" (Hawkins, 1997, p. 3). Literature supports the view that the use of technology may help students do the calculation fast and get access to the required information (Li, 2007). It is believed that technological tools can process information fast by making our computing and graphing function more efficient and accurate than otherwise we do it on paper (Li, 2007). "There is considerable evidence that students use handheld graphing technology when quick and accurate graphs will aide in their problem-solving" (Burrill, 2002, p. ii).

Technology for a short-cut, not for meaning: In many pieces of literature, it is stated that the use of technology supports students' learning of mathematics in a variety of ways (Benton et al., 2018; Han et al., 2013). The sample interview in Excerpt-3 is an example of how the participants in this study expressed their beliefs about using technology for learning mathematics in terms of a short-cut and meaning. Technology for short-cut means it provides a straight forward solution without giving details of steps in a solution, such as finding the average value of data.

Interview Excerpt-3. Narrative Excerpt of Students' Beliefs about Technology for a Short-cut, not for Meaning

R: Okay, let's look at how you calculated the median. You ordered the numbers and found the median. Next, you directly used the median function (in Excel). Which way do you feel better?

S1: Writing on paper. Because it (Excel) is a shortcut only.

R: Finally, tell me more about learning mathematics with technology?

S1: It is good. It is easier and faster. Sometimes we should use paper-pencil and using the brain than a calculator.

R: Okay. When you say meaning, what kind of activity helps you understand the meaning?

S2: Here (in Excel), you don't see what's going on. You apply formula. Here (on paper), you write everything. You understand from this (paper-pencil work) what you are doing.

R: Okay. When you say meaning, what kind of activity helps you understand the meaning?

S4: Here (in Excel), you don't see what's going on. You apply formula. Here (on paper), you write everything. You understand from this (paper-pencil work) what you are doing. In Excel, one cannot see the details.

S1: We don't get meaning from it. We don't use a lot of formula and stuff in it. If you know how to find it and use it, it is easy and quick, but that doesn't show you meaning.

R: If I ask you to explain about median, what way will you explain to me first?

S3: I will arrange the numbers and show the middle value from it.

R: Does Excel show this process?

S3: No.

R: Now, we have the technology (Excel), and you first did it (mean) without technology on the paper. If I ask you what is the meaning of an average, how would you explain it?

S3: Aa… add all the numbers and then divide it by how many numbers you added.

R: Is this meaning clear from this one with paper-pencil or from the Excel function?

S3: It (Excel) does not tell you the details. If you write on paper, you can see the details. On a computer, it only gives you the answer.

S4: If someone does this way in the Excel function for you, then you will not know what that means. But, if you do this on paper, then you will know it.

R: If we directly start with Excel, then will it help in learning about mean?

S4: You will not know what a mean is.

[R=Researcher, S1= Student 1, S2 = Student 2, S3 = Student 3, and S4 = Student 4.]

The major concepts from the above Excerpt-3 are –computing the central tendency value (e.g., median) in Excel is a short-cut, do it mentally without a calculator for understanding, invisible computing in technology, understanding the process through paper-pencil work, and not getting meaning of mathematical process in technology. It is easy to give input in a calculator or Excel function and get the output as a solution to the problem, and it is considered that these technological tools provide shortcut ways to do mathematical problem-solving.

