Technology Decisions of Engineering Students for Solving Calculus Questions

Dr. Emre Tokgoz, Quinnipiac University

Emre Tokgoz is currently the Director and an Associate Professor of Industrial Engineering at Quinnipiac University. He completed a Ph.D. in Mathematics and another Ph.D. in Industrial and Systems Engineering at the University of Oklahoma. His pedagogical research interest includes technology and calculus education of STEM majors. He worked on several IRB approved pedagogical studies to observe undergraduate and graduate mathematics and engineering students' calculus and technology knowledge since 2011. His other research interests include nonlinear optimization, financial engineering, facility allocation problem, vehicle routing problem, solar energy systems, machine learning, system design, network analysis, inventory systems, and Riemannian geometry.

Samantha Eddi Scarpinella , Quinnipiac University

Samantha Scarpinella is a Senior Industrial Engineering major at Quinnipiac University with additionally pursuing mathematics and business minors. Her research interests include healthcare, human factors and engineering education. She is planning to be an engineering professor as her profession.

Mr. Michael Giannone, Quinnipiac University

Michael Giannone is currently a Senior at Quinnipiac University majoring in Industrial Engineering. He currently has been accepted to Pennsylvania State University to pursue a Master's in Industrial Engineering. Michael is interested in working either in the Healthcare of Manufacturing industry. Michael has worked at Pratt and Whitney located in East Hartford, CT as well as Crash Safety located in East Hampton, CT. Both of these experiences has helped him strengthen his knowledge in data analytics and optimization. One of Michael's biggest interests in Ergonomics and Human Factors which he plans to purse later in his career.

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[1]Emre Tokgöz, [1]Samantha Scarpinella, [1]Michael Giannone

[1]Emre.Tokgoz@qu.edu, [1] Samantha.Scarpinella@qu.edu, Michael.Giannone@qu.edu

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

Technology choices of engineering students for solving calculus questions can depend on technologies they learned in high school, web-based resources they are aware of, major specific programming requirements, and technologies taught by their mathematics instructors. STEM students are usually expected to demonstrate paper-pencil solution and critical thinking ability to questions 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 [Author 1, 2020; Author 1, 2015]. In this work, quantitative analysis consists of the statistical analysis of 23 STEM students' responses to three research questions, and the qualitative nature of the data is the transcription of the participants' video recorded interviews. The focus of this research is different from majority of the other existing research that focuses on the learning preferences of students to solve engineering problems; (see for example Felder and Silverman (1988) and Rosati (1998).) Students' preferences on using technology versus paper-pencil solution to solve the research questions is also investigated for improving technology education of STEM students with the impact on their calculus educational experience.

1. Introduction

Many different technologies can be used by STEM students to solve challenging calculus problems. The engineering students are normally expected to solve the questions using paper and pencil but are also expected to use technology to find the solution to the given question. STEM students are expected to strategically select a technology that they can use to solve a question on their own. Often, students choose a specific technology based on what they learned in high school, web-based resources that they are aware of, major specific programming requirements, and technologies taught by their mathematics instructors. There are many challenging problems that might require the use of one of the following technologies:

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

The following research questions are used to perform both Qualitative and Quantitative data analysis:
- *To draw the graph of a given function, what kind of technologies would you use? Please explain your answer and explain why.*
- *If there is a definite integral given, which technology would you prefer to use to calculate the given integral? Please briefly explain why.*

- *If you needed to calculate numerical values of power series or error term graphs/values which method (algebraic calculations, computer program (please specify), calculator etc.) would you use? If you are required to pick a computer program what programming language would you prefer to use? Please explain why.*

Below are the main objectives of the three research questions analyzed in this article:

- Technology preferences of undergraduate engineering students for solving function graphing, definite integral, and mathematical series questions.
- Technology variation of participating engineering students' technology preferences when calculus concepts change. I.e. Do the students prefer a different technology (or not prefer at all) when calculus questions change?
- Engineering students' interest in determining the solution to a calculus problem by using paper and pencil rather than technology.
- The engineering majors' consistency in using the same technology as calculus problems change.

