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Steven M. Toepfer, Ph.D., M.S.
Editor, *AURCO Journal*
Kent State University Salem
2491 State Route 45 South
Salem, OH 44460
stoepfer@kent.edu

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Editor

Steven M. Toepfer, Ph.D.
Associate Professor of Human Development & Family Studies
Kent State University Salem
stoepfer@kent.edu

Associate Editor

James R. McKean, Ph.D.
Associate Professor of Law Enforcement Technology
Ohio University Chillicothe
mckean@ohio.edu

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The engine of the journal is the reviewer. Without good reviewers, we simply cannot produce a quality scholarly journal. The AURCO Journal currently has stellar reviewers but we need to grow our ranks to increase diversity of backgrounds and disciplines. Diversity will provide a stronger match between author content and reviewer expertise. It ensures a deeper pool of knowledgeable scholars to review manuscripts and allows us to return review decisions to authors faster. More reviewers will enrich the AURCO family. Please consider applying.

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Reviewers should have published articles in scholarly journals and demonstrate familiarity with the publication process to be considered. A copy of your vita is required.

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Changes will be made to the review platform in 2023. Please visit the AURCO website for more information.

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Editor's Commentary

Spring 2026

The AURCO Journal Goes Digital!

After 31 years of print history, the AURCO Journal is moving to an exclusively digital future. Starting with the 2026 issue, we will provide our publication solely in electronic format. Both individual articles and the full journal will be available. Each year on the day of the annual AURCO Conference the journal will be available for download at the AURCO website (<https://aurco.org/journal> – this link is now “clickable!”). Copies will also be sent to EBSCO soon after the conference.

We investigated an option to print a small number of paper copies but it is cost prohibitive. Many other journals do one or the other so why consider doing both? It's a good question. I keep saying, “because I like holding paper journals,” but apparently that is not a compelling argument. I'm going to work on my reasoning skills but for now it's digital all the way.

A reason for doing this is to save money. The price of printing goes up each year. It has been the biggest expense of the organization by far. It was expensive, in case you are wondering. Without that expense we will have extra revenue to put into things like the conference, student scholarships, or a Tour de France level road bike for the editor. The significant savings may also help AURCO try some new things.

Another reason to be exclusively digital is that it cuts out a series of laborious steps with the printer. It makes the production of the journal smoother and more efficient. We become nimble academic gymnasts!

Nope. Not this year. I discovered that the printer provided a six-week schedule of deadlines which kept me on track. That structure has been in place my entire tenure as editor and was suddenly missing. How did March get here so fast? Oh no, it's April! I was behind on everything. So far nothing horrible has occurred but don't panic, there is still time for disaster.

Next year we're going to make some changes to help get the most out of our fully digital process. You may or may not notice them but they'll be lurking in the form of a back-end schedule and possibly new deadlines for authors. It will all be in the service of getting things done earlier and

easier. Nothing has been decided yet but we need a replacement for the printer's schedule to keep us honest.

Enjoy the AURCO Conference and the journal. Our reviewers and authors work hard to make it all happen. They help us showcase the great scholarship happening around Ohio.

Finally, if you're an AURCO representative, enjoy the lack of back pain because you won't be lugging boxes of journals back to your campus.

Sincerely,

~Steve Toepfer, *Editor*



The AURCO Journal...

- is peer reviewed.
- has been in print since 1993.
- is electronic only starting in 2026.
- is published in April each year.
- accepts manuscripts until October.
- is on EBSCO.
- emphasizes but is not limited to data driven research.
- focuses on but is not limited to teaching.
- focuses on but is not limited to regional campus issues.

The AURCO Journal is now on **Scholastica**. Scholastica is the review platform we use to submit, review, edit, and render decisions about manuscripts. The 2023 volume of the journal was the first to use the platform.



- <https://aurcojournal.scholasticahq.com/>

To submit manuscripts, please visit the Scholastica website or visit the AURCO website at <https://aurco.org/journal>

I hope you enjoy this year's AURCO Journal.

Send questions and comments to stoepfer@kent.edu.

Sincerely,
Steven M. Toepfer
AURCO Journal Editor
<http://aurco.org/journal/>

Awards

2026

Editor's Choice Award for Outstanding Article

**GenAI does NOT negate Bloom's Taxonomy
for Sustainable Learning Outcomes – An Analysis of
ChatGPT Prompts by Students**

Subbu Kumarappan, *ATI The Ohio State University*
Urmila Pal Chaudhuri, *Kent State University at Stark*

Outstanding Reviewer Award

Allison White
Ohio University

Publication Guidelines

Please read the guidelines carefully before submitting a manuscript. **Failure to follow the guidelines will result in delay or rejection of submitted work.**

The *AURCO Journal* publishes only refereed articles.

Article Focus

The AURCO Journal accepts a wide variety of research including theoretical, pedagogical, qualitative, and quantitative manuscripts. Three factors are preferred but *not* mandatory:

- 1) Manuscripts based on *original data*.
- 2) Manuscripts which include a *regional campus focus*, and
- 3) Manuscripts with a *pedagogical or teaching focus*.

Such manuscripts are considered stronger candidates for publication. These criteria are *not* mandatory but preferred.

Style Guidelines & Reference

The AURCO Journal is an interdisciplinary publication which does not enforce a specific set of standardized Guidelines. There is no preferred style for article submissions. However, MLA (Modern Language Association) and APA (American Psychological Association) formats are commonly used but not mandatory. If you cannot use MLA style or APA style, be consistent and professional. Regardless of the demands of your discipline, avoid using abbreviations, acronyms, and jargon. Define or explain all terms. Pay close attention to the format requirements and other guidelines described below.

Format

Except for italics, and boldface, the document should be free of pagination, word-processing formatting, colored font, and style commands, including headers and footers.

Avoid and do the following

- **Do not use endnotes or footnotes. Do not embed notes in the document.** Please use references at the end of the document.
- **Do not submit a paper with “review mode” on.** No review comments, highlighting, or other relics of *review* should exist in a submission.
- **Insert figures and images directly into the manuscript.** Do not upload figures and images separately.
- **Use single spaces after periods.**
- **Remove hyperlinks;** remove the link and all HTML in the body of the paper. Links are permissible in the *Reference* section.
- **Left-justify** the document.
- **The journal is published in Calibri, size 11 font.**

Starting in 2026, ignoring the above guidelines will result in the manuscript being returned to the author before it is assigned to reviewers. It may also result in a denial regardless of review status. Use previous editions of the AURCO Journal as a general guideline.

File Format

Files must be PC versions of Word or .RTF (rich text format). Do not submit PDF or Mac files.

Charts, Illustrations, & Tables

Figures, tables, graphs, and illustrations should be included within the body of the manuscript. This includes .GIF or .JPG files. No other graphic formats are accepted. Make tables simple and attempt to conserve space. **Do not allow tables to extend beyond the margins.** Manuscripts with poorly behaved tables will be returned to the author.

Abstract

An abstract must be included at the front of the paper. Each article should be summarized in an abstract of *not more than 200 words*.

Identifying Information & Anonymity

Place no identifying information in the body of your paper or in the abstract. Identifying information is collected separately during the online submission process. Manuscripts are subject to a blind review process so identifying information may result in the return of a manuscript or a delay. Remove personal names and institutions prior to submitting the manuscript. Once accepted, final versions of a manuscript should contain the information authors wish to be in the finished article.

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Instructions for online submission can be found on the website (www.aurco.net/journal) or directly at the Scholastica portal (<https://aurcojournal.scholasticahq.com/>). Editors will not accept submissions via eMail or on paper. If your manuscript is approved by the reviewers and Associate Editor, it will be submitted to the Editor for final review and approval. Decision letters will be sent to the lead author by the Editor-in-Chief via eMail. Most decision letters are sent in January.



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Refereed Papers

Building a heatmap rubric to assess student's meaningful learning based on the Interaction Equivalency Theorem

Adam Chekour
University of Cincinnati Blue Ash

In the evolving landscape of education, understanding how different modalities of course delivery impact student learning is crucial. Anderson's Interaction Equivalency Theorem (2003a) (IET) provides a guideline for designing effective interactions in distance learning. Anderson's two theses in his theorem are:

- *"Thesis 1. Deep and meaningful formal learning is supported as long as one of the three forms of interaction (student–teacher; student–student; student–content) is at a high level. The other two may be offered at minimal levels, or even eliminated, without degrading the educational experience."*
- *"Thesis 2. High levels of more than one of these three modes will likely provide a more satisfying educational experience, although these experiences may not be as cost- or time effective as less interactive learning sequences."*

*While Anderson's Theorem was based on the distance education system in its modeling it can be extended to various modalities such as hybrid and traditional learning. The Interaction Equivalency Theorem (IET), proposed by Garrison (2017), emphasizes that a balance of three types of interaction (student-content, student-student, and student-teacher) can lead to meaningful learning. In this article, we propose the development of a **heatmap rubric** based on a meta-analysis of a large body of literature and established best practices, aimed at assessing meaningful learning through a comparative analysis of interactions across diverse course delivery modalities.*

Understanding the Interaction Equivalency Theorem

The IET posits that meaningful learning occurs when a learner actively engages with content, peers, and instructors (Miyazoe, M., & Anderson, T., 2010). Here's a breakdown of the three types of interaction according to Moore (1989):

1. **Student-Content Interaction:** This involves students engaging with course materials, such as readings, videos, and assignments.

2. **Student-Student Interaction:** This encompasses collaboration, discussion, and peer feedback among students, fostering a community of learners.
3. **Student-Teacher Interaction:** This includes feedback, guidance, and support from instructors, which can greatly enhance the learning experience.

By assessing these interactions, educators can gain insights into how effectively a course delivery method facilitates meaningful learning. However, the IET lacks delineating meaningful learning at the intersection of students' interaction type and course delivery modality. We suggest developing a heatmap rubric, which will characterize different levels of this intersection, and enable the identification of the highest level of meaningful learning.

Designing the Heatmap Rubric

The term heatmap was first trademarked in the early 1990s, when software designer Cormac Kinney created a tool to graphically display real-time financial market information (Jurkonytė, 2023). The practice we now call heatmaps is thought to have originated in the 19th century, where manual gray-scale shading was used to depict data patterns in matrices and tables.

The heatmap rubric here will serve as a visual representation of the levels of meaningful learning in a course. Here's how to create one:

Step 1: Define Learning Outcomes

Establish clear, measurable learning outcomes that reflect meaningful learning. These outcomes should align with the course objectives and provide a foundation for assessing meaningful learning.

Step 2: Identify Course Delivery Modalities

Different course delivery modalities may include:

- **Face-to-Face:** Traditional classroom settings.
- **Blended Learning:** A mix of face-to-face and online instruction.
- **Fully Online:** Courses delivered entirely through digital platforms.

Step 3: Develop Interaction Metrics

Create specific metrics to measure each type of interaction. Possible metrics could include:

- Frequency of engagement (e.g., number of posts in a discussion forum).
- Quality of interactions (e.g., depth of responses).
- Diversity of interactions (e.g., variety of sources used in student-content engagement).

Step 4: Create the Heatmap Framework

Design a heatmap table that includes:

- Horizontal row: Course delivery modalities (face-to-face, blended, fully online).
- Vertical row: Types of interactions (student-content, student-student, student-teacher).

Each cell in the table will represent the intensity or effectiveness of interaction for that modality and type. Use color coding to indicate levels of engagement ranging from low (e.g., red) to high (e.g., green).

Step 5: Collect Data

Gather data through surveys, learning analytics, and observational methods.

This may include:

- Student feedback on their interactions.
- Analysis of discussion posts, assignments, and assessments.
- Instructor observations of engagement levels.

Step 6: Populate the Heatmap

Input the collected data into the heatmap. Each cell should reflect the observed levels of interaction, indicating how well each modality supports meaningful learning.

Step 7: Analyze and Reflect

Once populated, analyze the heatmap to identify trends. For example, you might find that:

-
- Face-to-Face: High levels of student-teacher interaction but lower student-student interaction.
 - Blended Learning: A balanced approach, with moderate levels of all three interactions.
 - Fully Online: High student-content interaction, but lower student-teacher engagement.

Reflect on these insights to inform future course design and delivery.

Implications for Course Design

By utilizing a heatmap rubric, educators can tailor their courses to enhance meaningful learning. If a particular modality shows low interaction levels, adjustments can be made, such as:

- Incorporating more collaborative activities in online settings to boost student-student interaction.
- Increasing opportunities for feedback and engagement from instructors in blended courses.

Generating Heatmap Rubric

Based on a meta-analysis of 200 peer-reviewed articles (refined to 187) research studies were classified according to the combination of course modality and interaction type that most effectively promotes meaningful learning (Anderson, 2003; Moore, 1989). This classification produced nine unique combinations: *face-to-face* × *student-content* (Rossi et al. 2021; Buhl-Wiggers et al. 2023; Lewohl et al. 2023; Photopoulos et al. 2022; Li et al. 2023; Scager et al. 2016; Dubinsky et al. 2024; Xu et al. 2023; Mebert 2020; Ipinnaiye et al. 2024; Ramos-Vallecillo et al. 2024; and Carnegie Mellon University 2021), *face-to-face* × *student-student* (Bailey et al. 2018; Bennett et al. 2014; Bernard et al. 2009; Borokhovski et al. 2012; Bruffee 1999; Chickering and Gamson 1987; Chim et al. 2024; Dziedzic Kristiansen et al. 2019; Gillies 2023; Guiller et al. 2008; Herrmann and Kims 2013; Huang et al. 2023; Johnson and Johnson 1999; King 1998; Lewohl et al. 2023; Means et al. 2013; Mesghina et al. 2024; Ocker and Yaverbaum 1999; Peterson et al. 2023; Ransom et al. 2022; Scager et al. 2016; Slavin 1995; Tenenbaum et al. 2019; Topping 2005; Van Ryzin et al. 2019; Webb 1989; Webb 1994; Yang et al. 2023; and Zhang et al. 2022), *face-to-face* × *student-instructor* (Bernard, R. M., Abrami, P. C., Borokhovski, E., Wade, C. A., Tamim, R. M., Surkes, M. A., & Bethel, E. C., 2009;

Buhl-Wiggers, J., et al., 2023; Chickering, A. W., & Gamson, Z. F., 1987; Cornelius-White, J., 2007; Garrison, D. R., Anderson, T., & Archer, W., 2000; Hamre, B. K., Pianta, R. C., & others, 2013; Hattie, J., 2009; Lewohl, J. M., et al., 2023; Li, L., 2021; Means, B., Toyama, Y., Murphy, R., Bakia, M., & Jones, K., 2013; Ong, S. G. T., et al., 2023; Pennings, H. J. M., et al., 2020; Photopoulos, P., 2022; Pianta, R. C., and colleagues, various years; Roorda, D. L., Koomen, H. M., Spilt, J. L., & Oort, F. J., 2011; Tao, Y., 2024; Zhang, Q., 2024), *blended × student-content* (Akai, G. 2022; Al Mamun, M. A. 2022; Arnett, T. 2016; Bondarenko, O., Pakhomova, O., & Lewoniewski, W. 2020; Bonk, C. J., & Graham, C. R. 2006; Child Education Through Animation 2014; Columbia Center for Teaching and Learning 2018; De Bruijn-Smolders, M. 2024; Doubet, K., & Carbaugh, E. M. 2020; Farhat, A. 2025; Garrison, D. R., Anderson, T., & Archer, W. 2000; Gitinabard, N., Xue, L., Lynch, C. F., Heckman, S., & Barnes, T. 2017; Islam, M. B., Ahmed, A., Islam, M. K., & Shamsuddin, A. K. 2014; Kettlehake, K. 2025; Li, L. 2022; Means, B., Toyama, Y., Murphy, R., Bakia, M., & Jones, K. 2013; Rabadi, S. 2025; Seaton, D. T., & Thoms, B. D. 2016; Smith, D. P. 2022; Tayebinik, M., & Puteh, M. 2015; Ye, Y., Zhang, G., Si, H., Xu, L., Hu, S., Li, Y., Zhang, X., Hu, K., & Ye, F. 2023; Zhang, L. 2025), *blended × student-student* (Ajibade, O. 2016; Armellini, A. 2021; Avci, H. 2017; Bekele, A., Melese, W., & Sime, T. 2025; Borup, J. 2013; Bruffee, K. 1999; Challob, A. I. 2016; De Bruijn-Smolders, M. 2024; De Bruijn-Smolders, M. 2024; Garrison, D., Anderson, T., & Archer, W. 2000; Han, F., & Ellis, R. A. 2021; Istenič, A. 2024; Islam, M. K. 2022; Jong, J. P. 2016; Kintu, M. J., Zhu, C., & Kagambe, E. 2017; Lacaste, A. V. 2022; Li, J. 2023; Li, R. 2025; Mahgana, A. J. 2025; Malsakpak, M. H. 2024; Means, B., Toyama, Y., Murphy, R., Bakia, M., & Jones, K. 2013; Meulenbroeks, R. 2020; Mohammadi, M. 2025; Moodley, K. 2023; Pham, A. T. 2025; Platonova, R. I. 2022; Platonova, R. I., Armellini, A., & colleagues 2021; Pokhrel, S., Rasheed, A., et al. 2021; Ruijuan, L. 2023; Sareen, S. 2024; Scager, K. 2016; Sharma, D. 2022; So, H. J. 2008; Tang, J. T. 2025; Wang, P. 2024; Yang, X. 2023; Younas, M. 2025; Yu, Q. 2025; ResearchGate / cooperative study 2012–2013; ResearchGate / Ajibade 2016), *blended × student-instructor* (Alammary, A., Sheard, J., Carbone, A., 2014; Arbaugh, J. B., 2014; Borup, J., Graham, C. R., Drysdale, J. S., 2014; Borup, J., West, R. E., Thomas, R., Graham, C. R., 2020; Brundage, M. J., Malespina, A., Singh, C., 2023; Chen, P. D., Lambert, A. D., Guidry, K. R., 2010; Chickering, A. W., Gamson, Z. F., 1987; De Bruijn-Smolders, M., 2024; Farhat, A., 2025; Garrison, D. R., Anderson, T., Archer, W., 2000; Hsu, L., Ching, Y., 2013; Lee, R. A., 2011; Li, L., et al., 2022; Martin,