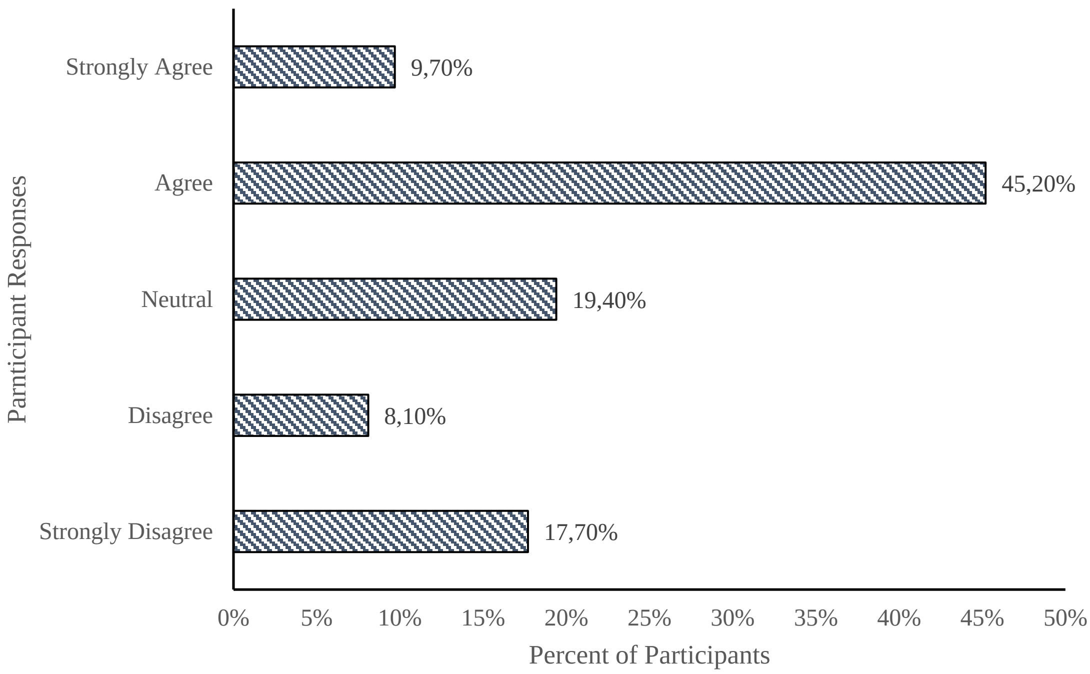

Figure 6. Percent of students who believe the technology for a shortcut and easy

The graph in Figure 6 above demonstrates the percent of students having different beliefs about learning mathematics with technology. A majority of participants (54.9%) believed that technology helps them in learning mathematics by making it a shortcut and easy for problem-solving. However, 25.8% do not believe that technology makes it a shortcut and easy. There were 19.4% of students who seemed neutral about this belief.

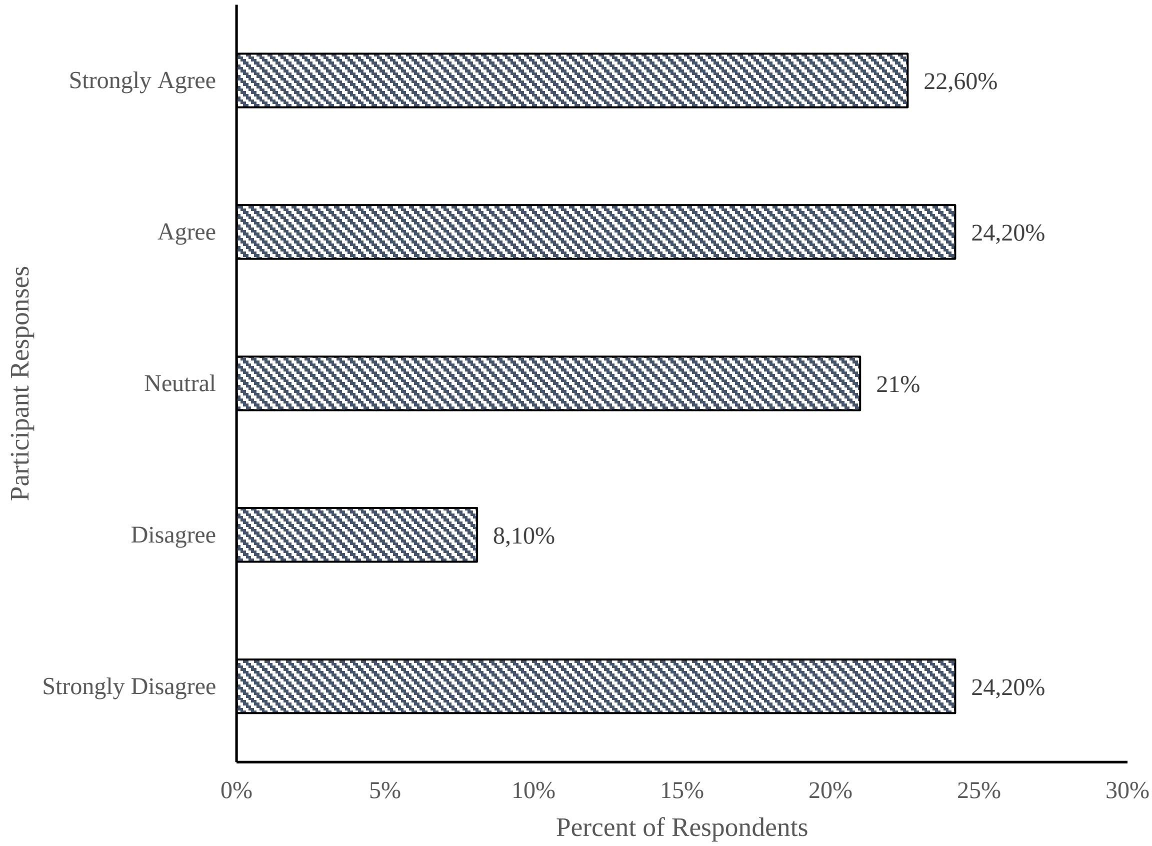

Figure 7. Percent of students who believe the technology vs. paper-pencil for learning maths

