

Solving Simultaneous Equations via a Large Language Model (ChatGPT): Help or Hindrance?

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Abstract

In today's global society, generative artificial Intelligence (Gen-AI) is gaining traction across numerous industries and institutions of higher learning, as recent breakthroughs have the potential to transform the way students learn. AI is based on a set of heuristics and utilizes specific tools such as large language models (LLMs) [1]. The most notable of which is ChatGPT (i.e., generative pre-trained transformer) which is well established upon Machine Learning (ML). ChatGPT and other Gen-AI tools have the potential to assist educators in preparing students for novel work, personalized education, reducing time-consuming tasks, and inclusivity [2]. This tool has 100+ million users and was available at no cost to the public until February 2023. This paper explores the impact of ChatGPT as an interactive aid for solving simultaneous equations. As STEM students in a two-year technical degree program, familiarization with solving techniques may not be uniform across this population. The initial approach was to design a survey, administer it, and compile the responses. A small percentage of students are proficient in solving a set of 3 simultaneous equations. This research proceeds to utilize ChatGPT as a teaching tool for solving a set of 3 independent equations with constant coefficients containing 3 unknown values. Applications have implications in statics problems, electrical circuit problems, physics problems, and other areas of technical study. From a teaching perspective, there are several techniques for solving such a set and we assume the student has minimal background in their mathematical preparation. The results are presented in a descriptive form, the parameters and limitations of this study are discussed, and several suggestions for future directions are presented.

Introduction

Advances in technologies are occurring at a rapid pace and continue to be transformative in today's high-tech society. Examples of advanced technologies include autonomous vehicles, cloning, fusion, 3D printing, on-demand drug manufacturing, facial recognition, digital computing, advanced materials, and many other applications such as those listed in Table 1. These technologies are producing significant benefits to aid humankind to solve demanding socioeconomic challenges and technological issues. However, the pitfalls must be studied and considered with appropriate levels of constraints.

Table 1. Lising of applications for ChatGPT.



This paper considers a version of an LLM, ChatGPT and the relative consequences of utilizing this tool in secondary education. This technology is sometimes referred to as a computer robot design where 570Gb of data representing over 300 billion words and approximately 175 billion parameters are encapsulated [3], [4]. Artificial intelligence has recently become more prevalent in higher education as it enables students to seek packaged answers without engaging in traditional learning methods, self-directed study and research, practice, and peer collaboration. The investigation will commence by reviewing the background of LLMs and the fact they demonstrate remarkable capabilities in the field of natural language processing tasks. The overview of LLMs shall be limited to architectural innovations, benchmarking, efficiency, and applications. This paper will proceed by defining the need for students in STEM programs to understand and achieve proficiency in solving simultaneous equations (i.e., serial elimination of variables by defining one or several variables in terms of another, substituting, and solving for simplification) using various approaches to solve. A hypothesis is formulated to inquire whether students can achieve this learning outcome satisfactorily using ChatGPT as a standalone tutoring agent or if instructor interaction is preferred. Several researchers have concluded that ChatGPT-generated hints or instruction can be beneficial in algebra and math word problems [5]. A Qualtrics™ survey is designed and administered to first year STEM students (i.e., anonymously) using the standard institutional internal review board (IRB) practices. The results are analyzed and presented.

Background

The sophistication of LLMs has been driven by advancements in neural network architectures, increased digital computer computational capabilities, and the accessibility of training data available from the internet. The training process involves massive data sets to make predictions regarding societal issues or to solve complex reasoning tasks. Today, LLMs can perform various tasks such as code generation, text generation, tool design, manufacturing support, electromechanical actuation, data visualization, deductive reasoning, and alternative ways of expressing ideas. The histogram plot depicted in Figure 1 depicts an increasing trend in the number of available open-source and closed-source LLM models in recent years [6]. An open-source model or architecture is defined where its layered hierarchy structures are independent

from one another whereas a closed-source model contains layered hierarchies that are dependent upon each other.

