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INFORMATION SYSTEMS EDUCATION JOURNAL

Editors

A Comparison of Generative AI Solutions and Textbook Solutions in an Introductory Programming Course

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Abstract

Generative AI has recently gained the ability to generate computer code. This development is bound to affect how computer programming is taught in higher education. We used past programming assignments and solutions for textbook exercises in our introductory programming class to analyze how accurately one of the leading models, ChatGPT, generates solutions. We selected the ChatGPT-4 available through the Bing search engine for our testing. We used a one-tailed test to calculate success percentage of the textbook versus ChatGPT solutions to determine if there was a statistically significant difference. Neither the book nor ChatGPT provided perfect solutions. Analysis of the results showed that the generated code does not always meet the programming requirements, but also that instructions for generative AI coding and for traditional programming can be improved. We conclude with recommendations for incorporating generative AI in programming classes.

Keywords: artificial intelligence, generative AI, ChatGPT, C++, introductory programming courses.

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A Comparison of Generative AI Solutions and Textbook Solutions in an Introductory Programming Course

Ernst Bekkering and Patrick Harrington

1. INTRODUCTION

When the news reported that chatbots using GPT-3 could write comprehensive answers to test questions, we tried to see how well they did on essay questions from our CS3343 Computer Operating Systems course. The contrast between ChatGPT answers and textbook answers was eerie. Computer answers were well-written and provided good examples in contrast with the official answers (
Figure **1**). We reported this to faculty at our department meeting in January 2023, but did not give it much mind for the remainder of the semester. Then came the news that large companies had started using generative AI in their IT departments.

Companies using generative AI include Google, Microsoft, Meta, Insider, Duolingo, Slack, Snap, Coca Cola, Instacart, SalesForce, and Shopify (CNBC.com, 2023; Yahoo News, 2023). Companies like Code Academy (Johnson, 2023) and Udemy (2023), as well as traditional educators like Vanderbilt University (Classcentral.com, 2023), the University of Michigan (Michigan Online, 2023), and MIT (2023) have started offering course in generative AI.

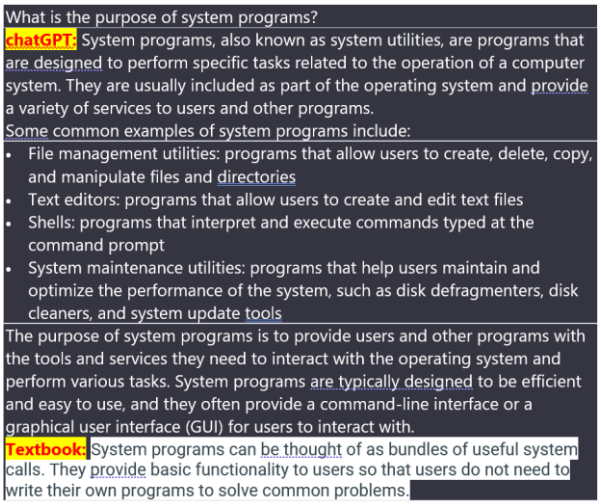

Figure 1:Comparison of answers (personal communication, January 2023)

The revolution in artificial intelligence is now hitting higher education. David Foster, a prominent researcher of AI, states the impending shift as "necessitating a reevaluation and adjustment of current teaching methods and assessment criteria." (Foster, 2022, p. 410).

Because generative AI can write source code, we sought to investigate its limitations and strengths, and begin to determine its usefulness of whether it should be incorporated in teaching Computer Science.

We took the assignments in our Spring 2023 introductory programming course. We compared the results of ChatGPT generated code with our own instructor solutions as posted on the course management system after the assignments were due. Then, we took the end-of-chapter exercise solutions and compared them with the solutions generated by ChatGPT.

The structure of this paper is as follows. We review the literature on generative AI in general and ChatGPT in particular. We briefly review the history of artificial intelligence, describe different types, focus on generative AI, and discuss relevant artificial intelligence in education. Then we describe our methodology in more detail. Following the description of sample and data collection, we analyze the results. Finally, we discuss our conclusions and make recommendations.

2. LITERATURE REVIEW

History of artificial intelligence (AI)

Multiple definitions of AI exist, but a common one is "a system's ability to interpret external data correctly, to learn from such data, and to use those learnings to achieve specific goals and tasks through flexible adaptation" (Kaplan & Haenlein, 2019, p. 17). AI has become a societal focus with the rise of Big Data and increases in computing power (Haenlein & Kaplan, 2019).

Shao et al. (2022) describe the development of AI in three generations. The first generation, Symbolic AI, simulated human intelligence based

on knowledge and experience. Examples are Expert Systems built on knowledge of human experts, natural language processing, financial modeling, and game playing systems. IBM Deep Blue defeated the chess world champion based on raw processing power and analyzing Kasparov's previous games, even though it lacked human understanding of chess strategy.

The second generation (Shao et al., 2022) is data-driven and based on deep learning. New algorithms, such as Convolutional Neural Networks, Recurrent Neural Networks, and Generative Adversarial Networks, emerged. Growth has been accelerated since the models depend on the growth of data without the need for extracting features, and the installed base for storage capacity worldwide is forecast to grow at an annual rate of 19.2% (Statista, 2023). In the future, Shao et al (2022) predict that the third generation of AI will combine knowledge-driven and data-driven theory. Rather than copy brain function, the structure of the brain will be mimicked. This could lead to true Artificial General Intelligence (AGI), but this is in the future. We will now focus more on the development in the second generation of AI since it underlies the current generative AI applications.

AI rapidly changed with the introduction of Deep Learning applied first to the game Go (Silver et al., 2016), followed by a generalization applied to chess and shogi (Silver et al., 2017). This approach is now the basis for applications like virtual assistants, chatbots, entertainment recommendations, humanities compositions, self-driving cars, and fraud detection (Simplilearn.com, 2022). In 2016, DeepMind Applied used Deep Learning to optimize and reduce the energy consumption of its data centers by up to 40% (Evans & Gao, 2016).

The 2017 Google Brain paper, "Attention Is All You Need" describes text generation and conversational AI (Vaswani et al., 2017). It introduced the Transformer Model, which is a neural network architecture that uses attention mechanisms to compute representations of its input and output. Google has made significant contributions with Google Brain (Google, 2023) and TensorFlow (Tensorflow, 2023) as a means for programming convolutional neural networks.

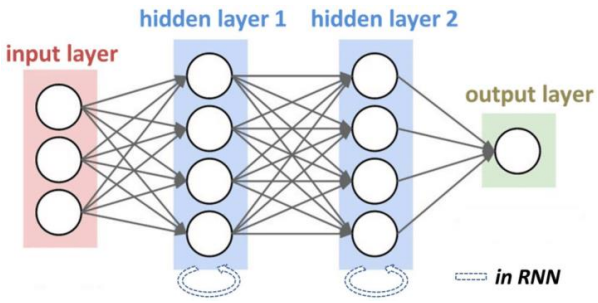

Figure 2:RNN structure (Researchgate.net, 2019)

Before the Transformer Model, recurrent neural networks processed input sequences one element at a time from input layer to hidden layer to output layer (Figure 2). The Transformer Model replaced the fixed internal weights with attention mechanisms to compute the relationships between inputs and outputs (Figure 3).

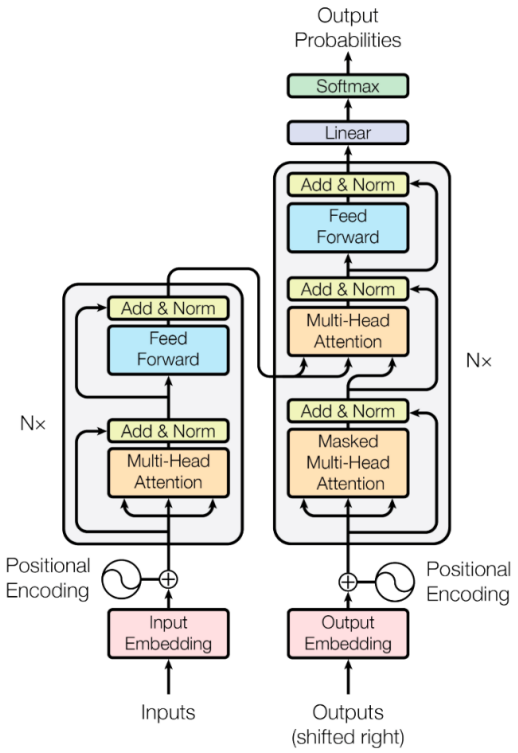

Figure 3: Model architecture of transformer (Vaswani et al., 2017)

In 2018, researchers from OpenAI demonstrated that natural language understanding could be improved by generative pre-training on large amounts of unlabeled text, followed by discriminative fine-tuning for each task (Radford et al., 2018). Researchers from Google reported bidirectional pretraining simplified the fine-tuning phase (Devlin et al., 2018). Other Google

researchers presented a unified framework that addresses text-based language problems and called it T5, "Text-to-Text Transfer Transformer" (Raffel et al., 2020). The wide field of use is illustrated in Figure 4.

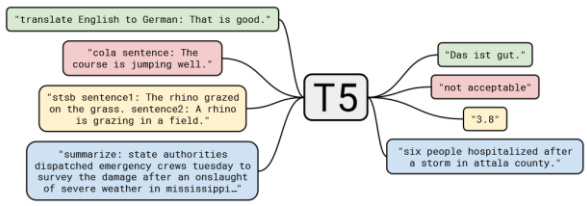

Figure 4: T5 model (Raffel et al., 2020)

Text normalization was improved by augmented use of Batch Normalization (BN), previously used for Computer Vision. Through parameter adjustment, Shen et al. (2020) improved the traditional Layer Normalization (LN) and called it Power Normalization (PN).

Increasing the size of the language model does not necessarily improve the performance. Using human feedback, Ouyang et al. (2022) fine-tuned the performance of GPT-3 in the InstructGPT model, which showed improved truthfulness and reduced toxic output generation with minimal performance reduction despite using 100x fewer parameters in the model.

Types of artificial intelligence

Machine learning includes three types of learning: supervised, unsupervised, and reinforcement learning (Brown, 2021). Supervised learning presents the model with a large data set with example inputs labeled according to the desired output or result. After training, the model can predict outputs in response to new inputs. Unsupervised learning uses large amounts of data without specifying the outcomes. The model produces groupings of sufficient similarity. In reinforcement learning, AI observes and records responses to its actions generated by a simulator running large numbers of cases and evaluates responses using a reward function.

Generative AI is a broad term for AI systems designed to generate content in multiple forms. Images can be generated with websites like Midjourney (2023) or Stable Diffusion (2023). Audio generators include VALL-E (Microsoft, 2023) and resemble.ai (2023). Large Language Models (LLMs) work with language. GPT-4 is the most prominent example, but other models exist (Table 1). Whether code generation tools like Github's Copilot (Github Inc., 2023) and TabNine (TabNine, 2023) should be considered a separate category of content is up for debate because they are computer language tools. Code generation tools offer special features such as code completion, review, and documentation (Tech Point Magazine, 2023).

LLM	Company
GPT-4	OpenAI
Bloom	Hugging Face
AlexaTM	Amazon
ESMFold	Meta AI
Gato	DeepMind
WuDao	Beijing Academy of Artificial Intelligence
LLaMa	Meta
MT-NLG	Nvidia and Microsoft
LaMDA	Google
PanGu-Σ	Huawei
PaLM-2	Google

Table 1: Selected language models

Chat programs

In the area of generative AI, chatbots are special programs that respond to human language in a contextually relevant way. They adapt over time and provide nuanced responses. The programs have the same objective function: "Given a sequence of text, guess what comes next" (Roose, 2023). The best-known example is Chat Generative Pretrained Transformer (ChatGPT).

ChatGPT is a product of OpenAI, a company founded in 2015. Major milestones in its development are (Marr, 2023):

- June 2018: release of GPT-1 with 117 million parameters. It used language understanding tasks for word prediction.
- February 2019: release of GPT-2 with 1.5 billion parameters. It could produce coherent, multi-paragraph text.
- June 2020: release of GPT-3 with 175 billion parameters. It could draft advanced text, answer factual questions, and generate programming code.
- March 2023: release of GPT-4 with 1 trillion parameters. It can use text, video, sound, and image input, output in the same formats, decrease error rates, and is more responsive to user intent (Techradar.com, 2023).

Using LLMs for code generation has not been a deliberate undertaking. As LLMs learn to predict the next word in a sequence, trained over millions or billions of repetitions, they can develop surprising new abilities as emergent behaviors (Mok, 2017). AlphaZero came up with moves such as sacrificing a queen to improve position in chess (Kissinger et al., 2021). In generating the

antibiotic Halicin, new relationships between molecules and lethality to bacteria were discovered (Kissinger et al., 2021).

Generative AI can improve the workplace. In a survey of GitHub developers, 60-75% reported improved work satisfaction, 73% had less effect of context switches, and 87% worked better in repetitive tasks when using Github's AI CoPilot (Kalliamvakou, 2022). Meta evaluated CodeCompose and found that 20% of users reported acceleration of their coding activities, as well as increasing internal and external documentation (Murali et al., 2023).

Use of AI in higher education

Students have flocked to using ChatGPT (Terry, 2023). According to Intelligent (2023), 30% of college students used ChatGPT for schoolwork in the past academic year. Faculty have raised concerns, ranging from cheating and plagiarism, using it to create scholarly work, threats to privacy, fabrication of quotes and references, and lack of trustworthiness (Brandon Paykamian, 2023; Dempere et al., 2023; Freeman-Wong et al., 2023; Lachheb, 2024).

These concerns are not without foundation. ChatGPT is a powerful tool. The new AI tools have now been used to pass multiple exams (Table 2). Educators fear not only that students will use generative AI to create and submit work that is not their own (Kayla Jimenez, 2023), but also that the software may present false, misleading, or ideologically based information. On average, generative AI programs are truthful 25% of the time and absorb underlying social biases from their training data (Stanford University, 2022).

Exam	Percentile score
Uniform bar exam	90th
SAT reading and writing	93rd
SAT math	89th
GRE verbal	99th
GRE quantitative	80th
GRE writing	54th
USA Biology Olympiad	99th

Table 2: GPT-4 exam scores

Use of AI is inevitable, and we should use it in education to help prepare students for a workforce where it will be used (McMurtrie, 2023). Chen (2022) found that machine learning is already at the core of the AI curriculum in the top 46 business schools. Increasingly, experts advocate educational use (Cardona, 2023; Renbarger, 2023).

Furthermore, AI can be used for higher levels of learning (Denny et al., 2023). Students can use AI to create functions with the appropriate sorting algorithm and focus on the structure of the software. Traditional coders could see their job market vanish in a shift to software engineering. As Kissinger et al. (2021, p. 90) explain: "AI coders will complete programs sketched by human developers." Bansal (2024) argues that generative AI will shift the workload from generating code to quality assurance of code.

If higher education does not provide pathways to deep learning, alternative providers will. Cloud services such as Amazon Web Services (AWS) and Microsoft Azure offer pre-built deep learning tools (Amazon, 2023; Azure, 2023). Coursera with DeepLearning.ai are providing a series of online courses. (Coursera, 2023a). IBM offers a similar six course sequence leading to the IBM AI Engineering Professional Certificate (Coursera, 2023b).

Artificial intelligence is like any tool that can be used either for good or for harm. It is the intent and action of the user that matters, not the existence of the tool itself.

3. METHODOLOGY

CS2014 Computer Science I is our introductory programming class. It is taught in C++. The textbook is shared with the follow-up class, CS2163 Computer Science II. CS2014 uses the first 8 chapters of the book; CS2163 uses the rest.

It consists of 3 hours lecture and one hour lab, for a total of 4 credit hours. During the lecture, the instructor demonstrates programs in Visual Studio Code. The programs consist of code in the body of the chapters and the end-of-chapter exercises. The labs use special short exercises with problems and solutions for independent practice. The course has six hands-on programming exercises and a multiple-choice final exam.

The book comes with solutions for the end-of-chapter exercises. We decided to use these solutions to check how well ChatGPT can meet the requirements of these exercises and assignments, as they have been formulated by the textbook author and the class instructor. Since the assignment descriptions are frequently adjusted from semester to semester, we took the most recent instructions from the Spring 2023 semester.

Spring 2023 assignments
The six assignments follow the material presented in the book chapters and focus on specific topics:

- Assignment 1 involves numerical input and sum and average.
- Assignment 2 focuses on loops and output formatting with decimals and tables.
- Assignment 3 introduces file reading, subtotals, and grand totals.
- Assignment 4 uses random number generation, file writing and reading, and nested loops.
- Assignment 5 focuses on functions.
- Assignment 6 works with arrays, sorting, and searching.

The specific descriptions of the assignments are listed in Appendix A.

We used the assignment descriptions to generate ChatGPT instructions and minimized the changes as much as possible. We omitted references to unknown context such as the four-step process (declare variables, assign values, data manipulation, and output or file writing). The ChatGPT instructions are listed in Appendix A next to the assignment instructions for comparison.

Textbook end-of-chapter exercises
Textbooks currently come in paper and electronic format. We used the instructions from the electronic version and made minimal modifications. We had to specify the C++ language. For exercises building on a previous exercise, we copied the instructions from the older exercise and added the modification instructions. Figure 5 gives an example.

We encountered minor problems with incompatibilities between the textbook and exercise solutions. Occasionally the solution numbering was off or no textbook solution was provided, so we matched the solutions with the proper exercise number. If we did not have a textbook solution, we make notes in Appendix B which has the results of the analysis.

Finally, since we did not want to list the textbook instructions with the textbook solutions in this paper, we do not include them in an appendix. They are, however, available upon request to the corresponding author.

Selecting the AI instrument
Multiple tools are currently available for free. We will briefly discuss three of them. All three are web-based rather than software plugins. Students have different preferences for their Integrated Development Environments (IDEs) and copying and pasting from a browser allows them to use their favorite IDE.

First exercise: Random Number Guessing Game Write a program that generates a random number and asks the user to guess what the number is. If the user's guess is higher than the random number, the program should display "Too high, try again." If the user's guess is lower than the random number, the program should display "Too low, try again." The program should use a loop that repeats until the user correctly guesses the random number.
Second exercise: Random Number Guessing Game Enhancement Enhance the program that you wrote for Programming Challenge 20 so it keeps a count of the number of guesses the user makes. When the user correctly guesses the random number, the program should display the number of guesses.
Combined ChatGPT instructions: Random Number Guessing Game Enhancement Write a C++ program that generates a random number and asks the user to guess what the number is. If the user's guess is higher than the random number, the program should display "Too high, try again." If the user's guess is lower than the random number, the program should display "Too low, try again." The program should use a loop that repeats until the user correctly guesses the random number. Enhance the C++ program so it keeps a count of the number of guesses the user makes. When the user correctly guesses the random number, the program should display the number of guesses.

Figure 5 - Combined ChatGPT Instructions

The original ChatGPT is available on the OpenAI website at https://openai.com/chatgpt . It requires setting up an account and logging in. Traffic may be throttled with high use, leading to the error message "ChatGPT has too many requests in 1 hour. Try again later." Since availability to students is a major issue, this disqualified OpenAI for this study.

ChatGPT-4 has been integrated into the Bing search engine on the Microsoft Edge Browser and now also at https://www.bing.com/ (MIT Technology Review, 2023). The Bing chatbot is also plugged into the Bing search engine (Figure

6), so it can get current information from the internet to use in the responses (Tomsguide.com, 2023).

Google Bard is based on the Google LaMDA language model. On April 21, 2023, the CEO of Google announced that Google Bard could generate code including the C++ language. Users must visit the Google Bard page (https://bard.google.com/) and choose "Join the waitlist." Waiting does not exist at the time of this writing. Bard is currently not integrated with a search engine, relies on updates, and can only be used for personal accounts.

We selected the Bing search engine site because it was free, easy to use, and we did not notice any performance issues in our initial testing.

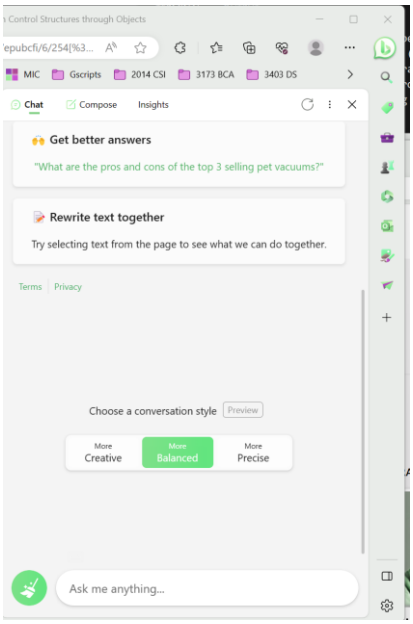

Figure 6: Chatbot in Edge

Using the Bing chatbot
The chatbot is available as part of the Microsoft Edge browser. On each new page, an icon with a "b" opens the chat pane (Figure 6, top right). Users enter their questions and requests in the "Ask me anything" bar and can choose between three conversational styles (Warren, 2023). The default is More Balanced, and we used this style for most of our work. Occasionally, when the chatbot declined to answer and wanted to go to another topic, we used the More Precise style. "More Creative" did not seem appropriate for our work. One reason to go to "More Precise" is the character limit on the ChatGPT input. Whereas More Balanced has a 2,000-character limit, both More Creative and More Balanced have a 4,000-character limit.

4. SAMPLE AND DATA COLLECTION

Legacy assignments
The six course assignments have been discussed in the previous section. Their complete instructions and solutions, and ChatGPT equivalents, are listed in Appendix A.

Textbook exercises
The textbook has eight chapters used for the CS2014 class. The remainder of the chapters are used in the follow-up class, CS 2163 Computer Science II. Table 3 provides an overview of the topics and the number of end-of-chapter exercises.

Scoring assignments and exercises
We copied and pasted the ChatGPT instructions in Appendix A to generate the C++ code for the ChatGPT version. We then copied both the book solutions and ChatGPT code to programs in Visual Studio Code. All programs were scored by the first author on whether (yes/no) all requirements in the instructions were met.

We focused on the explicitly stated requirements as provided in the book description. For instance, textbook authors made extensive use of constants. We only considered the presence or absence of constants when it was specifically mentioned. As another example, chapter 6 on functions preceded chapter 8 on searching and sorting. We did not penalize ChatGPT unless separate functions were specifically mentioned (which they usually were not). The only exception we made was in chapter 2 where the book solutions ran without output. We did consider that an (unspoken) requirement.

5. ANALYSIS AND FINDINGS

Legacy course assignments
ChatGPT was able to meet most requirements.

Assignment 1 was the simplest, with identical source code answers. Both versions met all requirements.

Assignment 2 was more demanding, but standard for repetition and output formatting. Both versions met all requirements.

Assignment 3 used file input to generate a table with annual and grand totals. ChatGPT added arrays, which had not yet been covered. In the Spring 2023 class, this issue was addressed with the general instruction to only use material previously covered. This context was not available to ChatGPT. Both versions met all

requirements. It is a good example of needing to use specific instructions to get specific results.

#	Name	Focus	ex.
2	Introduction to C++	Output #include variables numerical data types C++ strings Operators	20
3	Expressions and Interactivity	Mathematical operations type casting assignment output formatting string class	25
4	Making Decisions	If , if/else, if/else if/else logical operators input checking switch	28
5	Loops and Files	(do) while loops for loops (sub) totals nested loops intro to files	27
6	Functions	Functions (definition, calls, prototypes) return values static variables Reference variables	24
7	Arrays and Vectors	Arrays (definition, accessing, processing) range-based for loop multi-dimensional arrays STL vectors	21
8	Searching and Sorting Arrays	Bubble sort insertion sort linear search binary search	12

Table 3: Textbook Chapters

Assignment 4 is where ChatGPT first failed. The program was to generate a user-specified number of random numbers, to read and calculate on the first 50 numbers, and then to read and calculate on all numbers in the file. Of course, this required closing the file after reading the first 50 numbers so all numbers could be accessed. ChatGPT did not, so the second table was based on 50 too few numbers. In experimenting with requests to fix this error, ChatGPT came up with innovative solutions including setting the file pointer back to the start of the file, but it did not initially meet the requirements.

Assignment 5 required breaking down seconds to days, hours, and minutes. The calculations were correct, but there was one minor deviation in the output. In the original instructions, an example of output was given where 0 days would not be displayed. It is again an example of needing explicit instructions.

In assignment 6, where 25 floats were processed in an array, ChatGPT met all requirements. It used the algorithms library to sort the array, but this was not specifically forbidden.

As a last remark, we would like to note that giving sample output helps ChatGPT to generate code with the same look and feel as originally intended. In the assignments, we have included sample output for students to practice proper input and output. In the end-of-chapter exercises, ChatGPT did not have this advantage.

Textbook exercises

Except for chapter 2, where the book solutions omitted the output, the book solutions outscored the ChatGPT results. Appendix B shows the results by exercise, summarized by chapter and overall. Five exercises did not have a book solution, and even though ChatGPT created working solutions, we excluded the pairs from the sample.

Comparing the chapters, ChatGPT had most difficulties in chapter 6 on functions. On further investigation, this was not due to inability to create separate functions. Most failures resulted from lack of input checking and some logic errors.

Overall, neither the book nor ChatGPT provided perfect solutions. Whereas ChatGPT successfully met the stated requirements 78.9% of the time, the book managed only 90.8%. Examples of book solutions not meeting requirements are in Appendix C. With a valid total of 152 exercise pairs, we wanted to determine if there was a statistically significant difference of the two proportions. This is a simple test that can be performed with a Z-test in Excel (Statology, 2019). Since the book success percentage was higher than the ChatGPT success percentage, we used a one-tailed test. The null hypothesis was

$$H_0: p_b <= p_c$$

and the alternative hypothesis

$$H_a: p_b > p_c$$

where p_b is the book proportion and p_c the ChatGPT proportion. We calculated the z-value as

follows: the book proportion p_b is 0.908; the ChatGPT proportion p_c is 0.789. Both sample sizes s_b and s_c are 152. The pooled sample proportion p_s

$$p_s = (p_b * s_b + p_c * s_c)/ (s_b + s_c) = (0.908 * 152 + 0.789 * 152) / (152 + 152) = 0.84868$$

The test statistic z:

$$z = (p_b - p_c) / \sqrt{p_s * (1- p_s) * [(1/ s_b) + (1/ s_c)]} = (0.908 – 0.789) / \sqrt{0.84868* (1- 0.84868) * [(1/ 152) + (1/ 152)]} = 2.88085.$$

The p-value can be found on a Z table or calculated with the Excel formula

$$p = 1 – NORM.S.DIST(z,true) = 0.00198$$

At a value of 0.00198, the null hypothesis is rejected and the alternative hypothesis of the book success percentage being statistically greater, is correct.