F., Bolliger, D. U., 2018; Miller, J. B., 2013; Ong, S. G. T., et al., 2023; Prokopetz, R. Z., 2021; Rabadi, S., 2025; Rovai, A. P., Jordan, H. M., 2004; Schmid, R. F., 2023; Su, F., 2023; Vaughan, N., 2007; Woo, Y., Reeves, T. C., 2007; Zafonte, M., Parks-Stamm, E. J., 2016; Zafonte, M., Parks-Stamm, E. J., 2016; Bernard, R. M., et al., 2009; Vaughan, N., 2007; Arbaugh, J. B., 2014), *online × student-content* (Al Mamun, M. A., 2022; Baber, H., 2020; Bond, M., Bedenlier, S., & Zawacki-Richter, O., 2020; Dikbaş-Torun, A., 2020; Garrison, D. R., & Cleveland-Innes, M., 2005; Garrison, D. R., Anderson, T., & Archer, W., 2001; Joksimović, S., et al., 2019; Kidder, L. H., 2015; Koernig, S. K., 2003; Kuo, Y. F., et al., 2013; Lee, J., 2010; Meyer, K. A., 2014; Moore, M. G., 1989; Murray, M., 2013; Orcutt, D., & Dringus, L. P., 2017; Pham, T. T., et al., 2019; Reisetter, M., LaPointe, D., & Korcuska, J., 2007; Sweetman, D. S., 2020; Xiao, Y., et al., 2024; Zhao, Y., et al., 2023; Zhao, Y., et al., 2023), *online × student-student* (Ascough, R. S., 2007; Blackmon, S. J., & Major, C. H., 2012; Collier, A., & McDonald, J., 2019; Gao, L., 2020; Garrison, D. R., Anderson, T., & Archer, W., 2001; Johnson, D. W., Johnson, R. T., & Smith, K. A., 1991; Kearsley, G., & Moore, M. G., 1996; Liu, M., & Hwang, G. J., 2010; Moore, M. G., 1989; Ramsden, P., 2003; Rasheed, R. A., Khan, S. U., & Dufresne, R., 2020; Rovai, A. P., 2002; Swan, K., & Shih, L. F., 2005; Vygotsky, L. S., 1978; Wang, M., & Chen, L., 2019), and *online × student-instructor* (Arbaugh, J. B. 2008; Dixon, M. D. 2015; Leem, B. H. 2023; Li, X. 2022; Mullen, G. E. 2006; Ong, S. G. T. 2023; Su, C. Y. 2021).

Articles were tallied within each combination, and the results were visualized using a 3 × 3 heatmap grid illustrated in table 1 below. Each cell of the grid represents a specific modality–interaction pairing, with the vertical axis denoting instructional modality (face-to-face, blended, online) and the horizontal axis denoting interaction type (student-content, student-student, student-instructor). The numerical value in each cell indicates the number of studies supporting meaningful learning within that combination. The color gradient reflects the magnitude of meaningful learning – darker shades correspond to a greater number of studies and thus stronger evidence of meaningful learning within that instructional context.

		Type of Interaction		
		Student–Content	Student–Student	Student–Instructor
Course Modality	Face-to-face	12	29	17
	Blended	22	37	27
	Online	21	15	7

Table 1. Results of heatmap grid pairing course modality & type of interaction

Results Discussion

The heatmap grid shows that areas of high intensity are concentrated around the blended learning modalities, indicating higher levels of meaningful learning across all interaction types – a consistent conclusion of meta-analyses. Face-to-face learning remains strongest for *relational and collaborative engagement* but less efficient for content interaction alone. Online learning supports *autonomy and content mastery* but often yields lower *social and instructor presence* unless meticulously designed.

It is notable to mention the above classification echoes a robust body of scholarship and empirical synthesis, drawing on both foundational frameworks and meta-analyses, including Chickering and Gamson (1987), Moore (1989), Garrison, Anderson, and Archer (2000), Bernard et al. (2009, 2014), Means et al. (2013), and Borup et al. (2020), which collectively highlight the relative impact of various interaction modalities across in-person, blended, and online learning contexts.

Conclusion

A heatmap rubric offers a valuable tool for assessing the interactions that drive meaningful learning, grounded in the Interaction Equivalency Theorem. By examining the course modality and type of student interaction combinations, this meta-analysis aimed to identify patterns in which instructional approaches and interaction types most strongly support meaningful learning outcomes. The results provide a framework for understanding how different learning environments and interaction dynamics contribute to student engagement, knowledge construction, and overall satisfaction with the learning experience.

By understanding the dynamics between course delivery modalities and interaction types, educators can create more effective learning environments that cater to diverse student needs, ultimately enhancing the educational experience. Embracing this approach will ensure that all learners can thrive, regardless of the modality through which they engage with course content.

Considerations for future research

The next phase of this research will proceed in two stages. First, the heatmap analysis will be refined to categorize each mode of student interaction according to the topical concepts proposed by Rodriguez and Armellini (2014). These concepts may include: (1) level of engagement with course activities, (2) depth of reflection on course topics, (3) extent of instructor support in content comprehension, (4) sharing of valuable learning experiences with peers, and (5) overall satisfaction with the learning experience. The heatmap will then be expanded to provide a more detailed and comprehensive depiction of the three-way interactions among these factors.

The second stage will involve follow-up empirical confirmatory research to further examine the heatmap rubric's content, design, and implementation. Data will be collected on the rubric's specific components as it is applied across a variety of classroom settings and teaching modalities, enabling the establishment of its validity and reliability.

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COPAN Analysis: An Innovative, Community-Determined Approach to Rural Development

Nathan Crook

Ohio State ATI, The Ohio State University

D. Rose Elder

Ohio State ATI, The Ohio State University

A COPAN analysis, a method for including collaborations, opportunities, priorities, assets, and needs, articulates and examines multiple perspectives for guiding rural development. This article outlines the authors' development and testing of their COPAN analysis for not-for-profit, non-governmental organizations (NGO) operating in Ghana to learn the development needs of rural populations. Since the Ghanaian government lacks a centralized approach to rural development, the Ghanaian people rely on NGOs, religious organizations, and traditional leaders to fill the void. The creation of this needs assessment derives from 20 years of sustained collaboration with women farmers in Ghana's Volta Region through which the authors have built relationships of trust as they addressed immediate humanitarian and social issues. Working through their NGO, the authors tested their COPAN analysis on the planning process for an agricultural maker space project that will benefit farmers and petty traders in four, neighboring small towns. Initiating numerous community conversations that culminated in a community listening session, the authors designed a flexible, adaptable approach to learning rural development needs and priorities that focuses attention on what is important to the local communities. Because of the success of this process, the authors are poised to design projects with greater impact when using the COPAN analysis.

INTRODUCTION

Subsistence farmers engaged in rain-fed agriculture in Ghana meet obstacles every day such as climate change, illness, currency devaluation, back-breaking labor due to lack of modern equipment, and the high cost of inputs. When conditions allow for a productive harvest, the farmers report their frustration. A woman farmer explains the gravity of the situation, "You

send foodstuffs to the market and bring it back because there is no money...You put too much in and get less profit.”

This article outlines the authors’ collaborations with farmers in Ghana’s Volta Region that led to the development and testing of their COPAN analysis for rural developers who want to hear from the people themselves what they identify as their development needs. The COPAN analysis is an adaptive approach requiring a long-term commitment to building relationships of trust, which encourages community willingness to be more open in sharing their successes, challenges, and needs.

The authors did not start their interactions in Ghana as rural developers. In fact, we started by leading a regional campus study abroad. For the first fifteen years, our work was all about relationship building with local farmers, community leaders, and cultural preservationists starting in Ho and expanding our reach to nearby small towns. Through the process of getting to know people in Ghana, we encouraged our student travelers to find and respond to the farmers’ expressed needs using their disciplinary skills and abilities as agricultural students at the university. For example, they provided animal health interventions and immunizations, planted orange groves for beekeepers, and taught enrichment courses in agriculture and animal husbandry to area farmers and high school agricultural students.

During the years of successful trips, we worked with a dedicated group of community developers and American and international scholars. We focused our rural development efforts in eleven towns in and around the Ho Municipality, Volta Region, Ghana. We recognized that women farmers are the backbone of subsistence agriculture but rarely have access to traditional loans to grow their businesses. Additionally, commercial banks in Ghana are reluctant to loan to any small-holder farmers because of the precarious nature of their rain-fed agricultural system. Because of this, women farmers are doubly denied, first as women, second as subsistence farmers (Oxfam, 2022). To ameliorate this situation, we implemented a dynamic, co-operative microloan and savings (MLS) program for women farmers. From 2011 to the present, we created the organizational process and eventually raised the funds to support 16 groups. These groups provide a community and financial support system for more than 160 farmers and small businesspeople, approximately 85% of whom are women. These efforts ripple out to their families and their communities.

PROJECT BACKGROUND

In 2018, we reorganized from an education abroad to a not-for-profit, non-governmental organization (NGO) Ghana Beyond Subsistence (GBS). With a commitment to economic justice, we focused our efforts in rural development. While we recognize that we can't bring all Ghanaians to a point "beyond subsistence," we have seen how we can impact the lives of the people with whom we work. In the past six years, we have expanded our work with Ghanaian farmers, petty traders, extension officers, traditional and municipal leaders, educators, and other cultural producers to assess and improve the efficacy of our international rural development efforts in the region.

In our years of working with farmers in Ghana, we have observed that many rural development efforts retain a colonial approach of top-down decision-making, which means that local communities have not been given much choice in directing their rural development. On the other hand, through listening, we have learned many of the indigenous cultural practices for organizing and managing communities, such as traditional community entry expectations, or group codes for interactions, like excusing themselves, "We will consult the old lady," meaning the farmers want to discuss an issue in private, then return with a common response. We have learned to value and trust local expertise and to champion their causes. We have learned that the best foreign investment in Ghana is supporting locally identified needs as opposed to imposing foreign structures. We have also observed that the authors' backgrounds and experiences afford us the opportunity to bring people together, to conduct productive discussions, and to discover the needs and priorities of rural people.

During regular sessions year after year, the farmers have offered their own ideas and requests about what they need to be more sustainable and to move beyond subsistence. Noting that these suggestions and requests cluster in common areas, we envisioned an accessible, common, multipurpose facility, in contemporary terms an Agricultural Maker Space, where farmers and traders can take their agricultural produce to add value through preparation and preservation prior to sending them to market.

PROBLEMS FACING RURAL DEVELOPMENT IN GHANA

Despite persistent national challenges, Ghana has been a stable democracy since 1992 and has made tremendous progress toward reducing poverty (USAID, 2023). When offshore oil was discovered in 2007, the

subsequent boost in GDP (Ghana Energy Database, 2024) put the Republic of Ghana on a fast track to being reclassified by the World Bank and the International Development Association (IDA) from a developing nation to a lower-middle income country. This reclassification meant that Ghana lost access to the highly concessional IDA loans with long grace periods and low interest rates, which led to unstable currency and rapid inflation, which hurt the poor the most (Bollyky, 2019). Still, as of 2018, Ghana was among the 10 fastest-growing economies in the world and the second-largest economy in Africa. Oxfam International reports that Ghana has succeeded in reducing poverty particularly in the southern part of the country that includes Accra, the capital city, and Tema, the industrial port city. Yet, much of the population in the northern half of the nation subsists on less than \$1 per day.

Additionally, Oxfam points out:

- Inequalities between women and men continue to be very high.
- Between 2006 and 2016 the country saw 1,000 new US dollar millionaires created, but only 60 of these were women.
- A girl from a poor family is 14 times more likely never to have been to school than one from a rich family (Oxfam, 2022).

The Food and Agriculture Organization of the United Nations reports that 68% of Ghanaians reside in rural areas. More than 52% of the labor force engages in agriculture, and approximately 39% of the farm labor force is women. Even though agriculture contributes to 54% of Ghana's GDP, it accounts for over 40% of export earnings and provides over 90% of the food needs of the country, Ghana's agriculture remains predominantly smallholder, traditional rather than scientific, and rain-fed (FAO, 2023).

In 2012, Ghana agreed to integrate the Sustainable Development Goals of the United Nations into their own domestic development goals. Against UN recommendations, the national government decentralized the planning approach, limited its own development efforts to the construction of roads, ports, and other infrastructure, and invited other stakeholders such as NGOs, religious organizations, traditional leaders, and UN agencies to pick up the slack. In the absence of centralized guidance, government leaders left the nation without a coordinated, holistic approach, and development groups scrambled to pick up the pieces.

With so many diverse groups taking on the challenge, cooperative extension, state universities, and others produced manuals to give advice on how to prepare and plan development efforts. Each resource offers its own approach to best practices for learning rural development need and priorities, (XXXX, 2024). For example, *The Nuts & Bolts of Community Needs Assessment: Pros and Cons of Assessment Methods* outlines the needs, benefits, and approaches, such as Focus Group Interviews, Asset Mapping, and Community Survey Questionnaires, (University of New Hampshire, 2024). The Kellogg Foundation's *Building a Healthier Tomorrow: A Manual for Rural Coalition Building* offers tools for assessing community needs and evaluating program effectiveness through conducting surveys, interviews, and focus groups, (Landis, et. al., 1995). The Center for Community Health and Development at the University of Kansas, *The Community Toolbox* offers guidance in listening, information gathering, and analyzing problems. The Better Evaluation Global Evaluation Initiative, *Outcome Harvesting* looks at rural development reports and works backwards from an outcome to determine whether the intervention is the agent of change (Wilson-Grau et al, 2024).

INNOVATING AN APPROACH TO LEARNING RURAL DEVELOPMENT NEEDS

Rural development needs can be learned through quantitative research and analytical methods such as the analysis of widely available census data and vital statistics records. Typically, the quantitative method of content analysis is limited to the data gathered by governmental and official community sources to identify patterns, trends, and relationships. However, if rural developers were only to focus on national statistics, they would find that the studies usually overlook rural communities.

A more nuanced method to learn about people, their successes, their challenges, and what they want in their personal, familial, and community lives is qualitative research. Qualitative research can provide deeper insights into real-world problems by gathering and studying participants' experiences, perceptions, and behaviors. Employing qualitative research methods, researchers can see another way to identify community assets and resources, to assess specific community needs, and to express and set priorities. Qualitative research can help researchers understand how and why programs or interventions may work or fail to work as intended.

One of the most common approaches to qualitative research is participant observation. This approach places the researcher within the

cultural group to learn from group insiders. From participant observation with the informants, researchers can learn life histories, develop case studies, identify and analyze social networks, conduct surveys, and identify community gatekeepers and experts to serve in advisory groups, steering committees, and community forums. A significant advantage of participant observation derives from the potential of building relationships of trust and establishing long-term friendships.

Relying on their years of participation observation, the authors devised a plan, the COPAN analysis. In this analysis, researchers consider the Collaborations, Opportunities, Priorities, Assets, and Needs, or COPAN for guiding rural development as outlined in this article. This analysis builds upon sustained collaborations to explore community opportunities, to set priorities, to map out assets, and to articulate local needs. This approach is similar to a SWOT analysis that details the strengths, weaknesses, opportunities, and threats facing an organization (Puyt, 2024). While a SWOT analysis is appropriate for programs, we contend that the COPAN analysis more precisely targets issues and arrives at better solutions for rural development projects.



Figure 1. COPAN Analysis diagram of interactive process

The COPAN diagram provides a quick overview of the evaluative process (See Figure 1). Similar to a pie chart, this circular chart is divided into four equal quadrants with a central circular field overlaying the other four quadrants intending to illustrate that the collaborations field is in constant contact with the other categories. Where a Venn diagram uses overlapping and intersecting fields to demonstrate the common relationship between the fields, a COPAN analysis foregrounds collaborations as a constant component in determining the relationship between the other four fields of inquiry: opportunities, priorities, assets, and needs. Although the feedback identified within these categories will vary from project to project, a COPAN analysis requires consideration of each of the following categories:

- **Collaborations** is the starting point of a COPAN analysis. As outlined in Table 1, Collaborations is central to the analysis and is ongoing. Collaborations requires a developer and community commitment that evolves over time, recognizes shared humanity, makes common cause, and builds relationships to meet the shared interests of all parties.
- **Opportunities** refers to a set of favorable circumstances that make it possible to accomplish a goal, such as potential community improvement, social engagement, increased educational attainment, community pride, and access to funding or resources.
- **Priorities** places a ranked value on which potential project meets the most pressing needs, or offers the greatest benefit for the community.
- **Assets** describes useful or valuable tangible and intangible community resources, persons, or qualities. For example, community ethos, knowledge, experience, leadership, property, equipment, and materials that can be used to produce positive economic value.
- **Needs** observes deficiencies, something required for an individual or community to flourish. They include necessities of community life, sustenance, economic empowerment, and personal development.

An effective COPAN analysis elicits locally appropriate solutions based on thorough, deep, and sustained discussions with community

partners, such as farmers, extension officers, community leaders, experts in their fields, and other interested parties who have a stake in the outcome.