The following are reasons the data displayed in this work will benefit engineering educators and researchers:

- Undergraduate engineering students' reasons for choosing various technologies.
- The technological shortcomings that arise in engineering education for solving mathematics problems.
- The limitations of engineering students' knowledge of technology.
- Correlation of participants' technology choices for a variety of calculus questions.

2. Nature of the Research & Collected Data

The data collection protocol of this research received Institutional Review Board (IRB) approval. The data was collected from a university located on the Northeast side of the United States. The quantitative data consists of the participants statistical analysis of the responses to the research questions while the qualitative data analysis of the data is the transcription of the 23 participants' video recorded interviews. The research participants preferences of using technologies versus using a paper and pencil was analyzed to improve calculus education.

The participants in this study were asked to participate in pre -and post- interview phases. The pre-interview consists of the students written response to a questionnaire, and during the interview the students are asked by the interviewer to analysis their written responses deeper. The students were given a set of questions to answer with written responses. Three of the questions in the set of questions will be analyzed in this work. After the student completed the questionnaire they were asked to participate in a recorded interview, where the interviewer asked the students to investigate their written response further. Twenty-three undergraduate and graduate STEM students in the United State volunteered to respond to the research questionnaire used for data collection. These students had to complete the calculus courses offered to STEM students in order to participate.

The following sections are each dedicated to a qualitative and quantitative analysis of the research participants technology preferences to solving the three research questions. The three questions involve

function graphing, solving definite integrals, and calculating power series or error terms. The sixth sections purpose is to analyze the participants correction analysis.

3. Analysis of Technology Choices for Function Graphing

In this section, the technology choices of the research participants to solve the function graphing question is analyzed both qualitatively and quantitatively. The goal of the question below was to investigate the students' technology choices to graph the given function.

Q1) 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 _____

The results of this question were skewed; The most popular choice among the students with 41% was the use of a Texas Instrument (TI) calculator. The other preferred technologies were Excel, LabVIEW, Mathematica, MATLAB, and Walfram Alpha.
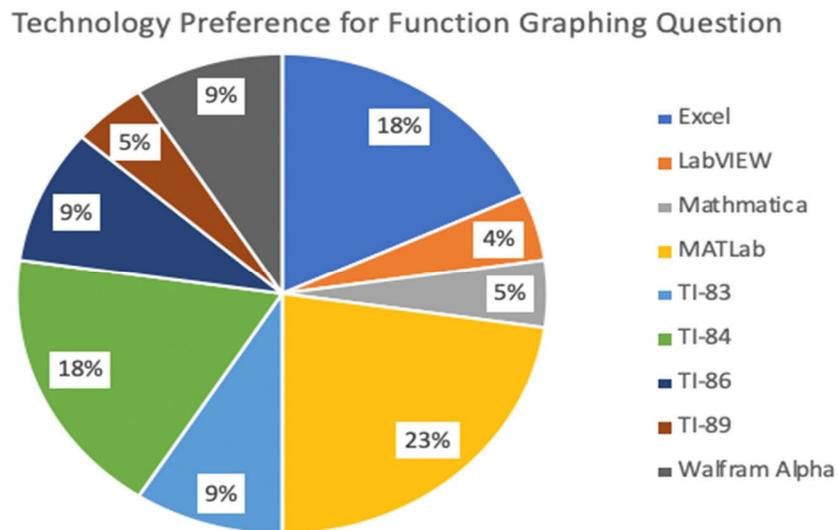
Figure 1. Participants technology preference distribution to graph a function.