In the course of analysis of the data, combined with our experience using AI in the class, we have several recommendations for using generative AI in introductory programming classes.

- Specify the programming language. ChatGPT would generate solutions in the wrong language.
- Require students to explain each line of code to make sure that they understand the whole program (Figure 7).
- Instruct students that they can only use what has been covered in class. For instance, the use of arrays in assignment 4 was superior to repeatedly reading files. However, arrays had not been covered yet.
- Consider specifying what you want the AI to do, as opposed to instructing it not to do. It worked in 2-15, where the instruction "Please don't use loops. We have not covered that yet" resulted in the proper sequence of output. It did not work in the more complicated 2-16 which used a diamond instead of a triangle, and instructing the AI to avoid loops was not successful. Likewise, in 3-13, ChatGPT used constants because it was explicitly instructed to do so. In contrast, in 3-14, tax rates were not used as constants because there was no instruction to do so.
- Unless you ask for something, you may not get it. The AI would not use variables but hard-coded values. We suggest specifying data types like "use doubles for the membership rates."

```
// with shortened inner loop and smart stop when there are no swaps
void sortArray4(int array[], int size)
{
   int temp; // temporary storage for swapping two values
   bool swap; // track if a swap occurs
   int loop = 0; // for counting the loops to measure performance

   do // start the loop
   {
      swap = false; // we have not swapped pairwise values yet
      // the loop gets shorter each time because the sorted area
      // on the right grows
      for (int count = 0; count < (size - 1 - loop); count++)
      {
        // if left greater than right, need to swap left and right
        if (array[count] > array[count + 1])
        {
           temp = array[count]; // store larger left safely in temp
           array[count] = array[count + 1]; // move larger value to left
           array[count + 1] = temp; // move larger value to the right
           swap = true; // we have made a swap
        }
      }
      loop+=1; // we needed yet another loop
   }while(swap); // continue as long as a swap has taken place

}
```

Figure 7: Commenting to demonstrate understanding.

- The input on the website has a maximum of 2000 characters for input. If one exercise is a modification of an earlier exercise, there may be enough room to paste the instructions for the old exercise before the new one. If there is not, consider going to the slower More Precise style with the 4,000-character limit.
- The outcome of the AI cannot be trusted completely. This allows us, and indeed forces us, to introduce the concept of testing much earlier than before. Tests should be dependent on the requirements of the program. For instance, if the program specifies input range checking, this requires additional tests with out-of-bound inputs. Without the requirement, only valid values should be used and clearly incorrect inputs (e.g., negative ages) avoided. Generative AI has also been known to create non-existing data. We saw this in exercise 6-2, where ChatGPT made up an interest rate. This does not mean that testing the book solutions is any less important. In exercises 4-12 and 4-20, ChatGPT got the math correct and the book did not.
- When running the program to test the output, consider using different numbers than the book sample output. We did not find any instances of hard-coded output but is a (remote) possibility. More importantly, numbers from the book don't always appropriately test the program. For instance, prices like $25 could easily overlook lack of output formatting, whereas prices like $24.78 might give additional information without additional tests.
- ChatGPT often gives explanations of how its generated code works. This could be used in

questions like "Where can you see that the input is between 0 and 100?"
- ChatGPT cannot read figures because it is only text-based at this point. It could not do exercise 4-27 because it was based on a figure. Thus, figures could be used in class to discourage or prevent the use of ChatGPT for tests.
- Book instructions often contain formulas that students need to solve an exercise, but that ChatGPT may not need. For instance, formulas for Future Value or Present Value may not need to be given.
- It helps to give sample output as part of the instructions. This automatically led to the inclusion of the setw() function to create columns of the exact same width as the book solution. We recommend monospaced fonts in the code editor to facilitate checking the results. Wording may matter, e.g. "The program should display a report similar to the following" versus "This is what the program should look like to the user."
- When starting another program, begin a new conversation so old instructions do not influence the results. When modifying the results, specify that the current solution must be used. We found words like "Now use …" helpful.
- Using an online engine is dependent on availability of the service. There are times that the system may not be available or runs slowly.

6. CONCLUSIONS AND RECOMMENDATIONS

Even though the book solutions outperformed the ChatGPT solutions, the comparison is imperfect. With more precise instructions, we might have been able to generate solutions that better met the requirements. The other issue is the quality of the code for both versions. Even though it may not be specified, ChatGPT often provides solutions with higher-level or better programming logic. For instance, sorting and searching algorithms have long been formalized. It may simply be enough for students to recognize the algorithm, learn the relative strengths and weaknesses in a course like Data Structures and Algorithms, and learn to use the algorithm library in this course.

Regardless, generative AI is here to stay, and we will need to incorporate it in our programming classes, starting with introductory classes and progressing to more advanced programming classes as the software gains power. The current competition between technology giants like Microsoft, Google, and Amazon will continue to drive advancements. At the same time, the workflow of software engineers is going to be significantly streamlined and automated.

With the current limitations of AI and the expected rapid development, can we expect to use AI in advanced programming classes? We plan to examine this in the follow-up class CS2163 and the Java-based CS3033 Object-Oriented Programming classes.

Future directions

This study only compares literal copies of book instructions for C++ programming exercises. ChatGPT shows success especially in earlier parts of the book. We plan to expand our work by taking textbook solutions and building instructions to ChatGPT from scratch to recreate the book solutions as closely as possible. We expect this to yield valuable information for faculty and students how to specifically instruct ChatGPT to get specific answers.

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Appendix A – Description of Assignments and ChatGPT Instructions

The appendix has been moved online due to restrictions on the file size of submitted manuscripts.

Link: appendixA.docx

Appendix B – Pairwise Comparison of Book and ChatGPT Solutions

Exercise	ChatGPT	book	Exercise	ChatGPT	book	Exercise	ChatGPT	book	Exercise	ChatGPT	book	Exercise	ChatGPT	book	Exercise	ChatGPT	book	Exercise	ChatGPT	book
2-1	yes	no	3-1	yes	yes	4-1	yes	yes	5-1	yes	yes	6-1	yes	yes	7-1	no	yes	8-1	yes	yes
2-2	yes	no	3-2	yes	yes	4-2	yes	yes	5-2	no	yes	6-2	yes	yes	7-2	yes	yes	8-2	yes	yes
2-3	yes	no	3-3	yes	yes	4-3	yes	yes	5-3	yes	yes	6-3	yes	yes	7-3	yes	yes	8-3	yes	yes
2-4	yes	yes	3-4	yes	yes	4-4	yes	yes	5-4	yes	yes	6-4	yes	yes	7-4	yes	yes	8-4	yes	yes
2-5	yes	yes	3-5	yes	yes	4-5	yes	yes	5-5	yes	no	6-5	yes	yes	7-5	no	yes	8-5	yes	no
2-6	yes	yes	3-6	yes	yes	4-6	yes	yes	5-6	yes	yes	6-6	yes	yes	7-6	yes	yes	8-6	no	yes
2-7	yes	yes	3-7	yes	yes	4-7	no	yes	5-7	yes	yes	6-7	yes	yes	7-7	no	yes	8-7	no	yes
2-8	yes	yes	3-8	yes	yes	4-8	yes	yes	5-8	no	yes	6-8	no	yes	7-8	yes	yes	8-8	yes	yes
2-9	yes	yes	3-9	no	yes	4-9	yes	yes	5-9	yes	yes	6-9	no	yes	7-9	yes	no	8-9	yes	yes
2-10	yes	yes	3-10	yes	yes	4-10	yes	yes	5-10	yes	yes	6-10	yes	yes	7-10	no	yes	8-10	yes	yes
2-11	yes	yes	3-11	yes	yes	4-11	no	yes	5-11	yes	yes	6-11	no	yes	7-11	yes	no	8-11	yes	yes
2-12	yes	no	3-12	yes	yes	4-12	yes	no	5-12	yes	yes	6-12	no	yes	7-12	yes	yes	8-12	*	*
2-13	yes	yes	3-13	yes	yes	4-13	yes	yes	5-13	yes	yes	6-13	yes	yes	7-13	yes	no			
2-14	yes	yes	3-14	yes	yes	4-14	yes	yes	5-14	yes	yes	6-14	no	yes	7-14	yes	yes			
2-15	yes	yes	3-15	yes	yes	4-15	yes	yes	5-15	yes	yes	6-15	no	yes	7-15	yes	yes			
2-16	yes	yes	3-16	yes	yes	4-16	yes	yes	5-16	no	yes	6-16	yes	yes	7-16	no	yes			
2-17	yes	yes	3-17	no	yes	4-17	yes	yes	5-17	yes	yes	6-17	yes	no	7-17	yes	yes			
2-18	yes	yes	3-18	yes	yes	4-18	yes	yes	5-18	no	yes	6-18	no	yes	7-18	yes	yes			
2-19	yes	yes	3-19	yes	yes	4-19	yes	yes	5-19	yes	yes	6-19	no	yes	7-19	*	*			
2-20	no	no	3-20	yes	yes	4-20	yes	no	5-20	yes	yes	6-20	no	yes	7-20	*	*			
			3-21	yes	yes	4-21	yes	yes	5-21	yes	yes	6-21	yes	yes	7-21	yes	yes			
			3-22	yes	yes	4-22	yes	yes	5-22	yes	yes	6-22	no	yes						
			3-23	yes	yes	4-23	yes	yes	5-23	yes	yes	6-23	yes	yes						
			3-24	yes	yes	4-24	no	yes	5-24	yes	yes	6-24	no	yes						
			3-25	no	yes	4-25	yes	no	5-25	no	yes									
						4-26	yes	yes	5-26	*	*									
						4-27	no	yes	5-27	*	*									
						4-28	no	yes												
ch02			ch03			ch04			ch05			ch06			ch07			ch08		
ChatGPT	19	95.0%	ChatGPT	22	88.0%	ChatGPT	23	82.1%	ChatGPT	20	80.0%	ChatGPT	13	54.2%	ChatGPT	14	73.7%	ChatGPT	9	81.8%
book	15	75.0%	book	25	100.0%	book	25	89.3%	book	24	96.0%	book	23	95.8%	book	16	84.2%	book	10	90.9%
count	20		count	25		count	28		count	25		count	24		count	19		count	11	

*	no solution in the book solution bank	ChatGPT total:	120	ChatGPT %:	78.9%
		book total:	138	book %:	90.8%
		count total:	152		

Legend	
yes	requirements met
no	requirements not met

Two sample -test (one-tailed)		source: https://www.statology.org/two-proportion-z-test-excel/
book proportion	0.908	
book sample size	152	
ChatGPT proportion	0.789	
ChatGPT sample size	152	

Pooled sample proportion	0.84868	=(D40*D41+D42*D43)/(D41+D43)
Test statistic	2.88085	=(D40-D42)/SQRT(E45*(1-E45)*((1/D41)+(1/D43)))
p-value	0.00198	=(1-NORM.S.DIST(E46, TRUE))

Appendix C – Examples of Incomplete Textbook Solutions

Example 1

Sum of Two Numbers
Write a program that stores the integers 50 and 100 in variables, and stores the sum of these two in a variable named total.

```
// Chapter 2, Programming Challenge 1: Sum of Two Numbers
int main()
{
	// Store the integers 50 and 100 in num1 and num2.
	int num1 = 50, num2 = 100;

	// Store the sum of num1 and num2 in total.
	int total = num1 + num2;
	return 0;
}
```

No output - the book forgot to use a cout statement.

Example 2

Software Sales
A software company sells a package that retails for $99. Quantity discounts are given according to the following table.

Quantity	Discount
10–19	20%
20–49	30%
50–99	40%
100 or more	50%

Write a program that asks for the number of units sold and computes the total cost of the purchase.
Input Validation: Make sure the number of units is greater than 0.

```
// Chapter 4, Programming Challenge 12: Software Sales
#include <iostream>
#include <iomanip>
using namespace std;

int main()
{
	// Constant for the unit price.
	const double UNIT_PRICE = 99.0;

	int unitsSold;	// Number of units sold
	double discountPct;  // Discount percentage
	double discountCost; // Unit cost after discount
	double totalCost;    // Total cost

	// Get the number of units sold.
	cout << "How many units were sold? ";
	cin  >> unitsSold;

	// Make sure a positive number was entered.
	if (unitsSold <= 0)
		cout << "Units sold must be greater than zero.\n";

	// Determine the discount percentage.
	else
	{
		if (unitsSold < 10)
			discountPct = 0.00;
		else if (unitsSold >= 10 && unitsSold <= 19)
			discountPct = 0.20;
		else if (unitsSold >= 20 && unitsSold <= 49)
			discountPct = 0.30;
		else if (unitsSold >= 50 && unitsSold <= 99)
			discountPct = 0.40;
		else    // unitsSold was 100 or more
			discountPct = 0.50;

	// Calculate the unit cost after the discount.
	discountCost = UNIT_PRICE * discountPct;

	// Calculate total cost.
	totalCost = unitsSold * discountCost;

	// Display the total cost.
	cout << fixed << showpoint << setprecision(2);
	cout << "The total cost of the purchase is $"
```

```
            << totalCost << endl;
        }

        return 0;
}
```

Output:
How many units were sold? -5
Units sold must be greater than zero.

How many units were sold? 55
The total cost of the purchase is $2178.00

Problem: the book solution is wrong. It gives a 60% discount.

Example 3

```
void getEmployeeInfo(long emp[], int hrs[], double rate[], double pay[], int size)
{
	cout << "Enter the requested information "
		<< "for each employee.\n";

	// Get the information for each employee.
	for (int count = 0; count < size; count++)
	{
		cout << "\nEmployee #" << emp[count] << endl;

	// Get this employee's hours worked.
	cout << "\tHours worked: ";
	cin  >> hrs[count];

	// Validate hours worked.
	while (hrs < 0)
	{
		cout << "Hours worked
		must be 0 or more. "
			<< "Please re-enter: ";
		cin  >> hrs[count];
	}

	// Get this employee's pay rate.
	cout << "\tPay rate: $";
	cin  >> rate[count];

	// Validate the pay rate.
	while (rate[count] < 15.00)
	{
		cout << "Pay rate must be 15.00 or more. "
			<< "Please re-enter: $";
		cin  >> rate[count];
	}

	// Calculate this employee's gross pay.
	pay[count] = hrs[count] * rate[count];
	}
}
```

The program crashes here because it should be hrs[count]

Teaching Case

Cleaning Out the Basement: Designing & Developing a Database to Support an Online Side Hustle Case

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Abstract

With the growing entrepreneurial spirit and ease of selling items online, many people are turning to virtual marketplaces to earn extra income or, in some instances, build a career. This case focuses upon the development of a database to assist in inventory management for an online reselling business that has grown from an occasional hobby to a full-blown business. The case provides a realistic scenario that can be used in a capstone business course, systems analysis and design, database development, or graduate level management information systems course. Some of the suggested case exercises were written so that the case could be used as an integrative capstone project across multiple disciplines including digital marketing, entrepreneurship, business management, project management, human resources, accounting, finance, information systems, and computer science. Multiple assignment options are provided allowing instructors to select an assignment based upon course material coverage. Suggested assignments include the investigation of developing an online business, development of process modeling diagrams such as a data flow or swim lane diagrams, and database design and development artifacts.

Keywords: Teaching case, Database design, Process design, Swimlane diagrams, multidisciplinary project

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Cleaning Out the Basement: Designing & Developing a Database to Support an Online Side Hustle Case

Dana Schwieger

1. CASE SUMMARY

In a short amount of time, Tim Carter went from an online resale novice, bent on cleaning out his overstuffed basement, to running a full-fledged online business with plans to hire a part time employee. Tim seeks the help of his next-door neighbor to design and develop a database that will help him keep track of his inventory and sales as well as prepare reports he can use to file his income taxes.

2. THE BASEMENT

"I thought I was going to have free time when I retired," Tim mumbled under his breath as he finished packing a shipping box in preparation for fulfilling a customer's Facebook Marketplace order.

"You did this to yourself, Timothy Carter," Robin, his wife teased. "Besides, you know you really enjoy the thrill of making a big flip."

Tim couldn't argue with that. It was exhilarating to make a big sale on something he had gotten for free or next to nothing. Tim had recently retired from Whispering Hills Parks District where he had worked as the supervisor of grounds and maintenance for forty years. He was a jack-of-all-trades and could fix anything. Over the years, their basement had been stuffed with an accumulation of rescued "treasures" park patrons had abandoned during their visits.
Tim had promised Robin, that he would start selling off his "basement bounty" when he retired; and they would use the money to go on a Caribbean cruise. Upon waking the first day of his retirement, Robin held Tim to start fulfilling his promise.

3. ONLINE RESELLING

Tim had friends who had been successful selling items on eBay, Facebook Marketplace, and other social media outlets. He didn't know anything about how it all worked, but he was a quick study and now had the time to learn.

Tim quizzed his friends to find out how to get started. He also watched numerous YouTube videos to learn how to attractively stage products for photos and craft their descriptions to maximize customer interest. When he thought he knew enough to give it a go, he posted his first item for sale and watched his inbox expectantly for a week before he even got a nibble of interest. Things weren't happening as quickly as he thought they should; so, Tim decided to do some more research before trying again.

On his second attempt, Tim's Facebook Marketplace post received a response in a matter of hours. He was already making arrangements to get the product to the customer by the end of the day. The thrill of having his first sale was exhilarating. This motivated him to continue researching ways to tweak and refine his marketing techniques to entice more customers.

In less than six months, Tim found the "secret sauce" that worked for him in selling his products. He had also expanded his online territory into eBay sales. He was making headway on the basement as well as helping his friends clean out some of theirs.

His part time basement cleaning project was turning into a full-time job. Tracking sales, shipping products, and keeping up with the paperwork was starting to get overwhelming. His simple spreadsheet system worked well in the beginning when he was only listing a few products and treated online sales as a hobby. Now, however, he was posting twenty or more products at a time and was getting concerned that he might have to start paying taxes on his online sales income. (eBay, 2022). He decided to treat his hobby as a business and keep track of his revenue and expenses in case he would need to pay taxes on his income. He was also taking his online sales business more seriously. The spreadsheet that once collected just a few fields of data for inventory purposes had grown to an unmanageable 35+ fields for tracking and analysis of inventory, sales, customers, and shipment modes.

Tim had made more than enough money to take Robin on that cruise he had promised. She was starting to get impatient for them to start making reservations. Truth be told, Tim was ready to go

as well. He needed a vacation from his "retirement vacation" and he couldn't do that until his paperwork was under control and he hired some part time help to handle sales and shipping while he was away.

4. LOOKING FOR HELP

"Tim," Robin started as she poured their morning coffee. "You are starting to look frazzled and exhausted. Retirement is supposed to be a time to rest and enjoy life. Why don't you see if Janie, from next door, would be interested in helping you with this online business of yours? She had mentioned wanting to find a part time, work-at-home job the other day so she would have time to finish up her online MBA and take care of the new baby."

"You know, Robin, that sounds like a great idea. I can at least ask her if she, or someone she knows, would be interested," Tim said as he picked up his phone to give her a call.

5. THE MEETING

Janie Collins was delighted to get Tim's call. She was excited about the prospect of having a part-time flexible job she could do from the comfort of her home. She invited Tim to come over to explain what he needed during the baby's morning nap time. Tim printed off his spreadsheet to show Janie. He hoped that, at the very least, she might have an idea of what he could do to better organize his data.

After welcoming Tim into her home and offering him a seat at the kitchen table, Janie watched Tim unroll a series of landscape printed spreadsheet pages that had been taped together end-to-end. "Wow!" she exclaimed as she glanced over the series of columns. "What is that!" (Appendix A)
"Well," Tim started, "it has become a hot mess and part of the reason why I called you this morning. I started selling things online to clean out the basement. However, I have done so well that it has become a small business and has taken over my life. I need help managing the business as well as managing the data. I had promised Robin that we would do some traveling once I retired, but my 'part time' job requires full time work, and I cannot just walk off and leave it. I need help running the business so I can actually enjoy my retirement. I also need help developing a system that will help me manage my data better so that I can keep track of inventory, sales, shipping, and end of year tax reporting."

"What you are seeing here is a portion of the spreadsheet that I use to keep track of my inventory, customers, and sales. I use this data to calculate my income as well as to determine my best-selling products and product categories, customers, and shipping methods. The data was very helpful when I first got started and could read it. However, now that it spans multiple pages, it is hard to decipher. I need some help on two levels, so I have two questions for you: Do you think you can help me run the business? And do you think you can help me organize my data better, or point me in the right direction to someone who can?"

6. THE ONLINE BUSINESS

"Tim," Janie said as she looked at the worry lines in Tim's face "If you show me the ropes, I think I can give you some of the help that you need. I would like to take some notes about your entire business process. Can you tell me about the business and the data you collect on this spreadsheet?"

Tim could see a little hope on the horizon. "Sure! Let me start from the beginning. I got started in the business by trying to clean out my basement. I had accumulated 'treasures' that were abandoned in the parks when I worked for the park district. Some of them just needed a good cleaning, but others needed some minor repairs. Items listed early in the spreadsheet are some of those items I found abandoned in the park. Since they were free, they do not have a purchase price, but they may have some costs associated with repair materials."

"So," Janie interrupted, "you track cost and repair data about your inventory. What else do you track about your inventory."

"Well," Tim began, "now that it has become a business, I have been purchasing a lot of my inventory. I buy things at thrift stores, consignment shops, and yard sales. I like to record the date I purchased the item, the item, the name of the place from which I purchased it (e.g., Jones' family yard sale, Thrifty Treasures store, Goodwill North, Goodwill South, etc.), the address of the place, the price I paid for the item, a general classification of the item, a description of the item so that I can tweak it for my online post, and the repairs required to get it ready for sale. I also take a picture of the item once it is sale ready."

"What kind of data do you collect about the selling of the item?" Janie asked.

Tim continued, "I record the date I placed the item up for sale and the date that the item actually sold. I use those two pieces of data to calculate the number of days that the product was on the market. I record the price at which I initially listed the product and, because some customers make counter offers, the actual price for which the item sold. I also record the taxes paid on the item and the online marketplace I used to make the sale. Once the item is sold, I record customer information such as the customer's name, their address, notes about our transaction, the satisfaction rating I give the customer, and finally, the satisfaction rating that the customer gives me regarding the transaction on the online marketplace."

"Tell me about the data you collect regarding shipping," Janie interjected.

Tim thought for a moment," I collect the sales price, the calculated shipping charge and the actual shipping charge, the packing materials used and their cost, the shipping label used and its cost, the mode that I used to ship the products (e.g., US postal services, FedEx, or UPS), the shipping company's local address, the day the item was shipped, and the day the item was received. I use those two dates to calculate the number of days it took to ship the product to the customer. I record whether the product shipped safely, my satisfaction level with the shipment, and any notes I may have accumulated about the shipping process."

"Why are there two shipping charges?" Janie asked.

"The online marketplace calculates an initial shipping charge for the listed item. However, based upon the buyer's location, the actual shipping charge may be a bit more or a bit less than what the online marketplace charged the customer. I need to keep that in mind when I calculate the full product cost and income-basis for the product. If the actual shipping charge is higher than the original shipping charge listed with the price, then the net income that I receive from that sale is less. If the actual shipping charge is lower than what is posted on the online marketplace price, then I need to claim more income on that sale."
"Wow!" Janie exclaimed. "There's a lot more to this than I thought. Can you give me a run down of the rest of the process so I can better understand how your business operates?"

The Sales Process
Tim started, "I have a section of my basement that has a bunch of shelves on which I store my inventory. When I get something that I want to place in my inventory, I record data about the item in the spreadsheet and tape an ID to the bottom of the item so that I can match it to the spreadsheet record. I also take a picture of the item in the staging area of my basement and save the picture on my computer using the assigned ID number.

The basement shelving is sectioned off according to inventory classifications. Items are shelved in numeric ID order so that I can find things… I learned this the hard way. If there is a particular class of inventory that is selling well, then I will go to that section of my basement storehouse and find similar items to list. When I list an item, I copy and tweak the item description from the spreadsheet and find the corresponding staging picture to post. The online marketplace will calculate shipping charges and taxes based upon the shipping choices I select and my location. Those charges are applied to my online post.

When a customer is interested in a product, they will usually ask a question about the product and make a counteroffer on the price. Rarely does a customer initially offer to pay the listed price. If the counteroffer is higher than my costs, depending upon how long the product has been on the market, I may accept their offer or return a counteroffer. If the product has not been on the market very long or the counteroffer is below the costs that I have in the item, I may reject the customer's counteroffer.

Once a customer offers the list price or makes an acceptable counteroffer, the sales transaction begins. The online system marks the item as sold, collects payment from the customer, and notifies us both of the sale. At that point, I start preparing the item for shipping. The online system has a wizard that I use to print off the sales label. Once I have prepared the item for shipment, I then take the package to the shipping business, and use the online marketplace to notify the customer that the item has shipped and provide a package tracking number.

After the package is out of my hands, I catch up on updating my spreadsheet. I enter transaction data such as data about the sale, customer, and shipping. Once the customer has received the

product, I will record my customer review in the marketplace system and update my spreadsheet with the customer's review of our transaction."

"You mentioned something about income taxes. Tell me a little about that," Janie prodded.

"The IRS has been considering setting a new income threshold for tax reporting for online transactions," Tim began. "I want to prepare for having to report my income. This process should be pretty easy since I record the final sales price for each product and all of the costs associated with the sale."

7. DEVELOPING A SOLUTION

Janie looked at her notes and said, "You've given me a lot to think about." I would like to create a process model of what I think you are doing so that I can make sure I clearly understand how your business works. I just started learning about databases in my MBA MIS course. I think a database would really be beneficial to you in keeping track of your data and minimizing data errors and redundancies. I think if I understand the processes better, it will help me as I try to normalize the fields on your spreadsheet to create the tables in the database. What would you like to do with this data if you had a better handle on it?"

Tim hesitated and then said, "I don't know what you mean about 'normalize the fields.' In addition, the data has gotten so out of hand that I can't make heads or tails out of it. What I wish I could do with the data is to determine which products are my best sellers; under which classification most of my best-selling products are listed; which product descriptions result in the fastest turnover time; who my best customers are; which mode of shipment is the fastest and least prone to damage; and of course, I need to be able to determine total costs of each product sold in order to calculate the net income generated for tax purposes."