DESIGNING AN AGRICULTURAL MAKER SPACE PROJECT

Over 20 years of working with MLS groups, we have listened to their successes, challenges, needs, and aspirations. We have provided immediate remedies to problems facing farmers, including animal vaccines, fertilizers and pesticides, and technical support. As previously mentioned, our early collaborations led us to form micro-loan and savings groups. In 2018, we decided to pivot our focus from an education abroad toward rural development allowing us to expand our fundraising efforts.

As our relationship developed with the people of the Kpenoe Traditional Area, their leader, Togbe Kotoku XI, Paramount Chief, asked us to consider a large-scale project in their community. Using early versions of the COPAN analysis, we started to formulate an innovative approach toward rural development through the construction of an accessible, multipurpose facility that provides space and access to equipment to boost economic opportunity and agricultural innovation for the farmers and petty traders in nine of our MLS groups in four neighboring rural communities, specifically Kpenoe, Takla Gborgame, Hodzo Achianse, and Akoefe Gadza.

Our annual meetings with our MLS groups made it clear that if the farmers and traders wanted to add value to their produce prior to sending it to market, they needed access to the processing and preservation equipment to do so. Togbe Kotoku offered to secure land in his centrally located community where we could build a facility that would serve the needs of Kpenoe and three neighboring communities with established GBS MLS groups. During our annual residency in Ghana in 2022, we conducted multiple community forum meetings with all the farmers and traders in the MLS groups. The following year, we scheduled a committee meeting and listening session to discuss and prioritize specific community, farming, processing, preservation, and marketing needs that an agricultural maker space could support.

AGRICULTURAL MAKER SPACE COMMITTEE MEETING

At the July 2023 committee meeting and listening session, we brought together the MLS farmer group leaders representing each of the four MLS groups in Kpenoe, one group in Takla, two groups in Hodzo, and one group in Akoefe, alongside a local advisory team of professional

community developers, traditional leaders, religious leaders, representatives of the Kpenoe Governmental School Feeding Program, and representatives of the local mental health program that serves all four communities. An architectural design team attended and carefully observed the proceedings so that they could convert the conversation into the plan for the physical building. In this meeting, we reiterated the main purpose to build upon current farming activities through an appropriately-designed maker space to help the farmers improve their businesses. To achieve clarity, we developed the following series of six questions designed to explore and review key development themes that cluster into COPAN analysis categories:

Questions	Themes	COPAN
1. What type of surplus produce do you currently grow?	Marketing	Assets
2. What do other farmers grow and make to sell?	community awareness	Opportunities
3. What ideas do you have to grow -> make -> sell?	potential adaptation, innovation	Opportunities
4. What facilities and equipment will you need?	project planning	Needs
5. How frequently will you need/ use _____?	priority setting	Priorities
6. Where do you see potential partnerships?	community, interconnections, collaboration, cooperation, relationship building	Collaborations

For the listening session, the group divided into five groups, each led by a member of the advisory team, to answer and report on the questions. We supplied the groups with sticky notes and markers and asked them to record every response on a single sheet of paper.

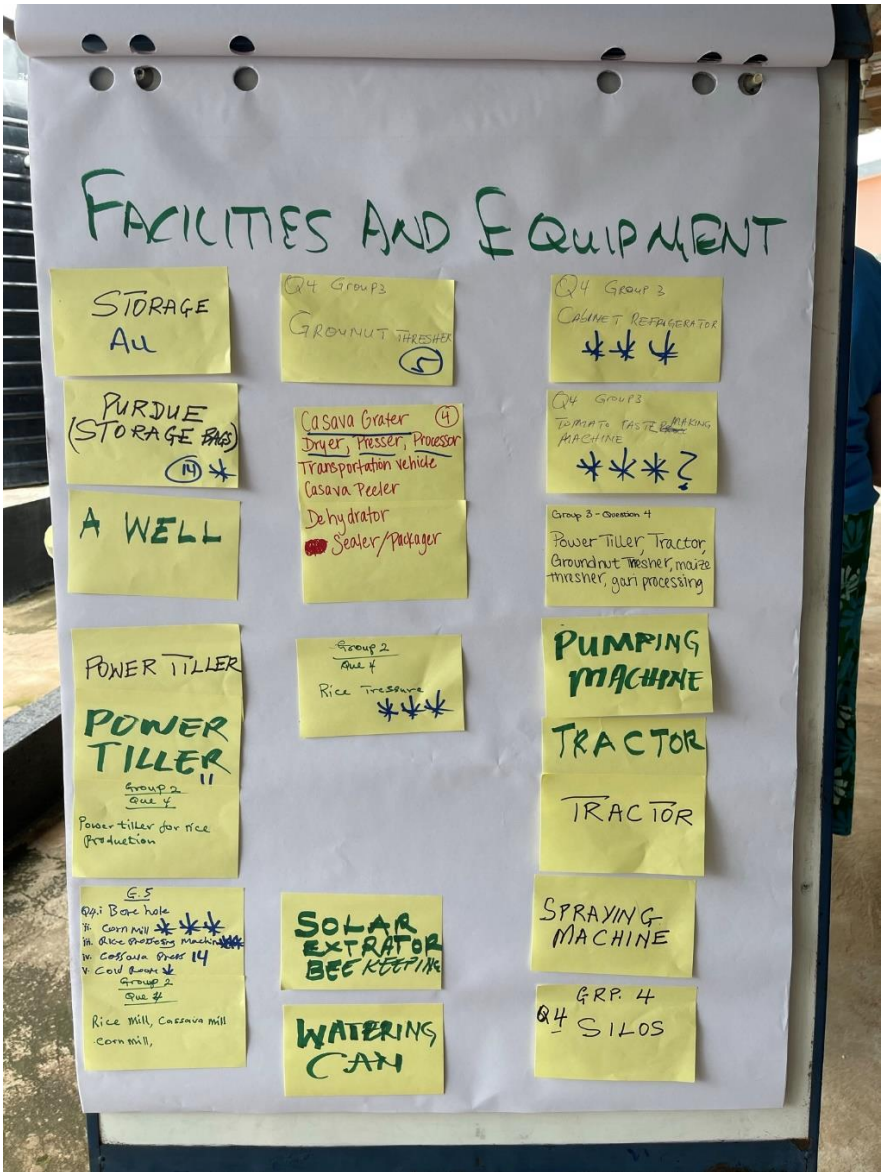


Figure 2. A visual aid from the committee and listening session documenting equipment needs and priorities (Courtesy of Nathan Crook, 28 June 2023).

We organized their responses on poster board so we could cluster similar responses. They offered their responses to the first four questions,

prioritized their facility and equipment needs, and identified potential partnerships:

1. What surplus produce do you currently grow?

Vegetables: Okro, tomatoes, green vegetables, garden egg, pepper (*kpakpo shitor*), cabbage
 Starches: Cassava, maize, rice, yam
 Animals: Poultry, goat

2. What do other farmers grow and make to sell?

Vegetables: Onions, peppers, garden egg (eggplant)
 Starches: Cassava, rice, yam, maize, sweet potato, plantain, cocoyam
 Other: Pineapple, groundnut (peanuts), beans (cow peas), cocoa, sugar cane
 Processed: Palm oil, palm wine, *akpeteshie* (palm gin), cassava dough, cassava *gari*

3. What ideas do you have to grow, make, sell?

Grow: Rice, maize, beans, groundnut, potato, cabbage, green pepper, sweet potatoes
 Make: Milled rice, processed cassava (*gari*), groundnut oil, palm oil, dried produce, honey

4. What Facilities and Equipment will you need?

Processing Equipment: Rice thresher, rice mill, corn mill, cassava processing peeler/ press/ grater/ dryer/ mill, groundnut thresher/ oil extractor, beans processor, palm oil press, produce drying and packaging, solar honey extractor, tomato paste processor
 Storage: Purdue Improved Crops Storage (PICS) bags, cabinet refrigeration, cold room, sealing packager, grain silo
 Farming Equipment: Power tiller, rice tiller, watering cans, pump sprayers for agrochemicals, transportation vehicle, tractor

Other: Well, cistern for collecting and mixing pumped and rainwater

5. How frequently will you need/ use these Facilities and Equipment?

Recorded using the following Likert scale: Daily, Weekly, Monthly, Seasonally, Annually, Never.

High Priority:	Storage, PICS bags, sealing packager, refrigerator/ freezer/ cold room, water well/ cistern, power tiller, power rice tiller/ thresher/ mill, corn mill, cassava processing peeler/ press/ grater/ dryer/ mill, tomato paste processor, pump sprayers for agrochemicals
Medium Priority:	Tractor, groundnut thresher/ oil extractor, transportation vehicle
Low Priority:	Solar honey extractor, watering can, produce dehydrator, beans processor, palm oil press, grain silo

6. Where do you see potential partnerships?

Ghana Education Service School Feeding Program, National Health Service Mental Health Clinic Feeding Program, Farmer Field School, Market women, Veterinarian, Welder, Electrician

The meeting ended with a tour of the building site and a blessing of the project performed by Togbe Samuel Acquency, a youth development chief.



Figure 3. Togbe Samuel Aquency blessing the agricultural maker space project site (Courtesy of Nathan Crook, 28 June 2023).

RESULTS OF APPLYING THE COPAN ANALYSIS

Through the committee meeting and listening session process, we tested the COPAN analysis and formulated our Agricultural Maker Space plan.

First, COPAN is proving to be an effective approach to guiding our thinking. Leaning into our sustained collaborations to explore community opportunities, we have formulated a template to set priorities, to map out assets, and to articulate local needs. Setting these parameters ensures that we do not overlook any aspect of the analysis.

The process of conducting the COPAN analysis resulted in the following:

Collaborations We deepened our relationships with long-term friends with whom we enjoy relationships of trust, openness, and honesty. We also identified potential

	partnerships as detailed in the responses to question six.
Opportunities	We recognized the communities would support a local market, benefit from a Farmer Field School geared toward a niche, organic, and/or sustainable agriculture, patronize a veterinary clinic, and contribute to a local school feeding program as outlined in questions two and three.
Priorities	We observed the group as they ranked their needs and set their own priorities as outlined in question five.
Assets	We listed the types of surplus foodstuffs as outlined in question one. We categorized areas of committed community support by expertise, materials, labor, and land. We also identified specific human and institutional resource collaborators, such as the Evangelical Presbyterian Church, traditional leaders, MLS group members, and extension services.
Needs	We learned the immediate, mid-, and long-term needs of the communities as outlined in the responses to question four.

Second, the committee agreed that the Togbe Kotoku XI Agricultural Maker Space will be a multipurpose facility that boosts opportunity and innovation for farmers and petty traders in the GBS network of co-operative MLS groups in the towns of Kpenoe, Takla, Hodzo, and Akoefe. We will design and build this maker space upon expressed farmer, trader, and community needs and priorities. It will be expandable by phases and will start with the ground floor of a multi-story design. The first phase will include a commercial kitchen where farmers and marketers can add value to their produce through processing and preservation, indoor and outdoor meeting and workspace, secure storage space for equipment, materials, goods, cold storage room or freezer, living space for a caretaker, retail, marketing space for vendors, secure work and storage space for welder,

electrician, seamstress, and tailor, and a block of restrooms that will be accessible to the community.

Knowing that the Agricultural Maker Space will require years to fundraise and build, in the short term, we have identified immediate needs in these communities. To fulfill these, GBS has already responded by providing Wellington boots, chicken hutches, bee hives and supplies (See Figure 4), as well as workshops in recordkeeping, beekeeping, and herd health. Funding for immediate needs will only improve the members' potential for success, their profitability, their education and skills. For the long term, we will continue to find ways to enhance market share for local farmers by way of improving communication and developing a wider, more reliable, commercial distribution network connecting the four towns.



Figure 4. Hodzo-Achianse bee house and scientific bee boxes constructed to consolidate hives in MLS group-owned orange groves, and to protect beehives from fires due to slash and burn agriculture (Courtesy of Dickson Asase, 14 October 2025).

CONCLUSION

In COPAN, we have designed a flexible, adaptable approach to rural development that focuses the developers' attention on what is important to the local communities. Collaboration is key. In this design, developers must always move through collaboration in order to identify the community's sense of available opportunities, priorities, and assets, along with perceived needs.

COPAN is as much a social analysis as it is a needs analysis. It identifies and articulates the people and relationships required to imagine, design, and complete a successful rural development project. This context-driven approach grounds rural development interactions in collaborations where the community is the driver and the individuals are valued assets. The presence and engagement of dynamic and trusted local leadership provides a critical asset. Local leaders often have a greater capacity for understanding local conditions, they tend to have systems of interaction and communication in place that engender cooperation, trust, and mutual respect.

By applying a COPAN analysis in the rural communities northeast of Ho, we have learned more about our community partners and their interests in expanding their farms and businesses. We have also learned to better focus our development agenda by applying the COPAN categories to our project discussions. While we recognize that as rural developers, we benefit from the fact that we are nimble and adaptable, this also means that we are disadvantaged by limited funds. By developing and employing the COPAN analysis, we have created a dynamic, cost-friendly process to identify and address the needs of the people within our MLS groups. It is our hope that other development groups will consider following the COPAN analysis and contribute to this developing discussion.

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The authors declare that generative AI or AI-assisted technologies were not used in any way to prepare, write, or complete this manuscript.

INFORMED CONSENT

The authors declare that we have sought and received informed consent.

CONFLICT OF INTEREST

The authors declare that there is no conflict of interest.

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Exploiting Buffer Overflows: A C Program for Software Security Education

Mohamed Elwakil
United States Coast Guard Academy

Buffer overflow vulnerabilities remain a pervasive threat in software systems, yet students often only encounter them in theory. This experience report presents LoginApp, a small C application intentionally designed with a buffer overflow flaw that allows an attacker to bypass authentication without a valid password. Used as a hands-on exercise in a junior-level software engineering course within a cybersecurity program, LoginApp was employed to bridge the gap between theoretical knowledge and practical exploitation. We describe the design of this instructional tool and its integration into the classroom, including a preliminary toy example that illustrates unsafe C functions, and detail how the buffer overflow exploit is constructed. We discuss the learning context and analyze the pedagogical outcomes – notably that only 1 of 47 students solved the challenge – to derive insights and identify improvements for future offerings. Our findings suggest that while LoginApp effectively engages students and instills a deeper appreciation of secure coding, proper scaffolding and safeguards are crucial to maximize learning and prevent misuse.

1. Introduction

Buffer overflow vulnerabilities remain among the most prevalent and dangerous software flaws—MITRE (2020) documents over 10,000 instances, nearly a quarter rated severe. While high-level languages like Java automatically prevent such errors, C and C++ place the burden on programmers, making them especially vulnerable.

Although buffer overflows are a standard topic in security education, students typically encounter them only through theory or code snippets, rarely through hands-on exploitation. This gap between abstract knowledge and practical skill leaves many unprepared for real-world threats (Zouahi & Talhi, 2023; Mirkovic & Peterson, 2014).

To address this, we introduce LoginApp, a deliberately vulnerable C program that simulates a login system and can be compromised via a buffer overflow to bypass authentication. Designed as a turnkey classroom

module, LoginApp enables students to experience firsthand how a small coding flaw can lead to a critical breach. By engaging in a controlled exploit, learners move beyond passive understanding toward active security reasoning—an approach supported by research on experiential cybersecurity education (e.g., CTF-style labs).

This paper presents the design, classroom deployment, and pedagogical insights from using LoginApp, along with reflections on its effectiveness, limitations, and future enhancements.

2. Literature Review and Related Work

Effective cybersecurity education requires hands-on experience, as passive lectures often fail to equip students with the practical skills needed to address real-world threats (Alnajim et al., 2023; Ramezani & Niemi, 2024). Buffer overflows—among the “big three” software vulnerabilities (SANS Institute, 2006)—are a critical focus for secure coding instruction due to their prevalence and impact.

To help students grasp these low-level concepts, researchers have developed interactive tools. Zhang et al. (2020) introduced a web-based visualization that improves comprehension by letting students step through memory corruption. Resch (2023) used an ARM emulator and debugger to give students direct insight into how overflows alter program state. While effective, such approaches often require specialized tools or systems knowledge.

In contrast, Capture-the-Flag (CTF) challenges offer gamified, practical experience but are typically standalone puzzles lacking pedagogical scaffolding. *LoginApp* bridges this gap: it delivers a realistic, relatable exploit (authentication bypass via data-only overflow) using only standard C and a typical development environment. Unlike abstract visualizations or open-ended CTFs, *LoginApp* is designed as a structured, classroom-ready module that guides learners from vulnerability recognition to mitigation—making hands-on security accessible even in general software engineering courses. In the following sections, we detail how the *LoginApp* exercise was implemented in the classroom and evaluate its effectiveness, while addressing various recommendations and challenges highlighted in prior work. Our focus is on the pedagogical insights gained from this experience: what students learned, where they struggled, and how we as instructors adjusted our approach.

3. Educational Design and Methodology

Learning Objectives

Before deploying the exercise, we defined specific learning objectives to align with our course outcomes. By the end of the *LoginApp* module, students should be able to:

1. Explain buffer overflow basics: Define what a buffer overflow is and explain in general how an attacker can exploit such a flaw.
2. Identify common causes: Identify common situations in C/C++ code where buffer overflows may occur (especially the use of unsafe string handling functions).
3. Analyze a vulnerable program: Analyze the structure and workflow of the *LoginApp* program to understand exactly how vulnerability is introduced and exploited.
4. Propose secure alternatives: Propose or create more secure alternative implementations of the program to mitigate buffer overflow vulnerabilities.

These objectives map to increasing levels of understanding—from basic knowledge and comprehension (objectives 1 and 2) to application and evaluation (objective 3), and finally to the synthesis of improved solutions (objective 4). In other words, the exercise was intended not only to illustrate the concept of buffer overflow but also to engage students in critical thinking about how to prevent such vulnerabilities.