The remaining part of the section is dedicated to participants' responses and their reasons for their technology preferences. The analysis of the collected data indicated software choices of students based on

the technologies' accessibility and ease of use as well as their experiences with the technology and 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. The figure below shows a participant's response for selecting MS Excel. This student believes Excel would be the easiest tool to solve the question.
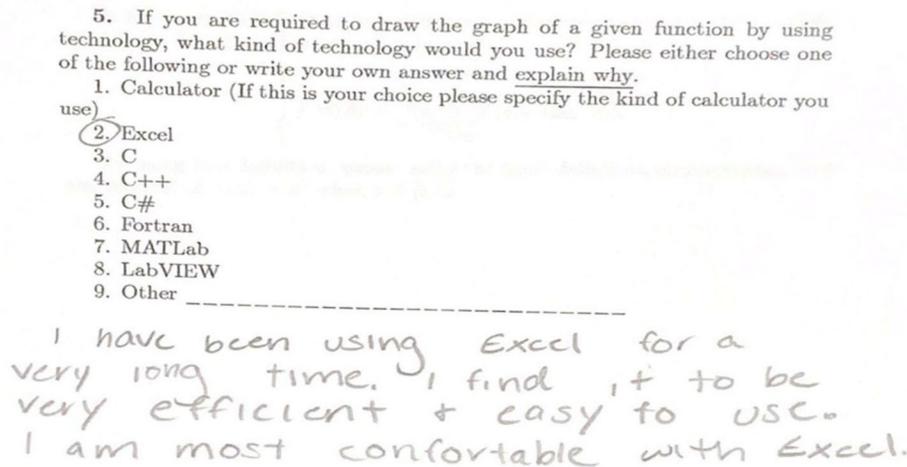
Figure 2. Participant 21 chooses Excel due to is simplicity to solve a graphing question.

Another common answer to this question is based on the participants' prior experiences with the technology choice that they selected to graph a function. Participant 17, in Figure 3, selected MATLAB based on prior experience. Participants who answered the question based on experience with the technology have previously used this technology.
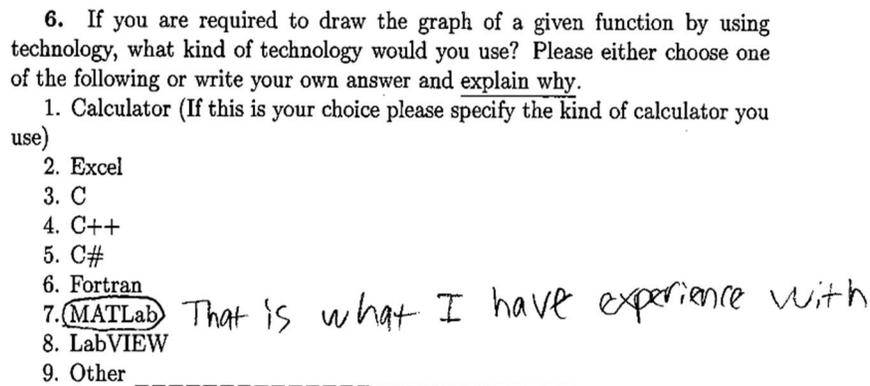
Figure 3. Experience based technology preference of Participant 17 for choosing MATLAB

Participant 5 selected MATLAB to solve a graphing question because of familiarity with the technology. The familiarity of the students are based on their prior course experiences and these courses are not the calculus sequence courses based on their prior education. The figure below shows the response of Participant 5 to this graphing question.

6. 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 ____ familiar with this .

Figure 4. Participant 5 chooses MATLAB because it is the most familiar choice.

The participant below, Participant 1, chose to use a calculator, specifically the TI- because this student has a calculator accessible. The student also indicated that they do not know how to graph this function on excel.

6. 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) TI-83+ → this is the most accessible tool for me & I don't know how to draw this type of graph in Excel
    2. Excel
    3. C
    4. C++
    5. C#
    6. Fortran
    7. MATLab
    8. LabVIEW
    9. Other _____

Figure 5. Participant 1 chose a calculator to graph a function because it is the most accessible tool.