The graph in Figure 7 shows that 46.8% of participants believed that they understand mathematical concepts on paper-pencil than on a computer. However, 24.2% of the participants strongly disagreed with the view that they understand mathematics on paper-pencil than on the computer. That means, these students feel that they can learn mathematics better on a computer than just by using the paper-pencil activity with mental calculations. There were 21% of the participants neutral to this view. That means a majority of students either disagreed or they were just neutral to the view that paper-pencil activity is more effective than a computer for learning mathematics. This also suggests that there is no concrete majority of views on either side.

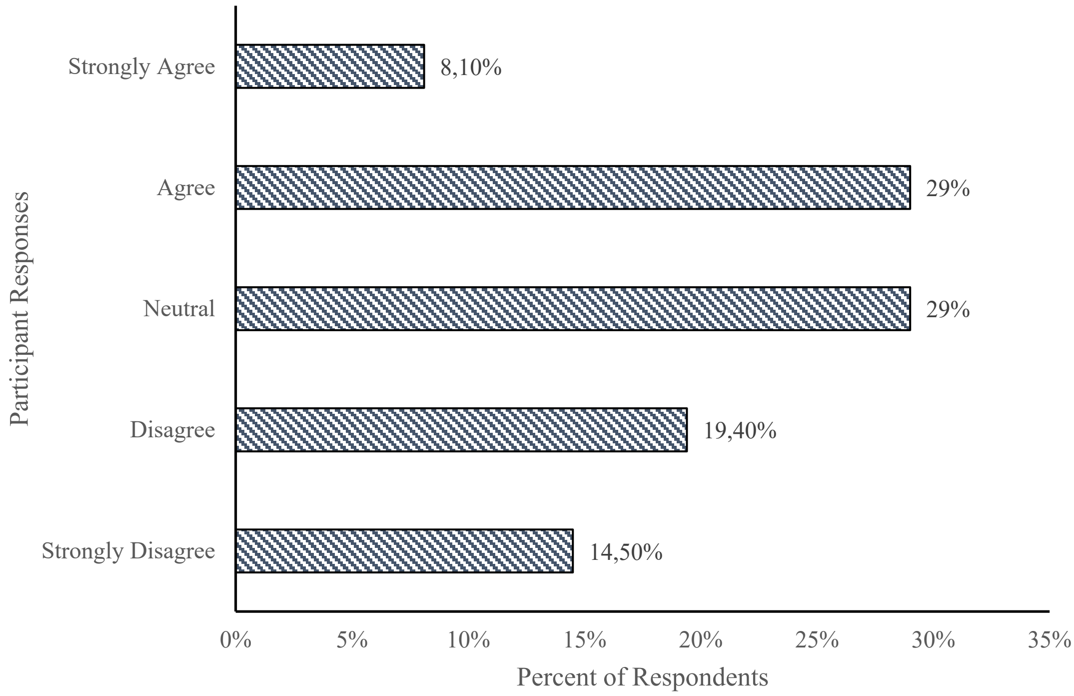

Figure 8. Percent of students who believe the technology for meaning and concepts of maths

The data in Figure 8 indicates that the participants' beliefs about the use of the technology for understanding the mathematical meaning are not founded strongly. About 33.9% disagreed with the belief that technology helps in understanding the meanings of math concepts better than without using it. However, about 37.1% believed it. Still, there was a large percent (29%) of participants who stayed neutral to this view.

The above results clearly indicated that a majority of students did not have a common belief regarding the use of technological tools for understanding the meaning of mathematics concepts. However, the views of participants that technology does not help in learning in the sense of making meaning of mathematical concepts contradict the views in some literature (e.g., Bray & Tangney, 2017). Some pieces of literature support the views expressed by research participants that the use of a computer or calculator may hinder their learning of mathematics (Young, 2017).