Classroom Context

The exercise was deployed in a junior-level Software Engineering course that is part of an undergraduate cybersecurity degree program. The 47 students in the class had a solid foundation in general programming, having taken introductory courses in Python and C/C++. Most had also taken operating systems and databases courses. However, none (aside from one exceptional student discussed later) had prior hands-on experience with actually exploiting vulnerabilities. The course primarily focused on software development practices, so this security module was a special segment designed to raise awareness of secure coding. We scheduled the *LoginApp* exercise for the middle of the semester, after covering basic secure coding principles in lectures. By that point, students had been

warned about dangerous library functions (like using *gets()* or unchecked *strcpy*), but they had not yet seen a full exploit in practice.

Procedure

The module spanned a single class period and included a follow-up assignment. We began with a brief lecture reviewing buffer overflow basics and the importance of bounds checking. To ensure students understood the low-level behavior of strings in C, we presented a toy example before introducing the main tool. This toy program in Figure 1 has two static character arrays and deliberately used unsafe input functions, resulting in an unexpected output. Specifically, the program asks for two inputs.

```
char first[3];
char last[3];
char full[6];

printf("Please type your first name ");
scanf("%s", first);
printf("Please type your last name ");
scanf("%s", last);

strcpy (full, first);
strcat (full, " ");
strcat (full, last);

printf("Your full name is '%s'", full);
```

Figure 1: Toy program that is susceptible to buffer overflows due to unsafe string functions

When a user enters "AB" for the first input and "DEF" for the second, most students predict the output will simply concatenate into AB DEF. In reality, due to a buffer overflow in how the program stores these inputs, the actual output was ▯. This surprise outcome immediately caught the students' attention and vividly demonstrated how writing past a buffer's end can alter the data in adjacent memory locations. We discussed why this happened, highlighting the distinction between safe vs. unsafe string functions in C. For instance, using *gets()* or *scanf("%s")* without length limits can overflow a buffer, whereas functions like *fgets()* or *scanf("%5s")* (with an appropriate field width) could prevent the overflow.

After this demonstration, we introduced the *LoginApp* tool—the main exercise. We explained that *LoginApp* is a simple authentication program written in C, and we walked through its intended functionality (without yet revealing the vulnerability).

Once students understood how *LoginApp* should work normally, we shifted to the security challenge: Could they log in without knowing the correct password? We told them to assume the role of an attacker who has the program's source code and at least one valid username. This models a

situation where the source might be leaked, or the attacker has reverse-engineered the binary. The task was phrased openly: *“Find a way to bypass the authentication — i.e., make the program grant access without entering the real password.”* We clarified that this likely involves exploiting a bug in the code. Importantly, we did not explicitly instruct them to perform a buffer overflow; rather, we let them reason it out from the hints (e.g., the presence of *strcpy*, fixed-size arrays, the suspicious use of *scanf* with *%s*, and the prior toy example demonstrating overflow). Students were allowed to work in pairs and use any tools at their disposal (code editors, compilers, even debuggers) to experiment with the program. The challenge was allotted roughly 20–25 minutes of class time.

During this hands-on period, the instructor walked around to observe and give light hints if students were completely stuck. We deliberately did not provide a step-by-step guide initially, as the intent was to let them engage in some adversarial thinking on their own.

Data Collection: Our evaluation of the exercise’s impact was primarily qualitative. After the challenge, we held a debriefing where we revealed the solution and dissected the exploit’s mechanics. We then gathered student feedback in two ways: (1) an interactive discussion in class about how they approached the problem, how they felt, and what they learned, and (2) an anonymous short survey afterward with a few questions about the experience (e.g., *What was most surprising? How difficult was it? Suggestions for improvement?*). We did not administer a formal pre-test/post-test on buffer overflow knowledge, but we did ask students to reflect on whether their understanding of buffer overflows had changed as a result of the exercise. Additionally, we noted the number of students (or teams) that successfully exploited the program within the allotted time (which, as we will discuss, was essentially just one individual).

4. The *LoginApp* Vulnerability and Exploit

Implementation Details

The core of *LoginApp* is implemented in C and consists of a simple *main* function orchestrating the input/output and a few helper functions (for user lookup and hashing). Key variables (allocated on the stack) include a list of valid usernames and their password hashes (e.g., stored in an array of structs or parallel arrays), as well as several fixed-size buffers to hold

user-supplied and processed data. In particular, the program defines something akin to:

```
char username[5];
char password[4];
char hashedStoredPass[4];
char hashedInputPass[4];
```

The program's intended flow is as follows: it prompts for a username and reads it into the *username* buffer. Next, it checks this username against the list of authorized users. If the username is found, the program uses *strcpy* to copy the corresponding stored hash from the "database" into the *hashedStoredPass* buffer. (If not found, it prints an error and exits.) After fetching the stored password hash, the program prompts the user for their password. It then reads the password from the input buffer into the *password* buffer (using a standard unsafe input function like *scanf("%s", password)* or *gets(password)* in the intentionally flawed version). The program computes the hash of the entered password, producing a 4-character hexadecimal string, and stores it in *hashedInputPass*. Finally, it uses *strcmp* (or equivalent) to compare *hashedInputPass* with *hashedStoredPass*. If they match, the login is successful and an access-granted message is displayed; if not, it reports a login failure.

Under normal conditions (with a correct username/password), this sequence works as intended. But there is an inherent weakness: the fixed-size buffers and unsafe functions leave the door open to buffer overflows. Specifically, the *password* buffer is only 8 bytes long in this design, meaning it can hold at most a 7-character string plus the null terminator. If a user enters a longer password, it will overflow into adjacent stack memory. In C, local variables are typically laid out contiguously in memory, in the order they are declared (though this is not strictly guaranteed, compilers usually arrange them sequentially). In our case, the memory for these buffers is arranged as: *[username] [password] [hashedStoredPass] [hashedInputPass]* on the stack. We intentionally wrote the code such that the *hashedStoredPass* buffer is placed next to the *password* buffer in memory. That way, an overflow of *password* could overwrite data in *hashedStoredPass*.

Nature of the Vulnerability

The bug in *LoginApp* is a classic stack-based buffer overflow. Uniquely, it does not overwrite a return address or function pointer; instead, it overwrites an adjacent data buffer (a non-control data attack). This is often referred to as a *data-only* attack – the overflow corrupts application data (in this case, a password hash) to manipulate program logic, rather than hijacking the program’s instruction flow. Data-only buffer overflow exploits are highly relevant, as many real attacks focus on modifying security-critical variables (e.g., flags, credentials) in memory when modern defenses block control-flow hijacking. Our scenario demonstrates that even without injecting shellcode or altering a return pointer, a buffer overflow can cause an unauthorized privilege escalation – here, logging in without the real password.

Crafting the Exploit Input

To exploit the vulnerability, an attacker needs to craft input that will spill over the *password* buffer and *tamper with hashedStoredPass*. The approach is as follows:

1. **Choose a target username:** First, the attacker picks an existing username.
2. **Prepare a fake password and its hash:** The attacker wants to fool the program into thinking the correct password was entered. To do this, they decide on a fake password – any string of their choice – and compute that string’s hash. In our class, we used the example *"bad"* as the fake password (3 characters) and computed its hash. Let’s call this hash `H("bad")`.
3. **Construct the overflow string:** The input that the attacker will supply as the *password* needs to achieve two things: (a) overflow the *password* buffer into *hashedStoredPass*, and (b) plant the chosen hash value into *hashedStoredPass*. To accomplish (a), the input must exceed 7 characters (the capacity of *password* minus 1 for the null terminator). To accomplish (b), the content beyond the 7th character (which will overflow into the next buffer) should correspond to the bytes of `H("bad")`. There is one catch: when reading the password, functions like `scanf("%s")` or `gets` treat the input as a C-string, meaning they will stop reading at a newline and also end the string with a `'\0'` byte. That null terminator is crucial – it

will be written into memory and can terminate a string if it appears in the middle of it.

As shown in Figure 2, the exploit takes advantage of this by structuring the input as: [FakePassword] [NULL] [FakePasswordHash]. In our example, this would be the bytes representing "bad", followed by a



Figure 2: Exploit File

'\0' byte, and then the 4-byte hash H("bad"). When this sequence is provided as a single string input, what happens in memory is: - The *password* buffer (8 bytes) receives "bad" followed by the null terminator, then the beginning of the hash, thereby overflowing it. Specifically, the first four bytes stored in *password* will be {'b', 'a', 'd', '\0'}. The remaining bytes (the hash) will not fit in *password* and thus will overflow into the subsequent region of the stack, which is where *hashedStoredPass* resides. - As a result, after the input read, the *password* buffer contains the string "bad" (with an implicit terminator), and the *hashedStoredPass* buffer has been partially or wholly overwritten with the bytes of the hash of "bad". Since *hashedStoredPass* initially held the real password hash for root (let's call that H(real)), it is now overridden to hold H("bad"). Essentially, *hashedStoredPass* now equals H("bad") – the attacker's chosen hash – instead of the original H(real).

4. **Trigger the comparison:** After reading the input, *LoginApp* proceeds to hash the provided password (which it interprets as "bad" because it read up to the '\0'). It stores that result in *hashedInputPass*. So now *hashedInputPass* contains H("bad") as well. Finally, the program compares *hashedInputPass* to *hashedStoredPass*. Thanks to the overflow, both buffers now contain the identical hash value H("bad"). The comparison returns that they are equal, and the program mistakenly believes the correct password was entered, thereby granting access.

Memory Layout Explanation

It may be helpful to break down the memory changes in stages, referencing the earlier described buffer layout on the stack:

- **Initial state:** When the program starts and allocates the buffers, memory for *username*, *password*, *hashedStoredPass*, and *hashedInputPass* is reserved on the stack. Initially, these buffers contain indeterminate data (whatever values were on the stack, or zeros if the compiler zero-initialized them, though typically local char arrays are not zeroed). We depict this initial state as Figure 3, showing the four buffers in order.



Figure 3: Memory layout after creating variables

- **After username input:** Suppose the user (attacker) inputs "root" as the username. The *username* buffer now holds "root\0" in memory. The program finds "root" in the user list and then copies her stored password hash (H(real)) into *hashedStoredPass* using *strcpy*. At this point, *hashedStoredPass* contains H(real) followed by its own '\0' terminator at the end of that string. The *password* and *hashedInputPass* buffers are still empty/unused at this moment. Figure 4 illustrates the stack after storing the hashed password, showing *username* filled and *hashedStoredPass* filled with H(real), while *password* and *hashedInputPass* remained untouched.)



Figure 4: Memory layout after hashing the entered username

- **After password input (overflow):** The user then inputs the crafted second line as described above. The first part, "bad," is placed in the password buffer, and then the '\0' from the input is written, effectively terminating the password at 3 characters. The subsequent bytes (the hash of "bad") overflow out of the bounds of *password*. These overflow bytes sequentially overwrite the memory where *hashedStoredPass* is

stored. By the time the input is fully read, the original H(real) in *hashedStoredPass* has been completely replaced with H("bad"). Figure 5 illustrates this overflow, showing the region corresponding to *hashedStoredPass* being overwritten with the new values.



Figure 5: Memory layout after reading the manipulated password

- After hashing the input:** Now the program calls the hash function on the *password* buffer. But the *password* buffer currently contains "bad" (since reading stopped at the null). The hash function computes H("bad") and stores the result in *hashedInputPass*. So *hashedInputPass* now also contains (H("bad")). Figure 6 shows both *hashedStoredPass* and *hashedInputPass* holding identical values at this point.



Figure 6: Memory layout after hashing the input password

- Comparison:** Finally, *strcmp(hashedImagePass, hashedStoredPass)* is called and returns 0 (meaning the two strings are equal). Therefore, the program prints "Access granted" and proceeds as if the correct credentials were provided.

Throughout this exploit, it's important to note that we did *not* crash the program or overwrite a return address. The overflow was carefully sized to only corrupt a specific piece of data and nothing further. This made the exploit more stable and easier to achieve under classroom conditions – students didn't have to worry about bypassing advanced protections like DEP or ASLR or other modern OS defenses that come into play for code injection.

Vulnerable Functions and Safer Alternatives

It's worth highlighting the specific C library functions at fault, as this ties back to secure coding lessons. We deliberately used *strcpy* to copy the hash and an unbounded *scanf/gets* to read the password to emulate common mistakes. These functions are part of a notorious group of C functions that do not perform automatic buffer-boundary checking. Classic examples include *gets()*, *strcpy()*, *strcat()*, *sprintf()*, and their variants. All of these can write past the end of an array if the input or data to copy is larger than the destination (Kak, 2020). Secure coding standards (such as CERT) strongly advise against using these in favor of safer alternatives (e.g., *fgets*, *strncpy*, *snprintf*, etc.) or, at least, manually checking lengths. In our program, had we used *fgets(password, sizeof(password), stdin)* instead of *gets/scanf*, the overflow would not occur because the input would be truncated to 7 characters (leaving space for the terminator). Likewise, using *strncpy(hash, dbHash, sizeof(hash) - 1)* and then explicitly adding a `'\0'` would prevent overflow when copying the stored hash. These are exactly the kinds of improvements we wanted students to consider for learning objective (4). After walking through the exploit, we explicitly discussed how to fix the code to eliminate the vulnerability – effectively turning the exploit into a lesson on defensive programming. Students readily identified that functions like *strcpy* and *gets* were risky; some suggested using *fgets* or *scanf* with width specifiers, others mentioned using *memcpy* with known lengths or simply using higher-level languages for such tasks. This discussion reinforced the practical importance of choosing safe functions and validating inputs.

Comparison to More Severe Exploits

One might point out that our example does not demonstrate the “most dangerous” aspect of buffer overflows, namely, arbitrary code execution (e.g., injecting shellcode or altering the return address to hijack control flow). This is true – our *LoginApp* exploit is intentionally a gentler introduction that demonstrates logical privilege escalation rather than a system takeover. We scoped it this way for our target audience and time frame. Executing code or spawning a shell via overflow typically requires more setup (controlling exact memory addresses, dealing with non-executable stack regions, etc.), which would be difficult for our students at their current level. Instead, we opted for an attack that manipulates program state in a meaningful way (bypassing a security check) without

digging into machine code or requiring debugger-intensive techniques. This approach still achieves the educational goal: students see that a buffer overflow can subvert security – in this case, an unauthorized user logs in – which is already an eye-opening outcome for them. That said, we do plan to extend the difficulty in future modules (as noted later in the Conclusion). After students digest this exercise, one could present a follow-up exercise that uses a buffer overflow to overwrite a return pointer and execute a payload, thus exposing them to the concepts of shellcode injection and return-oriented programming in a controlled manner. In fact, there are educational tools that visualize exactly that kind of attack (e.g., some of the advanced stack smashing visualizations mentioned in our related work). Our focus here, however, was foundational: to ensure students fundamentally understand what a buffer overflow is and why unchecked memory writes are dangerous, before tackling more complex exploits.

5. Classroom Results and Student Feedback

The *LoginApp* challenge proved to be very challenging for the students. Out of 47 students (working in roughly 20 small groups), only one student successfully crafted a working exploit during the class session. This student had attended a separate Dynamic Application Security Testing (DAST) workshop a few weeks prior, where they learned about common vulnerabilities and tools. In other words, the only in-class success came from a student with some extracurricular training in finding and exploiting bugs. The other 46 students, despite some getting partially on the right track, did not manage to achieve the login bypass without significant hints or assistance.

During the debrief, we analyzed this outcome with the class. First, we congratulated the single solver and asked them to briefly describe their approach. Interestingly, that student used a debugger (gdb) to inspect memory and noticed the layout of variables, which led them to the idea of overflowing into the hash buffer. They then wrote a small Python script to generate the input file with the embedded null and hash, tested it, and found that it worked. This process was far beyond what most others attempted – it combined skills in debugging, understanding memory layout, and using external tools (like scripting or hex editing), which were not explicitly taught in this course.

For the majority of students, the thought process during the

exercise unfolded as follows (gleaned from their feedback and our observations): Many recognized that the presence of `strcpy` and the fixed buffer sizes suggested a buffer overflow. Some even hypothesized, “*Maybe we can overflow the password input.*” However, they were unsure what the overflow would achieve or where to target it. A common misconception was: “Can we overflow the password buffer to overwrite the return address and skip the password check?” – a reasonable guess given what they know of classic exploits, but implementing it is complex and not feasible within the time or their skill level. They did not initially realize that a simpler target was at hand: the stored hash variable. The notion of inserting a null byte to truncate a string or to carefully overlay one buffer onto another was new to them. When we explained the actual solution step-by-step after the activity, we saw many “aha!” moments and also some frustration – “*I knew it was overflowing something, but I didn’t think of that!*” was a common sentiment.

From a pedagogical perspective, the low success rate was not entirely surprising. This was the first time these students attempted to develop an exploit from scratch. In hindsight, expecting them to independently discover the exact technique in a short time was optimistic. The exercise as given was perhaps too open-ended for most. Several students commented, “*It was hard to even start – we’ve never done anything like this.*” This suggests that additional scaffolding is needed if we want more students to arrive at the solution themselves. We discuss improvements below, but it’s clear that without prior training in exploit development, most students struggled to make the imaginative leap from recognizing a bug to weaponizing it.