"Wonderful!" Janie exclaimed as she continued to take notes. All of that information will help me as I start normalizing the fields to create the diagram that I plan to use to develop the database. I would like to send something to you next week so I can make sure I am on the right track."

"That would be great!" Tim said as the baby started to cry. "It sounds like our meeting is over and that is my cue to leave. I can't wait to get started. I look forward to getting something from you next week."

8. ASSIGNMENTS

8.1 Integrated Capstone Project

Assume that you have been asked to provide some additional resources to help Janie develop the database or to help Tim successfully run his business. Complete the tasks below as assigned by your instructor.

1. **Managing the project:** Develop a work breakdown analysis or create a Gantt chart to breakdown the needs of the project, allocate the work according to skills, and assign tasks and deadlines.
2. **Development of a business plan:** Create a business plan to provide guidance and direction for Tim's burgeoning business.
3. **Development of an employment contract:** Create an employment contract to solidify the expectations of the part-time job.
4. **Online marketplace recommendation:** Research and provide a short report recommending the best online marketplace(s) for Tim, or a business like Tim's, to sell his products.
5. **Digital marketing plan:** Develop a digital marketing plan to help Tim increase product sales.
6. **Income statements, Balance Sheet, and/or tax reporting documents:** Create accounting report templates to help Tim successfully run his business. You will also need to investigate current tax reporting requirements for online sales.
7. **Normalization of the spreadsheet fields:** Normalize the fields of the spreadsheet to create the entities for the database.
8. **Development of process diagrams:** Develop process diagrams to clarify your understanding of the business process.
9. **Excel Power Pivot or database:** Create an Excel Power Pivot file or database to manage Tim's data.
10. **Assumptions:** For each segment assigned, students should record any assumptions they make, regarding the process, in a separate document.

Create the assigned task deliverable(s), along with the assumptions made while developing the

deliverable(s) and submit the deliverable(s) as directed.

8.2 Internet Sales
Assume that you are Tim at the beginning of the case. Conduct research to learn about selling products through online marketplaces such as eBay, Etsy, or Facebook Marketplace.

1. Select a product type to sell and a marketplace to research. Record your choices and explain why you made those choices.
2. Research the process of selling products through that marketplace and record what you learned.
3. Research the process of advertising products to sell on that marketplace and record what you learned.
4. Research the way to collect money for items sold through that marketplace and record what you learned.
5. Research the way to ship products associated with that marketplace and record what you learned.
6. Research the way to maintain high reviews on that marketplace and record what you learned.
7. Research the current IRS tax policy for online sales and record what you learned.
8. Record anything else that you learned that would be beneficial in starting an online business.
9. Create a list of any online resources you find that would be beneficial to look into in the future.
10. Create a bibliography of the resources that you used for questions 2- 8.

Provide a report addressing the tasks above assigned by your instructor and submit the report as directed.

8.3 Process Modeling
Janie would like to draw the functional process out on paper to verify that she understands how everything will work. She does not want to overlook any important data, details, or steps in the process.

1. Create a diagram modeling the process.
2. Write a short narrative to accompany your diagram to verify and support your interpretation of the process.
3. As the diagram is developed, record any assumptions you make, regarding the process, in a separate document.

Compile the diagram, narrative, and assumptions into a short report and submit as directed.

8.4 Normalization and Database Diagram
Janie would like to normalize the fields and create a diagram design of the database.

1. Work through the normalization process.
2. Create a database design diagram using a diagramming tool.
3. Write a short narrative to accompany your diagram to verify and support your interpretation of the diagram.
4. As the diagram is developed, record any assumptions you make in a separate document.

Create a short report compiling the deliverables listed above and submit the report as directed.

8.5 Systems Analysis Design and Database Development
Assume that Janie is ready to create the database. She wants to:

1. Accumulate the functional and technical requirements for the system.
2. Prioritize the requirements.
3. Create system development diagrams (You may also want to use the diagrams created in 8.3 and 8.4).
4. Create a data dictionary.
5. Create data entry forms.
6. Create queries to generate records needed for determining the best-selling products and classifications; turnover rates for products and classifications; most active customers; best shipping modes; and costs and income.
7. Create reports for the queries including product sales ranking list; classification sales ranking list; product and product classification turnover ranking lists; customer ranking list; shipping mode ranking list; and product costs and income generated reports.
8. As the database is developed, record any assumptions that you make in a short report.

Create a short report compiling the deliverables listed above and submit the report as directed.

9. WORKS CITED

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APPENDIX A

Tim's Spreadsheet Part 1: Customers

Customer First Name	Customer Last Name	Customer Rating	Customer Notes	Customer Street	Customer Zip Code	Customer Email	Customer Phone	Product Name
John	Doe	2.5	Difficult customer	123 Main St	12345	johndoe@email.com	555-1234	Clothes
Alice	Smith	5	Very nice customer	456 Oak St	67890	alicesmith@email.com	555-5678	Book
Robert	Johnson	5	No problems	789 Pine St	34567	robertjohnson@email.com	555-9876	Record
Sophia	Miller	3.5	Lots of questions	303 Birch St	54321	sophiamiller@email.com	555-2345	Furniture
Michael	Chen	3	Kept countering price	404 Cedar St	76543	michaelchen@email.com	555-6789	Electronics
Emily	Brown	4.2	No problems	101 Elm St	23456	emilybrown@email.com	555-4321	Furniture
Olivia	Wang	3.5	Lots of questions	505 Walnut St	87678	oliviawang@email.com	555-3456	Camera
Daniel	Lee	4.8	Minor questions	202 Maple St	87654	daniellee@email.com	555-8765	Lamp
Lily	Kim	5	No problems	606 Pine St	78901	lilykim@email.com	555-7890	Record Player
Emma	Williams	5	No problems	456 Oak St	56789	emmawilliams@email.com	555-1234	Clothes
Benjamin	Nguyen	5	Very nice customer	789 Pine St	34567	benjaminnguyen@email.com	555-5678	Suitcase
Harper	Smith	5	No problems	101 Elm St	23456	harpersmith@email.com	555-9876	Watch
Ethan	Kim	2.5	Difficult customer	303 Birch St	87654	ethankim@email.com	555-2345	Radio
Ava	Lee	4.8	Minor questions	404 Cedar St	76543	avalee@email.com	555-6789	Sunglasses
Grace	Wang	5	No problems	505 Walnut St	87678	gracewang@email.com	555-3456	Handbag
Liam	Martin	5	Good customer	505 Walnut St	54321	liammartin@email.com	555-7890	Record
Zoe	Lopez	5	No problems	606 Pine St	78901	zoelopez@email.com	555-1234	Lamp
Mia	Kim	5	No problems	202 Maple St	87654	miakim@email.com	555-5678	Camera

Tim's Spreadsheet Part 2: Products

Product Description	Product Category	Product Purchase Cost	Product Repair Costs	Product List Price	Product Selling Price	Taxes	Product List Date	Product Notes
Cozy vintage sweater in excellent condition.	Clothing	$ 3	$ -	$ 15	$ 15	$ 1.05	7/1/2023	
Rare first edition book from the 19th century.	Books	$ 5	$ -	$ 25	$ 20	$ 1.40	6/28/2023	
Classic album in its original cover.	Music	$ 10	$ -	$ 30	$ 25	$ 1.75	7/2/2023	
Unique mirror with art deco design.	Home Decor	$ 15	$ 5	$ 35	$ 35	$ 2.45	7/3/2023	Minor scratches on the frame. Paint touch up.
Old typewriter with keys still working.	Office Supplies	$ 20	$ 8	$ 60	$ 50	$ 3.50	7/4/2023	Sticking keys. Oiled and repaired keys.
Charming wooden coffee table with some wear.	Furniture	$ 20	$ 10	$ 80	$ 65	$ 4.55	7/5/2023	Stripped wood and refinished.
Classic film camera with leather case.	Electronics	$ 7	$ 5	$ 30	$ 25	$ 1.75	7/6/2023	Replaced strap and shined.
Unique lamp with a mid-century modern design.	Home Decor	$ 7	$ 5	$ 25	$ 20	$ 1.40	7/7/2023	Replaced lamp shade.
Vintage record player with built-in speakers.	Electronics	$ 12	$ 5	$ 35	$ 30	$ 2.10	7/8/2023	Replaced needle and cleaned.
Elegant vintage dress in good condition.	Clothing	$ 4	$ -	$ 15	$ 15	$ 1.05	7/10/2023	
Classic suitcase with leather trim.	Accessories	$ 10	$ 1	$ 30	$ 25	$ 1.75	7/7/2023	Buffed leather.
Classic wristwatch in working order.	Accessories	$ 10	$ 1	$ 30	$ 25	$ 1.75	7/14/2023	Cleaned watch
Classic radio with retro design.	Electronics	$ 15	$ 3	$ 30	$ 30	$ 2.10	7/16/2023	Replaced one knob and cleaned out insides.
Stylish vintage sunglasses with UV protection.	Accessories	$ 2	$ -	$ 15	$ 15	$ 1.05	7/18/2023	
Classic handbag with a timeless design.	Accessories	$ 5	$ -	$ 35	$ 20	$ 1.40	7/20/2023	
Set of classic vinyl records in original packaging.	Music	$ 10	$ -	$ 30	$ 25	$ 1.75	7/22/2023	
Classic desk lamp with adjustable arm.	Home Decor	$ 5	$ 1	$ 25	$ 20	$ 1.40	7/24/2023	Buffed scratches on base.
Classic film camera with leather case.	Electronics	$ 3	$ -	$ 15	$ 10	$ 0.70	7/26/2023	

Tim's Spreadsheet Part 3: Product source

Listing Location	Purchase Location Name	Purchase Street	Purchase City	Shipper Name	Shipper Street	Shipper City
eBay	Bargains Galore	404 Cedar St	Whispering Hills	Express Shippers	456 Pine St	Whispering Hills
eBay	Thrifty Treasures - North	789 Oak St	Whispering Hills	USPS	789 Maple St	Whispering Hills
eBay	Thrifty Treasures - North	789 Oak St	Whispering Hills	FedEx	202 Cedar St	Whispering Hills
Marketplace	Affordable Tresures	303 Birch St	Whispering Hills	Hand Delivered		
Marketplace	Thrifty Treasures - North	789 Oak St	Whispering Hills	Hand Delivered		
Marketplace	Bargains Galore	404 Cedar St	Whispering Hills	Hand Delivered		
eBay	Affordable Tresures	303 Birch St	Whispering Hills	Reliable Shippers	505 Walnut St	Whispering Hills
eBay	Affordable Tresures	303 Birch St	Whispering Hills	Express Shippers	456 Pine St	Whispering Hills
eBay	Affordable Tresures	303 Birch St	Whispering Hills	Hand Delivered		
eBay	Thrifty Treasures - South	101 Elm St	Whispering Hills	Express Shippers	456 Pine St	Whispering Hills
Marketplace	Thrifty Treasures - North	789 Oak St	Whispering Hills	Hand Delivered		
eBay	Affordable Tresures	303 Birch St	Whispering Hills	USPS	789 Maple St	Whispering Hills
eBay	Thrifty Treasures - North	789 Oak St	Whispering Hills	Reliable Shippers	505 Walnut St	Whispering Hills
eBay	Bargains Galore	404 Cedar St	Whispering Hills	Express Shippers	456 Pine St	Whispering Hills
eBay	Thrifty Treasures - North	789 Oak St	Whispering Hills	FedEx	202 Cedar St	Whispering Hills
eBay	Thrifty Treasures - South	101 Elm St	Whispering Hills	Express Shippers	456 Pine St	Whispering Hills
eBay	Thrifty Treasures - North	789 Oak St	Whispering Hills	USPS	789 Maple St	Whispering Hills
eBay	Affordable Tresures	303 Birch St	Whispering Hills	Reliable Shippers	505 Walnut St	Whispering Hills

Tim's Spreadsheet Part 4: Sale data

Invoice ID	Sale Date	Ship Date	Tracking ID	Estimated Shipping Charge	Actual Shipping Charge	Ship Receipt Date	Shipper Notes	Customer Satisfaction Rating	Customer Satisfaction Rating Notes
123456	7/5/2023	7/7/2023	ABCD123	3	$ 3	7/8/2023	No problems	5	Item received as described.
789012	6/30/2023	7/3/2023	EFGH456	4	$ 3	7/5/2023	No problems	5	Good experience.
345678	7/4/2023	7/6/2023	IJKL789	3	$ 3	7/7/2023	No problems	5	Good transaction.
234567	7/6/2023	7/8/2023		0	$ -	7/10/2023	No problems	5	No problems.
345678	7/7/2023	7/9/2023		0	$ -	7/11/2023	Delivered	5	Good experience.
456789	7/8/2023	7/10/2023		0	$ -	7/7/2023	Delivered	5	Good transaction.
567890	7/9/2023	7/11/2023	YZAB789	12	$ 15	7/13/2023	No problems	5	Good transaction.
678901	7/10/2023	7/7/2023	CDAB567	10	$ 12	7/14/2023	Charged more than expected.	5	Good transaction.
789012	7/11/2023	7/13/2023				7/15/2023	Delivered	5	No problems.
234567	7/15/2023	7/17/2023	ABCDE234	4	$ 4	7/30/2023	Took longer for product to arrive than originally noted.	3	It took a long time for item to arrive.
345678	7/16/2023	7/19/2023		0	$ -	7/20/2023	Delivered	5	Item received as described.
456789	7/18/2023	7/21/2023	IJKL678	8	$ 8	7/22/2023	No problems	5	Good experience.
567890	7/20/2023	7/23/2023	KLMN678	15	$ 15	7/24/2023	No problems	5	Good transaction.
678901	7/22/2023	7/25/2023	MNOP678	5	$ 5	7/26/2023	Product damage in shipment.	1	Product was damaged.
789012	7/24/2023	7/27/2023	QRST678	5	$ 5	7/28/2023	No problems	5	Good experience.
890123	7/26/2023	7/29/2023	UVWX678	8	$ 10	7/30/2023	Charged more than expected.	5	Good experience.
123456	7/28/2023	7/31/2023	EFCD789	12	$ 12	8/2/2023	No problems	5	Good experience.
234567	7/30/2023	8/2/2024	CDAB789	12	$ 12	8/3/2023	No problems	5	Good experience.

Source: Data generated, in part, by OpenAI ChatGPT.

Empathy-Driven Student Transformations: Bridging the Gap in Software Development for Inclusive User Experiences

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Abstract

Developing empathy skills is crucial for software developers to create user-centric solutions and design exceptional user experiences addressing the diverse needs of customers. This paper presents the findings of a quasi-experimental study that aimed to enhance empathy among computer science students through the exposure of two interventions utilizing teaching accessibility design. The study included 15 participants from a computer science course. Qualitative data analysis of participants' reflections highlighted the transformative impact of the interventions, as participants expressed changes in their views towards people with impairments and reported the development of technical and soft skills, as well as enhanced empathy. The interventions also motivated participants to make changes to their team website designs, prioritize accessibility, and apply their learnings in their professional lives. A second measure assessed in this study was an expert website review which provided valuable feedback for improvement and yielded a high average score for screen reader accessibility. By equipping future computer scientists with these skills, we can ensure that technology meets the diverse needs of all users, promoting inclusivity and enhancing user experiences.

Keywords: Accessibility, Empathy, Career Readiness, Software Development, Inclusive Design, UX Design

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1. INTRODUCTION

Developing empathy is arguably one of the most vital skills a computer scientist can cultivate in today's educational and professional setting (Gunatilake et al., 2023; Karimi & Pina, 2021). Empathy offers a gateway to self-awareness, navigating interpersonal relationships, and is essential for software developers to create more relevant products. To be successful as a software developer a professional must be able to interact with a diverse group of colleagues, clients, stakeholders, and leaders. Due to the complexities of software development, teams of professionals must work closely together, putting a premium on teamwork, problem solving and communication skills (Singh et al., 2012).

Brené Brown (2018) defines empathy as a proactive, judgment-free approach to use perspective-taking to understand and resolve problems. Empathy enables developers to build better software that truly meets the needs and expectations of its users. Having empathy skills is essential for software developers because it enables them to understand and connect with the end users of their products. By empathizing with users, developers can gain valuable insights into their needs, challenges, and preferences, which in turn allows them to design and develop software that effectively addresses those requirements. Empathy also plays a central role in enhancing communication within development teams and with stakeholders, fostering collaboration and building trust (Rivas, Husein, 2022). Furthermore, empathy is a key component of user experience (UX) design, helping developers create intuitive interfaces and workflows that enhance user satisfaction. Finally, empathy promotes continuous improvement, as developers who empathize with users seek feedback and make iterative enhancements to their software. Overall, empathy skills empower software developers to create user-centered solutions, enhance communication, design exceptional user experiences, and successfully collaborate with others (Blanco, López-Forniés, and Zarazaga-Soria, 2017; Lariza Laura de Oliveira., 2020).

There are many definitions of empathy available to the scientific community. Most of the definitions characterize empathy as a multidimensional variable encompassing two major factors: cognitive empathy and affective empathy (Cuff et al., 2016). Cognitive empathy is defined as the ability to deduce and recognize the emotions of others, while affective empathy indicates one's ability to experience other individuals' emotions by observing their behaviors (Riess, 2017). It implies that people with higher levels of empathy can recognize the emotions of others and experience these emotions.

According to the World Health Organization (WHO, 2023), 16% of the population or 1.3 billion people have a disability. This includes visual, auditory, physical, speech, cognitive, language, learning, and neurological disabilities. It is crucial for computer science students, the engineers of future technology, to comprehend and empathically experience the usage of the technology they develop from the perspective of individuals with disabilities. This understanding is not just about accessibility; it's about deeply appreciating the challenges and barriers faced by people with disabilities. Such an experience can profoundly influence how these future experts design and innovate, ensuring their creations are inclusive, accessible, and truly serve the diverse needs of all users (Lay-Flurrie, 2021; Walther et al., 2017; Wolberger, 2023). Such technology will often require the implementation of special products such as screen magnification software, screen readers, speech recognition software, special keyboards for communication, and more. Moreover, these skills are rarely taught as part of computer science education (El-Glaly et al., 2020; Ferati & Vogel, 2020).

Empathy plays a pivotal role in the design of accessible software, ensuring it delivers robust solutions for its users (Paananen, Visuri, van Berkel & Hosio, 2023). When software developers

empathize with individuals who have different abilities, they gain a profound understanding of the challenges and obstacles they face when using technology. This empathetic approach empowers designers to proactively identify and address accessibility issues, creating inclusive software that can effectively cater to a wide range of individuals, including those with disabilities. By incorporating accessible features, intuitive navigation, clear interfaces, and alternative input methods, empathetic designers enable users with disabilities to access and engage with software effectively. Furthermore, empathy fosters an inclusive mindset that goes beyond mere compliance with accessibility standards, aiming to provide a meaningful and enjoyable experience for all users. By embracing empathy, software designers become catalysts for breaking down barriers and promoting universal access to technology, ultimately enhancing the lives of individuals with disabilities and fostering a more inclusive digital landscape.

The Empathy Lab experience utilized in this study consisted of two interventions designed to allow students to have an immersive experience from the perspective of a person with a disability using a variety of assistive technologies. Students were instructed to develop a website for a young elite triathlete. In the first intervention, students were informed that their client is blind. They learn firsthand about her lived experiences and how she engages in daily activities familiar to them such as taking notes in class, buying clothes at the bookstore and reading textbooks. After gaining insights regarding their client, students are offered the chance to use a screen reader while blindfolded per their client's suggestion. The second intervention focuses on five hands-on activities such as writing appropriate alt tags, understanding WCAG compliance requirements, hearing and physical ability simulations and developing accessible code. This is in alignment with studies reporting frustrations experienced by blind users (Lazar, Allen, Kleinman and Malarkey, 2007).

Students discover that designing technology with empathy for a diverse range of users can lead to a final product that is not only more enjoyable but also easier to use for everyone, not just the initial target audience. By focusing on inclusivity, particularly for those with disabilities, we inadvertently enhance the overall user experience for all. (Steere, 2008; Norman, 2013).

2. LITERATURE REVIEW

Empathy is increasingly recognized as a cornerstone of effective computer science education. Blanco, López-Forniés, and Zarazaga-Soria (2017) argue that empathy is a foundational skill for informatics students, crucial for fostering teamwork competences. This is further supported by Lariza Laura de Oliveira (2020), who explores the student perspective on empathy in the computer science classroom, offering valuable insights into its importance. The emphasis on empathy extends to accessibility education, where Baker, El-Glaly, and Shinohara (2020) highlight its significance for understanding the needs of users with disabilities.

In the realm of software development, the application of empathy has shown to be of paramount importance. Levy (2018) emphasizes the integration of empathy into software engineering courses to deepen students' understanding of user needs. This is echoed in the work of Levy and Hadar (2018), who stress empathy's critical role in privacy requirements analysis, designing systems that respect user privacy concerns. Lundström, Åberg, and Blomkvist (2015) highlight how empathy fosters effective collaboration between developers and designers, enhancing mutual understanding. For mobile applications, Papoutsi and Drigas (2017) demonstrate that empathy is crucial for user-centric app design.

Empathy enhancement through innovative methods has also been explored. Kletenik and Adler (2022) creatively utilize games to instill empathy and promote accessibility awareness. The potential of virtual reality to strengthen empathy and mastery learning is investigated by Abadia, Calvert, and Dasika (2019), with support from Zhongxiang's (2023) meta-analysis, which suggests that virtual reality can effectively enhance empathy. Additionally, gamification techniques have been shown to foster empathy, especially for individuals with invisible disabilities, as illustrated by Gonzalez, George, Miteva, and Singh (2023). The Accessibility Learning Labs (ALL) developed by a team from RIT exemplify the application of empathy in educational settings. These labs use an experiential learning approach to educate participants on creating accessible software, demonstrating the importance of accessibility across various topics

such as colorblindness, hearing, blindness, and dexterity (Shi, Malachowsky, El-Glaly, Yu & Krutz, 2020; Moses, Thazin, Nalachowsky & Krutz, 2023). This initiative underscores the need for empathy in designing accessible technology and educational materials.

Industry has also embraced empathy-centric design principles. Drouet, Sleeswijk Visser, and Lallemand (2023) showcase real-world applications of empathy-centric design. Their work highlights a series of case studies and examples where empathy is at the core of the design process, demonstrating its critical role in understanding and meeting user needs.

The literature reviewed underscores the growing recognition of empathy's significance across various domains of computer science education and software development. Empathy fosters effective collaboration, user-centric design, and a more inclusive digital world. Innovative methods to enhance empathy, such as virtual reality and gamification, alongside empathy-centric design in industry and educational settings, demonstrate the multifaceted approach required to cultivate empathy in the field of computer science.

3. METHODOLOGY

Our study included a sample of participants who had voluntarily registered for a software engineering II course offered in the Spring of 2023 semester. The institutional review board conducted an expedited review of this study, and their approval was received.

TABLE 1

Sample Distribution

Intervention	Client Reveal	Empathy Lab
Total number of participants	14	15
Gender - female	21%	20%
Gender - male	79%	80%

This study used qualitative methods approach along with an accessibility expert review. The qualitative research was based on the reflections collected after each of the two interventions: the reveal of the client's condition and the immersive Empathy Lab intervention in the software engineering II class. Reflective questions are listed in Appendix A. All students in the sample were seniors and the assignments were required and graded part of the class. However, students had to opt into the study for the authors to use their reflections. As shown in Table 1, not all students who gave permission completed the assignment for the first reflection.

Both conditions included six identical questions about the students' views on people with impairments, skills they developed, potential modifications of their project deliverables, views on future design and development of technology, application of key learning, and feedback on the effectiveness of the interventions. The reflections were typed and managed anonymously. Qualitative data interpretation was organized in four stages: 1. the researchers developed a codebook (appendix B & C), 2. researchers coded the data and 3. validity was established through interrater reliability and 4. data was analyzed and interpreted. The code book was developed using three distinct methods. The first method utilized traditional coding, the second was implemented through AI-assisted coding, and the third method employed the NVivo software. The NVivo software helped organize, analyze and discover insights for non-numerical or unstructured data. During the process of manual coding the researchers used inductive reasoning and identified major themes along with the codes for each response organized into a database. In the process of AI-assisted coding, prompts were fed to ChatGPT for refinement of the extraction. ChatGPT produced a list of key findings along with the corresponding quotes. The manual coding provided the frequency of codes along with deeper interpretations (appendix D). The AI-generated content was then integrated into the output produced by the manual coding. Finally, the responses input into NVivo for further refinement.

A final measurement in this study was an expert analysis the websites the student teams designed provided by the blind elite triathlete. The sites were reviewed twice during the semester with feedback for improvement. A final grade was assigned based on the "readability" of each of the sites. The user accessibility rating contributed to the assignment grade.

4. RESULTS

4.1 Qualitative Results

Intervention #1: Client Reveal

After coding, the researchers quantified the responses within each category. This involved counting how many responses fell into each

predetermined category or theme. The final step was to calculate the percentages based on the quantified data.

Question 1:
To the question inquiring as to whether the participants' view about people with impairments changed after revealing the client's condition, 71% claimed it changed, 7% reported an unchanged view and 21% remained neutral. Respondents whose view changed after the intervention noted the respect for people with impairments when it comes to navigating the website, spending time on making technology work for them, and running screen readers and narrators. Some respondents expressed how seemingly frustrating it could be for people with visual impairment to run "something you work with daily", empathy for spending "some time in their shoes."

Question 2:
Participants were asked if they developed any new skills during the workshop. All fourteen participants were positive about developing certain skills. And these skills were linked to navigating websites with the help of a screen reader (71%) and using a keyboard (7%). Of respondents, 22% claimed they developed their empathy skills: "I think my empathy skills developed some more. Getting to work with it and understanding the difficulty helps me see things from the point of view of others who may need this technology". Some respondents started to think how the experience might impact their future: "From now on I'll be more conscious of these things" and "I will take my time in everything I do from a perspective of an impaired person." Incorporating and testing accessibility might be a key element from this experience: "I learned how important it is to incorporate accessibility into our websites."

Question 3:
All fourteen respondents agreed to make changes to their existing website to "appeal to the clients" and to include "the basic accessibility features". They envisioned doing these with the help of divs (7%), better headers (14%), more efficient use of screen readers (21%), and more descriptive alt tags (50%). All students stated they need to make various changes: "will make many changes to our website after going through this workshop" to make the website "easier to navigate", "less cluttered", and to "include assurances that our images will be able to be read out in descriptive fashions".