When computers entered schools and education communities, then computer-assisted learning (CAL) was considered as a major breakthrough in education with a great potential to revolutionize teaching-learning (MacDonald, Atkin, Jenkins, & Kemmis, 1977). There was a strong belief that the use of technology in the mathematics classroom might enhance student learning (NCTM, 2000; Walen, Williams & Garner, 2003); however, there is meager evidence from the research. "The belief that technology can positively impact student learning has led many governments to create programs for the integration of technology in their schools *and universities*" (Hew & Brush, 2007, p. 224, italic is author's emphasis). A study by Walen et al. (2003) demonstrated that students do not tend to use calculators at first if the mathematical problems are doable either by mental operation or by paper-pencil. They tend to use the calculator only when the problems that they are solving are more sophisticated, and require many steps on paper-pencil. The students who use technology for mathematics problem-solving either already know it, and now they are using the technology for a short-cut, or they don't know it but are following the mechanical procedure just to get the correct solution. Ruthven, Hennessy, and Brindley (2003) reported several positive aspects of technology in teaching-learning, including effectiveness in working, correcting and checking, reducing the volume of tasks, fostering collaboration, enhancing better presentation, and authenticity. However, none of these qualities clearly reflect the quality of learning by the students.

Some past studies, for example, Bennison and Goos (2010), claimed that mathematics concepts integrated into technology improve students' learning. Such a claim has not been substantiated with evidence from classroom practice and students' learning experiences. A research participant in the study by Drijvers et al. (2015) pointed out that even when students use technology for computing or graphing such as calculators or computers, they should be able to provide the evidence of their learning by solving such problems by hand (on paper). In the report, Drijvers et al. (2015) stated, "The quality of student learning with technology is difficult to measure due, in part, to differences amongst mathematics educators: as to what 'learning' means; between those who see technology as a medium to communicate mathematics to students and those who see technology as a means for students to express mathematical relationships" (pp. 4-5). In a similar vein, Salomon and Perkins (1996) stated that "computers in and of themselves do very little to aid learning" (p. 112). There is skepticism around how technology, such as calculators and computers, help students in making the meaning of mathematical process and how to achieve such a goal to develop conceptual understanding, although it may support in visualization and concretization of many mathematical concepts (Utterberg & Lundin, 2017). Technological tools may not be effective for students to learn some content, such as algebra, because of the requirement of mental and operational manipulation by the learners (Yang & Leung, 2015). Some technological tools, such as multimedia technology, helps students make a connection between the contents they already knew to the new contents, thus facilitating their learning (Marshall, 2002). "The process of creating associations and making meaning is a part of learning" (Marshall, 2002, p. i). However, the mere presence of technological tools such as calculators and computers does not facilitate students' learning because it should be used as a tool for making sense of mathematical concepts, not just computing, graphing, or demonstrating (Shifflet & Weilbacher, 2015).

Affective aspects of student beliefs: It is claimed that a belief has both mental and emotional content (Lund, 1925). Therefore, in this sense, students' beliefs about learning mathematics with technology have both emotional and mental content in terms of confidence, feeling, trust, interest, ability, and value. Excerpt-4 is an example of how they expressed such beliefs.

Interview Excerpt-4. Narrative Excerpt of Psychological Aspects of Students' Beliefs about Technology for Learning Mathematics

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R: How would you feel if we did all the activities in the class using technology, like Excel?

S1: I would feel it more difficult to understand.

R: Okay, let's look at how you calculated the median. First, you ordered the numbers and then found the middle number as the median on paper. Second, you used Excel function [= median (A1:A8)]. Which way do you feel better?

S1: Writing on the paper, because it (Excel) is a short-cut only.

R: Does technology help in making you more powerful?

S1: Um, sometimes. All the time, it (technology) does not give us much power. We don't use our brains much. We should balance them.

R: When we learn mathematics, we can use technology, or we don't use it. Which way do you think it is easier?

S2: Without technology.

R: Without technology? What may be the reason for it?

S2: Because it does fast. I have not used it in my whole life. So, it is difficult with technology.

R: So, is it a new experience for you?

S2: Yeh.

R: So, if the program is right, you think technology never goes wrong. What other things do you want to add?

S2: It is not just about mathematics; it is about everything.

R: What kind of experiences you went through while learning mathematics without using technology and using technology?

S2: We didn't use technology in mathematics in school except a calculator.

R: What was the benefit of using a calculator at that time?

S2: In high school, we had too long calculations. We did not have time. Then, with a calculator we could do fast. Even we did not have time to check whether we did right or not.

R: What about in college?

S2: In college, I think technology is very important. Especially Excel. I had a part-time job, and one of the things I need to use was Excel. That's very important.

R: Would you be able to understand the meaning of average if we used Excel to calculate it without doing it on paper?

S2: Yes, I do understand.

R: Really. Can you write function of mean, median, and mode what you did there (in the Excel)?