Despite the difficulty, informal feedback from students was overwhelmingly positive about the experience. In the surveys and class discussion, nearly all students said that seeing a buffer overflow in action left a strong impression. Many remarked along the lines of, “*I understood what a buffer overflow was before, but only now do I really appreciate how it can be used to break security.*” The exercise succeeded in its primary goal: it raised awareness. Students were genuinely surprised that such a small program could be exploited so profoundly. One student wrote, “*Watching the login get bypassed felt like magic – scary magic. I won’t forget why we need to check array bounds.*” Another noted, “*It finally clicked for me why our professors kept telling us not to use `gets()`.*” These comments indicate that even those who did not solve it gained a deeper understanding once

the solution was revealed and explained.

In terms of the learning objectives we set, we observed the following outcomes:

- **Objectives (1) and (2)** were clearly achieved by most students through the combination of the lecture, toy example, and the attempt itself. They could define what a buffer overflow is and identify where it occurred in the code. Indeed, many pointed out (when asked) that the culprit was reading an overly long input into a too-small buffer (they zeroed in on the *scanf* on *password* or the *strcpy* usage). Thus, they learned to spot the dangerous pattern.
- **Objective (3)** (analyzing the vulnerable program’s workflow) was *partially* achieved. Students did inspect the structure of *LoginApp*; in fact, understanding the normal workflow was necessary to even consider how to break it. We observed that while only one student fully exploited it, several groups correctly outlined the program’s logic and pinpointed the variable relationships (e.g., recognizing that the password is hashed and compared to the stored hash). This shows they engaged analytically with the code and understood the intended behavior, even if they couldn’t fully subvert it.
- **Objective (4)** (creating secure alternatives) was addressed after we demonstrated the exploit. We prompted the students, “*So how could the developer have prevented this attack?*” Immediately, multiple hands went up with suggestions: “*Use fgets instead of gets,*” “*Make the password buffer bigger or check the input length,*” “*Don’t copy the hash into a buffer at all—just compare the strings directly,*” etc. They even discussed higher-level fixes, such as “*maybe double-check the input length before hashing or use safer languages.*” This discussion indicated that students were thinking about defensive coding. We followed up by showing a revised version of *LoginApp* with proper fixes (indeed, using *fgets* and *strncmp* with explicit length checks prevented the overflow). Although we did this code fix as a walkthrough rather than as a separate assignment, it reinforced objective (4). In future offerings, we might actually have students implement the fixes themselves as a short follow-up exercise to cement this knowledge.

One notable aspect of the feedback was that engagement was high throughout. Even though many were frustrated by not solving it, they reported enjoying the challenge. It was a novel experience compared to typical programming assignments. The competitive element (knowing at least one person solved it) also sparked curiosity – several students stayed after class to ask the “winner” how they did it, and to try the exploit themselves once they knew the trick. This kind of active interest is exactly what we hoped to achieve: students caring about a low-level detail like buffer management because they saw its real impact on security.

From the instructor’s viewpoint, the exercise was a success in terms of student motivation and in driving home the lesson, but it also highlighted areas to improve. The very low success rate is a double-edged sword. On one hand, even failure was instructive and perhaps humbling (several commented that they “*realized security is hard*”). On the other hand, if students never taste success in a hands-on activity, it could discourage them or make them feel such topics are beyond their capability. We want to adjust the difficulty so that more students can achieve at least partial success with some guidance.

6. Discussion

Pedagogical Implications

The fact that only 1 of 47 students solved the challenge unassisted highlights a key pedagogical insight: open-ended security tasks require careful scaffolding. While the exercise succeeded in raising awareness, most students lacked the foundational skills to independently bridge theory to exploit. To address this, we will restructure the activity into incremental steps, starting with a guided buffer overflow in a harmless toy program, progressing to memory inspection with a debugger (e.g., gdb), and culminating in the full exploit. This gradual release of responsibility aligns with best practices for teaching complex concepts.

The sole successful student had prior exposure to security tools through a DAST workshop, underscoring the value of basic tool literacy. Introducing brief, ethical training in debuggers or simple fuzzers can empower more students to systematically explore vulnerabilities—not to train hackers, but to build confidence in diagnosing and reasoning about low-level code.

Finally, while experiential learning significantly boosts retention

(Resch, 2023), its placement matters. A preparatory demo or lightweight lab earlier in the course—before the full challenge—would better prime students for this type of adversarial thinking.

Limitations of the Study

Our evaluation relied on informal feedback and observation rather than formal pre/post assessments or longitudinal tracking of coding practices, so we cannot quantify learning gains. While student comments and engagement were positive, future work should employ controlled studies with clear research questions—such as comparing hands-on vs. lecture-only instruction or measuring how scaffolding affects success rates—and include comparison groups or iterative refinements.

Additionally, our findings may not generalize beyond cybersecurity-focused students. The tool's effectiveness likely varies with audience background: general CS students might find it too unfamiliar, while advanced security students might find it too simple. Context and audience calibration are essential for broader adoption.

Improvements and Future Directions

Based on the feedback and our observations, we plan several enhancements for the next iteration of this module:

- **Guided Lab Format:** Convert the challenge into a semi-guided lab exercise. For example, provide a worksheet or structured handout that first asks them to run the program with normal input and observe the output, then to experiment with a long input and note what happens (likely causing a crash or odd behavior), then perhaps hint at examining the memory layout (e.g., drawing out where each buffer might be), etc., culminating in the full exploit. This way, even if they don't arrive at the final answer entirely on their own, they will have walked through the critical thinking process step by step and seen the key phenomena.
- **Use of Debugging Tools:** Introduce a short tutorial on using a debugger (like gdb) or a memory visualization tool as part of this exercise. We could show them how to set a breakpoint right after the password read and inspect memory addresses or the stack. Seeing the two hash variables in memory and how one might overflow into the other could prompt the realization of making

them equal. Essentially, teach a mini-skills lesson within the exercise.

- **Alternate Scenarios:** Develop additional scenarios as follow-ups. For example, modify *LoginApp* to be vulnerable in a slightly different way (maybe a heap overflow or an off-by-one error) and ask students to exploit that. This would broaden their skill set and keep the activity fresh for those who might take more advanced courses. We already mentioned plans for eventually showing more dangerous cases like return address overwrites in a future module. The idea is to provide a progression of difficulty: *LoginApp* being level 1, and later modules introducing levels 2 and 3 of exploit complexity.

7. Conclusion and Future Work

LoginApp successfully bridges theory and practice by letting students experience a real buffer overflow exploit in a controlled setting. Despite a low success rate (1 of 47), the exercise deepened students' understanding of memory safety and motivated secure coding—confirming the value of hands-on learning (Alnajim et al., 2023).

Future iterations will add scaffoldings such as guided labs and introductory debugger training to improve accessibility and success rates. We also plan to formally assess learning gains through pre-/post-quizzes and code analysis.

Long-term, *LoginApp* will be the first in a series of progressively complex vulnerability modules (e.g., stack smashing, ROP), forming a curriculum-integrated “mini-CTF” suite. Our goal is to equip students not just with knowledge, but with the mindset to prevent vulnerabilities in real-world software.

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Challenges of Higher Education Enrollment Trends in the US, Ohio and Ohio Regional Campuses

Diane Huelskamp
Wright State University Lake Campus

Joe Cavanaugh
Wright State University Lake Campus

Student enrollment and retention have continued to be a focal point for higher education as these numbers have predicted an “enrollment cliff” for universities. The enrollment and retention of students is a source of revenue for universities nationwide; colleges continue to scramble to meet budgetary needs by attempting to increase and retain students at their institutions. Public school funding is often tied to enrollment; as K-12 school's enrollment declines, ultimately state colleges' student base also declines, causing financial budgetary decisions to be made that impacts all aspects of university activities. This paper will delve into declining enrollment factors, and steps universities may take to meet the challenges.

There is an expected “enrollment cliff” in higher education in the United States, predicted by declining birth rates and a reevaluation of whether going to college is worth the cost. Universities are therefore faced with budgetary concerns as fewer students are projected to attend. This paper will present the causes of enrollment decline, the impact on colleges, and how colleges can navigate the challenges of a shifting student enrollment.

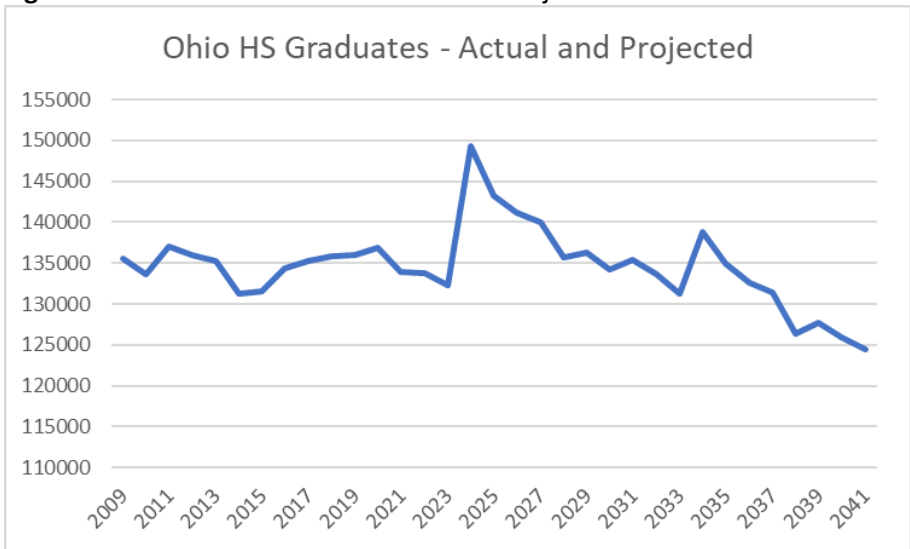
Factors feeding a declining college enrollment

Declining K-12 enrollment in public schools

Although there is the impact of a preference toward private, charter and home-schooling since COVID, demographically, there is also a declining birthrate, which means fewer students K-12 regardless of if public or private. In the long-term, universities are impacted as well. Peak enrollment K-12 was at 50.8 million students in 2019 and is expected to drop to 46.9 million by 2031 (Digest of Education Statistics, 2022, n.d.). The class of 2025

was the *largest* graduating class in the US, and graduating numbers are expected to decrease through 2041 (*Total Number, 2024*). These declining graduating HS seniors' rates will continue to trickle into universities in the upcoming years with continued decline. For Ohio, although the projection in high school graduates is at -6% between 2023 to 2041, other midwestern states are projected to drop more. For example, Michigan (-20%) and Indiana (-10%) have steeper declines (*Total Number, 2024*). Ohio faces the same enrollment cliff as seen for most states due to changes in demographics. After holding steady from 2009 to 2023 Ohio experienced a quick upturn as Covid recovery efforts allowed students to catch up from credits lost. Anticipating fewer students in the pipeline, the projected number of graduates then experiences a steady decline through 2041 (Lane, Pet al., 2024). See Figure 1.

Figure 1: Ohio HS Graduates – Actual and Projected



The impact of declining K-12 enrollment forces colleges to compete competitively amongst themselves for a smaller number of potential students, and many predict that smaller colleges and regional institutions will be more vulnerable to closures or mergers. For example, Penn State trustees voted in May, 2025 to close seven branch campuses, due to declining enrollments (Associated Press, 2025). These branch campuses

served a more local populace, and as the K-12 enrollment declined, so did the local branch campuses' enrollment.

Perceptions of Education

There is a shift in the perception of the value of a college degree toward the degree not being worth the cost. Satisfaction with U.S. public education went from 37% in 2017 to 24% in 2025 according to a Gallup poll (Saad, 2025). Parents question the value of education being received and the cost of education, either as a taxpayer or tuition provider (Kelderman, et al., 2019). Students also consider the balance of the cost of a college degree with the value they receive (Schanzenbach, et al., 2022). Will they get a job? Will the job pay their bills? Some jobs have weaker job placement rates, increasing their skepticism about the value of that degree. This skepticism on the value has shifted students to pursue credential programs, certifications in a trade, or skill-based training (National Student Clearinghouse, 2025), ultimately adding to the student population decline. For instance, in Mercer County Ohio, TriStar Career Compact has increased from 219 students in 2019 to 385 students in 2025; an increase of 75% in student enrollment (NCES, 2025). Tristar offers career technical education with certification in trades.

Student funding of college costs

Student loans are the second-largest debt in America after home mortgages (Federal Reserve Bank of New York, 2025). On average, in America, 50% of students have a loan upon graduation, and the average student loan debt per borrower is \$31,960 for a public university (Hanson, M., 2026). Currently the impact of the One Big Beautiful Bill Act on students involves their federal loan limits, Pell Grant eligibility and other financial plans. The Bill, signed into law on July 4, 2025, affects students and educational institutions (Cooper, 2025). According to Cooper (2025), other impacts on student funding can come from lowering the amount of money allowed to be borrowed to attend graduate or professional school each year, limiting the Parent PLUS plan, and terminating loans for Grad PLUS. These limitations narrow the student's options for making college affordable. The deficit in funding needs will have to be found elsewhere. The One Big Beautiful Bill also proposes a standard fixed-payment plan and Repayment Assistance Plan (RAP) to replace income-driven plans potentially

lessening monthly payments for students (Cooper, 2025). This may be a positive for students with college debt.

College Savings Plans

Often referred to as a 529 plan, these plans can be more than college tuition. Changes in the 529 plan include doubling the amount that can be withdrawn for K-12 expenses to \$20,000 annually, toward private tuition, obviously impacting K-12 public schools. It also broadens the plan to include workforce training, not just postsecondary expenses, according to Cooper (2025). These changes are all meant to help lessen the burden of college cost but does not address the value of the degree.

Pell Grants The new rules for student eligibility and changes to the Student Aid Index formula may make fewer students eligible for Pell Grants, increasing the need for other funding sources such as private loans. Donors—both individuals and businesses—can receive tax credits for contributing to state-approved scholarship organizations under the 'Big Beautiful Bill.' This also creates a new source of tuition funding for students.

Drop in international student enrollment

Another reason for declining enrollment in universities is a drop in international students. According to data from 2022, the United States still enrolls the greatest number of international students at approximately 24% (Project Atlas, 2024, n.d.). These numbers are now decreasing due to the suspension of visa interviews in the Spring of 2025 impacting fall enrollment, Visa restrictions on 19 countries in the Spring of 2025 and a decrease in consulate appointment availability for certain countries impacting international students seeking to enroll in American universities (*Fall 2025 International Student Enrollment Outlook and Economic Impact*, 2025). The estimated international student enrollment decline in the US is projected to be 150,000 students in Fall 2025 (*Fall 2025 International Student Enrollment Outlook and Economic Impact*, 2025), Bear in mind that this data is for Visa applicants and does not include those international students which currently reside in the US.

For Ohio, all Ohio colleges have seen a decrease in international student enrollment compared to last Fall (Henry 2025). The four universities which enrolled the most international students decline in number is shown in Table 1 (Morona, 2025). It should be noted that international and out-of-

state students often pay a higher tuition rate than in-state students, further impacting budgetary concerns.

Table 1: Four Colleges in Ohio with greatest international student enrollment, with changes 2024-2025

College	Fall 2025	Fall 2024	Year-over-year change:
University of Cincinnati	3,879.00	4,616.00	-15.97%
Cleveland State University	1,249.00	1,900.00	-34.26%
Kent State University	1,768.00	2,169.00	-18.49%
Ohio State University	5,996.00	6,305.00	-4.90%

The impact of lower international student enrollment on universities is not only the loss of tuition revenue, but also research talent. Lower graduate students impact research done at the graduate level. International students make up approximately 24% of graduate students in the US, but only 6% of college students overall (McKenzie, B.D. et al, 2023).

Challenge Accepted! How Universities are Responding

Continuing expected decline from 2025 onward has led to the term “enrollment cliff” projecting a steep decline in college enrollments starting around 2025-2026 and onward due to declining birth rates, which started in 2007. This projects financial strain on colleges or potential college closures as a result. However, the actual results of Fall 2025 in Ohio at least, are mixed. As of October 2025, Bowling Green, Ohio State, Ohio University, Shawnee State, U of Akron, U of Cincinnati, Wright State and Youngstown State all reported an *increase* in Fall Enrollment (Henry, 2025). Cleveland State, Miami and the U of Toledo all reported decreases in Fall 2025 enrollment. No data was reported for Central State or Kent State, and we could not find their data in our research as of this writing. For many colleges in Ohio at least, challenges are accepted. Their numbers went against expectations. We also have not found in our research a specific easy-to-copy reason *why* many have increased their enrollment that can be applied as a general “fix” for all. Perhaps it is intricate, nuanced, and specific to each University and how each seeks to reach students and retain them. One potential reason may be that high school students are taking college courses for credit, which may provide a small but potential niche for regional campuses in Ohio to increase enrollment. However, although Ohio’s universities do receive tuition for high school students to attend while still in high school to receive college credit, the tuition received is not the regular

tuition rate, is of often much lower, and paid for by the local public-school districts (Faber, 2023).

Decreasing college tuition costs

College is becoming more affordable. For public four-year institutions, college costs are down 4% from 2014 when adjusted for inflation and, when grants and financial aid are included, it has on average decrease ~40% since 2012 from \$4,340 to \$2,480 annually in 2024, according to College Board (2024). Lower tuition costs should entice more students to see college as an affordable option for them, although the idea of rising college costs still is presented by the media and financial institutions and the public tends to believe that tuition is increasing.

Continue to inform that college degrees are worth it

According to the US Bureau of Labor Statistics (US BLS) 2024, the median weekly earnings of a 25-year-old worker with a high school degree: \$930. For a worker with a bachelor's degree, the median weekly earnings are \$1,543. The difference is a 66% increase in earnings per week. Yearly, the difference is approximately \$32,000 more in earnings with the college degree.