Question 4:
The next question considered changes to designing and developing technology in the future. Of the respondents, 71% were positive about taking steps towards more accessible technology in the future while 28% found they would make changes if they are relevant Fifty-eight percent expressed their plans to help accommodate diverse needs and make everything they produce more accessible:

> "I will improve on what I know and create all my future technologies to be accessible to people with impairments and for them to easily navigate them and to have the ability to reach their goals at the same time as someone who does not have impairments."

Question 5:
The question enquired about how participants could apply the key learnings of the workshop in their professional life. Of the participants, 93% had a clear view on how to apply their key learnings, while the remaining 7% was unsure. Twenty-eight percent noted that the employers' expectations might play a role in how they utilize their newly acquired skills. They also found that possessing the skills and mindset of inclusivity might aid them when looking for jobs: "Some companies really care about this, so if I am applying for a job at that company".

These might be useful when already working for an organization: "The best companies and government websites put a large emphasis on things like accessibility so (…) having empathy for others will be a good thing to have and show to my employers". These skills might prove useful: "I will make it an effort (…) to always include accessibility settings to help people with impairments easily navigate through the product". The efforts to "make pages simpler and easy and short" and to create a good layout with "attention (…) to the way a site will be read from someone using a screen reader" were also considered by the participants. Fifty percent found that generally thinking of inclusive application would be a key requirement of developing any piece of technology. Of participants, 21% wished to be "informing others about using techniques that help with accessibility".

Question 6:
As far as the content and delivery of the workshop went, participants were asked to provide their

feedback and 93% found the workshop useful. Participants especially emphasized "many problems with trying to use the screen reader", the "format of the workshop", "the contrast between navigating through the website with the navigator when not blindfolded", and the overall "understanding how the [client] uses technology". Participants expressed their wishes to demonstrate "using the screen reader with other aspects of the computer such as desktop applications". They would have also wished to see real-life presentation from the client: "Something that would be helpful would be to see how [the client] uses a website herself in depth, so we get an even better understanding". However, the practical nature was highlighted: "with learning anything it is better to do it with practice and that is what this workshop has done so it was very helpful in helping us get a better understanding of the concept".

Intervention #2: Empathy Lab
The second intervention was the Empathy Lab after which students reflected on the same set of questions as the one after the first intervention.

Question 1:
To the question on the view about people with impairments 93% of the participants noted that their view has changed after the intervention while 7% remained neutral out of the total of 15 responses. Participants referred to empathy (64%) as the main factor that has changed after the intervention. Some views expressed milder sentiments: "Getting into their shoes, and actually feeling what they might makes me feel even more empathy for them". Others have shared stronger sentiments on the topic: "To pass judgment onto someone just because they're different from you is fairly obdurate and quite frankly inhuman".

Participants agreed that understanding the challenges faced by individuals with specific impairments is imperative in their personal and professional life: "Putting myself in their situation with the exercises has shown me how important it is to be able to make it easier for them". And this might contribute to changes in the way they complete tasks in the future: "The lab showed me how to create a more engaging software that will be able for people of all kinds of disabilities to use without any hitches".

Question 2:
The second question was enquiring about any new skills that students have developed as part of the exercises. Of the responses, 71% included mentions to different applications such as those related to images: "I improved my skill of being able to better explain a picture without (…) making the description too complex." Similarly, "I had to find creative and descriptive ways to explain a picture.", the use of alt tags: "I developed the ability to create more meaningful alt tags to make images more accessible", or more effective color selection: "One new skill I learned is finding more accessible colors.". Designing with accessibility was the main finding for them: "I feel I've gained the ability to better design things to fit people from all walks of life, not just for people like me". However, the findings were not only referring to technical skills but those of soft skills. As one participant claimed he "also learned how to apply teamwork to help with getting through a challenge caused by an impairment". Of the responses, 50% of the responses indicated the development of these soft skills as a result of the intervention: "Experiences like these are important to refining one's sense of empathy, especially for those that one may never consciously think of".

Question 3:
To the question of whether students were going to make changes on their teamwork website, all responses indicated unanimous agreement for the need for practical considerations inspired by the content of the workshops. Participants were looking at ways of redefining alt tags: "revising the alt tags for images to be better tailored to blind people.", color selection: "Our color scheme is lacking contrast between the text and different background colors.", and turning the content more concise: "In terms of length, it should be short and concise, with a lot of detail on colors". One participant even considered "testing every feature to make sure it works correctly and for everyone no matter the disability".

Question 4:
The next question looked at potential change participants could make to their way of designing technology in the future. All the 15 responses expressed the wish to do so; people-specific changes surfaced in 43% of the responses, while 64% of responses mentioned tech-specific ideas. Awareness and education were considered to be useful when planning for accessibility in the future with one participant referring to advocacy ("will apply to my professional life because I can advocate for more awareness for people with disabilities and impairments.") and another to education ("probably educate people on practical

programming and design with these thoughts already in mind."). User experience was another highlight in future-proofing design ideas: "I also want to make sure that any technology I work on is not only usable, but enjoyable for all people to use". In addition, "I will definitely adjust how I develop tech as a result of this workshop. (…) the simpler and more logical way they're designed and made to be used for, the easier it is for the average user to figure out."

Participants highlighted several technical considerations, such as easy navigability (21%), testing screen readers (14%), efficient use of alt tags (21%), clearer application of colors (28%), and overall design ideas (14%). It was apparent from the responses that students were not only thinking of what to change but also of how to change them:

> "I have made it a goal to study accessibility features and how to implement them in the best way possible…That includes alt texts, organizing the sections to make it easier for the navigation system, and making the color, font, and style much more visible and easier to look at."

Question 5:

The next question sought students' ideas on how they might apply the key learnings from the project in their professional life. Of the responses, 93% indicated firm ideas about future application of the learnings on accessibility and inclusion. One participant thought of testing their product: "Going forward I would make changes to my designs and be sure to have them thoroughly tested for usability". Others were thinking of what to do with the newly acquired skills: "I'm going to take the skills that I learned from this project and make sure to apply them daily whether I am a developer or have another job". And considerations of career prospects were introduced, too: "I want to be in the front-end developing career path which means I will need to pay attention to this". Some participants looked at the employers' perspectives: "change the ways they implement their products to meet the needs of impaired individuals". And someone already thought of what values to look for when applying for jobs:

> "There's a few values I want to see in companies when I apply for positions... I will advocate for accessibility development when I have a job."

This tied in with another response highlighting empathy as the key take-away from this project:

> "I can apply this workshop by showing stronger levels of empathy with the impaired, whether it's a client or teammate… I can also make sure the way I carry myself is more in line with peoples' disabilities so for situations where I'm with someone in person, I'm more empathetic."

Question 6:

The last question was asking for feedback on the delivery of the Empathy Lab workshop. Most participants found it useful (78%), only 7% was indifferent as they already claimed to have enough awareness on accessibility features. Of the responses, 43% indicated that students would have loved to spend more time on the activities. Participants also stated "the only thing that I would think would be useful in the future is more time at each station" and "something that can be addressed is the tools for those who can't type or touch the screen and would have to talk to make a command". Participants indicated that:

> "It was good to highlight the different disabilities that exist in a safe, learning environment... it was good to simulate some of these as it allowed us to properly gain insight into what people experience so that we may be more considerate when designing our future applications."

The Expert Website Review:

The client provided feedback throughout the lab after her blind condition was revealed. She remarked on her "readability" of the web sites and offered direct feedback for improvements. Some comments addressed screen reader "readability", poorly labeled images and links, and the heading structure. At the end of the semester, she provided a final rating from 1-10 on a screen reader accessibility: 1 being unusable and 10 being excellent. The four teams were rated between 5-10, with an average score of 7.6.

Acknowledging the absence of baseline measurements for the Expert Review, it is important to emphasize the qualitative benchmark it establishes for website accessibility post-intervention. Feedback from an individual adept in using screen readers due to visual impairment offers critical insights into the "readability" and usability of websites, insights that quantitative analysis alone may overlook. Such expert evaluations not only offer specific areas needing improvement—like screen reader compatibility, image labeling, and structural organization—but also provide actionable guidance for future development endeavors.

Furthermore, this process holds significant educational value for participants, offering a direct perspective from an end-user that enhances their understanding of web accessibility challenges and solutions.

5. DISCUSSION

The qualitative reflections generated rich discussions on the topics in question. The responses of the reflection exercise indicated the overall success of both interventions - especially the Empathy Lab. The notion of increased awareness and increased respect of people with accessibility challenges was mentioned in all the responses. Participants claimed that the workshops increased the level of respect they feel towards people with impairments. The interventions helped them with understanding the challenges and frustrations of working with technology, especially when accessibility is not a priority in design. Furthermore, participants reported that they developed technical skills, soft skills, and, notably, empathy skills for employment. They claimed that these skills may help them in applying for their future jobs and reported gaining a general sense of direction in their career. Participants also demonstrated a high level of adaptability in making changes to the original website design. Finally, the reflections assessing the quality of interventions indicated that the workshops were meaningful and life changing.

6. LIMITATIONS & FUTURE WORK

Despite promising results and the representativeness of our sample, making it generalizable to other computer science classes in similar university systems, further research is necessary to evaluate its generalizability beyond this specific academic context. Future studies should encompass larger sample sizes and incorporate participants from a diverse range of universities and professional environments, extending not only within the United States but also internationally.

Additionally, issues related to various types of accessibility impairments need to be examined. These could include speech, language, and hearing, as well as physical limitations like impaired motor skills, dexterity, and mobility.

To confirm these preliminary findings, more rigorously controlled studies should be conducted. These experiments should address potential ceiling effects and examine the effect sizes. Additional controlled experiments are essential for empirical validation to provide more conclusive evidence for our initial observations.

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APPENDIX A

Reflection questions after both interventions

1. Did your view about people with impairments change? If it did, how did it change?
2. Did you develop any new skills during this workshop? If so, what are they?
3. Will you make any changes to your team's website design as a result of this workshop?
4. Will you make any changes to the way you design and develop technology now and in the future as a result of this workshop?
5. How can you apply what you learnt from this project in your professional life?
6. Is there anything that could be changed in the delivery of this workshop to provide a better learning experience? For example, what did you find the most useful and what else could be addressed in this workshop?

APPENDIX B

Themes, codes and comments – Intervention 1 (Client Reveal)

Q	Themes	Codes	Comments
1	challenges	difficulty to navigate time consuming	changed view: in 10 responses; neutral: in 1; slightly changed: in 1 response
	tools	screen reader narrator alt tags	
2	developed skills	keyboard narrator navigating web page screen reader	all 14 responses were positive in developing certain skills
	developed empathy	developing empathy	
3	accessibility in general functionalities	general accessibility appeal divs headers screen reader alt tags	all 14 responses were positive on making changes
4	making changes	making change for diverse needs making change if relevant testing	10 responses were positive in making changes; 4 responses were tentative
5	employment	accessibility as per employers' expectations accessibility as per students' own discretion	13 had a view on how to apply the key learnings; 1 was not sure
	research	gather more information	
	advocacy	informing others of accessibility issues	
	being inclusive	Inclusive application	
	design	simplicity layout	
6	workshop	order of tasks more explanation understanding and empathizing	5 responses on usefulness without suggestions; 1 response did not find the workshop useful but made suggestion; 8 responses found it useful and made suggestions
	tools	application of screen readers more on accessibility features	

APPENDIX C

Themes, codes and comments – Intervention 2 (Empathy Lab)

Q	Themes	Codes	Comments
1	empathy application	application hard application soft application	13 changed their view; 1 neutral; 1 not changed
2	empathy application	empathy skills soft skills images software	11 responses were positive in getting new skills; 3x were neutral
3	inspiration practical consideration	ideas for accessibility alt tags colors	all 15 responses were positive on changes
4	people specific tech-specific	awareness and education legality and fairness user experience easy navigability screen reader alt tags color design	all 15 responses were positive on making changes in the future
5	take-away thought	think for inclusion think for usability empathize	all 15 responses had hints about accessibility
6	time spent on activities tools and resources skills	more time needed less time needed more tools and resources are required more skills required	12 responses found it useful (7 provided suggestions); 1 did not find it useful (provided suggestions); 2 did not address usefulness (1 provided suggestion).

APPENDIX D

Frequencies in qualitative analysis

Codes	Frequencies Intervention 1	Frequencies Intervention 2
alt tags	50%	67%
color	21%	53%
keyboard	7%	0
layout	14%	20%
screen reader	64%	33%
testing	14%	27%
advocacy	14%	67%
developing empathy and respect	50%	60%
do research	14%	13%
employment-related considerations	36%	40%
inclusion	71%	47%
adding specific examples to workshop	7%	7%
application of screen reader in workshop	29%	0
application of worksheet in workshop	0	7%
comprehensive workshop	7%	27%
duration of workshop	0	47%
teamwork skills	0	13%

Teaching Case

A Small Accounting Firm Must Meet the Challenge Posed by Artificial Intelligence

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Hook

A breakthrough in artificial intelligence might pose an existential threat to a small accounting firm. Can you help them devise a plan to compete against The Big Four accounting firms?

Abstract

Maloof & Associates (M&A), a well-regarded small auditing and accounting firm in Atlanta, kept a close eye on the media buzz surrounding ChatGPT. The partners knew that they must make decisions soon regarding the new technology, but they did not realize how soon until they lost a long-standing and substantial client to a rival that had moved aggressively and publicly to insert AI into their operations. Students, acting the role of consultants, must help M&A understand how ChatGPT and similar tools might be incorporated into the firm's existing infrastructure, identify potential risks, and identify sources of potential costs and benefits of adopting artificial intelligence-based tools.

Keywords: Case, Consulting, Artificial intelligence, ChatGPT, Auditing, Accounting

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A Small Accounting Firm Must Meet the Challenge Posed by Artificial Intelligence

Michael A. Smith

1. BACKGROUND

Maloof & Associates (M&A), a well-regarded auditing and accounting firm based in Atlanta, Georgia, has been the trusted partner of small and medium-sized businesses in the Southeast for over 35 years. With a team of 28 professionals, many of them "long-timers", M&A has carved a niche for itself by providing services for clients that the "Big Four" accounting firms often overlook.

The "Big Four" accounting firms, all headquartered in New York City, include Deloitte, Ernst & Young (EY), PricewaterhouseCoopers (PwC), and Klynveld Peat Marwick Goerdeler (KMPG). These firms have "practices", each headed by a partner or group of partners, in most major metropolitan areas in the United States. Together they account for over 80% of the revenue of the top 15 accounting firms in the USA. Practices often specialize in a consulting area, which might align with a functional area of business, an industry, or even a specific software system, e.g. Salesforce or ServiceNow.

M&A's expertise lies in helping businesses navigate the ever-evolving landscape of commerce and industry, offering personalized solutions that cater to their unique needs. This strategy has served them well for decades.

However, the winds of change carry whispers of a challenge of a kind that M&A has never encountered before—a challenge not to their clients' business models, but to M&A's.

A Potentially Threatening Development

There is a buzz about a breakthrough in artificial intelligence unlike anything the partners have heard since the widespread rollout of Internet connectivity in the late 1990s and the introduction of the iPhone in 2007. Major consulting firms are already capitalizing on the hype, offering paid seminars on how to integrate large language models into business operations and prepare for the impending AI-driven revolution.

Long-time friends of the firm's partners have mentioned hearing from their children and grandchildren about ChatGPT, a new tool they're using to help them with their homework at school. And in the halls of the Cherokee Town and Country Club and of the Piedmont Driving Club, where audible mobile phone use in the dining areas is prohibited, even members who pride themselves on having no personal email address are starting to talk about "this thing that students are using to write term papers".

The leadership team at M&A have never been "luddites" and they are not opposed to considering any new technology that will help the firm as they have many times in the past. However, this time seems different to them because they believe that failure to identify the threats and opportunities quickly, and to take appropriate actions, could result in smaller firms like theirs falling behind the "Big Four" and that it might change the economics of the auditing business, making M&A's clients more attractive to their larger competitors.

The path forward is shrouded in uncertainty. The partners, while they are familiar in a general way with what the technology is being used for, are unsure about the true capabilities of this technology, beyond the hype, and how they could implement it in a way that would benefit their operations.

Firm Leadership

M&A is steered by a veteran leadership team, each member bringing their unique perspective and expertise to the table. The team consists of the firm's principal partner, George Maloof, and two senior partners, Emily Hwang and Michael Thompson. Assisting them in technological decisions is the firm's Chief Technology Officer, Alice Martinez.

George Maloof (62) - CPA and founder of M&A. George is a Certified Public Accountant (CPA) who values traditional accounting practices and believes that personal relationships with clients are the key to success. His long-time connections are responsible for about 40% of the firm's business and he fears any developments that might affect his ability to retain those clients. He feels "caught in the middle", unsure which would be worse to the firm's reputation—automating

away some of that personal touch, or failure to automate and thus falling behind in terms of services offered or reduced time and costs.

Emily Hwang (48) - CPA and a partner for the past 16 years. Emily specializes in auditing and has an interest in technology, which she is always inclined to see more as a source of opportunities than of threats. While she recognizes the value of Maloof's network of contacts, she believes that embracing new tools like ChatGPT would allow the firm to enhance their services and attract new clients, helping M&A stay competitive while becoming less dependent on those contacts. She is particularly interested in the potential of ChatGPT to improve efficiency and accuracy in auditing and fraud detection.

Michael Thompson (55) - CPA and a partner for the past 25 years. Michael is also an expert in auditing and has a conservative approach to business, which extends to his views about technology. He is skeptical about the adoption of AI tools and fears the potential consequences such as job displacement and a loss of control over sensitive client information. Michael is concerned that the firm's long-term stability could be threatened if they rush into adopting AI without a well-thought-out strategy that is clearly articulated to their clients.

The partners are aided by their CTO, Alice Martinez (34), a tech-savvy professional with a background in computer science. Alice is responsible for implementing and managing technology solutions at M&A. She understands the transformative power of AI and the potential benefits of integrating ChatGPT into the firm.

The different perspectives within the leadership team of M&A reflect the broader debate about the role of AI in business, particularly after the introduction of ChatGPT, a remarkable generative AI, in late 2022. As they navigate this new landscape, their collective wisdom and diverse viewpoints will be essential in shaping the firm's future.

2. A RUDE AWAKENING

The leadership of Maloof & Associates have been keeping a close eye on the media buzz surrounding ChatGPT and they know that they must make some decisions, but they had not fully realized the urgency to formulate a strategic response until George informed the other partners of the unexpected loss of Sideways Industries, a long-standing and substantial client, to a larger competitor, Doghouse, Hedges, and Redd. Not only was this a personal loss for George, but DH&R was not even one of The Big Four. It was another specialized regional firm, younger and smaller than M&A, that George and his partners had regarded with polite disdain.

Doghouse, Hedges, and Redd had recently publicized the integration of ChatGPT into their auditing services, a move that drastically reduced the time and cost associated with providing them. That Sideways had switched providers so quickly was a clear indication to the M&A leadership of the shifting landscape in the auditing and accounting industry.

The loss of such a steady client sent shockwaves through M&A. The partners recognized that they could either embrace the technological advancements represented by tools like ChatGPT or risk being outpaced by their more aggressive competitors.

George Maloof called a meeting with the partners and the CTO, Alice Martinez. The agenda--to discuss the firm's future in an industry increasingly influenced by artificial intelligence and to determine how M&A could leverage these advancements to maintain their competitive edge.

3. AN URGENT MEETING

As George sat alone in the conference room waiting for the others to arrive, he found himself experiencing a mix of emotions. The stakes were high, and the weight of the firm's legacy weighed on him. He was not just the principal partner of Maloof & Associates; he was its founder, the architect of its success, and the guardian of its reputation…and his own.

George was proud of the one-to-one relationships he had cultivated with clients over the decades. These relationships were not just business transactions; they were the lifeblood of the firm, the cornerstone of its identity and of his. The thought of adopting artificial intelligence, a seemingly impersonal technology, made him uneasy.

But beyond the firm's identity, George's own leadership could be questioned. His ability to steer the firm through this period of change and uncertainty would define his legacy. The decision to adopt AI, or not, was not just about the firm's future; it was about his future as a leader in a rapidly evolving industry. About this, however, he

had some confidence. With a steady hand, he had guided M&A through the recession of the early 1990s, the dotcom bust and 9/11 in the early 2000s, the Great Recession beginning in 2007, and the COVID crisis. Despite his fears, he would project only confidence because that's what his people expected and needed.

"Thank you all for joining this meeting," George said. "Unless you've been living in a cave, you know we just lost Sideways to Doghouse. I spoke with Stumpy Towers over at Sideways this morning. He was blunt about it. Doghouse has begun incorporating ChatGPT into their auditing services—fraud detection for sure but probably in other areas as well. I hate to put it to the team on such short notice, but we need to discuss whether AI has a place in our firm and how we're going to deal with this. Michael, I know you are reluctant, but we can't wait any longer to decide. Once word gets out about Sideways, I fear other clients might start asking themselves questions we'd rather they not ask. So, I want to have everyone's thoughts. Michael?"

Michael sighed. His personal reputation as a prudent decision-maker was on the line. If the firm invested in AI and it didn't go well, his concerns would be validated but the firm would suffer. However, if they successfully adopted AI and thrived, his caution might be seen as a hindrance to the firm's growth, and he didn't want to get a reputation as a stick in the mud.

After a moment's pause, he spoke, "I agree. This is a serious concern. However, I'm worried about the implications of using AI in our services. The potential loss of jobs and the privacy risks involved with handling sensitive client information make me uneasy."

He looked like he wanted to say more but Emily leaned forward and interjected.

"Michael, I understand your concerns," she said. She tapped her finger on the table to emphasize her point. "But I think it's important that we consider the downside of not incorporating AI like ChatGPT into our services. If we don't adapt to the changing landscape, we risk being left behind by our competitors. I don't want any more clients going Sideways, so to speak."

Emily was a little surprised that she had been so blunt with Michael, but she had built her career on embracing technology and innovation. Her desire to see the firm grow and succeed in a competitive market was tied to her personal career growth. Successfully advocating for the adoption of AI could position her as the forward-thinking leader within the firm, while failure to do so might limit her influence.

Everyone leaned back in their chairs for a moment, thinking. Until a few months ago, no technological advancement had threatened the very existence of M&A.

Everyone turned to Alice, who was looking into her coffee going over the potential effect of the decision on her reputation. Successfully guiding the firm through AI integration would bolster her credibility and position her as a valuable resource within the company. However, if the AI adoption process was mishandled or led to negative consequences, Alice's expertise and judgment could be called into question, potentially jeopardizing her career at the firm and future opportunities in the whole industry. If M&A fared badly in an IT-based battle among accounting firms, who would want to hire their ex-CTO? But she knew where she stood.

"Emily's right," Alice said. "ChatGPT and other tools like it have the potential to significantly improve our auditing services by increasing efficiency and accuracy. If we integrated this technology, I think you could use it to attract new clients and keep up with the competition, maybe even pass them. George and Michael, I believe we can address the concerns you both raised by implementing AI responsibly as part of a comprehensive strategy that considers all parts of an information system—people and processes, not just hardware, software, and data."

"Just so I'm clear," George said, "I'm not opposed to any technology per se, but I am concerned that relying on AI might weaken our relationships with clients. Our personal touch is what sets us apart from the larger firms. I'm afraid we'll lose that if we become too dependent on technology.

Emily nodded. "I hear you and I believe that by combining our personalized approach with AI-driven solutions, we can find a balance that offers the best of both worlds," she said. "We can still maintain strong relationships with our clients while offering them the services they need at a price that makes sense for us."

"But what about the overhead costs associated with implementing and maintaining such a system?" Michael said. "We're a small firm and investing in AI could be a significant financial burden."

"That's a valid concern," Alice said. "However, if we do it deliberately, I think the long-term benefits of adopting AI technology could outweigh the initial investment. It's also worth considering that the cost of not adopting might be even greater as we lose more clients to competitors with advanced capabilities. I get the impression that a lot of firms consider this a do-or-die situation. It remains to be seen whether they are right, of course, but that's how people are acting."

"Okay. I appreciate the points that are being made," George said, "and it seems obvious to me that we're lacking some key information that we need to make a supportable decision. Given that time is of the essence now, I think we need some external guidance to help us navigate making this complex decision. What if we bring in a consulting team to help us evaluate our options?

"That's a great idea," Emily said. "At the last Association meeting, I listened to a presentation by a group of business school graduates who are so tech-savvy that they started a consulting firm specializing in AI implementation for businesses. They seemed to know their stuff, going by how the Q&A went. I think they could provide us with valuable insights into the feasibility and potential benefits of incorporating ChatGPT into our auditing services."

Michael smiled. "I'm willing to explore this further if we can make a better-informed decision with their help," he said.

"Me too," Alice said. "Having an external perspective could give us the confidence we need to make the right choice for the future. But why stop with auditing services? As long as we've got them, let's ask him to consider all aspects of our operations."

"Agreed and alright then," George said. "I'll write up a call for proposal and arrange a meeting with those bright young students.

"I hear they're pretty fond of their intellects," Emily said. "Let's see whether they're as good as they seem to think they are!"

4. THE CHARGE

The next day, George met Laura Callaway, a senior analyst from Tanyard Creek Services, a consulting firm that, a little research had revealed, had a good reputation for working with small and medium-size enterprises to solve IT-related problems. Laura was well-versed in AI applications for businesses and had a strong understanding of the accounting industry. Together, she and George discussed the challenges and opportunities that AI implementation, including ChatGPT, posed for the accounting firm.

Laura began by asking a series of questions to assess the current state of Maloof & Associates' technology infrastructure, their primary concerns, and their long-term goals. George provided an overview of the partners' differing opinions on AI adoption and the reasons behind their apprehension. He also expressed the desire to strike a balance between leveraging AI technology and maintaining the firm's personalized approach to client relationships.

Laura realized that the outcome of the analysis would not only affect the future success and direction of Maloof & Associates but also the reputations, career trajectories, and influence within the company of each of the partners and of the CTO. Navigating this complex issue would require a thoughtful and collaborative approach involving each stakeholder and considering the potential risks and rewards for each of them as well as for the firm.

Laura and George agreed upon the key objectives of the initial consulting engagement:

1. Assess the feasibility of incorporating ChatGPT into Maloof & Associates' auditing service, considering the firm's existing technology infrastructure and resources.
2. Identify the potential risks, including data privacy concerns, job displacement, and impact on client relationships, and propose mitigation strategies.
3. Identify the sources of potential costs and potential benefits of adopting AI technology, for example in terms of efficiency, accuracy, and competitiveness.