S2: (She tries it on paper.) Do you mean formula?

R: Yes, write a formula in Excel function.

S2: (She tries the Excel functions for mean, median, and mode in a wrong way and the researcher asks her to replace the semi-colon with a colon.)

R: Does it give you meaning this way (with Excel) or that way (on paper)? What do you think?

S2: I change my mind.

R: Which way do you feel more comfortable in finding the mean, median, and mode?

S4: I use paper-pencil.

R: Why?

S4: Even if I use technology, I will do that (in detail). I will write all.

[R=Researcher, S1= Student 1, S2 = Student 2, S3 = Student 3, and S4 = Student 4.]

The major concepts from the above Excerpt-4 are – difficulty in understanding the technology, the use of technology for student empowerment, the extended application of technology, difficulty with technology, integration of technology beyond the course, understanding the content with technology, changing one's mind, and comfort in using online materials. The students who have less experience of using a technological tool might feel difficulty in understanding mathematics with technology due to changes in the nature of tasks on technology than on paper. Those students who see the extended application of technology in life in different fields want to use it in the classroom for learning mathematics or other subjects. For them, technological tools not only help them in doing things accurately, quick and easy, but it also connects to different aspects of life, such as the future career. They consider that technology may not help in understanding each step of mathematical problem-solving because it is direct and quick. However, it might help students when they have learned concepts before the use of technology. Although students sometimes might consider that technology helps them in understanding the mathematical meanings and concepts, but that may not reflect their permanent beliefs. It even may get changed during the process of learning and conversing about the use of paper-pencil and technology. They may find it easy to get online materials and resources to learn mathematics through technology such as websites and YouTube videos.

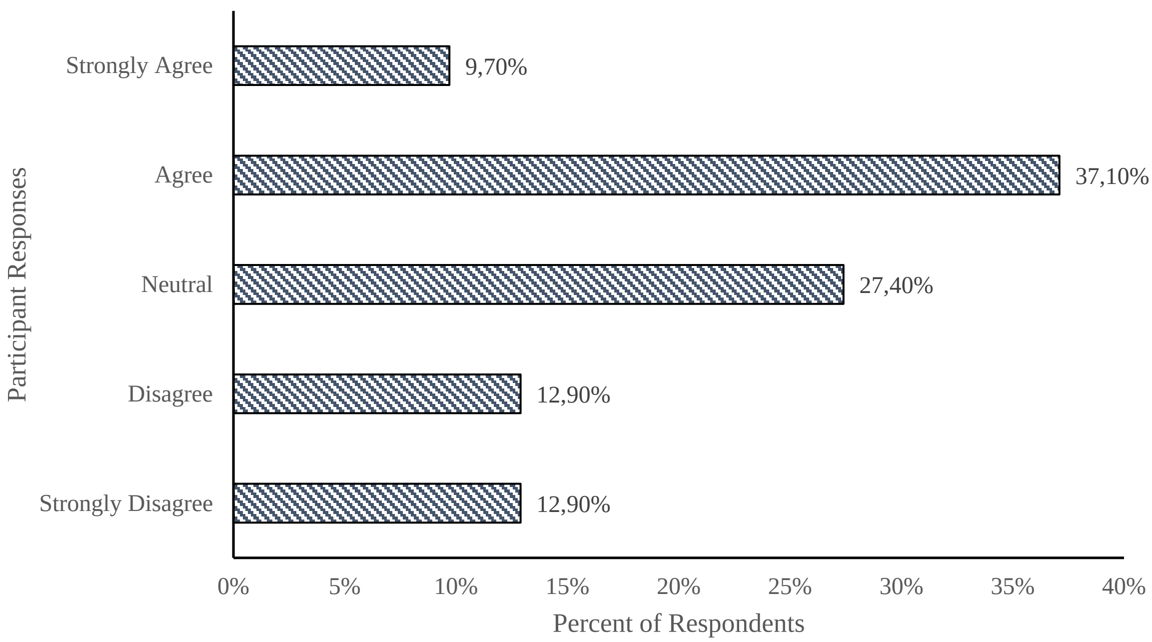

Figure 9. Percent of students who believe that technology is for making maths interesting

The graph in Figure 9 indicates students' beliefs that technology makes mathematics learning more interesting. However, this view is not the majority belief because it represents only 37% agree, and 9.7% strongly agree with it. About 25.8% of students did not believe it, and a large percentage of students (27.4%) remained neutral to this belief. The neutrality to this view, by a large percent of the participants, indicates that they are not sure about how the use of technology either makes mathematics learning interesting or not.