Also, there is an inverse relationship between level of degree earned and unemployment rates (US BLS, 2024), HS diploma unemployment rate is 4.2%, while Bachelors degree unemployment rate is 2.5%, showing that degrees are worth the time and cost involved to acquire and maintain employment. Because they are often more affordable, regional campuses can market themselves to prospective students by highlighting the strong return on investment of their degrees.

Innovation in attracting students

Recruitment efforts have included attracting students from diverse backgrounds, along with attracting non-traditional non-18-year-old students due to decreasing graduation rates of 18-year-olds. Research results are sparse in the effectiveness of reaching the non-traditional student to attend college. The potential is there, but large-scale enrollments are probably not going to be seen. Adult learners often have many tasks to juggle and even if they start, they may not be able to finish college in a timely manner. Regional campuses can continue to entice nontraditional (modern) students by offering courses online, with flexibility.

Finding alternative funding opportunities besides tuition

Besides tuition rates as a source of revenue, exploring other potential sources of revenue is a must in the present college market. Thinking outside the box may include rental of college facilities for local venues/activities, improving services to students which may be anything from healthy food choices to laundromat services, textbook rentals or a community bookstore. Reaching out to local businesses to establish partnerships between meeting their employment needs and the courses offered through the university. Online and flexible learning may also be an option. Developing a strong alumni base may pool monies toward the university, especially if sponsorships for students or particular development needs are presented. Every campus should assess the community it serves to find the particular niche it can fill and be financially secure. The solution depends on the unique needs and abilities of the campus.

Enhance student support and success

Attracting students toward the campus is one thing; keeping them through degree attainment is another. Community colleges have seen the highest gains in retention rates at 3.7% over a 10-year period, according to eCampus (Staff, 2024), while four-year institutions rate at 3.1%. At-risk students are those who are not attending right out of high school, basically the non-traditional student, whose retention rate is less than 50% (Staff, 2024). Four keys elements which impact student retention include academic support, financial barriers, social integration, and institutional culture (*Student Retention Strategies for Higher Education*, 2025).

Academic support

Having access to tutoring, advising, and faculty helps the student stay and track during their college career. Each of these can also be an informal mentor to the student as well, providing insight and direction to the student.

Financial Barriers

Obviously, debt can cause students to drop out of their program of study. Being aware of financing options and grants available may help the student stay the course.

Social Integration

Feelings of belongingness are important to the student. Being engaged socially and developing strong relationships with their peers and also with faculty maintains involvement and connection. Clubs, activities, teams, and hobbies help retain the student during their college career.

Institutional Culture

The healthy campus environment impacts the student by feeling supported, noticed, and valued. Universities can support a healthy campus culture by having activities which get students out and about with each other. These can include outdoor game days, free coffee/donut days to mix and mingle or campus-wide organizational game events.

Align degrees with workforce needs

This coincides with another part of the Big Beautiful Bill: Colleges are required to pass the “Do No Harm” test (*An Analysis of the One Big Beautiful Bill Act’s Effect on Student Loans*, 2025). Basically, a comparison is made between the median annual earnings of graduates four years after earning their degree with what a student might have earned if they had not pursued college at all. If they do not out-earn this benchmark, it is considered harmful to students. If the degree program fails two out of any three consecutive years, the university can no longer disburse federal loans to students in that program. Although this was passed into law and may change, ultimately this will streamline the degrees offered by universities with future employment opportunities upon graduation whether colleges want to streamline or not. In the end, it does address the question of whether a degree is worth the cost. And therefore, it will impact student enrollment and finances positively or negatively as students choose to, or not, attend college with the consideration of the degree possibilities offered at a particular campus. Regional campuses can continue to work with their local businesses in developing the skills and degrees needed to meet the employment needs of their locality. Our local regional campus has had success in doing just this alignment and has been successful at turning their financial crisis into financial reserves.

Wright State Lake Campus Success at Recruitment and Retention

According to a recent Regional Workforce Summit held at Lake Campus on March 11, 2025, Wright State has become an example of how to

turn around a financial crisis into a success. In 2017, WSU had just 23 days of cash on hand for expenses, and was required to reduce the 2018 budget by \$30 million dollars (Kincaid, 2026) and achieved this by eliminating at both Dayton and Lake a total of 57 employees and not filling 119 vacant positions. The focus of Wright State had been continuing to be three-fold: recruitment, retention and relationship. It is the focus on the relationship part of this triangle that helps build success, according to Andrea Faber, Vice Provost, and CAO of Lake Campus. WSU Lake has seen an increase in the Fall headcount from 10,491 in 2022 to 11,628 in 2025; an 11% percent increase.

To foster community relationships, WSU launched a strategic plan last year focused on three pillars: student success, experiential learning, and industry partnership. President Sue Edwards notes that this initiative creates a direct link between students, the university, and local businesses. This relationship building with the students includes providing for the students needs not only for their college success, but also providing the experiential learning that will help them become employed upon graduation. Building relationship with local businesses provides the links for our students to connect with career professionals and potentially provide future employment (Edwards, 2026). This 3-fold alignment is believed to be a key factor in the high job placement rate of Lake nursing students, where 90% have secured positions in west central Ohio (Faber, 2026). Keeping your students local with affordable tuition, can keep your workforce local upon graduation by linking job needs with what colleges can provide to local businesses. This in turn can help with the economic development of the region by maintaining job opportunities and businesses in that region.

Conclusion

Although a smaller number of high school graduates is expected in the forthcoming years, universities have available strategies to maintain or even increase their enrollment. Each campus needs to identify and take advantage of their own strengths to meet the needs of the community/students it serves. For Lake Campus, success seems to come from a focus on linking students, the college and local businesses in a concerted effort to keep the Region economically strong.

A drawback, not addressed here, would be the decrease in the importance of liberal arts degrees, especially when local businesses are looking, for instance the Lake Campus region, degrees in Engineering,

Business, Nursing, Education for example. Despite this, Lake Campus has been able to become financially stable.

There is no one-size-fits-all answer to declining enrollment and revenue. Regional campuses need to find and fill the niche that fits themselves and their community.

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Appendix A: AI-Generated Resources for Chemistry Instruction

The following tables summarize the types of instructional and assessment materials generated using ChatGPT to support General Chemistry students. These resources were designed to align with specific Student Learning Objectives (SLOs) and to facilitate mastery-focused learning through scaffolded worksheets, personalized study guides, real-world applications, and multi-version assessments for Specs Grading. Each table provides sample prompts, example questions, and descriptions of how these materials are structured to cater to diverse learning needs. By using AI, faculty can efficiently create adaptive learning materials that support both foundational understanding and complex problem-solving skills.

Table 7: Summary of AI-Generated Resources and Examples in Chemistry Instruction

Resource Type	Purpose	Sample Prompt/Description	Example Use Case
Scaffolded Worksheets	Support incremental mastery of complex concepts through structured steps	"Create a scaffolded worksheet on stoichiometry, starting with basic mole calculations and progressing to limiting reactants."	Topic: Stoichiometry Steps: 1) Mole Concept Basics – Calculate moles of NaCl for 5g 2) Stoichiometric Ratios – Identify limiting reactant 3) Applied Problems – Calculate yield based on limiting reactant
Study Guides	Reinforce key concepts and provide targeted practice for self-study	"Develop a study guide for acid-base reactions with key concepts and practice problems."	Topic: Acid-Base Reactions Content: Overview, key concepts, sample problems with solutions

Real-Life Chemistry Examples	Connect theory to real-world applications, enhancing engagement	"Provide examples of oxidation-reduction reactions in everyday life, with explanations."	Examples: Rusting, combustion, photosynthesis, with explanations of each reaction
Customized Worksheets	Adapt materials to different levels of prior knowledge	"Generate a worksheet that adjusts stoichiometry questions for various student skill levels."	Customization: Vary question complexity based on student proficiency
Multi-Version Quests for Specs Grading	Facilitate mastery-focused retakes by offering varied versions of assessments	"Create three versions of a quest question on molar mass calculation, each with different compounds and masses."	Quest Versions: 1) Yield of H_2 from $Zn + HCl$ 2) O_2 yield from $KClO_3$ 3) CO_2 yield from $C + O_2$
Practice Problems	Provide targeted problem-solving practice with step-by-step solutions	"Create five practice problems on acid-base titration with step-by-step solutions."	Example Problems: Titration calculations, identifying endpoints, acid-base balance

Appendix B: Sample Response for Scaffolded Worksheet on Stoichiometry

This scaffolded worksheet progresses from simple to complex concepts, reinforcing each step with examples and practice. This approach allows students to build a solid foundation in stoichiometry, setting them up for success in more advanced topics.

Prompt:

"Create a scaffolded worksheet on stoichiometry, beginning with basic mole calculations and progressing to limiting reactants."

ChatGPT-Generated Worksheet

Topic: Stoichiometry – From Moles to Limiting Reactants

Objective: This worksheet guides students through the fundamental steps of stoichiometry, starting with mole calculations and advancing to limiting reactants. Each section includes examples and practice problems to reinforce understanding.

Step 1: *Mole Calculations*

1. Introduction: Understanding moles is crucial in chemistry as it allows us to relate masses of substances to the number of atoms or molecules.
2. Example Question: Calculate the number of moles in 10 grams of NaCl.

Solution: $\text{Molar mass of NaCl} = 58.44 \frac{\text{g}}{\text{mol}}$

$$\text{Moles of NaCl} = 10 \text{ g NaCl} \times \frac{1 \text{ mol of NaCl}}{58.44 \text{ g NaCl}} = 0.171 \text{ mol NaCl}$$

3. Practice Problem: Calculate the number of moles in 25 grams of H₂O.

Step 2: *Stoichiometric Ratios*

1. Introduction: In a chemical reaction, substances react in specific ratios. Stoichiometry helps us calculate how much of each substance is needed or produced.
2. Example Question: In the reaction $2 \text{H}_2 + \text{O}_2 \rightarrow 2\text{H}_2\text{O}$, how many moles of O_2 are required to react completely with 4 moles of H_2

Solution: According to the balanced equation, 2 mol of H_2 reacts with 1 mol of O_2

$$\text{Moles of O}_2 = 4 \text{ mol H}_2 \times \frac{1 \text{ mol of O}_2}{2 \text{ mol of H}_2} = 2 \text{ mol of O}_2$$

3. Practice Problem: In the reaction $3 \text{H}_2 + \text{N}_2 \rightarrow 2 \text{NH}_3$ how many moles of NH_3 are produced when 6 moles of H_2 react?

Step 3: *Limiting Reactants*

1. Introduction: When reactants are not in perfect stoichiometric ratios, one will run out first and limit the reaction. This is called the limiting reactant.
2. Example Question: In the reaction $2 H_2 + O_2 \rightarrow 2H_2O$, if you have 3 moles of H_2 and 2 moles of O_2 , which is the limiting reactant?

Solution: According to the equation, 2 moles of H_2 requires 1 mole of O_2

$$\text{Moles of } O_2 = 3 \text{ mol } H_2 \times \frac{1 \text{ mol of } O_2}{2 \text{ mol of } H_2} = 1.5 \text{ mol of } O_2$$

Since you have 2 moles of O_2 , H_2 is the limiting reactant.

3. Practice Problem: For the reaction $2 Al + 3Cl_2 \rightarrow 2AlCl_3$, if you have 5 moles of Al and 5 moles of Cl_2 , which reactant is limiting?

Appendix C: Real-Life Chemistry Examples

To make complex chemistry concepts more relatable and engaging, ChatGPT was used to generate real-life applications of chemistry principles. These examples help students see the relevance of their studies beyond the classroom, enhancing their understanding and interest in the subject.

Sample Prompts for Real-Life Chemistry Examples

- Oxidation-Reduction Reactions: "Provide examples of oxidation-reduction reactions in everyday life, with explanations of how and where they occur."
- Acid-Base Reactions: "Generate real-life scenarios where acid-base reactions are essential, such as in cleaning products or food chemistry."
- Combustion and Energy: "Explain the chemistry behind combustion in engines and how it converts fuel into energy."

Example Responses from ChatGPT

1. Oxidation-Reduction in Batteries: "Batteries rely on oxidation-reduction reactions to generate electricity. In a zinc-carbon battery, zinc undergoes oxidation while manganese dioxide is reduced, creating a flow of electrons that powers electronic devices."
2. Acid-Base in Cleaning Products: "Many cleaning agents contain bases, like sodium hydroxide, which reacts with oils and greases to

form water-soluble substances, making cleaning more effective. Vinegar (acetic acid) is an acid commonly used to dissolve mineral deposits due to its acidic properties."

3. Combustion in Automobiles: "In car engines, gasoline combustion produces energy. The carbon and hydrogen in gasoline react with oxygen, releasing energy in the form of heat and producing carbon dioxide and water as by-products."

Appendix D: Full List of Likert Survey Questions

The following survey questions were previously published in Author (2024) and are provided here for reference. The average scores reflect student responses on a 5-point Likert scale (1 = Strongly Disagree, 5 = Strongly Agree).

1. Clarity of content (M = 4.4)
2. Usefulness in learning (M = 4.3)
3. Preparedness for assignments (M = 4.2)
4. Engagement level (M = 4.3)
5. Ease of application (M = 4.1)
6. Interaction with peers (M = 3.9)
7. Independence in learning (M = 4.0)
8. Preparedness for assessments (M = 4.2)
9. Preference for scaffolded worksheets (M = 4.5)
10. Overall experience (M = 4.5)

Why Online Students Outperform Hybrid Students: The Role of Attendance, Course Structure, and Engagement in a Project-based Mathematics Course

Poranee Khayo
University of Cincinnati

This study examines the effects of hybrid and online instructional modalities on student achievement, attendance, and attitudes toward mathematics in a project-based college course. Using a quasi-experimental design, 315 students across fourteen course sections were compared on multiple performance measures, including homework assignments, quizzes, projects, exams, participation, and overall course grades. Results consistently showed that online students outperformed hybrid students across all achievement categories. No significant differences were found in students' attitudes toward mathematics, with both groups showing stable attitudes from the beginning to the end of the semester. Attendance emerged as a significant predictor of academic performance, with online students maintaining substantially higher attendance rates than hybrid students. Mediation analysis confirmed that attendance partially explained the superior outcomes achieved by the online group. Survey responses further revealed that students valued the flexibility, pacing, and convenience of online learning, while hybrid students reported greater uncertainty about course expectations. These findings highlight the critical role of attendance, clarity, and course structure in determining instructional effectiveness and suggest that thoughtfully designed online formats can support strong learning outcomes in project-based mathematics courses.

1. Introduction

As a researcher who has taught the Foundations of QR (project-based) course in-person for eight years, we initially believed it was impossible to teach a project-based course online. However, in Spring 2020, due to the COVID-19 outbreak, all courses at the University switched to online formats. Faced with no other option, we had to adapt our course to an online format.

Over time, we modified our projects to fit the online environment and began to notice the benefits of offering classes online. Students with newborns, disabilities, military commitments, or caregiving responsibilities could attend our class online, overcoming challenges related to commuting to campus. This experience led us to question how we could provide the same quality of instruction to online students, allowing them to benefit from the flexibility of the online model while still achieving similar learning outcomes. This research aims to explore and address these questions, ensuring that online students receive the same content and achieve comparable learning achievements as their in-person counterparts.

The students in both formats received the same lecture videos and completed the same homework assignments online weekly. The quizzes and exams were identical and were done online. The hybrid sections completed projects in-class on campus, while the online sections did them on Zoom once a week. The projects were almost identical, with some modifications to better fit the online format. The quiz and exam scores were used to determine any significant differences in learning achievements between the two groups. We also tested students' attitudes towards mathematics at the beginning and end of the semesters to see which model improved students' attitudes more. Additionally, there was a set of survey questions addressing the advantages and disadvantages of both models.

2. Literature Review

Research comparing in-person, online, and hybrid learning formats has expanded considerably in recent years, revealing a multifaceted and often contradictory landscape. Rather than pointing to a single modality as consistently superior, the body of evidence suggests that instructional design, clarity, engagement, and student support play far more influential roles in shaping student performance than the delivery format itself. Still, the literature offers valuable insights into patterns, preferences, and pedagogical features that help explain differences in learning outcomes across modalities.

2.1 Comparative Effectiveness Across Modalities

A substantial portion of the literature finds that online learning can perform as effectively as face-to-face instruction when carefully designed. For example, Elzinga and Harper (2023) reported no significant difference in student performance between in-person and online sections, with students in their study even expressing a preference for the online format. Their findings suggest that when course expectations and instructional components are aligned, online environments can support student success as effectively as traditional classrooms. Similarly, Rojas (2023) found that online classes incorporating active learning strategies can be just as effective as traditional face-to-face instruction. These results align with broader trends showing that the quality of instructional strategies such as feedback cycles, opportunities for practice, and interaction which mediates performance more strongly than the physical environment in which learning occurs.

At the same time, other researchers have reported performance outcomes that vary across assessments and content areas. Little and Jones (2020), who conducted a comprehensive comparison of face-to-face, online, and hybrid classes, observed “mixed” results in which online and hybrid classes outperformed face-to-face classes on some assessments, while face-to-face sections excelled on others. Their study underscores that modality interacts with course content, assessment type, and instructional practices. Similarly, Rahmawati et al. (2022) found that hybrid learning significantly enhanced students’ critical thinking skills in mathematics, while Zein et al. (2019) reported substantial improvements in learning outcomes for students engaged in hybrid mathematics instruction. Together, these findings suggest that hybrid learning when well structured, can offer advantages by combining the strengths of online flexibility with the immediacy of face-to-face interaction.