Laura assured George that Tanyard Creek Services would provide a detailed report and that, if they decided to move forward, could also prepare a comprehensive implementation plan, including timelines, resource allocation, and training programs for employees.

5. DELIVERABLES

As a team, you should prepare assumptions and findings to be considered should a comprehensive implementation plan be called for. You may use online search tools and AI-based tools such as

ChatGPT, Bard, and Claude to aid your work. Depending on the instructions you are given, you should be prepared to offer your opinions during a class discussion or to present them to the class as a short slide presentation. In either case you must be prepared to justify your assumptions and findings. Therefore, it will not suffice simply to present the output of a tool. Each team member must be able to justify their team's assumptions and findings in their own words when questioned by members of other teams or by the instructor. This requirement mimics what is normal in business presentations, where the presentation is followed by questions designed to determine the depth of the presenter's knowledge of the topic and how they arrived at their conclusions.

6. SUGGESTED READING

These are general articles on AI use in auditing and on the challenges of AI implementation in small and medium-size companies. Your instructor might also suggest more current articles.

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Appendices

APPENDIX A. Maloof & Associates Human Resources

Maloof & Associates has a team of 28 dedicated employees, comprising a mix of Certified Public Accountants (CPAs), accounting support staff, IT support staff, and administrative personnel. The team's diverse experience and expertise enable the firm to provide a range of services to their clients.

- Certified Public Accountants (CPAs): The firm has 10 CPAs, including the three partners. They are responsible for managing client accounts and providing high-level services such as auditing, tax planning, and financial consulting. The CPAs at the firm have varying levels of experience, ranging from recent graduates to seasoned professionals with over 30 years in the industry.
- Accounting Support Staff: There are 10 accounting support staff members who assist the CPAs in their daily tasks, including bookkeeping, payroll processing, and tax preparation. These employees have relevant educational backgrounds and practical experience in accounting, with most holding bachelor's degrees in accounting or finance.
- IT Support Staff: The firm has three support staff, supervised by the CTO. They provide first-line technical support for hardware and software and also interact with software and hardware vendors to resolve problems that cannot be solved locally.
- Administrative Personnel: The firm has five administrative employees who handle essential office tasks, such as client scheduling, billing, and maintaining office supplies. These staff members have experience in office management and customer service, ensuring smooth day-to-day operations.
- The team at Maloof & Associates is committed to providing excellent service to their clients, which is reflected in their strong local reputation. The firm's leadership encourages a collaborative work environment, fostering strong communication and teamwork among employees.

The firm's employees regularly participate in continuing education programs and professional development opportunities to stay updated on industry trends and regulations. This dedication to ongoing learning helps ensure that Maloof & Associates can provide the most accurate and up-to-date advice to their clients.

In terms of technology proficiency, most of the employees have basic to intermediate skills, enabling them to use standard accounting software and productivity tools effectively. However, their exposure to advanced technologies, such as AI and data analytics, may be limited due to the firm's current infrastructure and focus on traditional accounting practices. However, the employees realize that, as the accounting industry continues to evolve, they may need to adapt their skill sets to stay competitive. This could involve learning new software, adopting advanced technologies, and embracing new ways of working, such as remote collaboration and cloud-based solutions.

Overall, the team at Maloof & Associates is a group of dedicated, skilled, and experienced professionals who work together to provide high-quality accounting services to their clients. Their commitment to maintaining a strong local reputation and staying current with industry developments positions them well for potential growth and adaptation in a changing landscape.

APPENDIX B. Maloof & Associates Technological Infrastructure

The current technology infrastructure at Maloof & Associates is typical for accounting firms of its size and location. The firm has a basic but functional IT setup that includes the following components:

- Local Servers: The firm has on-premises servers for storing client data, financial records, and other essential documents. These servers are protected with firewalls and regular security updates to ensure data privacy.
- Accounting Software: Maloof & Associates uses industry-standard accounting software to manage their client's financial records, bookkeeping, and auditing tasks. The software is regularly updated and compliant with local and federal regulations.
- Productivity Tools: The firm utilizes a suite of productivity tools for communication, project management, and collaboration among employees. These tools include email, video conferencing, and file-sharing applications.

- Data Backup and Recovery: Maloof & Associates has established off-site data backup and recovery protocols to protect their client's information and ensure business continuity in case of data loss or system failure.
- Basic Cybersecurity Measures: The firm has implemented basic cybersecurity measures, such as antivirus software, secure passwords, and employee training on best practices for data protection.
- Limited Cloud Adoption: While the firm has begun to explore cloud-based solutions for some of their services, most of their operations are still conducted on-premises. The proximity to Georgia Tech has allowed them to stay informed about emerging technologies and trends, but they have yet to fully embrace the potential of cloud computing.
- Network Infrastructure: The firm has a stable wired and wireless network infrastructure, enabling employees to access resources and communicate effectively. The network is safeguarded with firewalls and access controls to ensure data security.
- Hardware: Employees at Maloof & Associates use a mix of desktop computers, laptops, and mobile devices to access and manage client data. The firm maintains a regular upgrade cycle for hardware to ensure optimal performance and security.
- Customer Relationship Management (CRM) System: The firm has implemented a basic CRM system to manage client contacts, track communication, and store essential client information. This helps in maintaining strong relationships with clients while keeping their data organized and accessible.
- Remote Access and VPN: Employees at the firm can access resources remotely via a secure VPN connection when necessary, ensuring that they can work even when away from the office.

Despite the firm's adequate technology infrastructure, Maloof & Associates has yet to explore more advanced technologies, such as artificial intelligence and advanced analytics, which are now being adopted by larger competitors. The firm's proximity to several major universities in Atlanta provides an opportunity to stay informed about emerging technologies and trends, but fully leveraging these advancements would require a significant investment in upgrading their current infrastructure and reevaluating their technology strategy.

END OF MATERIAL FOR STUDENTS

Examining Impacts on Digital Discrimination, Digital Inequity and Digital Injustice in Higher Education: A Qualitative Study

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Abstract

Amidst escalating global crises, universities and colleges are becoming increasingly digitalized to respond to evolving educational demands. However, technology and digitalization are also introducing new forms of inequality and extending existing disparities. The purpose of this study was to investigate these disparities, their impact on education, and how academic institutions' responses during the COVID 19 crisis further impacted these disparities and inequalities. We used a grounded theory approach with an interpretive epistemology which is appropriate and well suited for this study. We interviewed 24 informants holding university leadership and decision-making positions, including deans, IT managers, university presidents, provosts, and chief information officers. Public and private universities, historically black colleges and universities (HBCU), and minority institutions were represented. Our findings showed that digitalization of learning and institution processes expanded gaps in digital access, equity, and socio-economic status. The findings also supported that some universities proactively implemented best practices that extended beyond investing in digital infrastructure to include initiatives to support equity, inclusivity, and accessibility. The outcome of the study can inform evidence-based decision making, develop targeted crisis interventions, and advocate for systemic changes that promote an equitable and inclusive digital learning environment.

Keywords: Digital discrimination, digital equity, socio-economics, digital injustice, grounded theory (GT), education

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Examining Impacts on Digital Discrimination, Digital Inequity and Digital Injustice in Higher Education: A Qualitative Study

Rachida F. Parks, Amy KB Paros and Marima Yakubu

1. INTRODUCTION

Organizational dependence on information technology is ever increasing, especially in times of crisis, like the COVID-19 pandemic (Wang & Wu, 2021). Organizations that can acquire and implement innovative technologies needed to respond during crisis are able to gain competitive advantage (Berman, 2012). Digitalizing organizational processes are expected to have a myriad of both long- and short-term benefits (Matt, Hess, & Benlian, 2015). The health crises caused by the pandemic created a dire necessity for increased digital capacity and innovation for higher education institutions' survival. (Benavides, Tamayo Arias, Arango Serna, Branch Bedoya, & Burgos, 2020).

While the digitalization of academic institutions has brought significant opportunities, it also introduced new forms of inequalities (Devlin, 2013). During the pandemic crisis, universities and colleges had to swiftly shift to online learning platforms. However, limited or no access to internet connectivity or to computers disproportionally affected lower socio-economic status (SES) students, faculty, and staff, thus uncovering digital discrimination and potentially widening existing disparities (Shohel, Ashrafuzzaman, Ahsan, Mahmud, & Alam, 2021). Without digital inclusion, academic stakeholders may face discriminatory access to work and educational opportunities thus exacerbating existing inequalities (Istenič, 2021; Van Deursen & Van Dijk, 2019). Current research calls for more actions to investigate these issues (Gran, Booth, & Bucher, 2021). It is critical to ensure that these stakeholders have equal access to digital resources and technology.

This study examined the extent or presence of digital discrimination, digital inequity, and socio-economic disparities within higher education institutions, during crises such as COVID. This study intends to bring awareness and to support inclusive attitudes and foster equity in an increasingly digital world.

2. BACKGROUND

Consistent with grounded theory (GT), our literature review took place during the data gathering and analysis. As such, we focused on several main themes that align with our study: (1) effects of crisis on educational institutions, (2) socio-economic impacts in education, (3) digital discrimination and technology access in higher education, and (4) digital inequity in education.

Effects of Crises on Educational Institutions

Crises—from emergency to catastrophe—effect organizations differently and the impact depends on their pre-event performance (Hiramatsu & Marshall, 2018). Research looks at how crisis affects organizations spanning from minor disruptions (Brenkert, 2010; Giannetti & Wang, 2016) through disasters, and global pandemics (Sydnor, Niehm, Lee, Marshall, & Schrank, 2017). Kato and Charoenrat (2018) concluded that having access to less institutional resources contributes to small and medium scale organizations suffering disproportionately. Impacts during crisis are largely related to revenue reduction (Aladejebi, 2020; Doern, 2016), disruption in operations (Omar, Ishak, & Jusoh, 2020), and losses in the workforce (Caminsky, 2020). Like any other business, higher education experienced significant operational and financial impacts during the COVID-19 pandemic (Hamouche, 2020). The effects of crises on higher educational institutions are arguably not uniform, some of the more wealthy colleges and universities see less operational impact than other institutions with lower available capital (Geiger, 2010; Sezen-Barrie, Carter, Smith, Saber, & Wells, 2023). Depending on the crises, publicly funded universities would have a different impact compared to private universities. According to Charoensukmongko and Phungsoonthorn (2021), private international universities were the hardest hit due to travel bans and movement restrictions (Sahu, 2020).

Looking at crisis impacts on education more broadly, Di Pietro (2018) found that students' academic performance and probability of graduating on time was reduced while dropout rates increased for students at University of

L'Aquila during a devastating earthquake. These effects fall back on the educational institutions' enrollments and revenue levels—requiring employee dedication, mitigation planning, and decisive leadership (Piotrowski & Vodanovich, 2008).

Socio-economic Impacts in Education

There has long been discussed a strong correlation between SES and educational level achieved (Anlimachie & Avoada, 2020). As artificial intelligence, data driven computing, business analytics, and technology know-how demands increase across the workforce, educational institutions have been expected to increase coursework focus to include digital technologies (Murphy, 2020). The relationship between SES and technology careers grows from access and equity during student training and education. Devlin and McKay (2014) reported that universities and students together are mutually responsible to help lower SES students bridge the transition into higher education. Additionally, true inclusive teaching and course design extends to a multitude of diverse students including disadvantaged SES (Wijeratne et al., 2022).

Murphy (2020) found that access to digital technology coursework was least available in the lowest SES areas due to the cost associated with purchasing and maintaining the equipment required for such subjects. Additionally, SES was found to positively corelate with academic performance in subject areas of technology, math, and science. Once students from lower SES enter college, Devlin (2013) noted that social and cultural barriers made the transition into universities more difficult for this population than their higher SES counterparts. Because of life situational changes associated with entering higher educational institutions weighed greater on students from lower SES, the transition can impact student motivation and confidence at school (Christie, Tett, Cree, Hounsell, & McCune, 2008). E-Learning has been seen as a tool to help lower SES students navigate the transition to university and better develop their personal and professional identity (Kaniadakis & Padumadasa, 2022).

These trends are being recognized as digital justice issues since poorer access to design, technology, and science courses for lower SES students makes it more challenging for them to pursue careers in technical fields (Murphy, 2020). Government is responsible for balancing the sometimes contradictory elements of social equity and budget constraints. For example, social equity initiatives require the commitment of financial resources, while fiscal responsibility remains an important responsibility of governments (Anlimachie & Avoada, 2020). Even life expectancy and health have been linked to the combination of SES and education levels (Enroth et al., 2022). SES and educational levels are positively correlated with involvement in government, education and public rights resulting in systemic advantages (Anlimachie & Avoada, 2020).

Digital Discrimination and Technology Access in Higher Education

With the COVID-19 driven shutdown of schools, the education of more than 290 million students globally has been disrupted and availability of digital technologies became the key for continuous education (UNESCO, 2020). George, Ward, and Jones stressed the importance of availability to digital technologies as a means for students and educators to continue engaging in learning; However, "There have been stark and widespread inequities in the availability and quality of digital technologies for education" (2022). Digital discrimination is defined by existing literature as the lack of access or reduced access to modern information and technology, including both software and hardware (Weidmann et al., 2016; Shohel et al., 2021; Gran, Booth, & Bucher, 2021). The COVID 19 pandemic has exacerbated this disparity and highlighted the need for more focus on digital inclusion.

Weidmann et al. (2016) confronted the opposition to digital inclusion as digital discrimination where individuals "suffer from reduced access to modern information and communications technology". Existing research including Australian Digital Inclusion Index, CISCO Country Digital Readiness, ITU Digital Access Index, The Economist Inclusive Internet Index, and the World Bank Digital Adoption Index have explored digital inclusion efforts. There still is disagreement on how it should be measured (Ochoa & Nonnecke, 2019). In education, there is increasing interest in inclusion, including digital inclusion (Lang, Freeman, Kiely, & Woszczynski, 2022). Moreover, the Sustainable Development Goals (SDGs) gathered by the 2030 Agenda adopted by the United Nations calls for more practical efforts to pursue a more sustainable path towards inclusive and equitable growth (Perales Jarillo, Pedraza, Moreno Ger, & Bocos, 2019). Digital inclusion, or the contrary reducing digital discrimination, should become a strategy to not only close the digital gaps at the local level

but also promote digital inclusion at the international level.

The commonly used 'digital divide' also represents a form of inequality in terms of accessing data, information, including education through new technologies (Lythreatis, Singh, & El-Kassar, 2022). The gap between digitally included and excluded students is substantial and widening for some groups (Jaggars et al., 2021). COVID-19 has been highly disruptive and many students were excluded due to both formative (devices, infrastructure, and connectivity) and substantive forms of digital divide (interaction and engagement) (Liu, 2021).

Digital Inequity in Education

As internet access grows it becomes evident that aspects related to *using* information and technology continue to widen the digital divide (Lebeničnik & Istenič Starčič, 2020). Providing access to technology does not simply close the digital divide, but coupling access with training and the knowhow to extract information is equally as important (Hargittai, 2002). Access to technology systems, opportunities to learn and use technology, and costs associated with maintaining access to technology and systems influences the digital divide (Istenič, 2021; Van Deursen & Van Dijk, 2019). While pricing and convenience have contributed to the growing use of mobile devices, smartphones do not improve the digital divide because of memory, storage, speed, and application limitations (Mossberger, Tolbert, & Hamilton, 2012)

Students who lacked access to technology needed for course content, during times of crisis, worried about future impacts and cumulative curriculum implications (Krishnakumar et al., 2022). Maximized by conditions of crisis, psychological aspects, low self-efficacy, and lack of confidence with computer skills can deepen the digital divide across student populations (Lythreatis et al., 2022). Student inequities associated with technology and internet access were common, however, sometimes other digital divide issues like a student's inability to turn on a camera or microphone due to in-home circumstances impacted faculty-student relationships and even the student-student sense of community (Goin Kono & Taylor, 2021). The digital divide impacts many demographic categories, and it is important to recognize technology constraints associated with digital learning resources that can have an impact on disabled students (Lebeničnik & Istenič Starčič, 2020).

There has also been information technology and digital effectivity research around course effectivity (Adedoyin & Soykan, 2023), learning outcome achievement (Bozkurt & Sharma, 2020) and student engagement (Pittaway, 2012). Faculty presence and engagement in the online learning classroom can have significant positive impacts on learning engagement, community connection, and course understanding for first generation and students of color (Salvo, Shelton, & Welch, 2019). When faculty were highly engaged in professional development their fluency with digital teaching and learning systems improved (Pandya, Patterson, & Cho, 2022).

3. METHODOLOGY

This study adopts an interpretive qualitative research method to investigate disparities of digital discrimination, digital inequity, and socio-economic disparities within higher education institutions. Trauth (2001) presented five factors influencing the choice of qualitative research: the research problem, the researcher's theoretical lens, the degree of uncertainty surrounding the phenomenon, the researcher skills, and, finally, the academic politics. These factors align with why we embraced a qualitative study; it starts with the intricacies of the research problem, the degree of uncertainty during COVID crisis, our expertise in qualitative research especially in grounded theory methodology, and the turbulent academic politics during the pandemic. Moreover, the theoretical lens we embraced reflects our philosophical assumption central to qualitative inquiry (Creswell & Poth, 2016). This consists of embracing a subjective ontology, an interpretive epistemology, qualitative rhetorical and terminologies, and an inductive approach methodology (Creswell & Inquiry, 1998). Therefore, a grounded theory approach with an interpretive epistemology is appropriate and well suited for this research (Corbin & Strauss, 2008; Trauth, 2001).

Data Collection

Data collection efforts spanned across 16 months collected from 24 informants holding leadership positions at higher academic institutions. Interviews averaged 65 minutes and were conducted by all authors in pairs. Informants included university presidents, provosts, university vice presidents, university chief information officers, associate provosts, deans, university technology directors and equity and inclusion cabinets. The institutions included nine private and nine public universities and colleges in the United States while also ensuring small,

medium, and large enrollment representation ranging from 1,500-38,000. Additionally, three historically Black colleges and universities (HBCUs) and minority-serving institutions were also included. We used snowball technique to connect with informants until we reached saturation where themes became redundant and no new concepts identified (Corbin & Strauss, 2008). We also followed a theoretical sampling approach where the emerging theoretical model drove our data collection (Strauss & Corbin, 1990).

Our study was prompted and initiated in response to the COVID-19 crisis. This period presented a unique, albeit challenging, opportunity for real-time data collection, offering insights that were immediately relevant rather than retrospective. We recognized the importance of a broader data collection approach. However, this timing also imposed constraints on our participant pool, notably affecting our ability to engage with a broader demographic, including students, parents, and professors, due to the tragic circumstances of the pandemic and the loss of lives it entailed. Even when limited to administrators, some interviews had to be cut short to respect the severity of the situation (e.g., an administrator describing the dorms turning into a morgue).

Data Analysis

As with grounded theory, data collection and data analysis occurred simultaneously (Parks, Xu, Chu, & Lowry, 2017; Urquhart, Lehmann, & Myers, 2010). Our data coding and processing applied first order concepts, second order themes, and aggregate dimensions (Gioia, Corley, & Hamilton, 2013).

First order analysis began with applying an inductive approach through open coding, meaning the labels that we used were drawn from the interviewers' words and no-apriori codes were applied. Axial coding followed in order to develop higher level categories (Corbin & Strauss, 2008). Second order themes included selective coding, which involves selected codes to generate categories and core categories (Adolph, Kruchten, & Hall, 2012). Categories were then integrated into a coherent theoretical framework where both constant comparison and saturation are fulfilled. Having embraced the constant comparative method, we continued looking for information until the categories were saturated (Glaser & Strauss, 1967).

Literature was reviewed during data collection and analysis, while the authors also heavily invested in a rigorous interpretation of the data by engaging interrater reliability (IRR) to understand the phenomenon being studied. We conducted IRR at a rate of 30% of the collected data, more than the 20% recommended by Syed and Nelson (2015) and completed it throughout various phases of data collection. When misalignment arose between two coders, interrater agreement techniques of discussion, clarification of intervention of the third coder were used. To ensure trustworthiness, we used the criteria of credibility, transferability, dependability, and confirmability (Lincoln & Guba, 1985). The assessment conducted indicates that the study results are credible, can be transferred to other contexts, and are consistent and confirmable. A detailed description and assessment of each criterion are provided in Appendix A.

4. FINDINGS

Figure 1 provides a visual in support of understanding and connections between our data and the findings. Details about findings are provided below and supported with informant quotes.

Challenges

While COVID-19 was the crisis used in this sample, we considered open questions to understand the overall impacts associated with large-scale crises. The data collected showed three challenges: (1) information technology challenges, (2) budgetary constraints, and (3) inequities and socio-economic challenges. We highlight these crisis challenges and will share findings using informant direct quotes.

Information Technology Challenges

The lack of proper access to hardware and software during crises can be a major challenge with navigating survival solutions. Faculty, staff and students found proper access to information technology and other technical resources was limited or unavailable. Our data collection identified technology challenges that impacted universities' ability to deliver learnings and operational objectives. Access to laptop computers was an essential challenge for university leaders. Some situations of crisis require virtual work environments, which needed the faculty and staff to have access to laptops and portable devices. Additionally, access to computers was an issue that also extended to the faculty because so much of student learning

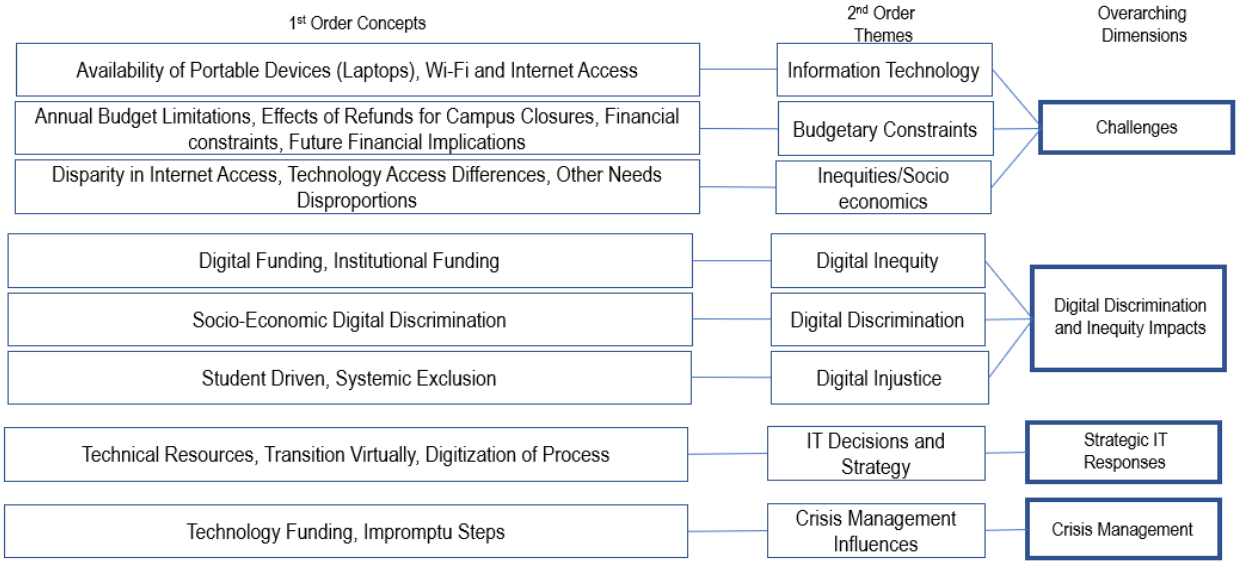

Figure 8: Emergent Concepts, Themes, and Dimensions

required access to labs and library software. This all happened at a time when the computer supply chain was overwhelmed. Also, while access to portable computers was a challenge, informants also identified challenges associated with internet access required to complete school and work.

Manifestations	Illustrative Quotes from Interviews
Availability of Portable Devices (Laptops)	"Desktops are cheaper than laptops… So in 9 times out of 10 that meant we bought them a desktop…That's a great idea, until we have to move out" #11
Wi-Fi and Internet Access	"I think people were shocked when kids went home, and they didn't hear from them anymore. I think people were like, "what do you mean everyone doesn't have Wi-fi at home? What do you mean everyone doesn't have a laptop?" … I think the pandemic has really opened people's eyes to see there's a digital divide." #23

Table 1. Manifestations and Illustrations of Information Technology Challenges

Our data collection uncovered digital discrimination promoting the digital divide. Some informants shared stories where they purchased hot spots for students, faculty, and staff. Table 1 provides direct quotes from informants identifying the indications of the effects on information technology.

Budgetary Constraints

Many crises come with financial challenges in addition to the other stressors of the crisis situation. Financial constraints manifested into the following themes: annual budget limitations, refunds for campus closures, financial constraints, and future financial implications. While higher educational institutions were already in financially strained situations of crisis add even more challenging financial pressures. In our study's crisis COVID-19 example specifically, requirements to close campuses and move coursework online meant a direct financial implication associated with on campus fees (i.e. room and board). Institutional leaders interviewed shared various combinations and levels of financial tightening that included hiring freezes, furloughs, layoffs, elimination of faculty travel and research stipends, and freezes on retirement contributions. Table 2 provides direct quotes from informants identifying the indications of budgetary constraints.

Manifestations	Illustrative Quotes from Interviews
Annual Budget Limitations	"We figured out that we were going to need to add $26 million to our budget in order to make it through the next year. Since we already had a budget, that meant we had to strip $26 million from our budget to pay for the things that we wanted." #20
Effects of Refunds for Campus Closures	"We had to refund also the students that were living on campus. We refunded their resources for room and board" #19
Financial Constraints	"I've had a tough time but some of my colleagues at the <anonymized>, they're really in in uncharted waters. The chancellors at all the <anonymized> were told they had a week to come up with two plans: one a 25% cut and the other a 50% cut." #7
Future Financial Implications	"We actually had a very successful final three months of the fiscal year with donors, because we had an effective outreach to them and engaged them appropriately." #6

Table 2. **Manifestations and Illustrations of Budgetary Constraints**

Inequities and Socio-economic Challenges

Limitations or lacking personal resources during a crisis can result in inequities and socio-economic differences for students, faculty, and staff. The inequities seen in our study were manifested into three subcategories: disparity in internet access, technology access differences, and other needs disproportions. Our findings showed that when crisis operations require remote work, teaching, and learnings than challenges associated with internet access impacted students, faculty, and staff. Other challenges associated with remote work and learning included a lack of computer systems, hardware, and software at home. This is because some students, faculty, and staff were reliant on university resources. During the crisis studied in our research, higher educational institutions that instated virtual responses drove socio-economic challenges and inequities beyond even just internet and computer system access. Some universities shared that a portion of their student body relied on campus to be a safe haven that provided shelter and food during the academic year. Therefore, having to implement the move towards virtual campus and sending students off campus could challenge more than their academic success, but also their survival. Table 3 provides direct quotes from informants identifying the indications of inequities and socio-economic challenges.

