ASEE 2022 ANNUAL CONFERENCE
Excellence Through Diversity
MINNEAPOLIS, MINNESOTA, JUNE 26TH-29TH, 2022 ASEE
Paper ID #36784

STEM Students' Technology Choice Differences for Solving a Graphing Question - Two Different Institution Students' Preferences for Solving a Graphing Question

Emre Tokgoz (Associate Professor)

Samantha Scarpinella

Pennsylvania State University Industrial Engineering PhD Student

© American Society for Engineering Education, 2022
Powered by www.slayte.com

STEM Students' Technology Choice Differences for Solving a Graphing Question - Two Different Institution Students' Preferences for Solving a Graphing Question

[1]Emre Tokgöz, [1]Elif. N. Tekalp, [1]Berrak S. Tekalp, [2]Hasan A. Tekalp,[3]Samantha Scarpinella, [3]Michael Giannone

[1]Emre.Tokgoz@qu.edu, [1]Elif.Tekalp@qu.edu, [1]Berrak.Tekalp@qu.edu, [2]Hasan.Tekalp@qu.edu
[3]ses6506@psu.edu, [1]Michael.Giannone@qu.edu

[1]Industrial Engineering, School of Computing and Engineering, Quinnipiac University, Hamden, CT, 06518, USA

[2]Mechanical Engineering, School of Computing and Engineering, Quinnipiac University, Hamden, CT, 06518

[3]Harold and Inge Marcus Department of Industrial and Manufacturing Engineering, Penn State University, University Park, PA

STEM students' decision making on the use of a technology for determining STEM related problems can be challenging. Web-based applications as well as computer and calculator programs are often used for engineering calculations Students' background in each institution is driven by the technological solutions that they are trained to use. These different technologies are impactful on students' learning paradigms. The objective of this work is to investigate undergraduate and graduate STEM students' technology solution choice differences and commonalities with the justifications of their choices to solve a calculus problem. The findings presented in this work can particularly help educators in making technology choices for different calculus concepts through the realization of STEM students' interest to solve different calculus questions as well as the variational analysis of STEM majors between two institutions located in the U.S. While majority of the participants preferred to use the technology that they are most familiar with or learned how to solve the research question, some of the computing students' chose to solve calculus problems based on the technology that they are proficient in using even if they didn't know how to solve such problems.

Key Words: Undergraduate and graduate STEM education; Technology preference; Computer Program; Calculator; Matlab; Mathematica; Python; N.I. LabVIEW; Java; C; C++; C#; Excel; Auto CAD; TI calculators; Wolfram Alpha; calculus

Introduction

There are challenging problems in STEM research that can be solved by using different technologies. STEM students are usually expected to have a good grasp of the paper-pencil solution to calculus questions to demonstrate critical thinking ability while they are also expected to use technology to determine solutions to these questions. The strategic use of technology by STEM majors enhances their engineering and mathematics learning. Technology education of students for making right decisions to pick the right technology for solving calculus questions is a crucial component of calculus education.

The research results shared in this work received Institutional Review Board (IRB) approval for data collection. Qualitative and Quantitative data are collected during the research period for the following research question that are based on the basic function knowledge that is commonly covered using technology.

Q. If you are required to draw the graph of a given function by using technology, what kind of technology would you use?

This question particularly helps with the determination of participants' interest in using calculator noting that functions are commonly covered as a part of high school education of STEM majors. STEM students' knowledge of various technologies to solve engineering and mathematics problems can be an important part of their learning practices. These students are observed to face major obstacles as a part of pedagogical research when they solve calculus related problems by Tokgöz (2017, 2019-1, 2019-2, 2016-1, 2016-2, 2015-1, 2015-2) and Tokgöz et. al (2021-2, 2021-3, 2020-2, 2018, 2018-1, 2018-2, 2017, 2015). Solving some of the STEM problems by hand can be challenging and technology can be used to solve such problems (Tokgöz et. al (2021-1, 2020-1), and Tokgöz (2017)). Advancement of technology today can help to solve a problem easily by using a calculator or a web-based application in few minutes, however the same problem's solution can be very complicated by using such a technology or by hand if the person doesn't know how to use the technology. Students may give up if they won't be able to determine the solution while trying to solve the problem due to missing knowledge of programming language's script or not being familiar with the technology used.

Majority of the existing research focuses on learning preferences of students to solve engineering problems; see for example Felder and Silverman (1988) and Rosati (1998). Education of various technologies in various engineering fields as a part of an undergraduate curriculum is discussed by researchers such as Clough (2002) and Maase & High (2008); however, to the best of our knowledge, a qualitative study similar to the one explained in this article was not conducted previously. In this work, the correlation analysis of the qualitative and quantitative data collected from two different institutions is accomplished for understanding the commonalities and differences between STEM majors of two institutions based on their preferences of using technology to solve a function graphing question. Research participant population consisted of 24 STEM students from a university located at the Northeastern side of the U.S. (to be called Institution 1) and 17 students of a university located at South-Central region of the U.S. (to be called Institution 2 throughout this work.)