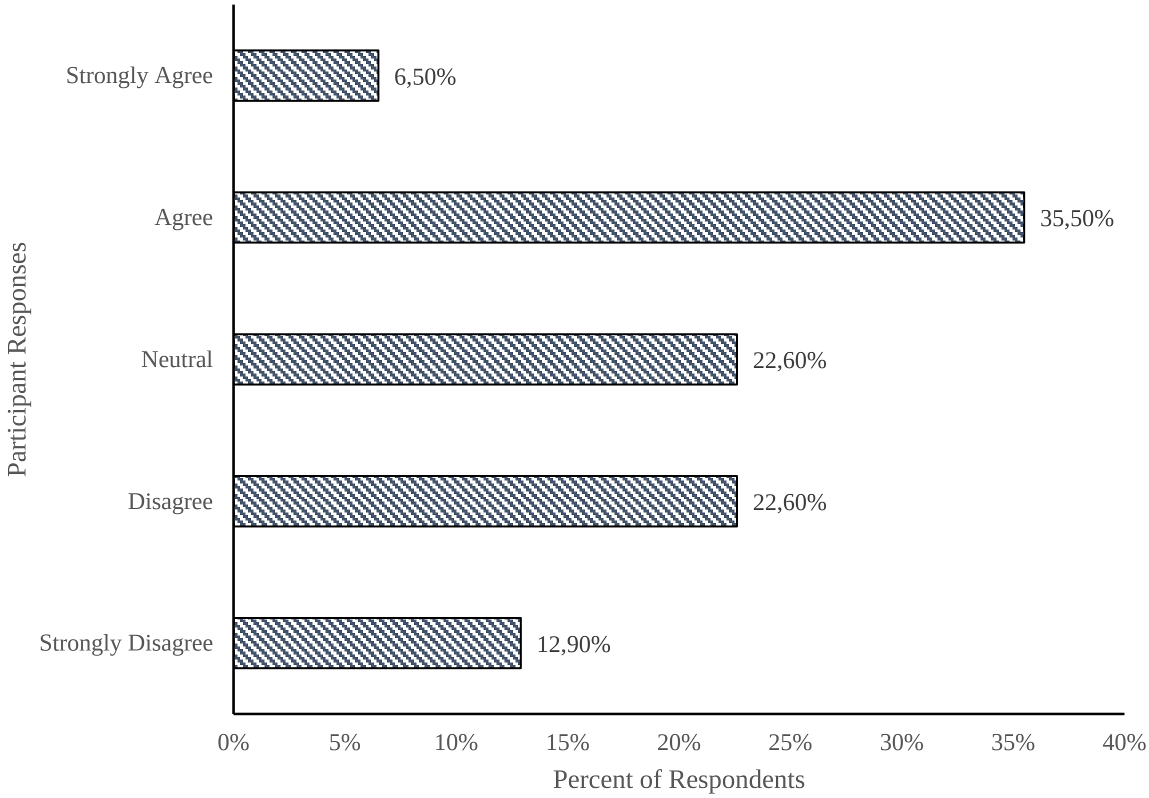

Figure 10. Percent of students who believe technology consumes time for learning maths