Manifestations	Illustrative Quotes from Interviews
Disparity in Internet Access	"Students often did not have technology at their homes." #13
Technology Access Differences	"They were overwhelmed because they were working at home with family members and siblings who were either impeding their time or space to try to study. Or overwhelmed because they didn't have the proper tools to do this. They didn't have laptops with cameras or they were in a house with five other kids going to school, so the bandwidth wasn't there for them to get on the Internet." #22
Other Needs Disproportions	"I think that this pandemic has shown the inequities in our economic situation. Where more black and brown people are essential employees without a central pay and put at risk, showing the inequities in our healthcare system...Showing inequity in our education system. Primarily through the idea of technology, that not all areas have the same technology, not al households have more than one computer...You got incredibly motivated young people who want to learn who suddenly don't have the ability to do that." #20

Table 3. Manifestations and Illustrations of Inequities and Socio-economic Challenges

Digital Discrimination, Injustice and Inequity Impacts

Our findings portrayed the energy regarding the magnification of unresolved issues associated with inclusivity/discrimination, equity/inequity, and accessibility within higher education magnified during periods of crisis. Our data showed three major manifestations: (1) digital inequity, (2) digital discrimination, and (3) digital injustice. These major manifestations are closely connected and therefore we have provided the illustrative quotes for all manifestations within Table 4. Technology influences success and

creates competitive advantages, however, we also saw the countereffects of less technology access, reduced technical systems training, and decreased software availability. These situations are exacerbated by crisis and extend the digital divide across universities while centering on a lack of digital equity (digital inequity) that affects universities, faculty, staff, students, and families. The digital inequity theme is associated with digital funding and institutional funding manifestations. The subtheme of digital funding came to light with consideration for adequate schools, labs, equipment, and faculty across regions. Institutional funding, as a subtheme, looked at situations associated with unequitable funding for universities traditionally focused on serving underrepresented populations. Technology-based discrimination was reflected by the manifestation of socio-economic digital discrimination. Digital discrimination focuses on the lack of access or reduced access to software and hardware. Like other emergencies, the COVID-19 crisis forced students, faculty, and staff to leave campus. This situation highlighted issues associated with the digital divide, digital inclusion, and digital discrimination. Once campuses were closed, students, faculty, and staff no longer had access to any on-campus resources including information and technology. As described by our informants, transitioning away from campus reduced access and exacerbated issues associated with digital discrimination. The subthemes of student driven and systemic exclusion represent the manifestation of digital injustice. Student driven, considered both internal aspects of diversity at universities and externally focused on involvement in justice movements. The systemic exclusion subtheme looked to transparently show the multifaceted findings associated with students and effects on faculty pertaining to challenges associated with affording university tuition and faculty review procedures. Table 4 provides direct quotes identifying the indications of digital inequity, digital discrimination, and digital injustice the informants faced.

Manifestations	Illustrative Quotes from Interviews
Digital Inequity	
Digital Funding	"The allocation of funds are not always equitable to smaller universities or universities that are not – that service minority students or alternative population. Even with that when you have universities that have this kind of equity gap in terms of the funding, that also impacts the amount you can pay your staff to be able to do this. Most small universities are not going to have a first class technologist to come and do this. Small universities are not going to attract the type of talent to be able to do that." #23
Institutional Funding	"Most HBCUs have the lowest tuition rates in the state. We don't have the money. We're always trying to do more with less. We don't charge enough. Everybody here is taking a discount. I'm the lowest paid <anonymized>. Most of our faculty members are not paid what their colleagues at another institution are paid." #20
Digital Discrimination	
Socio-Economic Digital Discrimination	"Some were taking the classes in bathrooms because that's the only space they could find privacy. We had initially required that all students had to turn the cameras on. We got push back from the students saying "I'm not comfortable with that." … There are all kinds of social economic issues that we need to get better about that weren't considering up front, but we were able to adjust as we move forward then." #22 "So, students often did not have technology at their homes. We started our own philanthropy donation" #13 "We have a significant population of the campus community that's food insecure.

	Which very well means that there's also a lot of students don't have enough access to technology at home, whether it's internet and computers. All those things are, unfortunately, interconnected." #17
Digital Injustice	
Systemic Exclusion	"We haven't really talked about what systemic racism exists in our Institutions of higher education and across the country…We need to look at our policies and procedures. There are some far more traditional hierarchical structures that have to change…We have to look at how resources are managed and how the sources are made available. I mean, for us, that's a lot of legislative advocacy, a lot of policy changes that are required, both at the state level, the federal level, but then again on our own campuses. So, it's actually a really exciting time to create change." #21
Student Driven	"<anonymized> has a very long history of being a leader in social justice…Our students have a have a tendency or attention to move towards social justice issues when they arise. Because were in Covid, we haven't had students who would be actively engaged on campus level, but we have had faculty who've tried to pull students into that realm." #22

Table 4. Manifestations and Illustrations of Digital Discrimination, Injustice, and Inequity Impacts

Crisis Management Influences

Intervention of crisis management or a lack thereof influenced digital access. In essence, intentional crisis management made a difference between creating equitable digital access on one hand and worsening the situation for those who already lacked digital access. Crisis management influences manifested into the following themes: technology funding and impromptu steps. Crisis management interventions that provided funding for technology led to wider access for teaching and learning, thereby mitigating the impact to any prior deprivation. Some of the crisis management interventions were direct, situational, and impromptu geared towards universal benefits of teaching and learning instructions, such as ensuring students' attentiveness in virtual classes during the height of the pandemic—the absence of which would negatively impact digital learning. Table 5 provides direct quotes from interviewees illustrating influences of crisis management interventions.

Manifestations	Illustrative Quotes from Interviews
Technology Funding	"I think the computer stipend, which was a genius move on my chief of staff, that was his idea. I think we'll do some form of that every semester. We'll either up our technology fee or get a grant, but we will provide some level of technology stipend, so that every student has something. Even though we haven't done a lot of hybrid yet because most of our stuff has been totally remote, I think in the new world hybrid is going to be the norm. #20
Impromptu Steps	I made sure to tell the faculty be on the lookout for kids who are either not turning the cameras on or not coming to class on a regular basis and give us those names. We fed those names to the student affairs office who did outreach to the students to kind of be ahead of the curve with regards to what their issues might be. We were trying to be as proactive as we could and making those types of decisions. Admittedly, it was really ad-hoc. We were kind of making it up on the fly. There was no structured approach. #22

Table 5. Manifestations and Illustrations of the Crisis Management Influences

IT Decisions and Strategy

The stressors of a crisis make those IT decisions and strategies more impactful to the educational system. IT decisions and strategy manifested into the following themes: technology resources, transition online, and unintended technology inequities. Access and availability to technology positively supported decision making and response options. Also, institutions with resources to adapt technology found the crisis as an accelerant enabling more responsive acceptance and inclusion of technological solutions. These preceding findings aligned with access to resources that allowed for the implementation of technology, which made findings associated with a lack of access that much more important. In some cases, universities working to enlist IT solutions found

that students, faculty, and staff did not have the means to utilize technology and virtual options. Table 6 provides direct quotes from informants identifying the indications of the IT decisions and strategy.

Manifestations	Illustrative Quotes from Interviews
Technical Resources	"I think several of these there are advantages to being part of a 20+ [quantity generalized for confidentiality] campus system. Because, a lot of the technology that we use across our campuses are the site licenses negotiated on Chancellor's Office level…I think there are lots of advantages, again, because we have the capacity of the entire [removed for confidentiality] to anticipate." #21
Transition Virtually	"Knowledge and the digitization of processes, I think have accelerated and will accelerate. The crisis from that perspective is welcome now, because some of these needed to happen. The brick-and-mortar universities are never going to go away, but they need to be more responsive to technologies." #8
Digitization of Processes	"We talked about mobile first. We talked about being agile, we talked about digital transformation." #14 "We had previously used an e-sign type tool at a smaller scale and it was cost effective. But as soon as the volume exploded very quickly, where everyone, all of a sudden needed to get signatures for things virtually, we migrated to a different tool that was just more cost effective." #16

Table 6. Manifestations and Illustrations of IT decisions and strategy

5. Emerging Framework Understanding Digital Resiliency, Inclusion, and Equity

While our themes may seem straightforward, how they emerged and interacted with each other did not follow a linear trajectory. Through constant analysis, major categories were identified – challenges, responses, and impacts. Close analysis of the data uncovered interrelations among these categories, facilitating their integration into a cohesive theoretical framework (Strauss & Corbin, 1998). This paper proposes a framework for the Crisis Impacts on Digital Equity and Inclusion (CIDIE), as illustrated in Figure 2. This framework connects the emerging themes and contributes to existing research by showing the interconnectedness and mediation between challenges, strategic responses, crisis management with impacts to digital discrimination, digital inequity, and expectations in digital justice.

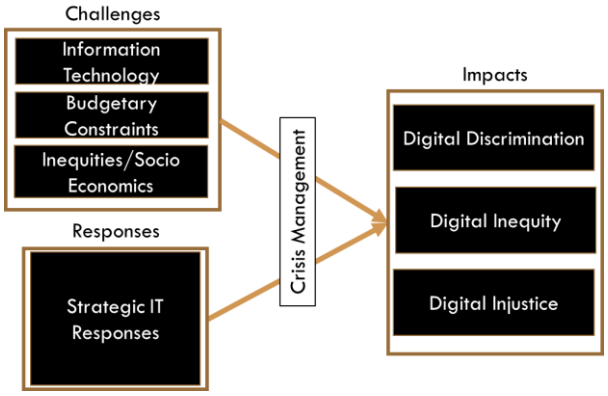

Figure 2: Framework of Crisis Impacts on Digital Equity and Inclusion

Challenges Pressure Learning Organizations (IT Challenges, Budgetary Constraints, Socio-economics)

The extent to which organizational IT challenges brought forth by crisis—negatively or positively—impact stakeholders and their performance levels depend largely on management's strategic response to a crisis. Educational institutions' leverage of effective crisis management leads to digital inclusion or digital discrimination on the other hand if response strategies do not take into consideration their marginalized population. However, pre-existing budgetary constraints of educational institutions are drawback to the influence of crisis management on digital justice/discrimination. Tight budgetary measures do not allow for adequate investment in the IT resources needed for providing digital equity to the underserved community. Crisis management that factors in socio-economic challenges of all stakeholders and the impacts they may have on productivity reduces digital inequity, such as providing hot spots and/or computers for students and employees who for socio-economic reasons do not have adequate IT resources to perform during crisis.

Strategic IT Responses

There is no doubt that technical resources largely supported how academic institutions responded during the pandemic (Cagin & Senvar, 2022). Such resources allowed university operations and education to transition online and maintain some business operations. The survival of educational institutions during time of crises depends largely on exploring innovative technical approaches to repurpose delivery of teaching and education,

utilization of by-products, application of data, and integration of technology (Davenport, Godfrey, & Redman, 2020; Von Krogh, Kucukkeles, & Ben-Menahem, 2020). The proactive and strategic IT responses to pivot to virtual platforms were critical especially when taking in consideration those with limited resources and no access to technology. However, IT Responses that prioritize addressing issues of inequity play a critical role in controlling the disparities in access, needs and affordability (Murphy, 2020). Therefore, organizations are more likely to contribute to a more equitable digital environment if they implement targeted strategies and responses. Like challenges faced by academic institutions, this relationship was also mediated by crisis management which is detailed in the next section.

Crisis Management Mediating Impacts on Digital Resilience, Inclusion, and Equity

How well a university or college manages a crisis influences inclusion/discrimination, and equity/inequality. Academic institutions' ability to leverage both financial and technical resources, balance socio-economic challenges and leverage information technology strategic responses enables or constrains that university during crisis. There is no doubt that institutional resources help contribute to an organization's resilience and the less institutional resources available the more crisis impacts can disrupt operations (Kato & Charoenrat, 2018). Of course, educational institutions who are already constrained by budgetary resources will also struggle more to offer cutting edge technology to faculty, staff and students. Access to online learning environments and skillsets prior to the crisis helped universities transition, but universities who serve lower SES areas are usually challenged financially and have less e-learning capability further straining digital resiliency (Anlimachie & Avoada, 2020; Murphy 2020; Devlin, 2013).

A lack of emergency preplanning or prior preparedness may have adverse impacts through inefficient resource use and unplanned investment in IT (Sing & Jain, 2022). Our study connected the influence of IT resources and impact of crisis challenges with effects associated with digital inclusion or discrimination and digital equities or inequities.

6. CONCLUSION

Educational institution responses to crisis challenges utilizing IT can have unintended impacts associated with digital equity, inclusion, and justice engagement. This study developed a framework for the digital effects of crises on digital learning inclusion and equity using qualitative interview data gathered during the actual crisis.

While this study's data set was limited to the United States, it sufficiently provides data from small, medium, and large sized, public, private colleges and universities with appropriate for HBCU representation. Future studies could expand the data set to explore unique circumstances involving HBCUs, and include perspectives from faculty, students, and parents in the interview data set.

This study notably advanced the fields of technology, education, and diversity research and practice. Most importantly, managerial implications of this study provoke college and university leaders to consider unintended digital inequities and digital discrimination while strategizing and implementing decision making during crisis.

7. ACKNOWLEDGEMENTS

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Appendix A - Evaluating Trustworthiness

Evaluative criteria	Description	Study Evaluation
Credibility	Evaluation whether the study findings represent a credible interpretation of the data collected	We used multiple type of sources (such deans. University presidents, provosts, vice presidents, CIO), different institutions (such as public, private, historically Black colleges and universities) across multiple States to ensure triangulation of the findings.
Transferability	Applicability and extension of the study's findings beyond the bounds of the project	To ensure transferability, we provide a detailed first-order analysis (along with illustrative quotes) of the phenomenon and context which is supposed to provide enough background for the readers to judge the plausibility of the findings and their applicability beyond the bound of this project (Van Maanen 1979).
Dependability	Assessment of stability and consistency of the study's processes of data collection, data analysis, and theory generation	Dependability was achieved by conducting inter-rater reliability or interrater agreement techniques to develop a shared understanding of the phenomenon being studied. Although, the gold standard is that 20% of the data go through the inter-rater reliability (IRR), we conducted 30% at different phases of our data collections (Syed & Nelson, 2015).
Confirmability	Measurement of how the study findings is supported by the data collected	To measure how the findings are supported by the data collected, the study was shared with professors, executives, as well as executives outside academia, in order to get critical feedback. Consensus suggests that this research analysis and theoretical model accurately reflect the data

Invited Article

On Becoming: Why Disposition Distinguishes Information Systems Education from Training. A Commentary on Model Curricula

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Abstract

In 2020, the IEEE/ACM Computing Curricula 2020 report, the ACM/AIS/ISCAP Undergraduate Model Curriculum, and the AASCB Standards for Business Accreditation were all released. Each expands on its predecessor to add aspects of disposition to the knowledge, skills, and capabilities in its curriculum. This curriculum is then used to shape, hone, and prepare graduates. Both the CC2020 and IS2020 reports specifically recommend a competency-based curriculum in which dispositions are both a relatively new addition as well as an addition that may be fraught as the consideration and/or adoption process proceeds. The competency model challenges Information Systems curriculum design in two key aspects that are the subject of this paper. First, the "disposition" dimension poses key challenges in the Information Systems discipline and provides a new area of focus in the literature on Information Systems curriculum development. Second, the inclusion of dispositions in the CC2020/IS2020 competency model provides an opportunity to explore interconnections that can be more informative than course containers, course descriptions, and lists of topics. We promote the uptake of the CC2020/IS2020 competency model by focusing on and advocating for dispositions as a means of accounting for, and designing for, students' *becoming* as a complement to students' application of skills and knowledge in the task environment. The "disposition" component of the competency model promises extended expression, facility of comparison, and clarity in exchange to bring utility and understanding in the Information Systems curriculum development process.

Keywords: professionalism, competency, mindset, dispositions, accountability, computing education, curriculum design.

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On Becoming: Why Disposition Distinguishes Information Systems Education from Training. A Commentary on Model Curricula

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1. INTRODUCTION

Recent computing curricula reports (CC2020), and specific disciplinary model curriculum reports (CC2020, IS2020, and the impending CS2023 and DS2023) have been authored using a competency approach to modeling computing curricula. A key component of the models in these reports is the inclusion of dispositions. The CC2020 report conceptualizes dispositions thusly (CC2020, p.134): *Dispositions enfold intellectual, social, and moral predilections or tendencies that influence behaviors that do not lend themselves as easily to a categorical assessment*. From our read of this statement and our experience, we find that dispositions relate to habitual behavioral tendencies that best facilitate the development of the skills and knowledge that support competencies. Thus, with the inclusion of dispositions, which are often considered subjective, some will find pathways for measurement and assessment to be less clear. This presented opportunities for friction and for growth. Others have conceptually drawn from dispositions in computing curriculum development and we review these next.

Knowledge Areas, Knowledge Units, and Learning Outcomes (KA, KU, LO) were common ontological organizations in model curricula development 20 years ago. While they are still useful to articulate the knowledge elements and skills levels inherent in the CC2020 competency model, these elements (KA, KU, LO) can usually be directly observed: a developed algorithm, a security policy, a normalized schema, or UX design. However, the potentially fraught and beneficial aspect of the CC2020 and IS2020 competency model is the inclusion of dispositions. Dispositions, which at first seem immediately familiar, quickly become inscrutable as they must be explicated, articulated, and reconciled as mediators and moderators of the full competency expression; more so when a competency expression attempts to match a given task environment.

Dispositions are arguably a matter of the affective cognitive realm (Ben-Ze'ev, 1997) and arguably occupy a similar space as that of Covey's (2020) seven habits. Like Covey's habits, dispositions may be understood as conditions, or habits of mind, which assist in problem framing and solution design. When we enter the behavioral and affective realm of dispositions in the competency model, they may strike some as being apart from the more concrete elements of computing knowledge.

Computing accreditors, such as ABET, do not shy away from specifying attention to sociologic and behavioral psychologic realms in their criteria for computing programs. However, the authoring and pedagogical implementation of dispositions remains relatively new ground in model curricula for Information Systems. That is, we are used to students' demonstration of computing knowledge and ability, via observable artifacts, and less so from the enabling habits and attitudes that facilitate those competencies.

In this paper we will explore the essential nature of the "disposition" component of the competency model and suggest that the investments in these dimensions of competencies can be meaningful and long-lasting as students progress in their careers. In this sense, we advocate that dispositions serve as a "glue" used to adhere the vital component of a competency's contextual application in a task environment to the foundational knowledge needed to facilitate computing solutions. We use this forum not as a traditional research paper, but as an outlet for our thinking about the role of disposition in computing education, based on the foundational elements of literature review and meta-analysis.

Dispositions may not be a common element in many skills-oriented technical courses and curricula. Also, other related disciplines (e.g., psychology) may be assumed to be addressing the basic principles of habit and behavior. Thus, it is likely that dispositions and their importance can be missed in the development of competencies. Whereas recent guidance from model curricula (IS2020) or accrediting bodies (the ABET CAC Criteria) place a firm emphasis on the indelible and concrete technical knowledge

and skills, the benefit of examining the seemingly esoteric role of dispositions is the appeal made in this paper. Dispositions are vital as they reflect the knowing-in-action (Schön, 1995) that can be best shaped by discovering both explicit and implicit purposes and placement of disposition in competency expressions of curricula.

Lastly, this paper proposes that the lasting value of dispositions is their reflection of the evergreen habits of orientation, perspective, and framing that are the hallmarks of reflective practice of an IS professional (Brown, 1995; Rein and Schön, 1996). We hope that the reader will develop a greater appreciation for the potential, pitfalls, and nuances possible with care for the value that dispositions bring to the table in the CC2020/IS2020 competency model.

The paper proceeds as follows. First, we examine the purpose and placement of dispositions within the competency model. We next review the literature on dispositions regarding competencies in computing curriculum development. We next explore how the CC2020 competency model was manifested in the IS2020 model curriculum with some text analytic techniques. With that, we next postulate on what typical challenges would be encountered in specifying dispositions during competency development. We conclude with potential benefits and purposes of dispositions with regard to overarching goals for academic computing programs and the student outcomes they facilitate.

2. THE SIGNIFICANCE OF DISPOSITION IN COMPETENCY

CC2020 asserts that adopting its competency model enables educating, prescribing, and evaluating a practice of computing that delivers a broad range of practical benefits: to students, benefactors, faculty, administrators, employers, accreditors, lawmakers, and society.

"Describing computing competence in a practical context shifts the focus of curricula away from describing a body of knowledge in relation to a disciplinary area and channels it toward pragmatic […] accomplishment and performance. It challenges […developing …] proficient computing professionals, and it allows society to recognize the purpose and benefits of […computing …] within a competency framework." (CC2020)

Indeed, at the CC2020 project's inception in early 2017 the capability and character of "proficient computing professionals" fused as the driving theme. The transformation from "knowing" to "practicing" was driven by both a commitment that students "learn better" and that graduates "perform better" in the real world. CC2020 expanded its notion of computing curriculum from being just a body of knowledge. It supplements the technical curriculum with a more comprehensive model, that of competent professional action and conduct (see Figure 1). CC2020's model of competency categorically represents professional action and conduct as "knowing what," "knowing how," and "knowing why."

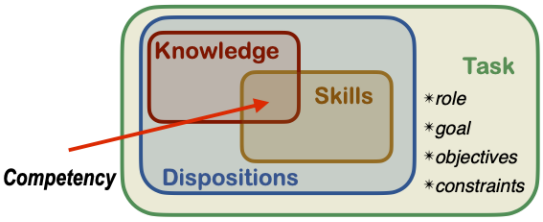


Figure 9: Competency = [Knowledge + Skills + Dispositions] in Task (Clear & Parrish et al., 2020).

The new, key element is **disposition** that explicitly fuses action and conduct to the effect of purposeful behavior.

> **disposition** … *Natural tendency or bent of the mind, esp. in relation to moral or social qualities; mental constitution or temperament; turn of mind…*
> (Oxford English Dictionary)

Disposition's role in competency (both formative and performative) requires delineating traits that characterize "professionalism." In concert these traits commonly interpret a "professional **mindset**." CC2020 elaborates their formative intention of disposition in competency as follows:

The meta-language of competency, "knowing what," "knowing how," and "knowing why," crisscrosses domains of scientific fact, practiced behavior, and cultural norms. Scientific (technically rational) fact and practiced behavior lend themselves to a categorical assessment: true or false, present or absent, consistent or inconsistent, it works, or it doesn't. Dispositions enfold intellectual, social, and moral predilections or tendencies that influence behaviors that do not lend themselves as easily to a categorical assessment. These predilections reflect value judgements that are not amenable to scientific proof. Values may differ or be held differently among individuals or cultures. And value

judgements are also often mutable over time—affected by the experience of practice!
…
Dispositional expectations enrich the description/assessment of competency and/or the related pedagogy. Ascribing a disposition to a competency indicates a clear commitment to self-reflection and a sober examination of mission, goals, and objectives to reach the clarity that enables its effective integration in curriculum design, the agency of pedagogy, and the character of professionalism.
…
Disposition is an area that clearly distinguishes competency from a learning outcome and is an essential characteristic of a well-structured competency. As such it represents [a richer description of learning goals], and adds language common to professional expectations. However, when used in free form, such terms may easily become vague or difficult to interpret. This is where the specification of a competency—that is the combination of the free-form text with its constituent K+S+D in [Task] framing—becomes more valuable. The competency statement is prose that succinctly conveys the essential intention of curricular details, while the structured enumeration of the K-S pairs and D elements conveys intention in action (CC2020 p. 134).

Discerning and incorporating disposition in a competency specification of computing actions and conduct described in practice, empowers agencies of licensure, managers, educators, and communities to formulate, recognize, and effectively assert a whole of values and commitments that they deem characteristic to the judgement and conduct of a practitioner who is worthy of trust and respect as a professional.

The CC2020 decision to enfold dispositions to stipulate the character of professional practice clearly articulates what distinguishes educating computing professionals from training computing practitioners.

train *… To subject to discipline and instruction for development of character, behavior, or skill… To give sustained instruction and practice to…*
(Oxford English Dictionary)

educate *… To teach (a child) a program of various academic and non-academic subjects, typically at a school; to provide with a formal education.*
(Oxford English Dictionary)

3. DISPOSITIONS IN THE LITERATURE

Since 2017 (Clear, 2017; Sabin, et al., 2017), the benefits of recognizing dispositions and task context in competency statements for computing curricula have become more obvious (Frezza, Daniels, Pears et al., 2018; Takada, Cuadros-Vargas, Impagliazzo et al., 2020). Furthermore, developing and including dispositions in competency statements is critical to advancing the use of competencies for describing the goals of tertiary education. In part, dispositions serve as a lens through which student behavior can be observed (Frezza, Clear & Clear, 2020; Watson, Besmer, Banks et al., 2021). In a professional setting, dispositions are observed in relation to conceptual and procedural knowledge (Billing, 2007). This study intends to understand and advance the development and inclusion of dispositions in competency statements.

To understand to what extent and where the dispositions proposed in the CC 2020 report (Clear & Parrish et al., 2020) appear in the literature, we formulated queries in Google Scholar for four major publication outlets. The primary audience for these outlets is educators in three computing disciplines, i.e., computer science, electrical engineering, and information systems. Appendix B shows the number of publications for each disposition that appeared in the *ACM Transactions on Computing Education* (ToCE), *IEEE Frontiers in Education* (FIE), ISCAP *Information Systems Education Journal* (ISEDJ), and ISCAP *Journal of Information Systems* (JISE).