Correlation analysis of the participants' responses is conducted at institutional level to the above listed research question based on their qualitative and quantitative responses by using the data of (Tokgöz et. al (2021-1) and (2020-1), and Tokgöz, (2017)). Therefore, correlations and differences between the students' preferences on using technology between the two institutions to solve the same research questions is investigated for improving technology education of STEM students to have a positive impact on their calculus educational experiences with suggestions to the educators. Next section is devoted to the research procedure conducted and the participant background information of both institutions. The following section is devoted to the analysis of the research question using both institutions' participant information and the corresponding correlation analysis. Last section is devoted to conclusions, suggestions to STEM educators, and future direction of research.

Research Procedure & Participant Information

In this work, the correlation analysis of the qualitative and quantitative data collected from two different institutions is accomplished for understanding the commonalities and differences between STEM majors of two institutions based on their preferences of using technology for solving a function sketching question. Research participant (RP) population consisted of 24 STEM students of Institution 1 and 17 students of Institution 2. Institution 2 is a research university with the 17 participants either being senior undergraduate or graduate STEM students that either

enrolled or completed a Numerical Methods/Analysis course. Institution 1 is an educational institution and the 24 participants of this research completed 8 credits of calculus.
Institutional Review Board (IRB) approval is attained from both institutions to collect the research data. All participants of both institutions are compensated money by the Principal Investigator (PI) for both the provided written responses and the video recorded interviews that they participated. The collected data spanned over three years. The participants of both institutions completed the same questionnaire that contained the research question listed in this work and calculus questions used for pedagogical research purposes. Each participant is scheduled a time frame with one of the research team members to complete the written questionnaire and another follow up interview is scheduled with each participant to conduct the video recorded interview. Follow-up interviews are completed by the PI of the research that allowed the research team to further understand the details on the participants' written responses. The data is solely collected by the PI from the participants of Institution 1 while the same PI mentored the collection of data from Institution 2. The research question is evaluated for each institution as well as observing correlations between the two institutions' participant responses to the research question.

A certain programming language or calculator is expected to be used in engineering and mathematics courses for solving math-based problems. The following are investigated by using the research question to outline the objectives of this research:

- Do STEM majors prefer solving calculus questions by hand or by using technology?
- What are the institutional variations for STEM majors' technology choices for solving calculus questions?
- What are the institutional differences in participants' existing technology interests to solve different mathematics problems?
- What is the institutional correlation between the technology choices of the participants based on the research questions analyzed in this work?
- Is there a correlation between the two institution participants' calculator choices due to their high school education to solve the calculus problems?

A list of technologies covered for the research participants of Institution 2 included but not limited to the following technologies based on the Numerical Methods/Analysis content coverage:

- Computer programming languages: Matlab, Mathematica, Python, N.I. LabVIEW, Java, C, C++, C#, Excel, Auto CAD, etc.
- Calculators: Texas Instruments 83, 83+, 84, 86, 89, 89-Titanium, etc.
- Online resources: Wolfram Alpha, etc.

The list of the technologies known by the research participants of Institution 1 included but not limited to the following technologies:

- Computer programming languages: Matlab, Excel, etc.
- Calculators: Texas Instruments 83, 83+, 84, 86, 89, 89-Titanium, etc.
- Online resources: Wolfram Alpha, etc.

The variational nature of the technology covered between the two institutions is the main driver of the results attained in this work, however the preferences of the participants was not necessarily based on these technologies' coverage as it will be outlined in the next section.

Research Question's Participant Response Analysis

The ability to graph a mathematical function is an important but yet one of the most basic calculus applications of technology that STEM majors are expected to know prior to the completion of calculus 2. The use of technology to sketch the graph of a function sometimes date back to the high school years of some of the students while it is not starting until the university level education. The use of technology can have an important role in the courses to be taken later by the students and these decisions made by the instructors have an impact on the following courses in STEM. For instance, a calculus instructor may only require TI 83 and TI 84 calculators while another calculus instructor may allow students to use any TI calculator including advanced ones such as TI 89. Similarly, technology choices of instructors in STEM courses influence students STEM related calculus concepts that is driven by the instructors' technology choices that may also be specific to the STEM field and industry dependent based on the popularity of the software in the industry. For instance, LabView is a software that may interest electrical and mechanical engineers depending on the application with its possible use for solving calculus questions. In this section the objective is to observe technology preference of undergraduate and graduate STEM research participants' technology preferences to sketch the graph of functions. Questionnaire and interview responses of the participants of both Institutions are analyzed based on their responses to the following research question.

Q) If you are required to draw the graph of a given function by using technology, what kind of technology would you use? Please either choose one of the following or write your own answer and explain why.