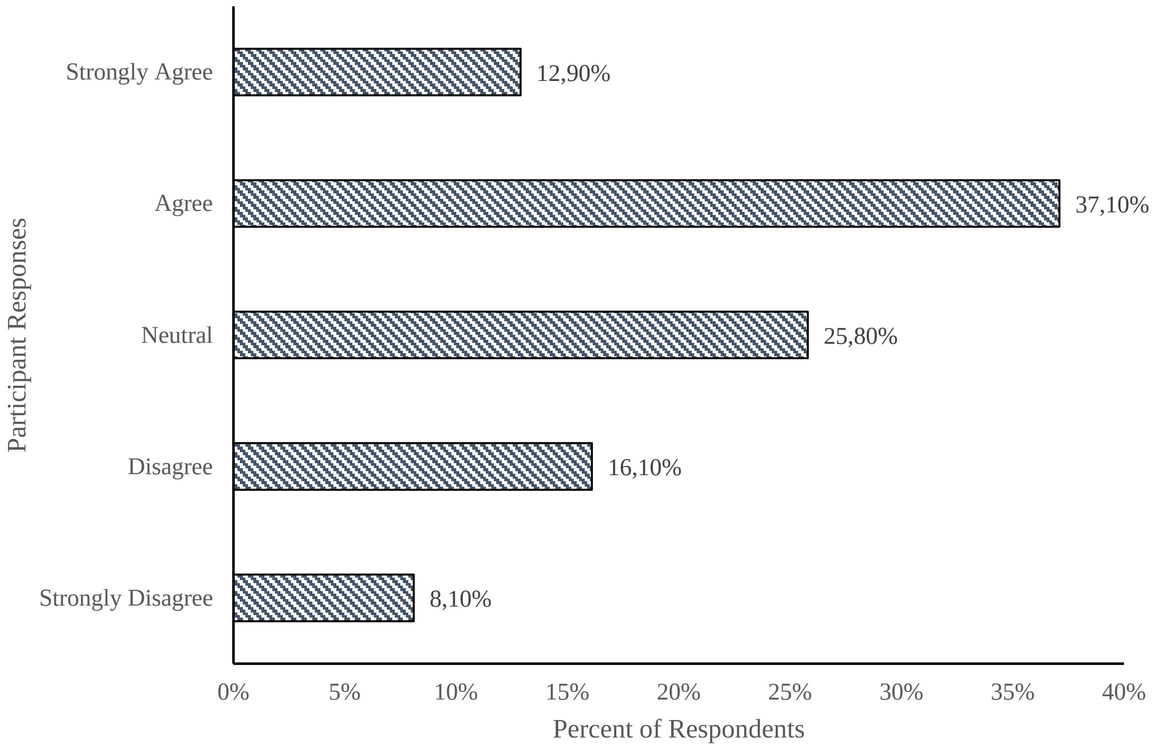

Figure 11. Percent of students who believe technology improves learning maths

The graph in Figure 10 shows that 42% of the participants (with responses both agree and strongly agree) believed that using technology in learning mathematics is a time-consuming process. That means these students think that using technology for learning mathematics means spending more time in learning technology together with mathematics while working on mathematics with technology. However, 35.5% of the participants (with responses disagree and strongly disagree) did not believe this view. About 22.6% of the participants could not align themselves to either side and remained neutral. For them, it may depend on the nature of the mathematical problems that may be time-consuming or fast. The findings in this figure somehow contradict their views expressed in Figure 4 because only 11.4% of students had disagreed that technology makes mathematics problem-solving fast and accurate. The graph in Figure 11 shows participants' beliefs about the use of technology for improving mathematics learning. About 50% of students (with responses agree and strongly agree) believed that the use of technology helped in improving their learning of mathematics. Whereas, 24.2% of the participants' beliefs were against this view. Again, a large percent (25.8%) of the participants remained neutral to this belief. That means many participants have no opinion or belief about whether the use of technology really improves the learning of mathematics.

There are different motivating factors to use technology in mathematics and other discipline learning—technology connected to the future job, preference of technology after learning concepts, difficulty with technology, and consequence of using technology while learning (De Vries, as cited in Ardies et al., 2015). Literature shows that students sometimes have difficulty in using technology for learning mathematics due to the demand for learning the technology first to use it to learn mathematics (Crompton et al., 2018). Using MS Excel spreadsheets may cause "students' anxiety in using formula, functions, and logical tests to solve math problems when learning software applications" (Shi, 2005, p. 3) instead of mathematical concepts. Students might feel that it is an additional burden to learn about technology to use it in mathematics learning. "Although, in general, teachers may agree there are potential benefits of technology for students' mathematics learning, many remain unsure or unconvinced about whether its use helps students explore mathematical concepts or unfamiliar problems" (Drijvers et al., 2015, p. 11). In this regard the findings of this study support what Cheung and Slavin, (2013) concluded: "Educational technology is making a modest difference in the learning of mathematics. It is a help, but not a breakthrough" (p. 102).

Limitations of the Study

The study had three major limitations. First, there were only four participants' in the first stage, who were all first-year undergraduate female students and sixty-two participants in the quantitative survey in the second phase of the study. Therefore, the findings cannot be generalized to the male population and even all other female populations due to the very small sample size. Second, while applying RCGT for the interviews and analysis, I had conducted only one interview with each participant instead of several interviews in the context of using different technological tools and mathematics contents. Third, the participants expressed their beliefs during the interviews were limited to the use of calculators and MS Excel on computers to find mean, median, and mode. The interview contexts with other technological environment and mathematical contents might affect their expressions of beliefs. There were only 62 participants' in this study in the quantitative part. Therefore, the findings cannot be generalized to the male student population and even all other female student populations due to the very small sample size.