Overall, the participants technology choices are based on the following categories for graphing a function:

- Simplicity
- Experience
- Familiarity
- Accessibility

4. Technology Choice Analysis of Engineering Majors for Calculating Integrals

STEM students' choices to solve an integral approximation question are analyzed qualitatively and quantitatively in this section. The question given below is designed for research team to observe student preferences to calculate a definite integral by hand or with a technology. The students are asked to choose a technology with the justification of the choice. The overarching goal of the question is to investigate

engineering students' interest to solve a problem by using the integral techniques they learn in calculus or by using a software.

Q2) If there is a definite integral given, which one of the following would you prefer to use to calculate the given integral? Please circle the option and briefly explain why.

1. Computer Program (which program)
2. Calculator (which calculator)
3. By hand
4. Other (Please type)

If you are required to use a computer program to find the solution of the given definite integral, which computer language would you prefer to use?

The figure below shows the participants' preferences to solve an integral question. The most popular answer chosen by the students is to solve the question by hand. The students are not allowed to use any specific software in the calculus course sequence.
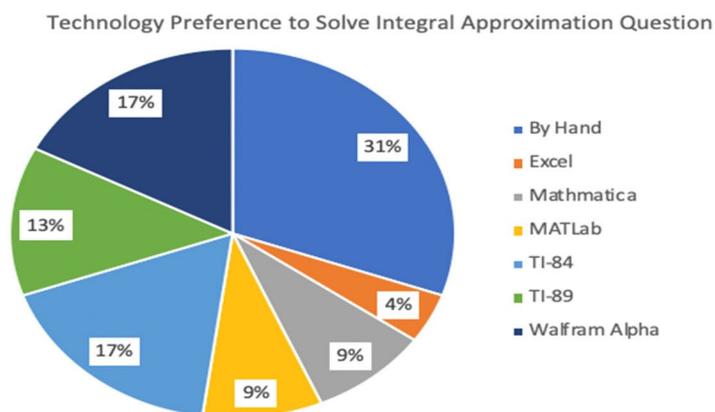
Figure 6. Statistics on participants technology preferences to calculate integral approximation

Throughout the rest of the section, examples of students' responses are displayed. Along with 30% of the participants, the choice of participant 1 is to solve the integral by hand. The student stated to solve the problem by hand because of not being good at programming.

Figure 7. Participant 1 chooses to solve the definite integrals by hand

Participant 23 chooses to solve the question using specifically a TI-84 because he/she is the most comfortable with this choice. In the case of using a computer program required, the student declared to use symbolab and mathway as alternatives to the use of TI-84.
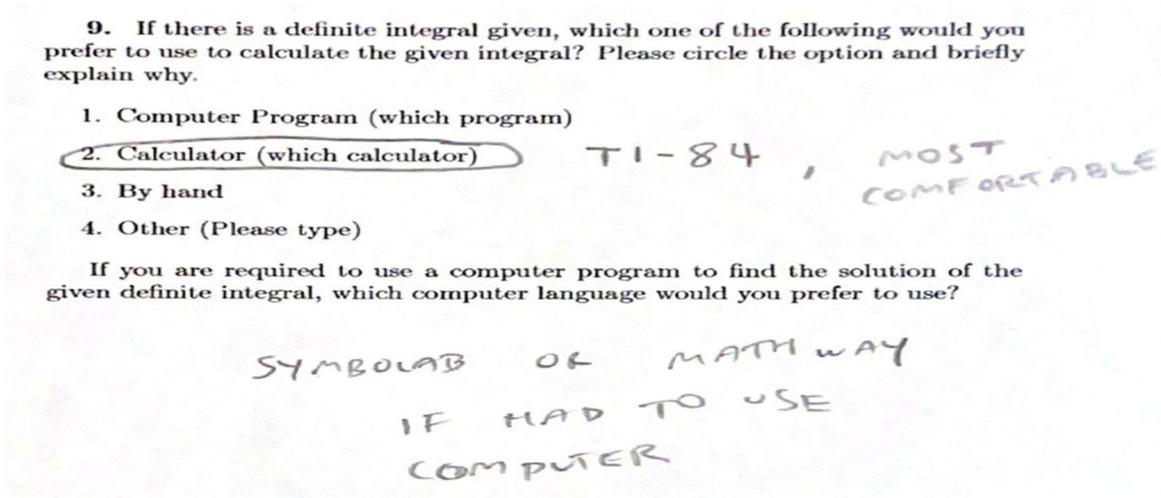
Figure 8. Participant 23 chooses to use a calculator to solve definite integrals.