1. Calculator (If this is your choice, please specify the kind of calculator you use)
2. Excel
3. C
4. C++
5. C#
6. Fortran
7. Matlab
8. LabVIEW
9. Other _____

Institution 1 Participant Response Analysis

The remaining part of this subsection is devoted to the analysis of participant responses. Figure 1 displays the distribution of these students' technology preferences. This figure contains all choices of the participants meaning if a participant decided to use both Excel and TI technologies then both options are entered in the figure. What follows this figure are some of the qualitative and quantitative participant responses justifying the reasons for using the technology as well as level of familiarity. Majority of the students selected a technology based on its simplicity, or the ease of technology's use depending on the belief of the student. Institution 1 participants' technology choices are distributed over the choices of Excel, MATLab, and TI calculators.

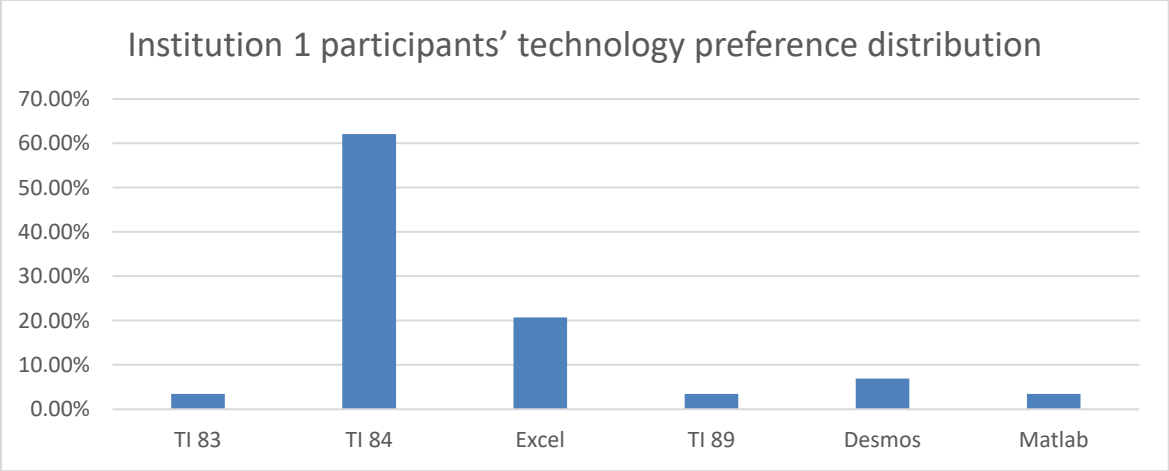

Figure 1. Institution 1 participants' technology preference distribution to graph a function.

The written responses to the first research question and the corresponding number of preferences are outlined in Table 1 below.

TI 83	TI 84	Excel	TI 89	Desmos	Matlab
3.45%	62.07%	20.69%	3.45%	6.90%	3.45%
1	18	6	1	2	1

Table 1. Percentage of Institution 1 participants' choices and the corresponding number of choices.

The response of RP 5 in Figure 2 below indicates preference of the use of a calculator, specifically the TI- 84+ calculator because this student has the calculator experience and makes a comparison to the use of Excel and other programming languages.

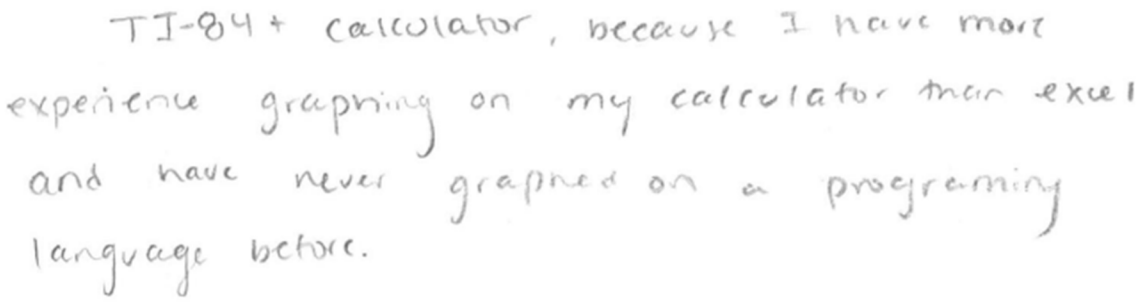
TI-84+ calculator, because I have more experience graphing on my calculator than excel and have never graphed on a programing language before.

Figure 2. Written response of RP 5 to the research question at Institution 1.

Another participant had a conditional statement as displayed in Figure 3 below for graphing a function that is driven by the input provided.