Implications and Conclusion

Students' beliefs about the use of technology in learning mathematics have pedagogical implications for improving the interplay between mathematics learning, technological tools, and transformative teaching of mathematics. This interplay may enhance the application of technology to create a positive image toward the use of the tools for mathematics learning by transforming student beliefs about using technology for learning mathematics meaningfully. The first category 'technology for computing and graphing' demonstrates that students prefer to use computers and calculators for a quick process of mathematics problem-solving and representations. Students who have such beliefs may use the tools to enhance speedy computing and graphing of mathematical operations, relations, and functions by increasing their efficiency by using technological tools. This kind of action also supports the second category 'technology for speed and accuracy,' which seems obvious that students do not want to spend a long time to solve most of the routine mathematical problems. Although students may use these tools as a short-cut to the mathematical procedure to reach the solutions without going through all algorithmic steps, this, in fact, may prohibit them from learning the meanings and concepts of what they are doing. Therefore, teachers can design the activities to engage students in creative mathematical operations and functions so that they can develop a positive-belief about technological tools for understanding mathematical meaning and concepts. The final category about the psychological aspects of beliefs relates to emotional and mental contents that might influence their long-term practice of using or not using technological tools in learning mathematics. Hence, these categories of beliefs have strong pedagogical implications for the meaningful learning of mathematics by using technological tools, such as calculators and computers.

The majority of the participants in the quantitative study used technology while learning mathematics, and mostly they used calculators (43.5%) for this purpose. The popular technological tool they used in learning mathematics was a calculator (90.2%). A percent (23%) of participants have used other online apps for learning mathematics. This indicates that mathematics learning is still dependent on traditional methods of calculations by using calculators. A majority of the participants in this study (66.2%) believe that technology helps in learning mathematics in terms of computing and graphing, 54.8% of them believe that technology, in fact, ensures speed and accuracy in mathematics learning and 50% of participants think that the use of technology helped in improving their learning of mathematics. These findings are in line with past studies. The use of technology not only helps to compute or graph fast, but it also provides students easy and fast access to other sources of learning, for example, online materials, videos, and apps and connects them to others (Marshall, 2002). However, further research is needed to establish the relationship between belief characteristics and their effects on students learning of mathematics with technology.

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Appendix: Interview Protocol

Title: Early Undergraduate Students' Beliefs about Learning Mathematics with Technology

Date of Interview: ______________________

Time of Interview: ______________________

Location of Interview: ______________________

Interview Type: ______________________

Interviewer: ______________________

Interviewee: ______________________

Sample Interview Questions (Modeling Central Tendency- mean, median, and mode with Excel)

1. What do you mean by central tendency in mathematics and statistics? What are the different central tendencies?
2. How did you learn about these central tendencies? For example, how did you first learn about average or mean?
3. If a distribution of mathematics scores of students in a class is given as-

   12, 14, 12, 12, 16, 18, 09, and 15; How will you find mean (or average) from this data?
4. How will you find median score? What is it?
5. How will you find modal score? What is it?
6. What is your experience of learning central tendencies (i.e., mean, median, and mode) with using Excel?
7. How was your experience when you first learn about the central tendencies?
8. Let's construct a dataset of scores of students in a class using RANDBETWEEN Function in the Excel. For this, let's start from generating a random number between 0 and 5 in a cell A2. Let's name the column A as Scores in Science in the cell A1. Let's copy the same formula from A2 up to the cell A16. Then calculate mean (or average) of the scores.
9. What is difference between calculating the average without using Excel and using the Excel?
10. Let's find the median of the same data set without using Excel function. How do you find the median without using Excel?
11. Now let's find the median using Excel?
12. What is difference between computing median with and without and Excel function?
13. What is the mode of this data set? How do you compute a mode of a data?
14. How you compute the mode using Excel function?
15. What is the difference between computation of mode with and without using Excel?
16. Now let's select the cells from A2:A16 and copy the same format to the cells B2:B16, C2:C16, D2:D16, and E2:E16. Name these columns in the cells B1, C1, D1, and E1 as Scores in Math, English, Social, and Art respectively.
17. Now calculate the mean, median, and modes of the data in the columns B, C, D, and E by using respective Excel Functions.
18. Now create a column-chart for the mean, median, and mode. Hold down the function key and then press and release the F9 key. Observe what happens to these central tendencies. Which one fluctuates more? Which one remains relatively stable (less fluctuation)? Why?
19. Now let's stop here. Think back to what we have just accomplished. Please share with me what do you believe about the use of Excel while calculating and modeling the mean, median, and mode.
20. Based on your experience of working with Excel (while modeling the central tendencies), what do you believe about use of Excel or other technologies in learning mathematics? (Probes: How, why, why not….?)