Participant 9 declared to use Walfram Alpha to solve a definite integral due to its ease of use. Seventeen percent of the students choose to use Walfram Alpha as their first method of solving this question. Participant 9 preferred to use LABview the use of a computer program is required to solve the question.
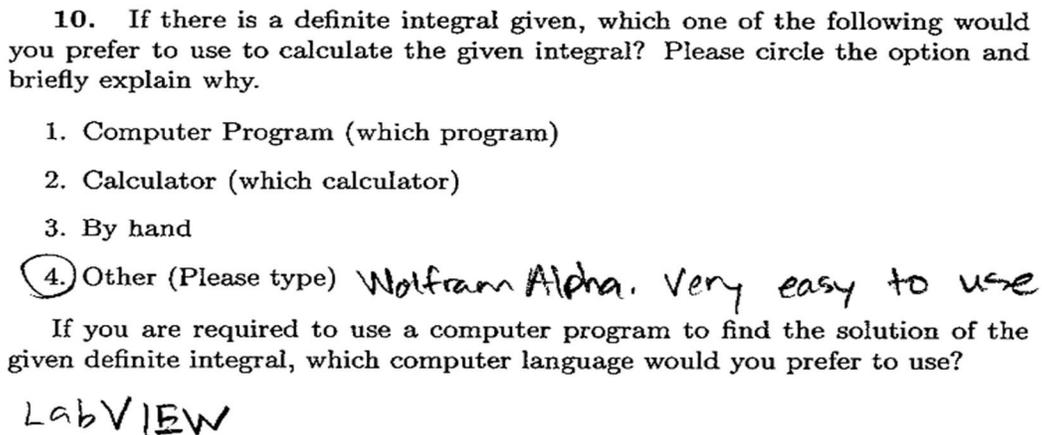
Figure 9. Participant 9 chooses Walfram Alpha and LABview to solve a definite integral

Participant 2 with the response below in Figure 10 would use MATLAB to solve this question because it had predefined functions which saves time. Only 9% of students declared to choose MATLAB to solve a definite integral.

10. If there is a definite integral given, which one of the following would you prefer to use to calculate the given integral? Please circle the option and briefly explain why.

1. Computer Program (which program)

2. Calculator (which calculator)

3. By hand

4. Other (Please type)

If you are required to use a computer program to find the solution of the given definite integral, which computer language would you prefer to use?

I will use matlab, it has alot of predefined functions and it saves time and efforts to compute the definite integral.

Figure 10. Participant 2 chooses to use MATLAB to solve a definite integral

Overall, the participants' technology choices are based on the following categories for calculating definite integrals:

- Preference
- Saves Time
- Easy to Use
- Experience
- Comfort

5. Analysis of Participants' Technology Choices for Power Series Calculations

Technology choices of the participants to calculate power series terms and error values are analyzed both quantitatively and qualitatively throughout this section. The research participants' handwritten responses are presented as a means to demonstrate a part of the student work used for the corresponding analysis.

The participants are called for choosing a technology to solve a calculus question involving numerical values or error terms for a given power series. The question below aims to determine the students' technology background and knowledge to determine such values.