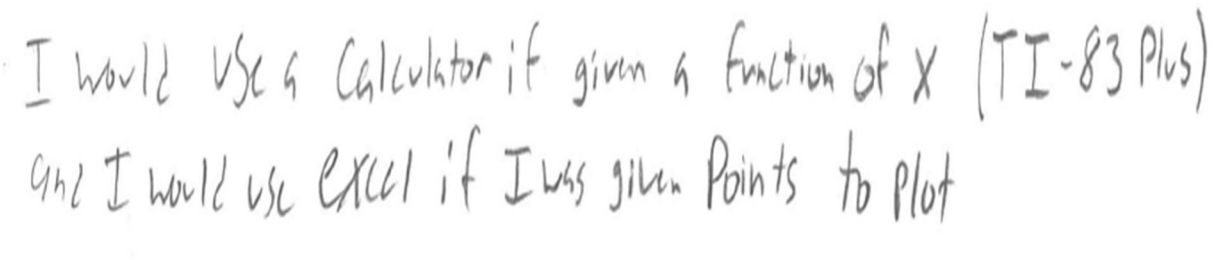

Figure 3. Technology preferences of RP 8 based on the possible format of input at Institution 1.

Along the same line of responses received for this research question, some of the TI users written responses are as follows:

RP 1: Calculator, easiest to plot points…TI-84 Plus
RP 2: TI 84
RP 3: Use TI 84…Plug in function into calculator and you would be able to see the graph.
RP 4: TI 83 is the most easily accessible to me and I have experience with it

During the oral interviews, the PI investigated further details on the participants' interest of use of other programming languages and their high school programming experiences as outlined below:

PI: Here, you said you would choose ti 84 or Excel. Did you learn any of these in high school?
RP: In high school, I used the charity for
PI: Okay, and did you learn Excel at university.
RP: Yes.
PI: Did you learn any other program that you could use it for?
RP: Yeah, I know. Matlab too
PI: Okay, so you've done MATLAB anything else. And you said calculators always very quick and easy to use. How about Excel, is it easy to use?
RP: Yeah, it's also very easy to use. But it's, um, I feel like I use it more for if I have data and I need to get graphs are trends and things like that. But, in this case, using this test, I would use the calculator.

Similar to the observations outlined by Tokgöz et. al (2021-1), the participants technology choices are mainly driven by the simplicity, experience of use, and familiarity with the technology.

Institution 2 Participant Response Analysis

Institution 2 participants' responses to the research question are analyzed in this section. Figure 4 below integrates qualitative oral interview responses to the written responses. Similar to Figure 1, some of the participants' multiple choices are entered in Figure 2 noting that they stated their equally likely technology choices. The interview responses indicated various reasons for participants to choose a particular technology to be able to solve the given research problem.

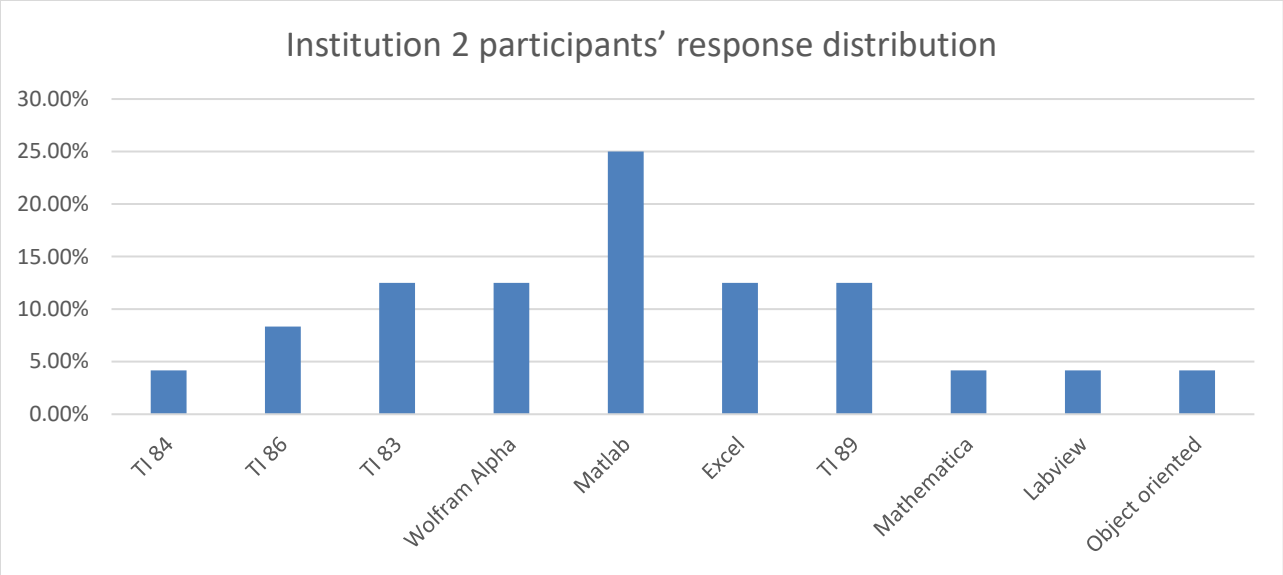

Figure 4. Institution 2 participants' research question response distribution.

The written responses to the first research question and the corresponding number of preferences are outlined in Table 2 below.

TI 84	TI 86	TI 83	Wolfram Alpha	Matlab	Excel	TI 89	Mathematica	Labview	Object oriented
4.17%	8.33%	12.5%	12.5%	25%	12.5%	12.5%	4.17%	4.17%	4.17%
1	2	3	3	6	3	3	1	1	1

Table 2. Percentage of Institution 2 participants' choices and the corresponding number of choices.