Appendix B also shows that all dispositions have been studied, albeit to different degrees. Being collaborative or professional has been studied most frequently in these outlets whereas being meticulous or passionate has been studied least frequently. The Google Scholar search queries for these dispositions are described in Figures 2 and 3. Most of these articles were published in the last ten years; for example (Cabo, 2021; Frezza & Adams, 2020; Groeneveld, Vennekens & Aerts, 2021; Jacob, Montoya, Nguyen & Warschauer, 2022; Knestis, Cheng, Fontaine & Feng, 2022; Podeschi & DeBo, 2022; Waguespack, Yates & Babb, 2022; Wijeratne, Dennehy, Quinlivan et al., 2022) have appeared since 2019. However, many relevant articles appeared before 2010, e.g. (Bryant, Campbell & Kerr, 2003; Graham & Caso, 2002; Guthrie & Navarrete, 2004; Richards, 2009; Saulnier, 2005; Sterling & Brinthaupt, 2003; Urquiza-Fuentes & Velázquez-Iturbide, 2009; Williams & Upchurch, 2001).

From the more than 2,000 articles counted in Appendix B, we wanted to discern the areas in which the authors had focused their research on dispositions. To do this we identified the six articles that Google Scholar considered most relevant for each of the dispositions and each of the publications in Appendix B. The result of this bibliometric analysis yielded 138 articles. Thirty-four of these articles appeared in ACM ToCE, 41 in FIE, 33 in ISEDJ, and 30 in JISE. The 25 words that appeared most frequently in the titles of these articles appear in Table 1. Several of the words in Table 1 reflect the fact that the audience of our four publication outlets are educators, e.g., learning, education, students, teaching, course(s), curriculum, and knowledge. Most of the other words are commonplace when describing computing disciplines, e.g., computing, engineering, computer, information, systems, programming, science, technology, etc.

Words in Article Titles (see Appendix C)	**Word Frequency**
Learning	43
Education	25
Students	24
Computing	23
Engineering	20
Computer	18
Information	16
Systems, Teaching	15
Course, Programming, Skills	14
Curriculum, Development	13
Assessment, Courses, Student	12
Study	10
Online, Science, Technology	9
Knowledge, Professional, Project, Thinking	8

Table 4: Word frequency distribution for titles resulting from bibliometric analysis.

We also wanted to visualize the 138 article titles in word clouds to understand what themes (not just words) appeared most frequently. The first diagram in Appendix D extends Table 1 from 25 words to 50 words. The words in yellow and orange in this figure add insights beyond those derived from the data in Table 1. For example, the word "design" reminds us that computing disciplines are disciplines of design (Brooks, 2010), including information systems (Babb, Waguespack & Abdullat, 2019). The word "attitudes" reminds us that most of the published work in computing education frames competencies in the language of knowledge + skills + attitudes (Volman, van Eck, Heemskerk & Kuiper, 2005) rather than knowledge + skills + dispositions (Clear & Parrish et al., 2020; Sabin, et al., 2017). Also, that "professional" and "collaborative" are the only two dispositions that appear by name in The first diagram in Appendix D is consistent with the fact that these are the most studied dispositions listed in Table 2.

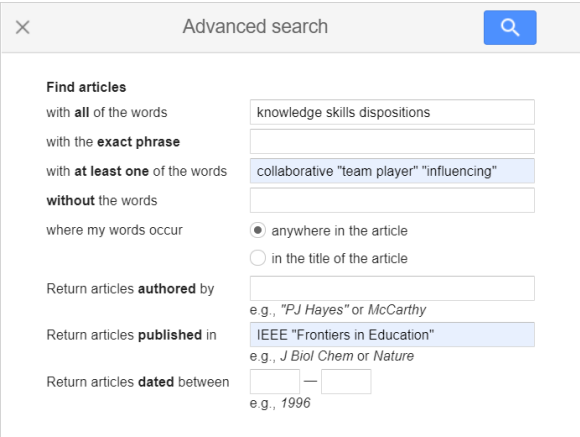
A word cloud analysis provided an additional perspective by considering both phrases and words. The most common word in our article titles – learning – isn't just about student learning. "Learning" also appears in article titles that refer to problem- or project-based learning [seven articles, e.g., (O'Grady, 2012; Woodward, Sendall & Ceccucci, 2010)], self-directed learning [two articles (Johnson, Ulseth, Smith & Fox, 2015; McCartney, Boustedt, Eckerd et al., 2016)], and learning enhanced by reflection (Barroso & Morgan, 2012) and technology (Motschnig-Pitrik, Kabicher, Figl & Santos, 2007). We saw in Table 1 that "information" (row seven) and "systems" (row eight) occur at about the same frequency. However, these words often appear as part of the phrase "information systems" (IS), referring to IS course(s), IS curriculum, and IS education, for example, as in (Saulnier, 2009; Nwokeji, Stachel, Holmes & Orji, 2019; Topi, 2019).

4. DISPOSITIONS IN IS2020

The IS 2020 report (Leidig & Salmela et al., 2020, p. 38) argues that dispositions are essential components of competency statements, because there "is often a character and quality of application inherent in the domain and context of application that suggests the qualifiers inherent to that domain." IS2020 goes on to refer to the *computing-of-x* and *x-computing* phenomena – where most non-computing disciplines will recognize an indispensable need for a computing element within them – and suggests that demand for the contextualized use of knowledge-skill pairing in IS will continue to rise in the years ahead (p. 38). This will be necessary to support computing as it becomes ubiquitous across nearly all aspects of society, organizations, government, and business, in a process often referred to as digitalization. Dispositions are the adjectives that bring the socio-technical aspects of technology use to bear" (pp. 38-39). Leidig and Salmela et al. (2020) go on to enumerate 178 competencies in the report (pp. 95-182), including their knowledge-skill pairs and "key dispositions" (p. 97).

For each of the dispositions in Appendix B, we ran Google Scholar queries to count the papers in

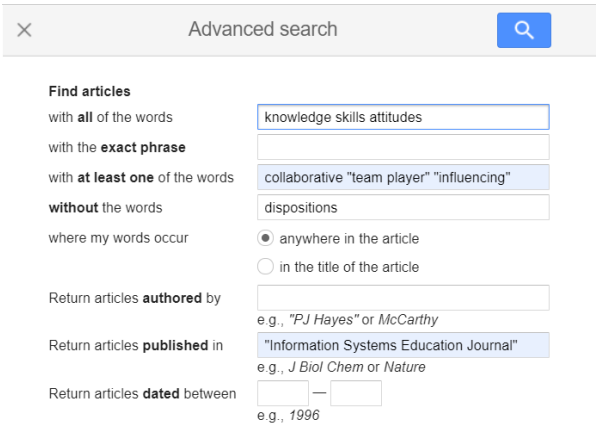
each of our four publication outlets. For each disposition, we included synonyms and adjacent concepts from Clear & Parrish et al. (2020) and Leidig & Salmela et al. (2020) in the queries. We also distinguished articles that included the term "attitudes" as an alternative to "dispositions." For example, Figure 10 shows the knowledge, skills, and dispositions (K-S-D) query *for collaborative in IEEE Frontiers in Education*. Similarly, Figure 11 shows the knowledge, skills, and attitudes (K-S-A) query for *collaborative in the Information Systems Education Journal.* Finally, Table 2 lists the dispositions, synonyms, and adjacent concepts used in these 88 queries.



knowledge skills dispositions collaborative OR "team player" OR influencing source: IEEE source: "Frontiers in Education"

Figure 10: Example user interface and Google Scholar syntax for K-S-D query for *collaborative*.

To help faculty, administrators, and professionals make sense of so many key dispositions, the IS 2020 report authors group them into the six competency realms shown in Figure 4. Since each competency names three key dispositions, Figure 4 shows 534 in total (the numbers in parentheses). For example, Systems Development specifies that a subset of the 11 dispositions in Table 2 are "key" for the 64 competencies within this competency realm. Hence, Systems Development explicitly requires 192 key dispositions, in aggregate, because each of these competencies includes three key dispositions. These dispositions, when tallied, appear in the proportions shown in Figure 4. A further elaboration in the Systems Development realm is shown in Figure 5.



knowledge skills attitudes collaborative OR "team player" OR influencing dispositions source: "Information Systems Education Journal"

Figure 11: Example user interface and Google Scholar syntax for K-S-A query for *collaborative*.

Disposition	Synonyms and Adjacent Concepts
Adaptable	flexible, agile
Collaborative	team player, influencing
Inventive	exploratory, curious
Meticulous	attentive to detail, attention to detail
Passionate	with passion, with conviction
Proactive	with initiative, self-starter
Professional	with professionalism, work ethic
Purpose-driven	purposeful, purposefully engaged
Responsible	with judgment, with discretion, rectitude
Responsive	respectful
Self-directed	self-motivated

Table 5: Dispositions, synonyms, and adjacent concepts used in queries to identify relevant articles.

Note that Figure 6 shows that the report suggests that being purpose-driven, meticulous, inventive, and self-directed are most important when learning and practicing the competencies within Systems Development.

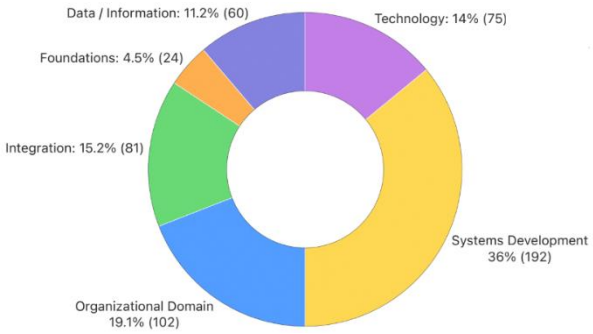


Figure 12: Distribution of key dispositions among six IS 2020 competency realms.

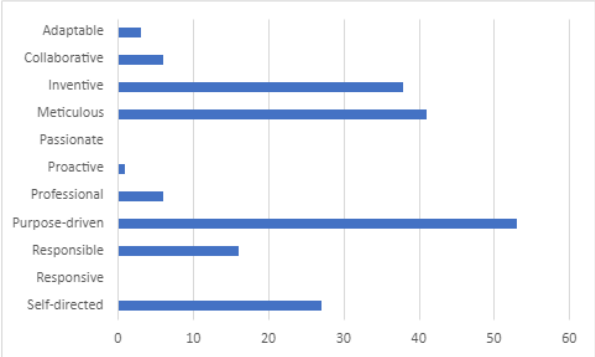


Figure 13: Distribution of key dispositions within the IS 2020 Systems Development competency realm.

Figure 6 shows the distribution of the 11 CC 2020 dispositions across all six competency realms in Figure 4. For IS as a whole, as envisioned by Leidig and Salmela et al. (2020), the most important key dispositions (in decreasing frequency of occurrence on pp. 95-182) are being purpose-driven, self-directed, meticulous, and inventive. The remaining seven dispositions occur between 51 times (professional) and one time (passionate).

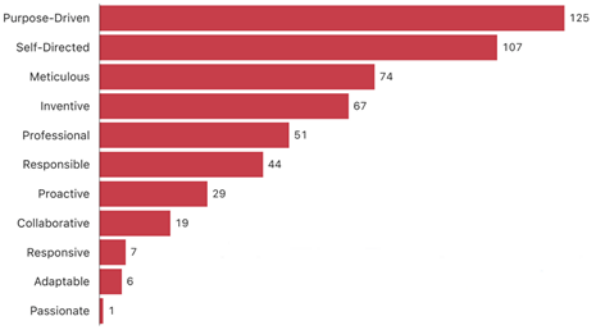


Figure 14: Aggregate distribution of key dispositions across all six IS 2020 competency realms.

5. THE CHALLENGE OF DISPOSITION IN COMPETENCY SPECIFICATION

[CC2020] offers a list of eleven prospective dispositions derived from the literature to round out the knowledge, skills, dispositions as components of competency. Disposition as an intrinsic component of competency represents the opportunity [for the competency author] to clearly express institutional and programmatic values expected in a graduate's work. Dispositional expectations enrich the description/assessment of competency and/or the related pedagogy. Ascribing a disposition to a competency indicates a clear commitment to self-reflection and a sober examination of mission, goals, and objectives to reach the clarity that enables its effective integration in curriculum design, the agency of pedagogy, and the character of professionalism. (CC2020 p. 134)

Indeed, the CC2020 competency model offers an enhanced and enlightened framework to detail technical expertise. It also expresses a purposeful intension of professionalism to serve society. The transliteration of the knowledge-centric aspects of past, traditional curricular descriptions is less fraught with challenge than the reflective process of discernment and specification of professional conduct and character in the medium of dispositions. It is the latter that we wish to explore in this paper.

Mindset Dimension – In cognitive psychology, a mindset represents the cognitive processes activated in response to a given task. (French & Chang, 2016) In decision theory and general systems theory, a mindset is a set of assumptions, methods, or notions held by one or more people or groups of people. (Cambridge English Dictionary)

In the adapted quotations that follow, the design theorist refers to *mindset* as "appreciative system" and *practitioner* as "stakeholder." (Waguespack, 2019, p. 27).

A [practitioner]'s [mindset] cues what facts to attend to in any particular experience while that same experience results in a learning effect that informs, reinforces and refines the [practitioner]'s apprehension of value and significance, thus altering that [mindset].

[A… mindset] is a complex and emergent agency of choice in [practitioner] behavior situated in a social context.

[Practitioners] possess [mindsets] individually as their experience and judgements are personal. In a community of [practitioners] there are recurrent threads of experience, shared knowledge, and commonly held norms that proceed from culture: social, professional, religious, or intellectual. A culture commonly promulgates a standard of appreciation that facilitates a shared cooperation and collaborative decision-making that reinforces community – intentionally or unintentionally. Formal education, professional training, and certification, as well as religious communities, all purposefully foster aspects of shared culture to shape community identity, goals, and expectations of behavior. Shared culture is a basic defining aspect of any community – formal or informal. Any human conception of satisfaction is founded upon [a mindset] that is subject in part to the subjective interpretation of norms and aspirations – individual and cultural metaphors.

Figures 7, 8, and 9 use mindmaps to extend the juxtaposition of the mindset dimension of the disposition with both the competency and the competency's task environment and context.

Figure 15: Mindset dimension of professionalism

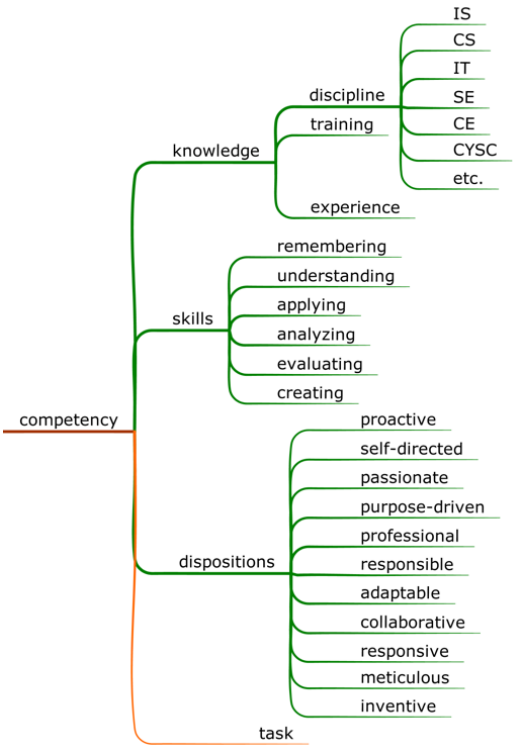


Figure 16: Competency dimension

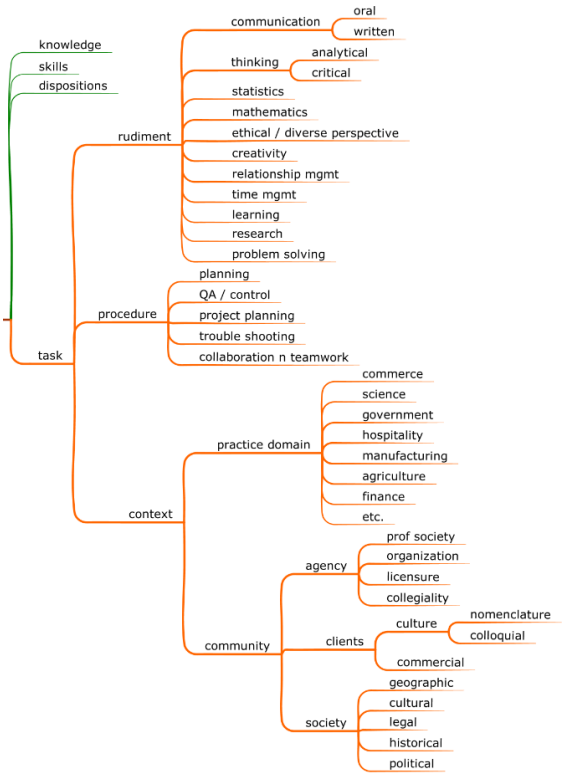


Figure 9*:* Competency: task aspect

6. THE REWARD OF DISPOSITION IN COMPETENCY SPECIFICATION

We argue that disposition specification provides a perspective of "meaning" that enables and activates the greatest promise of the consistency of a competency's availability and activation. As such, we claim that the greatest opportunity in the competency model is the degree to which dispositions, forged in practice, produce desirable behavior and outcomes. The connection between behavior and outcomes is framed by tasks and performance outcome expectations. The proof of a competency lies within the expected outcomes, artifacts, and action inherent in the competency. Time afforded to developing dispositions may well result in greater connection to the expected outcomes that the task environment desires.

To bolster this assertion, we take the position that Information Systems is inherently a design discipline where the appreciative system of the satisfaction of the "clients" requires an exquisite balance between feasibility and efficiency that demands dispositional maturity and acuity. As a designer, the IS professional, shaped by the performance expectations and responsibilities of competency, seeks a symmetric balance of quality and technical choice properties in a designed artifact. Dispositions, even the nascent list offered in the CC2020 report, provide the IS professional with an opportunity to balance motive and opportunity; to bridge the natural and artificial realms, and to explore and cultivate notions of satisfaction. This balance, perhaps the art of satisficing, becomes necessary when available models of satisfaction are emergent and incomplete, thus full client satisfaction is fleeting.

To satisfice is to recognize tradeoffs and engage in the design of generative metaphor. This reflects an ability to "critically think" and develop design actions in the face of uncertainty where clear paths to a satisfactory design outcome is not clear. McGilcrist (2019) and Lakoff (1993) suggest that to design amidst uncertainty is to engage in pattern recognition that is only possible via reference metaphors – to extrapolate from the known to categorize the emergent. An architecture or design concept will anchor the possible moves from one frame of reference for future possible design choices. Fred Brooks (1995) suggests that metaphor maps similar and dissimilar contexts and separates essence and accident. Extensions from metaphor is the constant process of situating emergent phenomenon into categorical "buckets" of the known.

These are the skills that bring robustness (does it endure in its construction and withstand change?) and vitality (does it continue to thrive?) to the IS professional's designs and the necessary grounding for these competencies lies within dispositions.

To do so is to embrace, as a regular practice, the esoteric. The discipline and habit to do so is a dispositive (disposition-related) challenge for the design of a competency-based curriculum. Dispositions hold the key to long-term development and mastery, in praxis, of the metaphor, technical rationality, appreciative systems, and mastery medium of construction required for robustness and vitality as a professional.

7. DISPOSITIONS ARE VITAL FOR BECOMING

An important goal here is that the reader considers the inclusion of dispositions as an element of the competency model that is critical to effective competency authoring. The greatest potential for the inclusion and use of dispositions would be in their ability to sustain and carry the knowledge and skills dimension of the competency model forward. In this paper, we have examined this premise by extrapolating the work of Scanlon (2011) about *becoming* as it relates to *professionalizing*.

Conceptually, *professionalizing* is a process that is fueled from a synthesis of the components of a competency – knowledge, skills, and disposition – over time and through experience. As such, Scanlon's (2011) work on professionalizing may provide further insight as it provides an archetypal model of a professional as having a body of knowledge based on abstract concepts and theories. However, the application of these concepts and theories requires the exercise of considerable discretion, an occupationally-controlled division of labor, credentialing procedures, training programs, and an ethic that encourages doing good rather than achieving economic gain.

Scanlon (2011) advocates that a professional's high social esteem is based on the provision of expert services from a position of power, trust, and discretion. Furthermore, it is proposed that professionals have fiduciary responsibilities to advance client well-being and to take responsibility for the governance and regulation of activities of their profession. Finally, Scanlon

(2011) suggests that engagement in lifelong learning to better serve client needs is an essential aspect of maintaining fidelity and trust. While professionalism of this sort is not yet fully realized in computing disciplines, dispositions are fundamental to professionalizing. Thus, the maturity arc of "becoming" for computing must embrace the dispositive dimension that goes beyond technical rationality (Schön, 1983, 1987). The "becoming" that Scanlon (2011) describes appears to comport well with the possibilities and opportunities available when explicit focus is afforded to dispositions in a competency specification and a competency-based curriculum.

8. CONCLUDING REMARKS

This paper has attempted to clarify that the dispositive dimension is the matter most important to successful use of a competency based curricular approach in IS curriculum design. One argument for this being the case is that dispositions are the newest and most untested element of the competency model. As such, the means for designing curricula for this, as well as measurement approaches to monitor continuous improvement, may be less developed. Given the esoteric nature of the dispositive dimension, we have articulated our concern that the true promise of dispositions may be under-addressed in the development of competency-based computing curricula.

We have not taken a prescriptive approach here where best practices are articulated and tested strategies are sold. Rather, what we have attempted here is to advocate for extra care, further study, and cautious focus on the novelty of dispositions given the history of computing curricula reports and models. It is possible that embracing further study and comprehension of dispositions can lead to much-needed institutionalization of professionalism and development (Berger and Luckmann, 1967; Schutz, 1962) of the Information Systems discipline itself.

As such, we suggest that the ability to successfully develop a competency-based approach to Information Systems curricula depends more on dispositions (orientations, behaviors, and instincts in our students) than on technologies and tools that facilitate our designs and solutions. It is likely that the positive development of dispositions will outlast the ongoing changes in technologies. This is the promise we see in the assimilation of dispositions to nurture the "becoming" of our students.

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Appendix A — CC2020 Prospective Dispositions

Disposition	Elaboration
D-1 Proactive	With Initiative / Self-Starter Shows independence. Ability to assess and start activities independently without needing to be told what to do. Willing to take the lead, not waiting for others to start activities or wait for instructions.
D-2 Self-Directed	Self-motivated / Self-Directed Demonstrates determination to sustain efforts to continue tasks. Direction from others is not required to continue a task toward its desired ends.
D-3 Passionate	With Passion / Conviction Strongly committed to and enthusiastic about the realization of the task or goal. Makes the compelling case for the success and benefits of task, project, team or means of achieving goals.
D-4 Purpose-Driven	Purposefully engaged / Purposefulness Goal-directed, intentionally acting and committed to achieve organizational and project goals. Reflects an attitude towards the organizational goals served by decisions, work or work products. e.g., Business acumen.
D-5 Professional	With Professionalism / Work ethic. Reflecting qualities connected with trained and skilled people: Acting honestly, with integrity, commitment, determination and dedication to what is required to achieve a task.
D-6 Responsible	With Judgement / Discretion / Responsible / Rectitude Reflect on conditions and concerns, then acting according to what is appropriate to the situation. Making responsible assessments and taking actions using professional knowledge, experience, understanding and common sense. E.g., Responsibility, Professional astuteness.
D-7 Adaptable	Adaptable / Flexible / Agile Ability or willingness to adjust approach in response to changing conditions or needs.
D-8 Collaborative	Collaborative / Team Player / Influencing Willingness to work with others; engaging appropriate involvement of other persons and organizations helpful to the task. Striving to be respectful and productive in achieving a common goal.
D-9 Responsive	Responsive / Respectful Reacting quickly and positively. Respecting the timing needs for communication and actions needed to achieve the goals of the work.
D-10 Meticulous	Attentive to Detail Achieves thoroughness and accuracy when accomplishing a task through concern for relevant details.
D-11 Inventive	Exploratory / Inventive Looking beyond simple solutions; Examining alternative ideas and solutions; seeks, produces and integrates appropriate alternative

Appendix B. Publications that mention disposition (or attitude), knowledge, and skills in four outlets.

Disposition	Publications				Publication (Total)
	ToCE (ACM)	FIE (IEEE)	ISEDJ (ISCAP)	JISE (ISCAP)	
Adaptable	52	243	34	56	385
Collaborative	155	867	91	149	1,282
Inventive	73	315	41	80	509
Meticulous	6	17	2	5	30
Passionate	8	34	2	1	45
Proactive	14	103	19	22	158
Professional	117	644	62	99	922
Purpose-driven	13	66	18	9	106
Responsible	40	301	27	52	420
Responsive	31	110	11	21	173
Self-directed	33	187	28	29	277

Table 3

Appendix C. URLs for, and dispositions within, unique articles extracted from "Top 6" articles returned by Google Scholar for eleven dispositions in Appendix B.