Q3) If you needed to calculate numerical values of power series or error term graphs/values which method (algebraic calculations, computer program (please specify), calculator etc.) would you use? If you are required to pick a computer program what programming language would you prefer to 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 _____

The pie chart below in Figure 11 shows the percent of students' choices of technology for the above-mentioned question. The top two choices chosen by research participants are by hand (30%) and by calculator (26%). The reasons behind these technology preferences are depicted throughout the rest of the section.
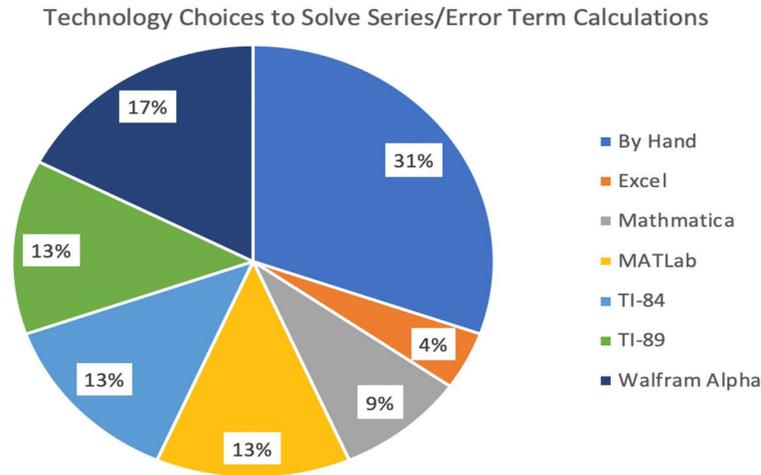
Figure 11. Probability distribution of participants' responses to solve series/error terms

The remaining part of this section is dedicated to analyzing the responses of the research participants. Participant 10 below chooses to solve the question using excel. This is an chosen by only 4% of the students. This student chooses to use excel because it was easy to use.

12. If you needed to calculate numerical values of power series or error term graphs/values which method (algebraic calculations, computer program (please specify), calculator etc.) would you use? If you are required to pick a computer program what programming language would you prefer to 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 _____

Easy to use, fast results

Figure 12. Participant 10 response to solving the numerical value calculations.

Participant 13 chooses to use MATLAB as the primary language and declares Mathematica as the second choice. The student has experience with MATLAB and can perform tasks quickly. MATLAB is chosen by 13% of the research participating students.

12. If you needed to calculate numerical values of power series or error term graphs/values which method (algebraic calculations, computer program (please specify), calculator etc.) would you use? If you are required to pick a computer program what programming language would you prefer to use? Please either choose one of the following or write your own answer and underline 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   or Mathematica
   8. LabVIEW
   9. Other _____

MATLab! I already have many different routines to very quickly calculate these numerical values. If I didn't have these, I would chose Mathematica since it can (most likely) calculate the values without any time spent programming

Figure 13. Participant 13's response based on determining solution quickly for the question

Below in Figure 14, participant 17 chooses to solve the question using MATLAB. This student has much more experience with this program and believes it's the best way to handle the given question. The student chooses this because of familiarity with MATLAB software.

12. If you needed to calculate numerical values of power series or error term graphs/values which method (algebraic calculations) computer program (please specify), calculator etc.) would you use? If you are required to pick a computer program what programming language would you prefer to use? Please either choose one of the following or write your own answer and underline 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   It is straightforward, powerful, and familiar
   8. LabVIEW
   9. Other _____

Figure 14. The response of participant 17 to use MATLAB to calculate numerical values of power series

Participant 23's response in Figure 23 to calculate numerical values of power series or error terms is shown below. This student chose Excel for solving this problem because he/she were "most used to" this program.

Figure 15. Response of participant 17 based on the being used to the program.

The technology choices of the research participants are based on the following categories for calculating numerical values of power series or error terms:

- Experience
- Familiarity
- Easy
- Comfort

6. Correlation Analysis of the Research Question Responses

In this section the correlation analysis of the students' responses to the three research questions are demonstrated. This analysis is used for establishing a connection between questions and determining cognitive consistency for choosing the same technology.