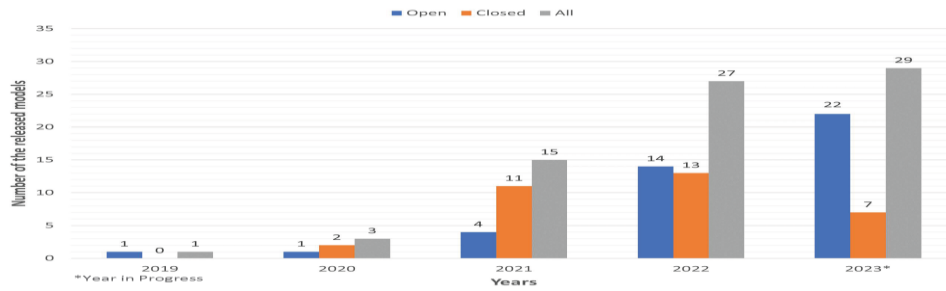


Fig. 1. Histogram depicting relative open-source and closed-source LLMs.

These historical developments have created enthusiasm and research interest in the creation of LLM architectures and training strategies listed in Table 2 below are a subset of those currently in the public domain [7]. By contrast, machine learning (ML), is defined as a field of study that deals with automated statistical learning and pattern detection by non-biological systems [8]. ML is seen as a sub-domain of artificial intelligence that specifically deals with prediction and modeling through tribal knowledge extracted from training data. As a multidisciplinary area, ML borrows concepts and principles from other areas like pure mathematics and cognitive science.

Table 2. A subset of LLMs.

A Subset of LLMs			
	Release Timing	Model Designation	Source Availability
1	1-Oct-2019	T5	Open
2	2-Oct-2020	MT5	Open
3	1-Jun-21	CPM-1	Open
4	1-Jul-21	Codex	Closed
5	1-Dec-21	Gopher	Closed
6	1-Apr-22	GPT-NeoX-20B	Open
7	1-Feb-22	Alpha Code	Closed
8	1-Nov-22	ChatGPT	Closed
9	1-Jun-23	MPT	Open
10	1-Jun-23	StarCoder	Open
11	1-Mar-23	GPT-4	Closed
12	1-Jan-23	WizardCoder	Open

Assessments from industry, commercial product producers, and university research professors are insisting on a slowdown in the development and adoption of AI technologies, as a slower rollout would allow for greater opportunity to identify potentially precarious threats. In contrast, areas of entertainment such as the 2009 epic science fiction film *Avatar*, used an AI to speed up workflow, produce computer-generated imagery (CGI) character and 3D video animations [9]. James Cameron, director of *Avatar*, makes the case in the context of increasing social ills, it will

be a challenge to believe what we see in AI videos unless we are present. Satya Nadella, Microsoft CEO says AI is a “tidal wave.” It will have a larger potential than the Internet. As of August 2023, the company has sunk \$13 billion into AI research and development (R&D), determined to capture a significant shar

e of this expanding market [10], [11]. OpenAI released an early version of ChatGPT in late November 2022, and it quickly went viral on social media. Sam Altman is credited with the founding of OpenAI in late 2015 and the entrepreneurial start-up received \$1 billion in funding from various investors [12], [13].

According to the Education Commission of the States, two trends are quickly becoming more evident. First, states are increasingly requiring students to complete four years of math in high school, and second states are beginning to require students to complete a math course each year of high school, to ensure students earn high school math credit before entering college or a specialized technical school [14].

Formulation of the Investigation

The primary intent is to determine to what degree of satisfaction students will receive ChatGPT as an acceptable tool to aid in the self-instruction of mathematical concepts. Specifically, first-year students electing to study STEM fields are expected to have sufficient levels of proficiency in secondary mathematics. By only leveraging ChatGPT, students miss the opportunity to engage in creative yet simplistic math tasks that support deep mathematical thinking, critical thinking, and problem-solving skills among students. Several areas of engaged learning involve the use of manipulatives, group activities, visual representations, and introducing real-world applications. A primary assumption is the students have been introduced to one or several methods for solving simultaneous equations. The equations are defined to be independent (i.e., the number of unknown variables is equal to the number of equations) and contain constant coefficients. It can be stated that our physical reality is modeled by mathematical equations as such, simultaneous equations can be used to represent engineering, business, agricultural, industrial, and aerospace innovations, and applications. For example, in electrical engineering, the need to solve for voltages and/or currents of circuits containing a DC voltage source and passive elements requires the use of Kirchhoff's voltage law (KVL) or Norton's nodal equations (NNE) which are direct applications for solving simultaneous equations. The above concept is also known as mesh analysis of AC/DC circuits [16]. To explore the above proposed application, a non-trivial exercise is formulated where the author defines a system of three equations and 3 unknown variables [17], [18]. The mathematical expressions containing variables x , y , and z are provided in Equations (1a), (1b), and (1c).