Unique Article URL	Dispositions from Unique Article	Title
http://jise.org/volume14/n1/JISEv14n1p41.html	Adaptable, Responsive	Impact of Web Based Flexible Learning on Academic Performance in Information Systems
http://jise.org/Volume14/n4/JISEv14n4p417.html	Meticulous	Faculty and Industry Conceptions of Successful Computer Programmers
http://jise.org/volume15/n2/JISEv15n2p181.html	Inventive	Project Management Courses in IS Graduate Programs: What is Being Taught?
http://jise.org/volume18/n3/JISEv18n3p357.html	Purpose-driven	Teaching Practices for Effective Cooperative Learning in an Online Learning Environment (OLE)
http://jise.org/volume18/n4/JISEv18n4p469.html	Professional	Requisite Skills and Knowledge for Entry-level IT Auditors
http://jise.org/Volume19/n1/JISEv19n1p111.html	Inventive, Self-directed	Assessing Individual-level Factors Supporting Student Intrinsic Motivation in Online Discussions: A Qualitative Study
http://jise.org/volume20/n2/JISEv20n2p199.html	Responsive	Selecting a Virtual World Platform for Learning
http://jise.org/volume20/n2/JISEv20n2p249.html	Purpose-driven	Action Learning with Second Life - A Pilot Study
http://jise.org/volume20/n3/JISEv20n3p289.html	Inventive	An Exploratory Review of Design Principles in Constructivist Gaming Learning Environments
http://jise.org/Volume20/n3/JISEv20n3p369.html	Adaptable, Responsible, Responsive	Practicing Learner-Centered Teaching: Pedagogical Design and Assessment of a Second Life Project
http://jise.org/Volume21/n2/JISEv21n2p203.html	Collaborative	Are Men More Technology-Oriented Than Women? The Role of Gender on the Development of General Computer Self-Efficacy of College Students
http://jise.org/Volume21/n3/JISEv21n3p323.html	Collaborative, Responsible, Self-directed	A Systematic Review of Developing Team Competencies in Information Systems Education
http://jise.org/Volume22/n1/JISEv22n1p31.html	Adaptable, Collaborative, Professional, Responsible	Curriculum Mapping as a Tool for Continuous Improvement of IS Curriculum
http://jise.org/volume24/n1/JISEv24n1p41.html	Responsive	The Need to Address Mobile Device Security in the Higher Education IT Curriculum
http://jise.org/Volume25/n2/JISEv25n2p125.html	Self-directed	A Case Study of Instructor Scaffolding Using Web 2.0 Tools to Teach Social Informatics
http://jise.org/Volume30/n1/JISEv30n1p1.html	Professional, Responsible	Reflections on the Current State and Future of Information Systems Education
https://aisel.aisnet.org/jise/vol16/iss3/8/	Proactive, Responsive	A Competency Based MSIS Curriculum
https://aisel.aisnet.org/jise/vol19/iss2/11/	Adaptable, Proactive, Professional	Integrating Soft Skills Assessment through University, College, and Programmatic Efforts at an AACSB Accredited Institution

https://aisel.aisnet.org/jise/vol20/iss1/8/	Meticulous	Designing IS Curricula for Practical Relevance: Applying Baseball's "Moneyball" Theory
https://aisel.aisnet.org/jise/vol20/iss3/10/	Inventive	Knowledge and Skill Requirements for Entry-Level Information Technology Workers: A Comparison of Industry and Academia
https://aisel.aisnet.org/jise/vol21/iss2/5/	Collaborative	The Importance of Emphasizing Individual Learning in the "Collaborative Learning Era"
https://aisel.aisnet.org/jise/vol23/iss1/8/	Meticulous	An Alumni Assessment of MIS Related Job Skill Importance and Skill Gaps
https://aisel.aisnet.org/jise/vol23/iss2/8/	Collaborative, Inventive, Professional, Responsible	Knowledge and Skill Requirements for Entry-Level IT Workers: A Longitudinal Study
https://aisel.aisnet.org/jise/vol24/iss2/6/	Self-directed	Teaching Introductory Programming to IS Students: The Impact of Teaching Approaches on Learning Performance
https://aisel.aisnet.org/jise/vol25/iss2/4/	Professional, Responsive, Self-directed	A Case Study of Instructor Scaffolding Using Web 2.0 Tools to Teach Social Informatics
https://aisel.aisnet.org/jise/vol28/iss1/5/	Passionate, Proactive	An Integrated Learning Approach to Teaching an Undergraduate Information Systems Course
https://aisel.aisnet.org/jise/vol29/iss2/2/	Adaptable, Self-directed	Do Pair Programming Approaches Transcend Coding? Measuring Agile Attitudes in Diverse Information Systems Courses
https://aisel.aisnet.org/jise/vol30/iss4/5/	Adaptable, Collaborative, Inventive, Proactive, Responsible	Teaching Critical Thinking, Problem Solving, and Design Thinking: Preparing IS Students for the Future
https://aisel.aisnet.org/jise/vol33/iss1/4/	Purpose-driven	Engaging Government-Industry-University Partnerships to Further Gender Equity in STEM Workforce Education Through Technology and Information System Learning Tools
https://aisel.aisnet.org/jise/vol33/iss1/8/	Purpose-driven	Learning Without Limits: Identifying the Barriers and Enablers to Equality, Diversity, and Inclusion in IS Education
https://dl.acm.org/doi/abs/10.1145/1513593.1513595	Purpose-driven	Designing Project-Based Courses with a Focus on Group Formation and Assessment
https://dl.acm.org/doi/abs/10.1145/1538234.1538236	Inventive	A Survey of Successful Evaluations of Program Visualization and Algorithm Animation Systems
https://dl.acm.org/doi/abs/10.1145/1993069.1993073	Purpose-driven, Responsive	Computational Thinking and Expository Writing in the Middle School
https://dl.acm.org/doi/abs/10.1145/2037276.2037283	Proactive	Universal Design: Implications for Computing Education
https://dl.acm.org/doi/abs/10.1145/2160547.2160550	Purpose-driven	The Curriculum Planning Process for Undergraduate Game Degree Programs in the United Kingdom and United States
https://dl.acm.org/doi/abs/10.1145/2275597.2275599	Inventive	Practical Problem-Based Learning in Computing Education

https://dl.acm.org/doi/abs/10.1145/2382564.2382567	Responsive	When Life and Learning Do Not Fit: Challenges of Workload and Communication in Introductory Computer Science Online
https://dl.acm.org/doi/abs/10.1145/2499947.2499951	Collaborative	Talking about code: Integrating pedagogical code reviews into early computing courses
https://dl.acm.org/doi/abs/10.1145/2534971	Collaborative, Inventive, Responsible	Introducing Discipline-Based Computing in Undergraduate Engineering Education
https://dl.acm.org/doi/abs/10.1145/2576872	Professional	Computational Thinking in Elementary and Secondary Teacher Education
https://dl.acm.org/doi/abs/10.1145/2662412	Proactive	Teaching Introductory Programming: A Quantitative Evaluation of Different Approaches
https://dl.acm.org/doi/abs/10.1145/2737596	Proactive	Translating Principles of Effective Feedback for Students into the CS1 Context
https://dl.acm.org/doi/abs/10.1145/2747008	Self-directed	Why Computing Students Learn on Their Own: Motivation for Self-Directed Learning of Computing
https://dl.acm.org/doi/abs/10.1145/2793507	Collaborative, Proactive	A Method to Analyze Computer Science Students' Teamwork in Online Collaborative Learning Environments
https://dl.acm.org/doi/abs/10.1145/2996201	Adaptable, Collaborative, Meticulous, Professional	A Meta-Analysis of Pair-Programming in Computer Programming Courses: Implications for Educational Practice
https://dl.acm.org/doi/abs/10.1145/3077617	Professional	Early Lessons from Evaluation of Computer Science Teacher Professional Development in Google's CS4HS Program
https://dl.acm.org/doi/abs/10.1145/3231710	Collaborative, Inventive, Professional, Responsible	Assessing Students' IT Professional Values in a Global Project Setting
https://dl.acm.org/doi/abs/10.1145/3277568	Self-directed	Searching for Global Employability: Can Students Capitalize on Enabling Learning Environments?
https://dl.acm.org/doi/abs/10.1145/3283070	Meticulous, Passionate	Identifying Pathways to Computer Science: The Long-Term Impact of Short-Term Game Programming Outreach Interventions
https://dl.acm.org/doi/abs/10.1145/3283071	Meticulous	Transformative and Troublesome? Students' and Professional Programmers' Perspectives on Difficult Concepts in Programming
https://dl.acm.org/doi/abs/10.1145/3294011	Adaptable, Collaborative, Inventive, Professional, Responsible, Responsive	Global Software Engineering Education Practice Continuum Special Issue of the ACM Transactions on Computing Education
https://dl.acm.org/doi/abs/10.1145/3322210	Responsive	Pedagogy that Supports Computer Science for *All*
https://dl.acm.org/doi/abs/10.1145/3381911	Passionate, Self-directed	Understanding the Motivations of Final-year Computing Undergraduates for Considering Accessibility

https://dl.acm.org/doi/abs/10.1145/3421254	Adaptable, Inventive, Professional	Knowledge, Skills, and Abilities for Specialized Curricula in Cyber Defense: Results from Interviews with Cyber Professionals
https://dl.acm.org/doi/abs/10.1145/3487052	Passionate, Proactive	A Sociocultural Perspective on Computer Science Capital and its Pedagogical Implications in Computer Science Education
https://dl.acm.org/doi/abs/10.1145/3487054	Adaptable, Passionate, Responsive, Self-directed	Interest Development Theory in Computing Education: A Framework and Toolkit for Researchers and Designers
https://dl.acm.org/doi/abs/10.1145/3500918	Responsive	Examining the What, Why, and How of Multilingual Student Identity Development in Computer Science
https://dl.acm.org/doi/abs/10.1145/3517134	Responsible	A Qualitative Study of Experienced Course Coordinators' Perspectives on Assessment in Introductory Programming Courses for Non-CS Majors
https://dl.acm.org/doi/full/10.1145/3453653	Passionate, Responsible	"What Happens to the Raspado man in a Cash-free Society?": Teaching and Learning Socially Responsible Computing
https://dl.acm.org/doi/full/10.1145/3458037	Passionate	Intercultural Computing Education: Toward Justice Across Difference
https://dl.acm.org/doi/full/10.1145/3464431	Adaptable, Meticulous, Responsible, Self-directed	Identifying Non-Technical Skill Gaps in Software Engineering Education: What Experts Expect But Students Don't Learn
https://dl.acm.org/doi/full/10.1145/3471573	Purpose-driven	Coding with Minecraft: The Development of Middle School Students' Computational Thinking
https://dl.acm.org/doi/full/10.1145/3485062	Self-directed	Toward a Framework for Teaching Artificial Intelligence to a Higher Education Audience
https://dl.acm.org/doi/full/10.1145/3511886	Adaptable	Adaptive Assessment and Content Recommendation in Online Programming Courses: On the Use of Elo-rating
https://ieeexplore.ieee.org/abstract/document/1158168	Meticulous	Fostering and managing curriculum change and innovation
https://ieeexplore.ieee.org/abstract/document/1158180	Inventive	Measuring engineering freshman attitudes and perceptions of their first year academic experience: the continuing development of two assessment instruments
https://ieeexplore.ieee.org/abstract/document/4117031	Responsive	Participatory Action Research in a Blended Learning Course on Project Management Soft Skills
https://ieeexplore.ieee.org/abstract/document/4417890	Responsive	Person centered, technology enhanced learning in action: Action research in a course on organizational development
https://ieeexplore.ieee.org/abstract/document/4720400	Inventive	An exploratory factor analysis of the Pittsburgh Freshman Engineering Attitudes Survey
https://ieeexplore.ieee.org/abstract/document/5673411	Proactive	Development of an assessment instrument to examine outcomes of entrepreneurship education on engineering students

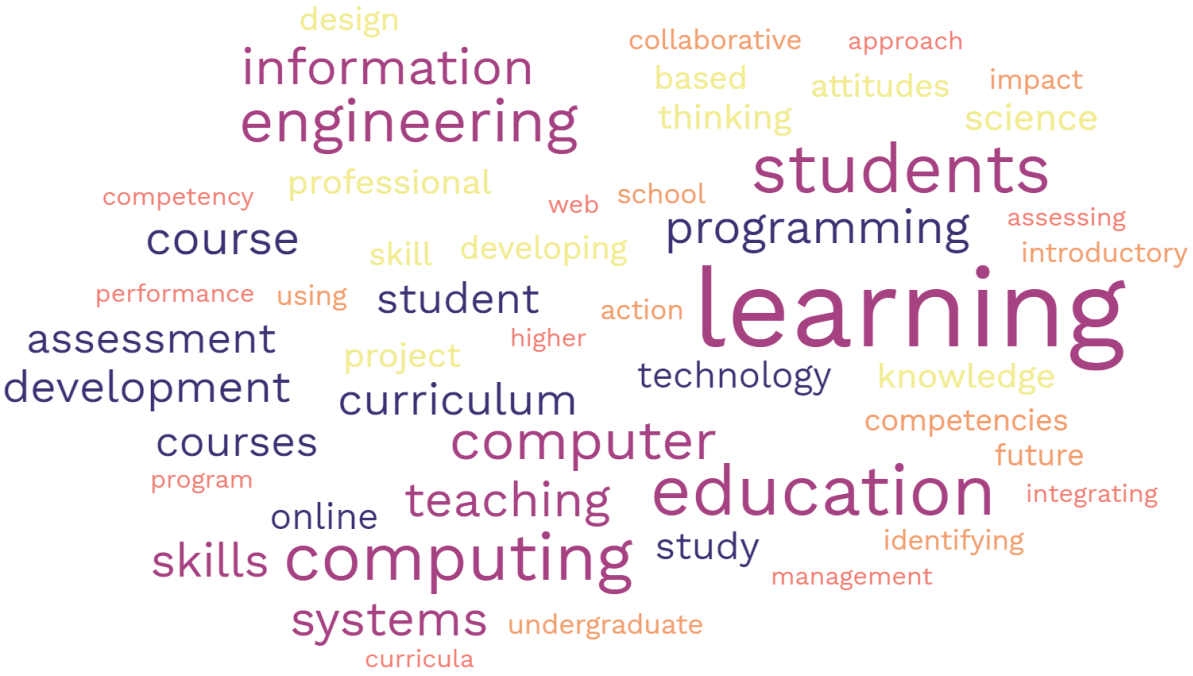
https://ieeexplore.ieee.org/abstract/document/6462335	Purpose-driven	Utilizing reflection in projects for increased metacognition and enhanced learning
https://ieeexplore.ieee.org/abstract/document/6462410	Collaborative	Student reflections on Collaborative Technology in a globally distributed student project
https://ieeexplore.ieee.org/abstract/document/6462502	Passionate	Identifying the impact of the SPIRIT program in student knowledge, attitudes, and perceptions toward computing careers
https://ieeexplore.ieee.org/abstract/document/6684830	Self-directed	PBL in teaching computing: An overview of the last 15 years
https://ieeexplore.ieee.org/abstract/document/6684939	Purpose-driven	Should Makers be the engineers of the future?
https://ieeexplore.ieee.org/abstract/document/6685132	Adaptable	Peer assessment in experiential learning Assessing tacit and explicit skills in agile software engineering capstone projects
https://ieeexplore.ieee.org/abstract/document/7044169	Adaptable, Proactive	Transversal competencies of electrical and computing engineers considering market demand
https://ieeexplore.ieee.org/abstract/document/7044218	Purpose-driven	Might young makers be the engineers of the future?
https://ieeexplore.ieee.org/abstract/document/7344028	Professional, Self-directed	The impacts of project based learning on self-directed learning and professional skill attainment: A comparison of project based learning to traditional engineering education
https://ieeexplore.ieee.org/abstract/document/7344057	Professional	An exploration of Bloom's knowledge, skills, and affective-based goals in promoting development of freshmen engineering students' professional identities
https://ieeexplore.ieee.org/abstract/document/7344118	Professional	Teamwork attitude, interest, and self-efficacy: Their implications for teaching teamwork skills to engineering students
https://ieeexplore.ieee.org/abstract/document/7344401	Proactive	Mapping career success competencies to engineering leadership capabilities
https://ieeexplore.ieee.org/abstract/document/7344408	Adaptable	Rapid improvement of students' soft-skills based on an agile-process approach
https://ieeexplore.ieee.org/abstract/document/736846	Collaborative	Pupils' attitudes to technology: a review of studies which have a bearing on the attitudes which freshmen bring with them to engineering
https://ieeexplore.ieee.org/abstract/document/738551	Responsible	Stimulating creativity: teaching engineers to be innovators
https://ieeexplore.ieee.org/abstract/document/7757677	Inventive	Development of an assessment for measuring middle school student attitudes towards robotics activities
https://ieeexplore.ieee.org/abstract/document/7757714	Passionate	Actualizing students' prior knowledge in engineering education
https://ieeexplore.ieee.org/abstract/document/7757720	Meticulous	Engineering and Computational Thinking talent in middle school students: A framework for defining and recognizing student affinities
https://ieeexplore.ieee.org/abstract/document/839080	Proactive, Self-directed	Developing the attribute of lifelong learning

https://ieeexplore.ieee.org/abstract/document/839085	Collaborative	Interactive dynamics: effects of student-centered activities on learning
https://ieeexplore.ieee.org/abstract/document/840438	Adaptable, Responsible	Engineering education curriculum: innovations to get a more flexible and dynamic course
https://ieeexplore.ieee.org/abstract/document/841732	Responsible	A cooperative model for orienting students to research groups
https://ieeexplore.ieee.org/abstract/document/8659152	Responsive	Authentic Knowledge, Learning Outcomes, and Professional Identity: A Mixed-Methods Study of a Successful Engineering Course
https://ieeexplore.ieee.org/abstract/document/9028350	Inventive	Addressing the Shortage of Big Data Skills with Inter-Disciplinary Big Data Curriculum
https://ieeexplore.ieee.org/abstract/document/9028355	Purpose-driven	Developing and Assessing Engineering Competencies at Experiential Learning Spaces
https://ieeexplore.ieee.org/abstract/document/9028408	Collaborative	Teaching Cybersecurity Using Guided Inquiry Collaborative Learning
https://ieeexplore.ieee.org/abstract/document/9028613	Collaborative, Meticulous, Passionate	Competencies Required for Developing Computer and Information Systems Curriculum
https://ieeexplore.ieee.org/abstract/document/9028621	Passionate	On the role of industry contact on the motivation and professional development of engineering students
https://ieeexplore.ieee.org/abstract/document/9273973	Adaptable, Collaborative, Inventive, Meticulous, Passionate, Proactive, Professional, Purpose-driven Responsible, Responsive, Self-directed	Unpacking Dispositions in the CC2020 Computing Curriculum Overview Report
https://ieeexplore.ieee.org/abstract/document/9274058	Meticulous, Professional, Purpose-driven, Responsible, Self-directed	Bridging Professionalism: Dispositions as Means for Relating Competency across Disciplines
https://ieeexplore.ieee.org/abstract/document/9274197	Responsive	Application of Adult Learning Theory to STEM Education in Online Learning Environment
https://ieeexplore.ieee.org/abstract/document/9274269	Passionate	Undergraduate Civil Engineering Students' Perspectives on Skills for Future Success
https://ieeexplore.ieee.org/abstract/document/9274288	Adaptable, Inventive, Proactive, Professional, Responsible, Self-directed	From Knowledge-based to Competency-based Computing Education: Future Directions
https://ieeexplore.ieee.org/abstract/document/9637302	Meticulous	Use of Machine Learning to Identify Predictors of Student Performance in Writing Viable Computer Programs with Repetition Loops and Methods

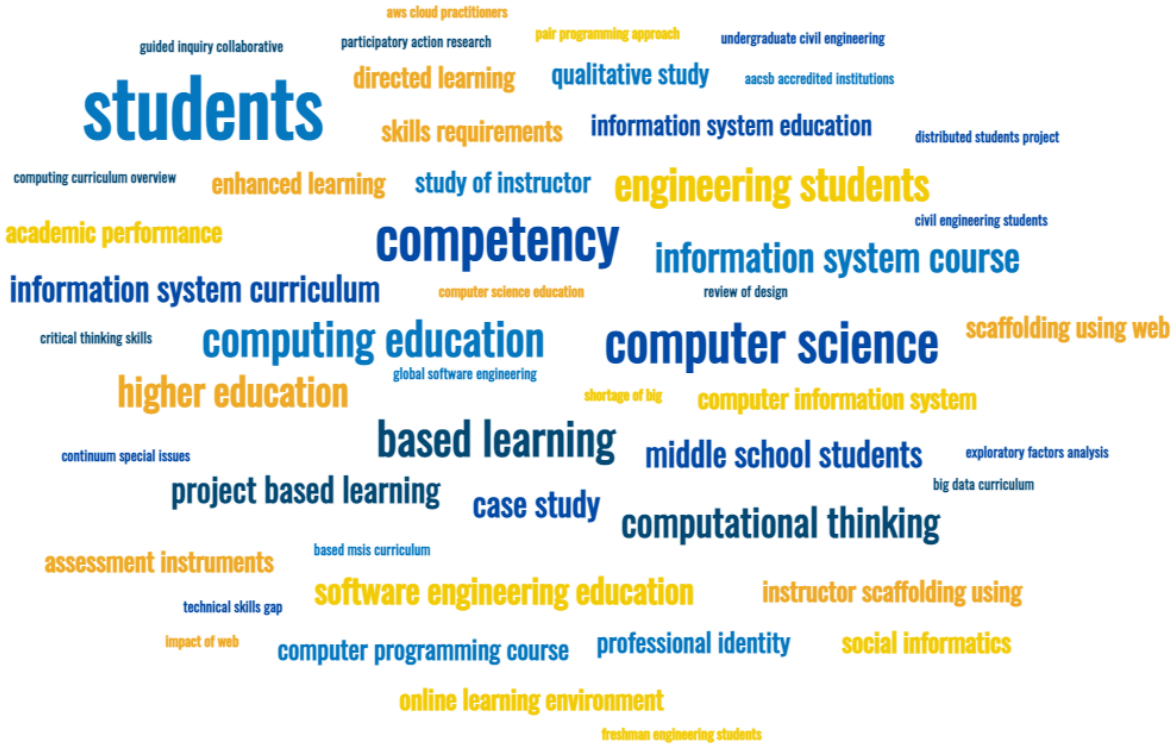
https://ieeexplore.ieee.org/abstract/document/963882	Responsive	Extreme programming for software engineering education?
https://eric.ed.gov/?id=EJ1137403	Purpose-driven	Where Do Student Outcomes Begin? Developing Professional and Personal Management Skills as a Strategy for Student Success in the First Computing Course and Beyond
https://eric.ed.gov/?id=EJ1146918	Self-directed	Critical Thinking Measurement in ICT
https://eric.ed.gov/?id=EJ1146931	Proactive	A Value Chain Approach for Attracting, Educating, and Transitioning Students to the IT Profession
https://eric.ed.gov/?id=EJ1146969	Collaborative, Professional	Integrating Soft Skill Competencies through Project-Based Learning across the Information Systems Curriculum
https://eric.ed.gov/?id=EJ1147031	Inventive	Factors That Influence Transfer of Learning from the Online Environment
https://eric.ed.gov/?id=EJ1258150	Proactive, Self-directed	Encouraging Lifelong Learning through Tech Explorations
https://eric.ed.gov/?id=EJ1258227	Professional, Purpose-driven, Responsible	eXtensible Computing Curriculum Reporting Language (XCCRL)
https://eric.ed.gov/?id=EJ1297703	Proactive	Effects of Teaching and Practice of Time Management Skills on Academic Performance in Computer Information Systems Courses
https://eric.ed.gov/?id=EJ1301236	Inventive	Cognitive Learning Strategies in an Introductory Computer Programming Course
https://eric.ed.gov/?id=EJ1329490	Responsive	Investigating Student Behavior in an Interdisciplinary Computing Capstone Course
https://isedj.org/2/12/ISEDJ.2(12).Guthrie.pdf	Purpose-driven, Responsive	Service-Learning Impact on IS Students in a Web Development Course
https://isedj.org/2012-10/N4/ISEDJv10n4p41.html	Inventive	A Case Study: Applying Critical Thinking Skills to Computer Science and Technology
https://isedj.org/2013-11/N3/ISEDJv11n3p42.html	Collaborative	Collaborative learning in online courses: Exploring students' perceptions
https://isedj.org/2013-11/N3/ISEDJv11n3p79.html	Professional	Reassessing the Skills Required of Graduates of an Information Systems Program: An Updated Analysis
https://isedj.org/2014-12/n1/ISEDJv12n1p42.html	Responsible	Confronting the Issues of Programming In Information Systems Curricula: The Goal is Success
https://isedj.org/2014-12/n6/ISEDJv12n6p36.html	Collaborative	Evaluating Effectiveness of Pair Programming as a Teaching Tool in Programming Courses
https://isedj.org/2016-14/n1/ISEDJv14n1p71.html	Adaptable, Purpose-driven, Responsible	Developing Capable Undergraduate Students: A focus on Problem Based Learning and Assessment
https://isedj.org/2016-14/n3/ISEDJv14n3p55.html	Collaborative	Developing Project Based Learning, Integrated Courses from Two Different Colleges at an Institution of Higher Education: An Overview of the Processes, Challenges, and Lessons Learned

https://isedj.org/2016-14/n5/ISEDJv14n5p44.html	Adaptable	Use of Failure in IS Development Statistics: Lessons for IS Curriculum Design
https://isedj.org/2017-15/n6/ISEDJv15n6p72.html	Adaptable, Professional	Identifying The Real Technology Skills Gap: A Qualitative Look Across Disciplines
https://isedj.org/2018-16/n3/ISEDJv16n3p45.html	Meticulous, Self-directed	Reaching and Retaining the Next Generation: Adapting to the Expectations of Gen Z in the Classroom
https://isedj.org/2019-17/n3/ISEDJv17n3p20.html	Inventive	Using Codecademy Interactive Lessons as an Instructional Supplement in a Python Programming Course
https://isedj.org/2019-17/n3/ISEDJv17n3p29.html	Passionate	A Preliminary Study: The Use of VoiceThread in Online Business Courses
https://isedj.org/2019-17/n3/ISEDJv17n3p41.html	Adaptable	Applying an Agile Approach in an Information Systems Capstone Course
https://isedj.org/2019-17/n4/ISEDJv17n4p51.html	Collaborative, Professional, Purpose-driven, Responsible	Toward Visualizing Computing Curricula: The Challenge of Competency
https://isedj.org/2019-17/n4/ISEDJv17n4p91.html	Responsive	Hour of Code: A Study of Gender Differences in Computing
https://isedj.org/2022-20/n5/ISEDJv20n5.pdf#page=17	Adaptable	Integrating AWS Cloud Practitioner Certification into a Systems Administration Course
https://isedj.org/2022-20/n5/ISEDJv20n5.pdf#page=67	Adaptable, Collaborative, Inventive, Meticulous, Passionate, Proactive, Professional, Purpose-driven, Responsible, Responsive, Self-directed	Beyond Competency: The Imperative to Foster Professionalism in Computing Graduates
https://isedj.org/3/10/ISEDJ.3(10).Saulnier.pdf	Self-directed	Service Learning in Computer Information Systems: "Significant" Learning for Tomorrow's Computer Professionals
https://isedj.org/6/19/ISEDJ.6(19).Eagen.pdf	Responsible	The Design Charrette in the Classroom as a Method for Outcomes-based Action Learning in IS Design
https://isedj.org/6/39/ISEDJ.6(39).Wolk.pdf	Responsive	How Important is Student Computing Ability? The Role of Information Technology Competence in Business School Accreditation
https://isedj.org/7/43/ISEDJ.7(43).Wolk.pdf	Inventive	Using the Technology Acceptance Model for Outcomes Assessment in Higher Education
https://isedj.org/7/60/ISEDJ.7(60).Saulnier.pdf	Self-directed	From "Sage on the Stage" to "Guide on the Side" Revisited: (Un)Covering the Content in the Learner-Centered Information Systems Course

Appendix D. Word Cloud Visualizations for Unique Article Titles



Word cloud from online tool that analyzes just words (freewordcloudgenerator.com).



Word cloud from online tool that analyzes words and phrases (monkeylearn.com).