The PI investigated reasonings of the research participants with varying interview questions. For instance, one of the participant's justifications to choose Matlab below in Figure 5 is due to the image processing experience that didn't relate to a mathematics course.

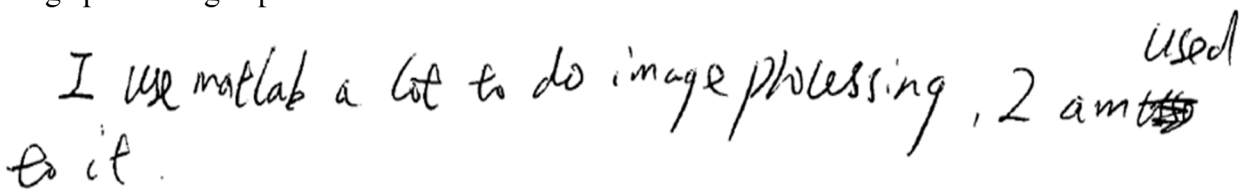

Figure 5. Institution 2 participant's choice for using Matlab

Some of the transcribed summaries of the oral interviews are presented below to display some of the participants view of choices and their high school experiences.

RP 1*: We used TI 83 in high school...I just know how to pretty much use them. I mean we started using them heavily really in 9th grade where I come from so. That's really what I had experience with…We weren't allowed to use anything else…we were not allowed to use TI-89s because like they do too much for you and they wanted us to learn…I used TI-89s of my friends, they are weird. I don't like them…I can't figure out how to back space…*

…

RP 2*: I learned Matlab before when I was working on data processing…imported and exported data...I used it for maybe two or three months…Actually I'm working on a project, I learned programming in my private work. In one year or two years maybe... I learned Matlab not by step by step…if I just have a problem and I just looked up the help document and find the function. I just*

plug in and then look at another problem, I just google it to see how to solve the problem. I didn't learn it step by step. How to define the variable, how to deal with matrix…I just directly go to the help document to solve the problem. Not so systematic I think.

…

***RP 6:** I learned to use one of these in high school and I haven't used a calculator since until enrolling again Numerical Methods. That is the first time that I have done sort of in actual solid number work, since I got here…I don't have any knowledge of any of these (pointing the programs written on the paper.) except Excel maybe but I don't know how powerful the analytical tool of Excel…I can't program in Excel…Using spreadsheets.*

…

***RP** 7: I would use Wolfram Alpha because I saw it at a news side long time ago and recently started looking at it as I started taking more math…I learned a very little of C++ in his school at a course but not much else really. I didn't really go too far in C++…*

…

***RP 8:** I would use LabVIEW, it is easy to use… I learned C++ and Java…I wouldn't use C++ or Java to create a graph…I might use them to calculate values but no to graph the function.*

The analysis of responses attained from Institution 2 resulted in different outcomes in comparison to the Institution 1 participants. Correlated outcomes on decisions made by both institution participants included ease of access, simple usage, and not knowing other technologies; however, there is a subtle difference. Those students who expressed that majority of the Institution participants who learned object-oriented programming during high schools or university preferred to not use the corresponding software for graphing a function; Only one participant showed interest in the use of such software. The interview responses regarding to the graphing problem indicated the following outcomes for the majority of the participants:

- The backgrounds in different technologies were not extensive for the ability to choose for graphing a function.
- Not knowing how to use several technologies to be able to choose from during their high school years or university degree for graphing a function.
- The interest to use a graphing calculator such as TI technologies carried over from high school years into their university education and they continued with this preference.

Institutional Participant Response Variation Analysis

In this section we display the institutional differences between participants' responses to the research question. Figure 6 below displays the variational bar graph differences between participant responses based at the institutional level. One of the outstanding results that can be realized from this graph is 37.5% of Institution 2 participants' preference to use a T.I. calculator while 62.5% preferred to use a software-based technology for sketching the graph of a function. The same ratio is skewed towards the calculator use for Institution 1 participants; 68.97% of Institution 1 participants preferred to use a T.I. graphing calculator while the remaining students preferred to use Excel, Matlab, or Desmos web-based graphing calculator application. Another result attained from this data is the use of Excel: 20.69% of Institution 1 and 12.5% of Institution 2 students chose to use Excel that appeared as the most correlated choice based on the number of choices between the institutions. TI 86, Wolfram Alpha, Mathematica, Labview, and object oriented programming languages (excluding Matlab) are only chosen by Institution 2 students while TI 86 and Desmos are only chosen by Institution 1 students. 20.83% of the participants of Institution 1 chose more than one different method to graph a function while the same percentage is 17.65%.