$$x + y - z = 4 \quad (1a)$$

$$x - 2y + 3z = -6 \quad (1b)$$

$$2x + 3y + z = 7 \quad (1c)$$

Applying the substitution method, a trivial solution yields $x=1$, $y=2$, and $z=-1$, then it follows that these values satisfy the above equations. A simple computational script was written and executed in MATLAB R2023b per the above equations and is provided in Appendix B [19]. Depending on how the mesh equations are derived, the solved values may represent voltages (Volts) or currents (Amperes). Specifically, Ohm's law is applied and is one of the most important laws governing electronic and electrical circuit design and analysis. By convention, Ohm's law is applied to any situation where a potential difference, current, or voltage must be

found. Alternatively in a mechanical 3-dimensional space, if the sum of all forces acting on a body is zero then the body is said to be in equilibrium. Mathematically Equation 2 expresses static equilibrium and may expand into 3 equations with 3 unknown variables for computation.

$$\Sigma F_x = 0, \Sigma F_y = 0 \text{ and } \Sigma F_z = 0 \quad (2)$$

State educational requirements for high school diplomas are moving to require students to take at least two math courses to graduate which typically include Algebra I, where students must demonstrate a mastery of solving simultaneous equations up to an order of 3 equations with 3 unknowns [20]. For brevity of this investigation, prior knowledge recollection, and ChatGPT there are several approaches to mathematically solving a system of simultaneous equations. High level paragraph-formatted descriptions for solving simultaneous equations are returned by ChatGPT. These methods are listed in Table 3 below and the corresponding detailed descriptions and computations are provided in Appendix A.

Table 3. Mathematical methods for solving simultaneous equations.

Mathematical Method	Solving Complexity	Notes
Substitution Method	Low	Simplify the equation by expanding; solve one equation in terms of the other, substitute, and solve using elementary arithmetic operations
Elimination Method (also called Addition/Subtraction Method)	Medium	Based on the Addition Property of Equality
Gauss-Jordan Method (obtaining all 1's on the diagonal and 0's elsewhere)	Medium	A sequence of row operations done to transform a matrix into reduced row echelon form
Matrix Method (using linear algebra, matrix inversion, the matrix is required to be invertible before proceeding)	High	Matrix inversion using adjoint matrix divided by the matrix determinate
Graphical Method	Medium	Graph equations in the same coordinate system, The solution will be the point where each line intersects

Next, we return to ChatGPT and command it to solve for the three unknown variables (x , y , and z). Utilization of ChatGPT indicates it elects to solve the simultaneous equations in 1a, 1b, and 1c by the substitution method which appears to be a random selection from several methods (i.e., see Table 3) by ChatGPT version 3.5. Therefore, the first assessment is that the student engaged in self-learning to solve the equation must have some background to understand why this method was selected. As many users ask the fundamental question, can we trust a query to produce the intended results? Published research by Aleksandr Tiulkanov during January 2023 provides a framework and the circumstances in which ChatGPT is questioned regarding the credibility of responses [21]. Figure 2 depicts ChatGPT and a systematic decision-making process for trustworthiness.