However, not all comparisons favor online or hybrid formats. Howard (2019) found that students in face-to-face cohorts achieved significantly higher summative course grades compared to their peers in hybrid sections. Moreover, online students in Howard’s study perceived the course as requiring more work than those in the face-to-face format, raising important questions about workload transparency, pacing, and instructional clarity in digital environments. These findings echo earlier work by Henry and Romeo (2017), who observed that although student outcomes in online and hybrid courses were comparable, online students often reported a

perception of increased effort even while appreciating the convenience of the format. Taken together, these studies highlight that differences in student performance across modalities may be shaped as much by learner perception, discipline-specific demands, and course structure as by modality itself.

2.2 Student Preferences and Perceived Advantages

In addition to performance outcomes, student preferences offer another lens for understanding modality effectiveness. Plescau and Drob (2023) reported that students favored hybrid formats over both online and face-to-face options, a finding that points to the value students place on the balance between flexibility and interaction. Jaleel et al. (2024) found that while online courses outperformed hybrid ones on certain performance measures, students nevertheless preferred hybrid courses because they perceived them as more interactive and supportive. These results align with broader evidence that students value flexibility, autonomy, and convenience, but also rely on synchronous interaction, instructor presence, and opportunities for collaboration to feel connected and supported.

2.3 Active, Applied, and Project-Based Learning in Mathematics

Several studies emphasize the importance of course design that fosters active engagement and relevance. Julian (2017) offers a notable example with her investigation of a project-based Foundations of Quantitative Reasoning course at a two-year college. Using pre- and post-surveys of mathematical attitudes and pre- and posttests of achievement, Julian compared the project-based course to a traditional College Algebra section. The project-based course produced significant improvements in both attitudes toward mathematics and mathematics achievement, suggesting that real-world application and hands-on tasks can greatly enhance learning particularly for non-STEM students who may not feel connected to traditional algebra. Julian's findings support the broader consensus that applied, context-based learning strategies can improve motivation, deepen conceptual understanding, and support stronger academic outcomes, regardless of instructional modality.

2.4 Instructional Clarity, Engagement, and Feedback

Beyond modality comparisons, the Scholarship of Teaching and Learning (SoTL) literature consistently emphasizes instructional clarity, engagement, and support as central determinants of student success. Bowers and Kumar (2015) found that student satisfaction and performance in online mathematics courses were closely tied to the presence of timely feedback and structured support systems. In parallel, Bawa (2016) highlighted that student persistence in online learning depends heavily on clarity of expectations, feedback loops, and opportunities for interaction. These findings suggest that online and hybrid formats do not inherently disadvantage students; instead, challenges arise when expectations, structure, or communication are unclear.

Martin and Bolliger (2018) further demonstrated that students value synchronous meetings, collaborative activities, and prompt instructor feedback in online environments which help replicate the engagement and accountability typically associated with face-to-face courses. Together, these studies highlight a critical theme: effective online and hybrid learning depends on thoughtful integration of engagement opportunities that reduce student isolation and promote active participation.

2.5 Connection to the Current Study

The themes identified across this literature directly informed the design of the present study. Both hybrid and online students received identical lecture videos, assignments, and assessments, ensuring that differences in student achievement could not be attributed to content or instructional materials. Weekly synchronous meetings were incorporated into both sections to support interaction, structure, and clarity, reflecting best practices identified in SoTL research (Bawa, 2016; Bowers & Kumar, 2015; Martin & Bolliger, 2018). Additionally, the course design included project-based elements similar to those shown by Julian (2017) to enhance student engagement and learning outcomes, offering relevance and application across modalities.

By standardizing instructional design while varying only the modality, the present study follows recommendations across the literature to isolate the true impact of delivery format. The study design aligns with research indicating that when clarity, engagement, structure, and applied learning are prioritized, online and hybrid modalities can support strong academic outcomes comparable to traditional environments.

3. Objectives of the study

The purpose of this study is to investigate the impact of hybrid and online instructional methods on students' learning achievements, attitudes towards mathematics, and their overall online learning experience.

4. Methodology

4.1 Study Design

The study was conducted using two quasi-experimental two-group designs since the participants were not randomly assigned to hybrid and online groups but selected based on the sections in which the students enrolled. There was some consistency in sample sizes across groups, as student enrollment varied by section. The sample consisted of 315 students (hybrid group: 151 students; online group: 164 students). The study took place during the Fall 2023, Spring 2024, Summer 2024, and Fall 2024 semesters at the University. Participants were enrolled in the Foundations of QR course. The hybrid group consisted of seven sections taught using a hybrid setting, while the online group comprised seven sections taught by the same instructor using an online setting. Both groups were similar since they were enrolled in the same course with the same prerequisite requirements. The hybrid group met once a week on-campus to work on their projects, while the online group met once a week on Zoom to complete their projects. The independent variable was the pedagogy approach. The dependent variables were learning achievement, measured by quizzes and exams, and students' attitudes toward mathematics, measured by pre-attitude-survey and post-attitude-survey using the Attitudes Toward Mathematics Inventory (ATMI) (Tapia, 1996; Tapia & Marsh, 2005). Attitude data were collected at the beginning and end of the semesters. The goal of this research was to determine whether hybrid or online instructions improve students' achievements more effectively.

4.2 Study Setting

The study was conducted in a total of 14 sections of the 3-credit-hour Foundations of QR course at the University (seven sections were hybrid and the other seven were online). Both groups received the same video lectures and completed the same homework assignments, quizzes, and exams online. The hybrid sections completed projects in-class on-

campus, while the online sections did them on Zoom once a week. A couple of projects needed some modifications to fit the online format while maintaining the same concepts. The homework assignments, quizzes, and projects were open-book, while exams were online, closed-book, and proctored by Honorlock. The same instructor taught both hybrid and online sections using the same textbook.

4.3 Participants

The participations in this study were recruited from all students enrolled in Foundations of QR course taught by the researcher. From a total enrollment of approximately 315 students, 151 students in hybrid sections chose to participate, and 164 students in online sections chose to participate.

4.4 Instrumentation

The instruments used to determine students' achievements in this study were homework assignments, quizzes, projects, and exams. The instrument used to measure students' attitudes was the Attitudes Toward Mathematics Inventory (ATMI) developed by Martha Tapia of Berry College (Tapia, 1996; Tapia & Marsh, 2005). The ATMI consists of 40 items rated on a five-point Likert scale (Strongly Agree, Agree, Neutral, Disagree, and Strongly Disagree) divided into five subscales: Value of Mathematics, Enjoyment of Mathematics, Motivation in Mathematics, and Anxiety toward Mathematics. It has a reliability Cronbach alpha coefficient of 0.97. Tapia and Marsh demonstrated that the ATMI is a reliable instrument for data collection and is appropriate for American college students (Tapia & Marsh, 2005). The sum of the subscales gives the total score of a student's attitudes towards mathematics, with a maximum score of 200 points. The higher the score on the ATMI, the more positive attitudes students exhibit towards mathematics.

4.5 Procedure

Participants for the research study were recruited in class during the first week of the semesters. The research instructions were read aloud by another faculty member as students listened at the beginning of their class period. Students choosing to participate in the study read a consent form and completed a short demographic questionnaire. Participants were informed about all research activities involved in the study. They were

assured that the data would be used for research purposes, that participation was voluntary, and that they could withdraw from the study at any time for any reason or no reason without penalty. Approval for this study was obtained from the Institutional Review Board (IRB) at the University. Participants completed the pre-attitude-survey at the beginning of the semester and the post-attitude-survey and online experience survey toward the end of the semester.

4.6 Data Analysis Strategy

The data was analyzed by using SAS and R with the level of statistical significance was set at 5%. An independent t-test was carried out to determine the effectiveness of hybrid and online instructions on students' achievements. The null hypothesis was "There is no significant difference in total, homework assignments, quizzes, projects, or exams scores among the hybrid and online groups." A Multivariate Analysis of Covariance (MANCOVA) was then used to compare learning outcome measures across the hybrid and online groups. The corresponding null hypothesis was "There is no significant difference in all achievement measures together among the hybrid and online groups." Lastly, a mediation analysis consisting of three sets of regression and a bootstrapping procedure was conducted in this research. The null hypothesis for this analysis was "There is no indirect effect of instructional modality on performance measures through the mediator."

5. Results

The results showed that overall the online group performed better in all parts: homework assignments, quizzes, projects, and exams, with a p-value (two-tailed) less than 0.05 using the Pooled method. Consequently, the total scores were higher with a p-value (two-tailed) less than 0.01 using the Pooled method. However, there is insufficient evidence to show that the students' attitudes towards mathematics in both groups are different or that the attitudes had improved after completing the course.

Table 1: the total scores of the hybrid and online groups

Total Scores	Hybrid	Online
Mean	65.18	73.88
SD	24.3	23.9
N	151	164
DF	131	
t value	-2.94	
p-value (two-tailed)	0.0036	

Table 1A: Equality of Variances of total scores

Method	Num DF	Den DF	F Value	Pr>F
Folded F	150	163	1.03	0.8499

The total scores consisted of 15% homework assignments and 10% quizzes on Pearson MyLabMastering, 15% projects completed either on-campus or online, 5% participation from watching the lecture videos, 15% Exam 1, 15% Exam 2, and 25% Final Exam. Table 1 shows that the total scores of the online students were higher. Since the Folded F-test from Table 1A indicates that the variances of the two groups are equal, we used the Pooled t-test and obtained a two-tailed p-value of 0.0036, which is less than 0.01. This means there is very strong evidence that the means of the total scores of the two groups are not equal. Given that the mean of the total scores of the online group was higher than that of the hybrid group, we can conclude that there is a very strong indication that the mean of the total scores of the online group is higher, with a one-tailed p-value of 0.0018, which is even less than 0.01.

Table 2: the exam scores of the hybrid and online groups

Exams	Hybrid	Online
Mean	62.10	70.83
SD	30.44	29.47
N	151	164
DF	131	
t value	-2.38	
p-value (two-tailed)	0.0181	

Table 2A: Equality of Variances of exam scores

Method	Num DF	Den DF	F Value	Pr>F
Folded F	150	163	1.07	0.7027

The exam scores were composed of 30% Exam 1, 30% Exam 2, and 40% Final Exam. Table 2 illustrates that the online students achieved higher exam scores. Since the Folded F-test from Table 2A confirmed that the variances of the two groups are equal, we employed the Pooled t-test, resulting in a two-tailed p-value of 0.0181, which is less than 0.05. This indicates the means of the exam scores of the two groups differ substantially. Given that the mean of the exam scores of the online group was higher than that of the hybrid group, we can infer very strong evidence that the mean of the exam scores of the online group is higher, with a one-tailed p-value of 0.00905, which is less than 0.01.

Table 3: the project scores of the hybrid and online groups

Projects	Hybrid	Online
Mean	73.68	81.58
SD	26.86	26.52
N	151	164
DF	131	
t value	-2.41	
p-value (two-tailed)	0.0166	

Table 3A: Equality of Variances of project scores

Method	Num DF	Den DF	F Value	Pr>F
Folded F	150	163	1.03	0.8752

Next, we examined how students performed on their projects. Both hybrid and online students completed nearly identical projects, with 1-2 projects modified to better suit the online format. Table 3 reveals that the project scores of the online students were higher. Since the Folded F-test from Table 3A indicated that the variances of the two groups are equal, we employed the Pooled t-test, resulting in a two-tailed p-value of 0.0166, which is less than 0.05. This suggests strong evidence that the means of the project scores of the two groups are not equal. Given that the mean of the project scores of the online group was higher than those of the hybrid group, we can infer a very strong indication that the mean of the project

scores of the online group is higher, with a one-tailed p-value of 0.0083, which is less than 0.01.

Table 4: the homework assignment scores of the hybrid and online groups

Assignments	Hybrid	Online
Mean	78.59	87.10
SD	20.45	17.50
N	151	164
DF	131	
t value	-3.69	
p-value (two-tailed)	0.0003	

Table 4A: Equality of Variances of homework assignment scores

Method	Num DF	Den DF	F Value	Pr>F
Folded F	150	163	1.36	0.0712

Table 5: the quiz scores of the hybrid and online groups

Quizzes	Hybrid	Online
Mean	51.39	58.95
SD	23.55	23.88
N	151	164
DF	131	
t value	-2.59	
p-value (two-tailed)	0.0101	

Table 5A: Equality of Variances of quiz scores

Method	Num DF	Den DF	F Value	Pr>F
Folded F	150	163	1.03	0.8817

Students in both groups completed the same homework assignments and quizzes online using Pearson MyLabMastering. Each week, students were assigned approximately 20-25 questions for their homework assignments, allowing seven attempts per question with no time limit. For quizzes, students were assigned about 1-2 questions, allowing only one attempt with a time limit. All assignments and quizzes were due the night before the class meetings. The results from Table 4, Table 4A, Table 5, and Table 5A indicate very strong evidence that the means of the homework

assignment and quiz scores of the online group are higher, with two-tailed p-values of 0.0003 and 0.0101 respectively, both of which are less than 0.01 for one-tailed.

Table 6: the participation scores of the hybrid and online groups

Participations	Hybrid	Online
Mean	70.55	80.25
SD	27.42	24.89
N	151	164
DF	131	
t value	-3.04	
p-value (two-tailed)	0.0026	

Table 6A: Equality of Variances of participation scores

Method	Num DF	Den DF	F Value	Pr>F
Folded F	150	163	1.21	0.2606

Following the surprising results above, we decided to investigate students' participation in the class. Participation points were awarded to students who watched the video lectures, with higher points given for watching more videos. As anticipated based on previous results, Table 6 and Table 6A indicate very strong evidence that the mean of the participation scores of the online group is higher, with a two-tailed p-value of 0.0026, which is less than 0.01. This suggests that online students watched more videos.

Table 7: the ALEKS scores of the hybrid and online groups

ALEKS scores	Hybrid	Online
Mean	42.44	44.95
SD	19.28	21.11
N	151	164
DF	131	
t value	-1.21	
p-value (two-tailed)	0.2267	

Table 7A: Equality of Variances of ALEKS scores

Method	Num DF	Den DF	F Value	Pr>F
Folded F	150	163	1.20	0.2154

Evidently, the online group performed better in every component: assignments, quizzes, projects, participation, exams, and overall grades. We then investigated the students’ knowledge background prior to enrolling in the class. At our college, we use ALEKS to assess students’ math levels before starting the course. We recommend students achieve at least a score of 30 on the ALEKS math test to enroll in this course. Students can take the test up to five times, and we used the highest scores they received before the semester’s start date. Our analysis (Table 7 and Table 7A) shows that there was no significant difference in students’ ALEKS scores, indicating that both groups had similar backgrounds in mathematics knowledge, as the p-value is large.

Next, we performed a MANCOVA in R to analyze the differences of all achievement measures (homework assignments, quizzes, projects, exams, participations, and total scores) between hybrid and online groups. This analysis allowed us to determine whether all achievement measures collectively are affected by the difference in modalities. Using MANCOVA also reduced the type I error that could have been inflated by performing separate tests earlier. Because both groups demonstrated similar backgrounds in mathematics knowledge, we used ALEKS scores as covariate.

Before running the analysis, we examined the assumptions of MANCOVA. Given the relatively large sample size, we assumed that multivariate normality was present in the data. Using boxM test in R, we concluded that the variance-covariance matrices of the two groups were equal (with Chi-sq (approx.) = 36.0493, df = 21, p-value = 0.02159). Next, we evaluated the assumption of homogeneity of regression slopes by testing whether there was a significant interaction (modalities*ALEKS).

Table 8: Homogeneity of regression slope results

	Df	Pillai	F	num	den	P(r>F)
ALEKS	1	0.022264	0.79320	6	306	0.57617
Modalities	1	0.062161	2.30879	6	306	0.03522
ALEKS:Modalities	1	0.016153	0.57188	6	306	0.75248

Table 8 shows that there was no significant interaction because p-value of 0.75248 is very large.

Table 9: MANCOVA results

	Df	Pillai	F	num	den	P(r>F)
ALEKS	1	0.022262	0.7969	6	307	0.57329
Modalities	1	0.062088	2.3169	6	307	0.03459

Table 9 shows that the p-value for the covariate (ALEKS scores) is relatively large, meaning that students’ mathematics background did not have a significant relationship with all the dependent variables (performance measures). In contrast, the p-value for modalities is small (less than 0.05), indicating a significant difference between the two groups across all achievement measures.

Additionally, based on the researcher’s observations, online students were more consistent in attending their class meetings. An investigation of attendance records confirmed this: the online group had a higher average attendance rate (62%) compared to the hybrid group (38%). We then performed a mediation analysis to test whether attendance (the mediator) fully explains the superior outcomes of the online classes over the hybrid classes. Specifically, we tested whether the direct effect of modalities on performance becomes statistically insignificant after attendance is included in the model.

We defined the independent variable (X) as the instructional modality (online vs. hybrid), the mediator variable (M) as attendance rate (percentage of classes attended throughout the semester), and the dependent variable (Y) as the performance measures (homework assignments, quizzes, projects, exams, participations, and total scores). The mediation analysis consisted of three sets of regression: X->Y, X->M, and X+M->Y. We first started with the first regression X->Y.

Table 10: X->Y regression

	Estimate Std	Error	t value	Pr(> t)
(Intercept)	65.175	2.286	28.504	<2e-16
Modalities	8.708	2.961	2.941	0.00355

Table 11: X->M regression

	Estimate Std	Error	t value	Pr(> t)
(Intercept)	69.560	2.572	27.046	<2e-16
Modalites	7.019	3.330	2.107	0.036

Table 12: X+M->Y regression

	Estimate Std	Error	t value	Pr(> t)
(Intercept)	20.02459	3.00240	6.670	1.43e-10
Modalites	4.15178	2.04330	2.032	0.0431
Attendance	0.64909	0.03683	17.622	<2e-16

Table 10 indicates that modalities significantly affect achievement measures since p-value is small (<0.01). Table 11 shows that modalities also significantly predict attendance rates because p-value is small (<0.05). Table 12 reveals that the effect of modalities on performance measures still exists after including attendance in the model, but in smaller magnitude. Therefore, attendance partially mediates between instructional modality and achievement. We then conducted a bootstrap analysis in R with at least 5,000 stimulations.