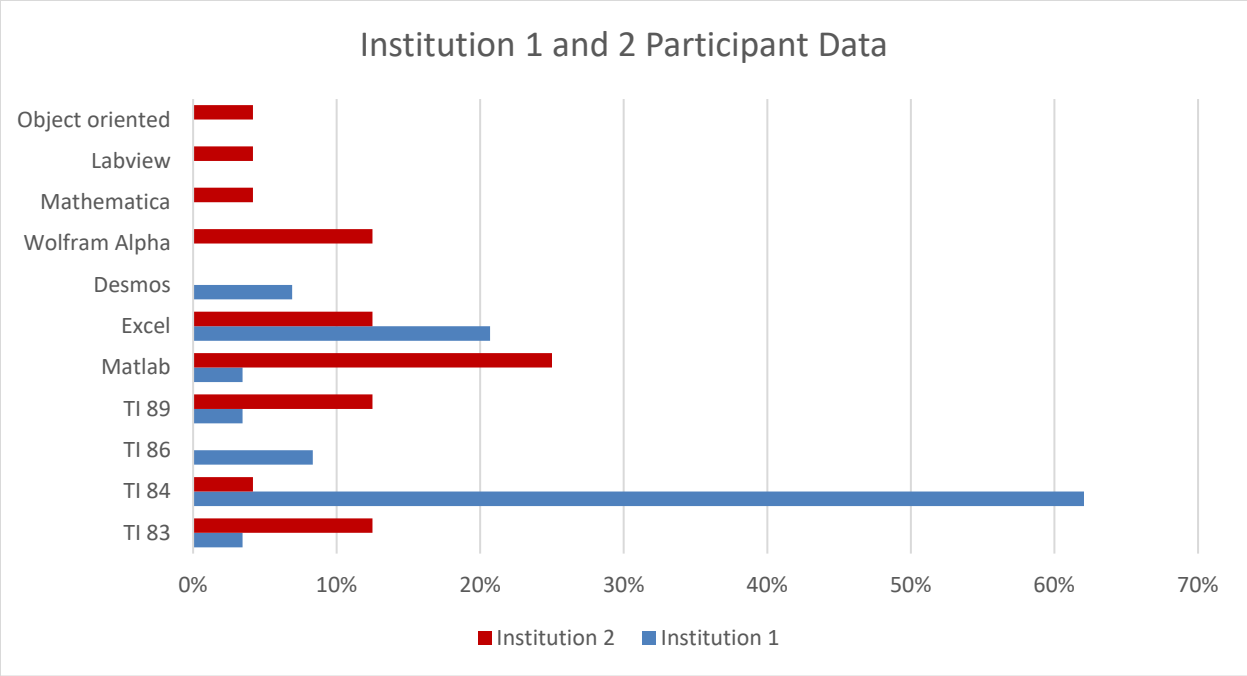

Figure 6. Summary of the participants' responses to the research question from both institutions

The following graph contains only the common technology use interest from both participants that are extracted from Figure 6 above with Table 3 displaying the percentage summary of these common choices.

	TI 83	TI 84	TI 89	Matlab	Excel
Institution 1	3.45%	62.07%	3.45%	3.45%	20.69%
Institution 2	12.5%	4.17%	12.5%	25%	12.5%

Table 3. Common technologies chosen by both institution students.