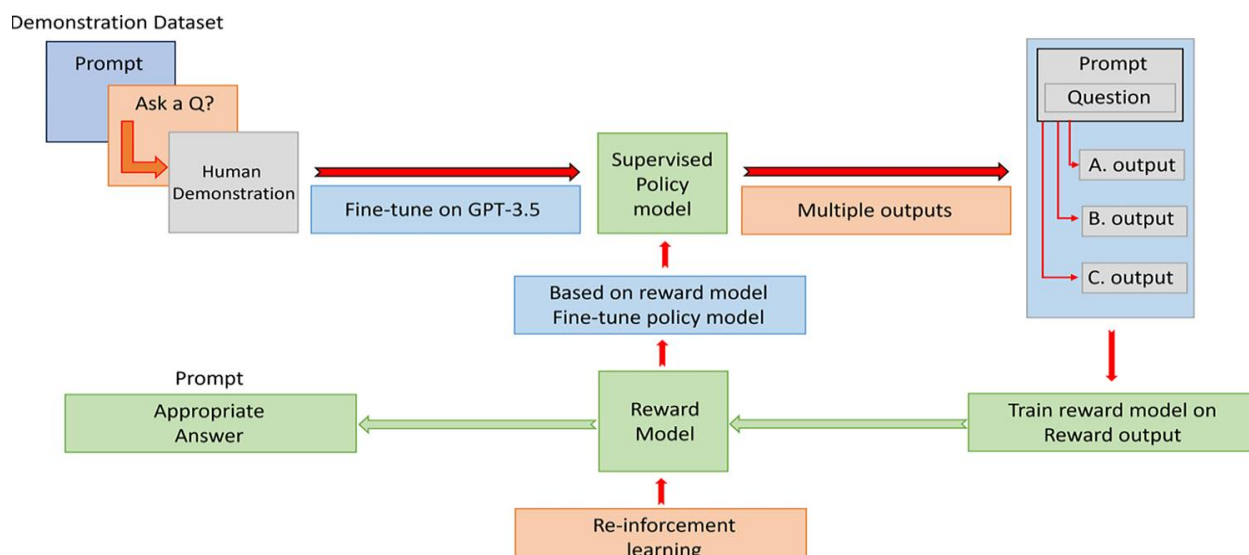


Fig. 2. Methodological information flow for the ChatGPT model.

Student Reception of Large Language Model ChatGPT

In this section, we will describe the lecture provided to students on how to solve simultaneous equations using the substitution method. An initial straw poll of students indicated very few students were confident in their ability to solve simultaneous equations. Throughout the class period of instructor lecturing, student enthusiasm increased significantly and ownership of understanding the need and necessary mathematical steps became very apparent. As the author attempted to show the results in real-time by engaging ChatGPT and in class using *SmartBoard* resources, it was surprising to see the results did not correspond to the earlier solution of $x = 1$, $y = 2$, and $z = -1$. As seen in Appendix A, Instead, we see the ChatGPT results are now in a spatial form where x can be any real number, $y = 5/2 - 2x$, and $z = 1/4 - 2x$. As the instructor of record, I did not instantly recall the solution to three simultaneous equations in a 3-dimensional space where the values of x , y , and z vary along that line.

Demonstrating the results of ChatGPT alone may not be an effective self-study tool if students do not have basic knowledge of the applicable principles in the context of problem-solving. The mistrust and unacceptance of this technological aid in the understanding of a mathematical concept are exacerbated. For this investigation, specifying the specific method to solve simultaneous equations was paramount and thus the results do not satisfy the right-hand-sides as a standard requirement, ChatGPT results can be very confusing to the novice student who is attempting to learn to solve simultaneous equations for the first time. To further explore the students' reception and awareness of ChatGPT, we designed a survey using Qualtrics. The survey was administered to approximately 32 first-year STEM students and the questions are provided in appendix B. In this plan of study, students will subsequently migrate to different majors such as mechanical, nuclear, electrical, industrial, and manufacturing technology programs having the knowledge and confidence to solve simultaneous equations.

Summary and Conclusions

While digitally automated authoring tools have improved in both usefulness and efficiency, course instructors still spend significant time transcribing tutoring content [1], [21], and the creative process of generating content remains time intensive. As Generation Z and Centennial students progress through the higher education ranks, it is vitally important for there to be active engagement in their learning process and demonstration of critical thinking skills. Although engagement has a broad definition, there is no common approach that will apply to tens of individuals in a classroom at the same time. Each student will have a unique set of aspirations and styles of engagement. Recent research findings suggest there is a direct relationship between the level of engagement and the likelihood of achieving a fulfilling lifestyle.