- 22% the research participants choose to use the same technology to solve all three questions based on the primary choices.
- The highest correlation is determined to be the use of the same technology for Q1 and Q3 with 52% correlation; This meant 52% of the participants preferred to use the same technology to solve these two questions.
- 26% of the participants correlated to solve Q1 and Q2 by using the same technology, calculator.
- 33% of the participants correlated to solve Q2 and Q3 by using a calculator.
- 35% of the research participants selected different technologies for all three questions.

Figure 16 below reflects a summary of the correlation analysis.
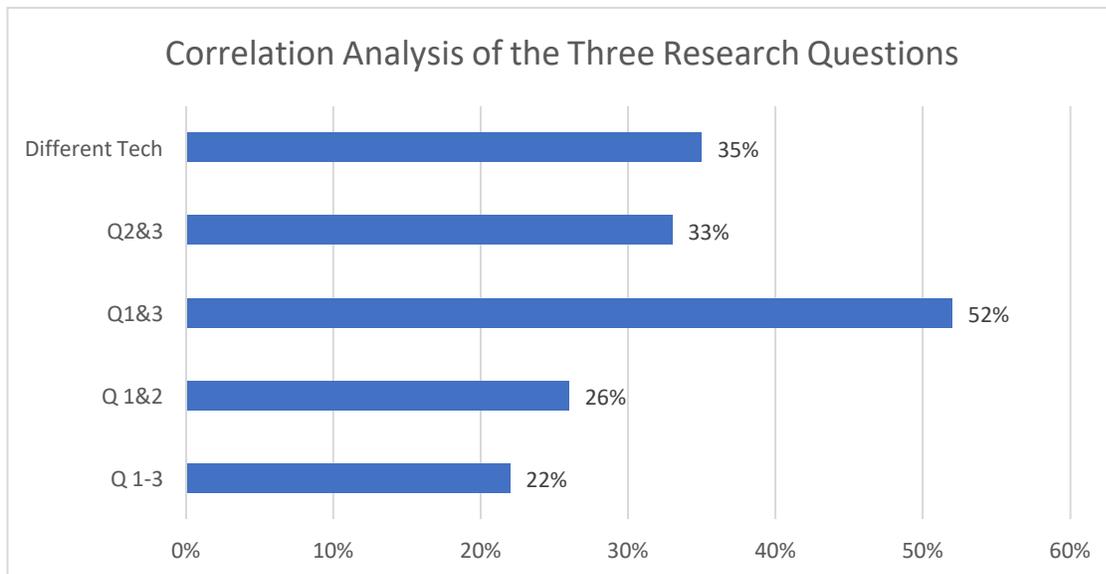
Figure 16. Correlation of technology use of participants for the research questions.

7. Conclusion

In this work, we investigated how undergraduate engineering students choose a technology for solving three different calculus concept related questions. The calculus concepts included function graphing, integrating functions, and power series concepts. Twenty-three STEM students' answers to the research questions are assessed both quantitatively and qualitatively after attaining IRB approval. The participants are compensated for responding to the written questionnaire and the interview.

The data collected in this research has the following statistical findings: 22% of the students choose the same technology to solve all three research questions whereas 35% of the students chose a different technology for all three technology related questions. 52% of the students choose the same technology for questions 1 and 3, 26% choose the same for technology questions 1 and 2, and 33% choose the same technology for questions 2 and 3. These finding can benefit engineering educators and researchers significantly for understanding how STEM students make preferences and impact their learning.

Engineering educators and researchers can use this study in many different ways. The common technology preferences given by students can be more utilized in engineering courses to better the students' education. Mathematics and engineering professors can use certain technologies to better their courses. For example, both Symbolab and Desmos are free online resources. The findings of this research showed that many students do not choose these as their technology preferences on the contrary to the benefits that these websites offer to the students. These technologies can be used to form a strong foundation for the students to solve many different calculus-based engineering and mathematics questions. 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.

8. References

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