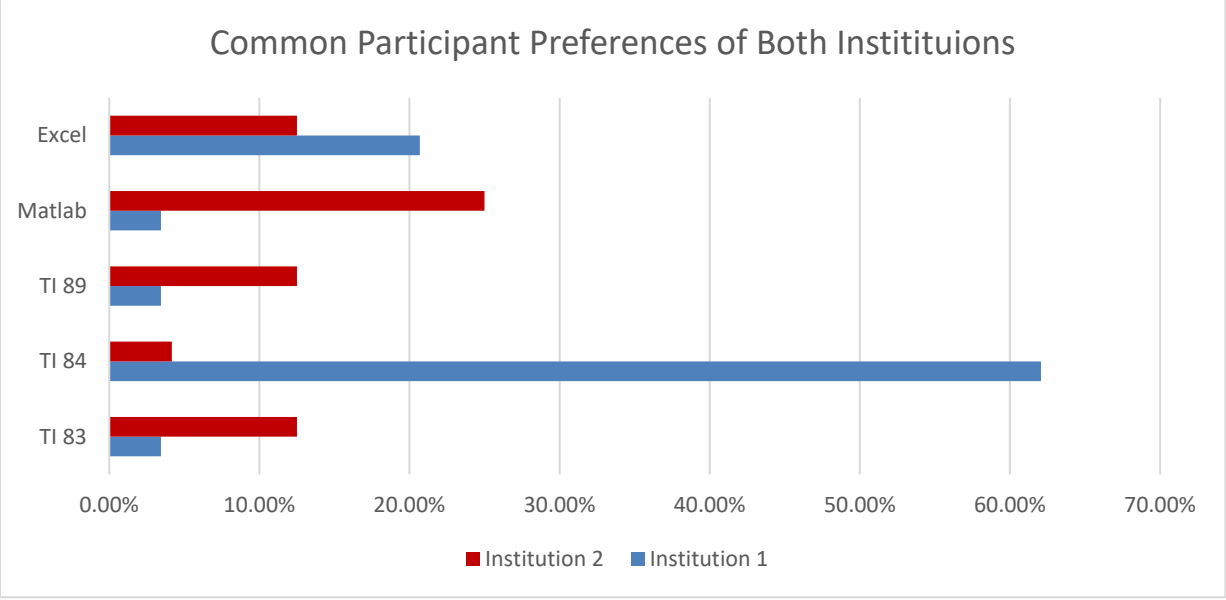

Figure 7. Common technologies chosen by participants of both institutions

These common technology choices outlined by the participants of both institutions including Excel, Matlab, and TI technologies cover 93.11% of Institution 1 participants' technology choices. Similarly, justification correlation to use the chosen technology is driven by Institution 1 participants for both institutions: the participants' technology choices are mainly driven by the simplicity, experience of use, and familiarity with the technology. Experience with calculator during high school years of Institution 1 participants are observed to have a strong impact on the decisions made by them during the video recorded interviews. Institution 2 participants had similar reasonings with different technology experiences that were gained during high school years however it was not as high as Institution 1 participants; majority of the choices of Institution 2 participants were driven by their most recent experiences. This difference can be due to most of these participants' being senior undergraduate or graduate level students while Institution 1 students being junior or senior undergraduate students.

Conclusion & Future Work

This work contained the variational analysis of participants' technology choices for sketching the graph of a function based on the data collected from two different institutions. The corresponding qualitative and quantitative data was collected in three years. The major goal of this article is to investigate the commonalities and differences between STEM majors of two institution students based on their preferences of using technology for solving a function sketching question. The results attained from this research can help STEM educators to make adjustments in the technologies used for similar questions. Research participant population consisted of 24 STEM students of Institution 1 and 17 students of Institution 2. Institution 2 is a research university with the 17 participants either being senior undergraduate or graduate STEM students that either enrolled or completed a Numerical Methods/Analysis course. Institution 1 is an educational institution and the 24 participants of this research completed 8 credits of calculus.

Institutional Review Board (IRB) approval is attained from both institutions to collect the research data. Each student of both institutions is compensated money by the Principal Investigator (PI) for both the provided written responses and the video recorded interview participation. The collected data spanned over three years.

Technology cannot replace conceptual calculus understanding, computational fluency, or problem-solving skills; however, its strategic use enhances STEM education. One of the ways to improve STEM students' calculus technology choices would be to educate them about possible web-based resources that they can utilize. Another way would be helping the students to learn a software package during high school years or early university education that is user friendly and commonly used in industrial settings such as Microsoft Excel. It is possible to code in Excel for extensive solutions and design calculus-based solutions.

Similar to the results presented by Tokgöz et. al (2021-1), STEM educators and researchers can use this study in many different ways. The common technology preferences given by students can be more utilized in STEM courses to better the students' education. Professors can use certain technologies to better their courses and multiple software packages can be used to give the freedom to the students to use the one that they favor the most. This "freedom of choice" is important because some of the students of both institutions indicated to choose the software that they are the most comfortable with, readily available and enjoy using it. Additionally, being fluent in the corresponding use of software is mentioned to be important therefore the software packages would either need to be extensively covered in a course or multiple courses to teach the

same technology for a variety of applications. The mental construction of conceptual understanding may take time and effort therefore professors spending extensive time to teach certain STEM discipline software packages appears to make sense. If time is limited, this can be done by flipping the classroom work for teaching software packages. For instance, the P.I. of this work teaches three software packages in at least one of the courses he teaches and lets the students choose their favorite software package to complete a semester project. One of the software packages that is observed to be enjoyed by the students through collected data that is also used commonly in industrial settings is also used in several other discipline specific courses. This approach doesn't only make the students be comfortable with the software package they choose but also give them the enjoyment of what they prefer to use instead of being forced into use one specific software.

Another technology that can be easily utilized but not commonly known is the web-based applications. Examples of such applications include Symbolab and Desmos that are free online resources. The findings of this research indicated majority of neither one of the institutions the students' preferences to utilize such resources. It is without a doubt that STEM students should develop the necessary mathematical background to understand concepts and answer questions for analytical mental development and improving the ability to solve problems (Tokgöz (2017, 2019-1, 2019-2, 2016-1, 2016-2, 2015-1, 2015-2) and Tokgöz et. al (2021-2, 2021-3, 2020-2, 2018, 2018-1, 2018-2, 2017, 2015)). Hence, several technologies can be taught extensively by redesigning calculus or engineering courses to include more technologies to help students better solve calculus questions since calculus questions are at the heart of STEM education. We encourage researchers and educators to further investigate along the line of this research. It is essential to learn and improve engineering students' technology preferences to solve calculus questions. Additionally, mathematics education can extensively benefit from gaming and artificial intelligence integrated into teaching design and curriculum development.