As LLMs are considered game changers within the higher education domain, students and instructors need to achieve the correct balance regarding the use of such resources. The survey results in Appendix C are intended for such an analysis. The survey questions were formulated to determine the population of technical college student's awareness, and their user experience with unregulated Gen-AI tools such as ChatGPT. The question of how these new Gen-AI tools will be regulated to maintain accessibility while mitigating discrimination, privacy, cognitive bias, and academic integrity remains to be addressed in universally accepted practices [22]. Upon an analysis of the survey responses, we can conclude the following:

- This specific group of students requires education on the capabilities (and limitations) of ChatGPT to use it as an effective learning supplement.
- Students have greater familiarity with “Google,” “Yahoo,” or other search engines to answer and/pr research questions and topics of interest.
- At the time of the survey, most students did not have a ChatGPT account.
- Students are less likely to utilize ChatGPT as a resource to complete both a liberal arts assignment and a STEM assignment.
- This group of students does not see themselves working in careers that will involve VR, AR, AI, and ML
- Most students view “global warming” as a concern to society and believe LLMs can be useful tools.
- Students are optimistic regarding the use of AI in fun and entertaining ways.

Taking a holistic and integrated approach to incorporating artificial intelligence into this ever-increasing digital society. It will be important to the success of educating the next generation of critically thinking individuals. Fundamentally, we assumed students elected to utilize ChatGPT to learn or refamiliarize themselves with the mathematical approach to solving simultaneous equations. It is asserted from this research and for this population of students, that human interaction with a live instructor has greater receptiveness than electing to use an interactive resource (i.e., ChatGPT). However, as additional tools of the kind are launched, like Khanmigo, an AI tutor by Khan Academy, this paradigm may change [23]. We acknowledge that additional research is needed to determine the impact of student use of Gen-AI tools for achieving student learning outcomes (SLOs) and best student engagement practices that support student learning, and how teachers must tailor instructional practices to accommodate student Gen-AI use. A primary result of this research investigation leads to the conclusion that students must have a baseline knowledge of solving simultaneous equations otherwise this tool will introduce

confusion and discontent relative to learning. Lastly, we conclude this population of students will in aggregate, prefer a mathematics instructor of breadth and depth to communicate the principles of solving simultaneous equations rather than a Generative AI system.

Acknowledgment

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Biography

H. BRYAN RILEY has an extensive set of professional work experiences to include working in private industry and as an engineering educator within university settings. Upon completing the PhD degree in electrical engineering, his early career was spent with General Motors Research and Development developing advanced technologies for autonomous vehicles (i.e., adaptive cruise control, reverse backing aids, blind spot warning, automated lane change warning, and other advanced driver safety functions). As the company restructured, Dr. Riley transitioned to Ohio University as an associate professor in the ECES Department. His most recent experience includes professor of practice at Clemson University in the College of Engineering, Computing, and Applied Science. Dr. Riley has published extensively, currently serves as an ABET program evaluator of Electrical Engineering Degree programs, and is a senior member of IEEE, ASEE, and SAE.

Appendix A – ChatGPT Explanations for Solving Simultaneous Equations

solve $x + y - z = 4$; $x - 2y + 3z = -6$; $2x + 3y + z = 7$; find the value for x , y , and z that satisfies the simultaneous equations

To find the values of x , y , and z that satisfy the simultaneous equations:

- $x + y - z = 4$
- $x - 2y + 3z = -6$
- $2x + 3y + z = 7$

You can use the elimination method. Here's how to do it:

Step 1: Start with the three equations:

- $x + y - z = 4$
- $x - 2y + 3z = -6$
- $2x + 3y + z = 7$

Step 2: Add Equations (1) and (2) together to eliminate x :

$$(x + y - z) + (x - 2y + 3z) = 4 + (-6)$$

This simplifies to:

$$2x - y + 2z = -2$$

Step 3: Add the equation obtained in Step 2 to Equation (3) to eliminate z :

$$(2x - y + 2z) + (2x + 3y + z) = -2 + 7$$

This simplifies to:

$$4x + 2y = 5$$

Step 4: Divide both sides of the equation by 2 to isolate x and simplify:

$$4x + 2y = 5$$

$$(4x + 2y) / 2 = 5 / 2$$

This gives:

$$2x + y = 5/2$$

Step 5: Now, you have a system of two equations:

$$2x + y = 5/2$$

$$2x - y + 2z = -2$$

Step 6: Solve the first equation for y :

$$y = 5/2 - 2x$$

Step 7: Substitute the expression for y into the second equation:

$$2x - (5/2 - 2x) + 2z = -2$$

Simplify and solve for z :

$$2x - 5/2 + 2x + 2z = -2$$

$$4x - 5/2 + 2z = -2$$

Add $5/2$ to both sides:

$$4x + 2z = -2 + 5/2$$

$$4x + 2z = 1/2$$

Now, you have two equations:

- $2x + y = 5/2$
- $4x + 2z = 1/2$

Step 8: Solve Equation (2) for z :

$$4x + 2z = 1/2$$

$$2z = 1/2 - 4x$$

$$z = (1/2 - 4x) / 2$$

$$z = 1/4 - 2x$$

Step 9: Substitute the expression for z into Equation (1):

$$2x + y = 5/2$$

Now, substitute the expression for z into Equation (1):

$$2x + (5/2 - 2x) = 5/2$$

Simplify and solve for x :

$$2x + 5/2 - 2x = 5/2$$

$$5/2 = 5/2$$

The equation is always true, which means that there are infinitely many solutions, and x can have any value.

Step 10: Find y using the value of x :

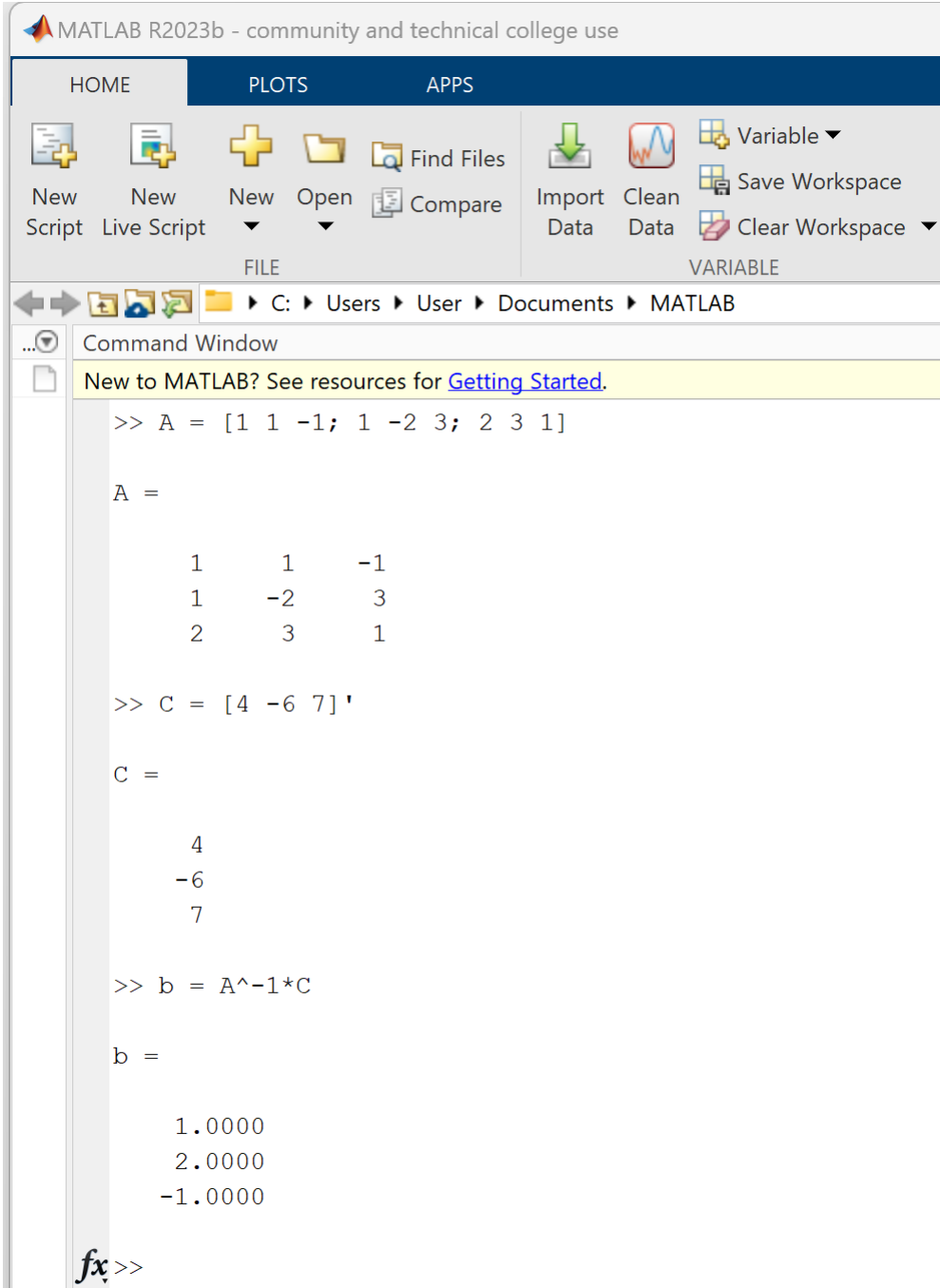
$$y = 5/2 - 2x$$

So, the solutions to the system of equations are:

x can be any real number.
 $y = 5/2 - 2x$
 $z = 1/4 - 2x$

This means there is a line of solutions in three-dimensional space, and the values of x , y , and z can vary along that line.

Appendix B: Solving a system of 3 simultaneous equations using MATLAB R2023b



MATLAB R2023b - community and technical college use

HOME PLOTS APPS

New Script New Live Script New Open Find Files Compare Import Data Clean Data Variable Save Workspace Clear Workspace

FILE VARIABLE

C: \Users\ User \Documents \MATLAB

Command Window

New to MATLAB? See resources for [Getting Started](#).

```
>> A = [1 1 -1; 1 -2 3; 2 3 1]

A =

     1     1    -1
     1    -2     3
     2     3     1

>> C = [4 -6 7] '

C =

     4
    -6
     7

>> b = A^-1*C

b =

     1.0000
     2.0000
    -1.0000

fx >>
```

Appendix C ChatGPT Survey Questions and Summary of Responses

ChatGPT, which runs on "Large Language Model" is a word predictor that has been trained with enormous amounts of data. It is considered a game changer and has often been compared with the arrival of the handheld scientific calculator. The results below are a summary of 27 student responses.

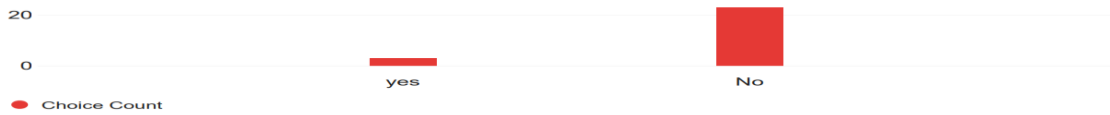
Q_RecaptchaScore

Field	Min	Max	Mean	Standard Deviation	Variance	Responses	Sum
Q_RecaptchaScore	0.20	0.90	0.77	0.16	0.03	27	20.90

Q1 - This survey will help us understand your awareness of Artificial Intelligence Technologies. How would you characterize your level of familiarity/comprehension of LLMs?



Q2 - Are you able to name other LLMs in addition to ChatGPT? If yes, name the other LLMs of which you have some familiarity.



Q3 - Are you likely to utilize ChatGPT or an equivalent model to assist in completing a STEM-related homework assignment?



Q4 - Are you likely to utilize ChatGPT or an equivalent model to assist in completing a Liberal Arts homework assignment?