References

[1] Clough, David E., "ChE's Teaching Introductory Computing to ChE Students-- A Modern Computing Course with Emphasis on Problem Solving and Programming," Proceedings of the 2002 ASEE Annual Conference & Exposition.

[2] Maase, Eric L. and High, Karen A., Active Problem Solving and Applied Research Methods in a Graduate Course on Numerical Methods, 42(1) 23-32, 2008.

[3] Felder R. and L. Silverman. "Learning and Teaching Styles in Engineering Education, ASEE journal of Engineering Education, 78(7), 674-681, 1988.

[4] Rosati, P. "The Learning Preferences of Engineering Students From Two Perspectives," Proceedings of the 1998 ASEE, Frontiers in Engineering (FlE) conference, November 1998.

[5] LabVIEW, National Instrument (NI), https://www.ni.com/

[6] Tokgöz, E., Scarpinella, S. E., and Giannone, M. Technology Decisions of Engineering Students for Solving Calculus Questions, 2021-1, ASEE Annual Conference, paper ID # 33062.

[7] Tokgöz, E., Tekalp E. N., Tekalp S. B., Tekalp H. A., Undergraduate STEM Students' Role in Making Technology Decisions for Solving Calculus Questions and the Impact of These Decisions on Learning Calculus, 2020-1, 127th Annual ASEE Conference Proceedings, Computer Science Division, paper ID # 29730, Montreal, Canada.

[8] Tokgöz, E. “Technology Choices of Undergraduate Engineering Students for Solving Calculus Questions”, 2017, ASEE Annual Conference Proceedings, paper ID # 17810.

[9] Tokgöz, E., Scarpinella, S. E., and Giannone, M., Analysis of STEM Students’ Ability to Respond to Algebra, Derivative, and Limit Questions for Graphing a Function, 2021-2, ASEE Annual Conference, https://peer.asee.org/36685

[10] Tokgöz, E., Tekalp, E. N., Tekalp S.B, and Tekalp, H. A., Undergraduate STEM Students’ Comprehension of Function Series and Related Calculus Concepts. 2021-3 ASEE Annual Conference, https://peer.asee.org/37950

[11] Tokgöz, E., Tekalp S. B., Tekalp E. N., Tekalp H. A., Qualitative and Quantitative Analysis of University Students’ Ability to Relate Calculus Knowledge to Function Graphs, 2020-2, 127th Annual ASEE Conference Proceedings, Mathematics Division, paper ID # 29726.

[12] Tokgöz, E. “STEM Majors’ Ability to Calculate Taylor Series’ Derivative & Integral”, 2019-1, ASEE Annual Conference Proceedings – Mathematics Division, paper ID # 25091.

[13] Tokgöz, E. “Undergraduate Industrial Engineering Majors’ Software Preferences for Solving Statistical Process Control and Operations Research Questions”, 2019-2, ASEE Annual Conference Proceedings – Industrial and Systems Engineering Division, paper ID # 24769.

[14] Tokgöz, E. & Ceyhan, H. “University Students Ability to Interconnect the Calculus Concepts & Function Graphing”, 2018, ASEE Annual Conference Proceedings – Mathematics Division, paper ID # 21382.

[15] Tokgöz, E. “Engineering Majors’ Cognitive Function Differentiation Ability”, 2018-1, ASEE Annual Conference Proceedings – Mathematics Division, paper ID # 21381.

[16] Tokgöz, E. “Conceptual Power Series Knowledge of STEM Majors”, 2018-2, ASEE Annual Conference Proceedings – Mathematics Division, paper ID # 21246, 2018.

[17] Tokgöz, E. & Ceyhan, H. “Integral Concept & Decision Making: Do the STEM Majors Know When to Use Numerical Methods for Integral Approximation?” 2017, ASEE Annual Conference Proceedings, paper ID # 17833.

[18] Tokgöz, E. “Evaluation of Engineering & Mathematics Majors' Riemann Integral Definition Knowledge by Using APOS Theory,” 2016-1, ASEE Annual Conference Proceedings, paper ID# 14461.

[19] Tokgöz, E. “STEM Majors’ Ability to Relate Integral and Area Concepts,” 2016-2, ASEE Annual Conference Proceedings, paper ID # 14462.

[20] Tokgöz, E. & Gualpa, G. C. “STEM Majors’ Cognitive Calculus Ability to Sketch a Function Graph,” 2015, ASEE Annual Meeting Proceedings, Mathematics Division, Seattle, Washington, Paper I.D. #: 12661.

[21] Tokgöz, E. “Analysis of STEM Majors’ Calculus Knowledge by Using APOS Theory on a Quotient Function Graphing Problem,” 2015-1, ASEE Annual Meeting Proceedings, Mathematics Division, Seattle, Washington, Paper I.D. #: 12664.

[22] Tokgöz, E. “Undergraduate and Graduate STEM Majors’ Technology Preference for Solving Calculus Related Questions,” 2015, ASEE Annual Meeting Proceedings, Paper ID#: 12668.