Q5 - Currently OpenAI offers a free account for limited access to ChatGPT. Do you plan to replace your favorite search engine (i.e., Google, Yahoo, ect) with ChatGPT?



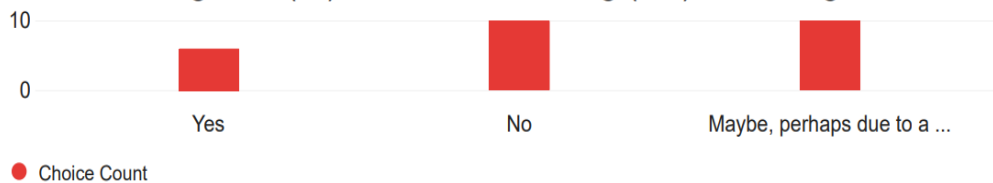
Q6 - Going forward, do you foresee ChatGPT as a software tool which will be helpful or harmful to society



Q7 - Do you currently have an active ChatGPT account? Select the length of time for your active ChatGPT account.



Q8 - Are you considering or planning to work in a profession that will be heavily dependent upon Virtual Reality (VR) / Augmented Reality (AR) / Artificial Intelligence (AI) / Machine Learning (ML) technologies?



Q9 - How do you think AI can be utilized as a resource for addressing and determining solutions to global warming?

How do you think AI can be utilized as a resource for addressing and determining solutions to global warming?

It may help foresee, using data, where we will be in the future at the rate of pollution we are emitting.

By having them tell us what the weather is and if you have a question and don't have any useful sources to get a response.

It could be very helpful to create algorithms and put together laws with current information we have

By all who are researching the problem should share it on AI for the world to use it.

It can't

I guess giving us the sources on how they came up with the information

it can pool data and research together fast and help present known solutions

Monitoring the Climate

It can't.

As it is, it won't generate any solution. Any output will be generated from inputs. It isn't actually a creative solution engine. I'm not personally as concerned about global warming as I am about AI killing most people either through misery or outright killing us (even if it's just used as a tool for a major world war). World War 3 is closer to us than a runaway greenhouse effect is. The question should be how can AI help us avoid war? Especially a war that will very likely occur on the heels of its advancement. WW1 was predicated on similar technological conditions.

Feeding it data can help to pinpoint a solution

not too sure, i personally do not put much stock in global warming/global cooling

AI will possibly be able to come up with solutions that humans haven't thought of before.

It can be used to run simulations of potential actions taken.

For data science, or general data manipulation and presentation, having chat gpt help make that research and data understandable in graphs or articles can help bring awareness to the crisis

Minimal.

I am not familiar with A concept like this and am unaware how that could be implemented.

I think it could be used in making predictions about what is to come with global warming and possible some examples of solutions depending on how advanced AI is used.

i think AI is not a good thing, it's like the government is taking more control than it already has.

Help find ways to solve global warming

Q10 - From your perspective and experience to date, what are some ways AI can be utilized as a "fun" or "entertaining" software application?

From your perspective and experience to date, what are some ways AI can be utilized as a "fun" or "entertaining" software application?

Utilizing the app to ask trivia questions on game nights.

Asking random question and see what type of responses you will get compared to a humans.

Script writing, Playing D&D with ChatGPT as the DM. Prompt creation

IDK

Finding a way to learn something new that you didn't know

Making story scripts



it says funny things sometimes but can also replicate books, movies, etc.

Yea

Making music

It instantly generates art and media.

AI can be used to see what people find entertaining and help to replicate it

entertainment systems, video games, etc

It can be used to create different softwares using AI designed to write code.

It can be used to create entertaining or fun videos depending on the receiving audience

I really like chess so engines such as stockfish really expand our knowledge about the game of chess.

Reverse keyword search.

I think that AI could be integrated into video games to randomize certain aspects.

It can be used for communicating back and forth with someone of AI which some find entertaining as it creates realistic answers as if you were talking to someone real.

i don't think there is any.

Assist you on different activities you will come across



We thank you for your time spent taking this survey.
Your response has been recorded.