Table 13: Bootstrap Analysis

	Estimate	95% CI lower	95% CI upper	p-value
ACME	4.555766	0.492332	8.760794	0.0272
ADE	4.151782	-0.036322	8.302431	0.0524
Total Effect	8.707548	2.840054	14.272664	0.0040
Prop Mediated	0.523197	0.094430	0.997549	0.0288

Table 13 shows that ACME = 4.555766 with a small p-value (<0.05). We therefore conclude that the mediation (attendance rates) effects are statistically significant.

Table 14: the pre-attitude scores of the hybrid and online groups

Post-attitudes	Hybrid	Online
Mean	118.1	121.6
SD	10.97	10.86
N	151	164
DF	313	
t value	-1.31	
p-value (two-tailed)	0.1960	

Table 14A: Equality of Variances of pre-attitude scores

Method	Num DF	Den DF	F Value	Pr>F
Folded F	150	163	1.02	0.9445

Table 15: the post-attitude scores of the hybrid and online groups

Pre-attitudes	Hybrid	Online
Mean	121	120.9
SD	14.96	15.91
N	151	164
DF	313	
t value	0.04	
p-value (two-tailed)	0.9689	

Table 15A: Equality of Variances of post-attitude scores

Method	Num DF	Den DF	F Value	Pr>F
Folded F	150	163	1.13	0.5375

To assess the effects of the classroom formats on students' attitudes towards mathematics, we asked participants to complete the Attitudes Toward Mathematics Inventory (ATMI) at the beginning (pre-attitude survey) and the end (post-attitude survey) of the semesters. The ATMI consists of 40 questions that address the value of mathematics, enjoyment of mathematics, motivation in mathematics, and anxiety towards mathematics. The highest possible score is 200, with higher scores indicating more positive attitudes towards mathematics. Tables 14, Table 14A, Table 15, and Table 15A show that there is no significant evidence of differences in attitudes towards mathematics both at the beginning and the

end of the semesters between the two groups, as the p-values are large ($p = 0.1960$ for pre-attitude and $p = 0.9689$ for post-attitude).

Table 16: the pre-post survey scores of the hybrid and online groups

Attitudes	Hybrid	Online
Mean	-5.72	4.48
SD	15.47	12.32
N	63	74
DF	62	73
t values	-1.57	1.67
p-values	0.1350	0.1114

We then conducted paired sample tests within the hybrid and online groups. A total of 63 students in the hybrid group and 74 students in the online group completed both the pre- and post-attitude surveys. The results in Table 16 indicated a slight increase in attitude scores for the hybrid group and a slight decrease for the online group. However, the p-values for both paired tests were relatively large, indicating no statistically significant evidence of either an increase or decrease in attitude scores between the pre- and post-surveys.

Lastly, we asked participants to complete a survey regarding their online learning experience. The survey included three sets of questions with responses: Strongly Agree, Agree, Neutral, Disagree, and Strongly Disagree. The first set of questions addressed the reasons for considering taking a math course with online lectures (videos): *I would consider taking a math course that has lectures online (videos) because...*

Table 17: the percentages of responses from hybrid and online groups to the question:

I would consider taking a math course that has lectures online (videos) because ...

<i>I would consider taking a math course that has lectures online (videos) because ...</i>	Strongly Agree or Agree	
	Hybrid	Online
It is easier to schedule.	60.27%	60.43%
It allows me to move at my own pace.	74.03%	64.75%
It saves me the time and money of commuting.	73.97%	59.71%

I can work during a time of day I feel best suits me.	74.70%	80.58%
I don't have to volunteer answers in front of my peers.	52.83%	30.94%

The second set of questions addressed the reasons for considering taking online math courses with class meetings: *I would not consider taking an online math course with no class meetings because...*

Table 18: the percentages of responses from hybrid and online groups to the question:
I would not consider taking an online math course with no class meetings because ...

<i>I would not consider taking an online math course with no class meetings because ...</i>	Strongly Agree or Agree	
	Hybrid	Online
I would not be able to ask questions and get immediate feedback	56.34%	52.17%
I would not be able to interact with my classmates.	43.14%	22.46%
I would not be sure how I rank with the rest of the class.	63.51%	42.75%
I think it would be more difficult to follow the lessons on my own.	57.38%	39.13%
I need more instructions from the professor during the class meetings.	69.44%	47.10%

The last set of questions addressed student’s online learning experience.

Table 19: online learning experience survey responses from hybrid and online groups

Questions	Strongly Agree or Agree	
	Hybrid	Online
I feel I would be likely to cheat on an exam in an online course rather than face-to-face course.	27.27%	7.09%
I don't believe a reliable exam is possible to administer online.	28.85%	17.73%

I feel that an online course should have graded projects/assignments rather than exams.	76.92%	65.96%
I would like to have seen/know the person giving me my grade.	50.00%	38.30%
I don't think exams would be treated differently in an online course versus a face-to-face course.	53.52%	49.65%
I feel like I would do/learn better if my class meetings are in-person.	78.21%	34.04%
I think the online class meetings are just as good as in-person meetings.	52.94%	58.16%
I would save my time and gas by not having to go to the campus to attend the meetings in-person.	76.00%	87.94%
I believe going to the campus to attend my class meetings motivates me to do well in the class.	77.03%	39.72%
I prefer to have class meetings in-person rather than online.	64.94%	24.11%
I can avoid technical issues by attending class on campus in-person.	84.42%	46.10%
It does not matter to me if my class meets in-person or online. No preference to me.	49.30%	46.81%
I like the flexibility of online class meetings so I can attend my class anywhere even when I travel.	81.48%	90.78%
If I don't have transportation to the campus, online meetings would be helpful to me.	84.81%	90.78%
I believe attending online class meetings takes away from my college experience.	50.00%	21.99%
I think online courses are favorable in any subject area.	58.93%	45.77%
I think online courses are favorable in certain subjects, but not math.	55.56%	33.10%
If an online math course is offered, I will sign up.	55.00%	64.08%
An online course would have the same level of difficulty as a face-to-face course.	59.62%	26.06%
I would feel that my grade in an online course would be less significant to me as my grade in a face-to-face course.	67.69%	59.86%

6. Discussion

Based on the data collected, online students performed better in every area: assignments, quizzes, projects, participation, and exams. Attitudes toward mathematics, however, remained constant in both the online and hybrid groups and did not show meaningful improvement or decline over the semesters. The online group also maintained significantly higher attendance rates than the hybrid group, and our findings indicate that attendance had a measurable impact on student learning.

Although the online group demonstrated significantly higher academic performance, this improvement did not coincide with a significant change in attitudes toward mathematics. This pattern is well-documented in mathematics education research, where affective constructs such as attitudes, beliefs, and anxiety are understood to be relatively stable, trait-like characteristics that do not shift easily over a single semester (McLeod, 1992; Hannula et al., 2016). Research has shown that beliefs are the most stable and least malleable affective constructs, with attitudes occupying a middle position between beliefs and emotions, which change more readily (Hannula et al., 2004). Similarly, work by Hannula and colleagues indicates that many affective variables operate along a continuum from rapidly fluctuating “states” to long-term, stable “traits,” with attitudes and beliefs typically falling on the trait end of the scale (Hannula et al., 2016). Longitudinal research also shows that emotional and motivational profiles in mathematics tend to remain consistent across grade levels unless targeted interventions are applied (Zakariya et al., 2024). In our study, online students benefited from clearer course structure, consistent weekly meetings, and higher attendance, all of which directly supported performance. However, these structural advantages do not necessarily alter students’ long-standing feelings about mathematics. Many students enter the course with fixed perceptions shaped by years of prior experiences, and improvements in course performance alone may not be sufficient to shift these attitudes within a single semester. Thus, the online format appears to enhance learning behaviors and outcomes without substantially influencing students’ affective relationship with mathematics.

A related factor that may help explain the performance gap involves attendance differences between groups. One possible explanation for the lower attendance rates in the hybrid group is the convenience of attending class meetings online rather than traveling to campus for in-person sessions.

As a result, even though students may benefit from in-person instruction, those advantages cannot be realized if students do not attend regularly. In contrast, online students attended class meetings more consistently, allowing them to engage with the content more continuously and achieve better outcomes by the end of the semester.

Another contributing factor to the higher achievement outcomes in the online group may be confusion regarding the expectations of the hybrid format. Hybrid students may not have fully understood all of the tasks and requirements that needed to be completed online and may have relied too heavily on their in-person meetings. By the time they recognized the extent of the online responsibilities, they may have already missed important assignments or lost points.

Additionally, differences in student characteristics may have played a role, even if only indirectly. Hybrid students may have selected the hybrid format because they felt less confident in their math skills or believed that in-person meetings would provide the one-on-one support they needed. Conversely, online students may have felt more confident in navigating course materials independently or been better prepared for the demands of the course. They may also have had clearer expectations that the course would involve substantial work, making them more prepared to engage from the start.

This rationale led us to investigate the student demographics further. We found that 20.7% of students in both groups are in Pre-health Professions, 10.8% in Psychology, 10.2% in Pending Veterinary Technology, 9.2% in Applied Media Communications, 8% in Criminal Justice, 29% in Communications, and the rest in other fields. One notable group among the others is College Credit Plus, which comprises only 2.9% of the total student population. The majority of these students are in the online group, making up 85.7%. This could be because these students already have busy schedules in their high schools and prefer attending classes online rather than commuting to campus.

Table 20: Ages of students in online group

Ages	Percentages
Younger than 18	0.73%
18-23	87.96%
24-29	5.84%
30-39	3.28%
40-49	1.82%
50 or older	0.36%

Table 21: Ages of students in hybrid group

Ages	Percentages
Younger than 18	0%
18-23	92%
24-29	6%
30-39	2%
40-49	0%
50 or older	0%

We also examined the ages of the students. The hybrid group had more traditional students, while the online sections served a slightly higher proportion of non-traditional students. However, most of the student population still consists of traditional students. Thus, we do not believe that student demographics significantly contributed to the observed results.

Regarding the students’ online experience, we conducted a survey. Students recognized that the online lectures helped them with scheduling, allowed them to move at their own pace, saved time and money on commuting, and provided flexibility.

Regarding synchronous and asynchronous classrooms, students in both groups preferred meetings to ask questions and receive immediate feedback, but they didn’t particularly care about interactions with their classmates or getting to know their instructor. Hybrid students believed that meetings helped them gauge their performance compared to other students and felt that without meetings, it would be difficult to follow the lessons on their own. They also felt they needed more support from the instructor during class meetings. On the other hand, online students did not share these beliefs.

Regarding online exams, both groups stated that there is no difference between in-person or online exams and that they would be just as honest during online exams as during in-person exams.

Regarding online and in-person meetings, hybrid students valued the in-person meetings and found them helpful, believing that attending meetings in-person would motivate them more. However, online students did not share these beliefs. Both groups agreed that online meetings would save them time and gas by not having to commute and appreciated the flexibility of attending class from anywhere. Hybrid students believed that attending online meetings would detract from their college experience and felt that online courses were not suitable for math, while online students thought otherwise. Moreover, online students recognized that completing an online course would involve more work and be more challenging. Both groups agreed that if an online math course were offered, they would sign up, whether the meetings were in-person or online.

In conclusion, students tend to favor synchronous learning over asynchronous formats due to the immediate feedback provided during live sessions. They also appreciate the flexibility and cost savings associated with online courses, particularly in terms of reduced commuting expenses. Hybrid students value the in-person interactions more, while online students believe that virtual meetings can offer comparable support. Therefore, by offering both synchronous online and in-person meetings, students can select the format that best suits their individual needs.

The findings of this study align with and extend current SoTL research on mathematics instruction in online and hybrid formats. For example, Hoffman and colleagues found that combining instructional platforms with strong human support such as learning assistants and structured communication significantly improved student participation and performance in online asynchronous math courses (Hoffman et al., 2025). Similarly, our study observed that online students, who had consistent access to structured meetings and clear expectations, demonstrated higher attendance and better academic outcomes than their hybrid counterparts.

Bishop and colleagues emphasized that hybrid instruction, when implemented without adequate planning or support, may fail to deliver its intended benefits (Bishop et al., 2024). This resonates with our observation that hybrid students may have misunderstood course expectations or relied too heavily on in-person meetings, leading to missed opportunities and

lower performance. These findings suggest that hybrid models require intentional design and clear communication to be effective.

Moreover, Engelbrecht and Borba highlighted the importance of digital tools in transforming mathematics classrooms, especially during and after the COVID-19 pandemic (Engelbrecht and Borba, 2023). Our study supports this by showing that online students, who engaged more consistently with digital resources such as lecture videos and online meetings, achieved better outcomes. This underscores the potential of well-integrated technology to enhance learning in mathematics, provided students are supported in using it effectively.

In light of these findings, our study contributes to the growing body of evidence that online instruction when thoughtfully designed and supported can lead to strong academic performance in mathematics. However, it also cautions that hybrid formats may not automatically confer advantages unless students are fully engaged and understand the structure of the course. These insights reinforce the need for ongoing research and refinement of instructional strategies to ensure equitable and effective learning experiences across modalities.

7. Conclusion

This study examined the effects of hybrid and online instructional methods on students' learning achievements and attitudes toward mathematics in a project-based college course. The findings revealed that students in the online group consistently outperformed their hybrid counterparts across all measured components, including assignments, quizzes, projects, participation, and exams. Despite these performance differences, there was no statistically significant change in students' attitudes toward mathematics in either group over the course of the semester.

One of the most compelling findings from this research is the role of attendance and engagement. Online students demonstrated higher attendance rates and greater consistency in participating in class activities, which evidently contributed to their superior academic performance. Additionally, survey responses highlighted the value students place on flexibility, convenience, and the ability to learn at their own pace. These factors may enhance motivation and performance in online settings.

While hybrid instruction offers the benefit of face-to-face interaction, its effectiveness in this study appears to have been hindered by

two key factors: lower attendance and potential confusion about course expectations. Because our data showed that attendance significantly impacts student learning, the hybrid group's reduced participation likely prevented students from fully benefiting from in-person instruction. Additionally, if hybrid students were uncertain about when and how to attend class sessions or how the hybrid structure operated, this confusion may have further limited their engagement. These findings suggest that the success of any instructional format depends not only on the delivery method but also on consistent student participation and clear, well-communicated course expectations.

Ultimately, offering both hybrid and online options may best serve the diverse needs of students, allowing them to choose the format that aligns with their learning preferences, schedules, and personal circumstances. Future research could further explore how to optimize hybrid models to improve attendance and engagement, ensuring equitable learning outcomes across instructional formats.

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**GenAI does NOT negate Bloom’s Taxonomy
for Sustainable Learning Outcomes – An Analysis of
ChatGPT Prompts by Students**

Subbu Kumarappan
Agricultural Technical Institute, The Ohio State University

Urmila Pal Chaudhuri
Kent State University at Stark

Will the use of Generative Artificial Intelligence (AI or GenAI) software such as ChatGPT negate the standard – often sequential – learning phases according to Bloom’s taxonomy: ‘knowledge, understanding, applying, analyzing, evaluating, and synthesizing?’ or will GenAI help bypass or even invert the Bloom taxonomy where the students gain knowledge and basic understanding through synthesis and evaluation (Damaševičius, 2023). To answer this question, we analyzed student queries, answers, and reflections using AI software ChatGPT in undergraduate business (finance, supply chain management) and chemistry classes. The student queries were classified according to Bloom’s taxonomy; most of the student queries were basic and introductory asking for definitions and explanations. With consistent practice, the students showed improvements in their querying capabilities. A non-linear, circular learning process is identified that encapsulates the accelerated learning potential presented by the GenAI software. Overall, this exercise using ChatGPT queries add credence to the fact that students should learn the basics (understanding, remembering) before the advanced levels (creating/synthesizing, evaluating). Incorporation of ChatGPT indeed markedly improve the pace of learning in the classrooms. The students showed distrust with the system upon realizing the wrong numerical answers and their inability to verify the correctness of the answers.

Introduction

With the advent of the Generative Artificial Intelligence (GenAI) software such as ChatGPT, a large language model (LLM) for dialogue from OpenAI, the knowledge building has assumed significantly different and newer dimensions (Baidoo-Anu & Ansah, 2023; Grassini, 2023; OpenAI, 2023). Despite the philosophical questions on whether GenAI would further

or hamper human-centric development, the AI will define the future of learning in myriad ways (Chomsky et al., 2023; Fui-Hoon Nah et al., 2023; Williams, 2023); including that of academic pedagogy in a significant manner (Haque, 2022; Wardat et al., 2023). Will the use of GenAI software such as ChatGPT negate the standard – often sequential – learning phases according to Bloom’s taxonomy: ‘knowledge, understanding, applying, analyzing, evaluating, and synthesizing?’ or will GenAI help bypass or even invert the Bloom taxonomy where the students gain knowledge and basic understanding through synthesis and evaluation (Damaševičius, 2023).

Given the nature of GenAI such as ChatGPT to generate answers and refresh them regularly, there are high chances that the student will be forced to ‘Learn, Unlearn, and Relearn’ (LURE) which can create exhaustion or lack of urgency to learn new concepts (Ramkumar et al., 2023). This will affect how the students retrieve the needed information later (Adeshola & Adepoju, 2023; Ambrose et al., 2010; Zhai, 2022). Since GenAI has tremendously improved the variety, novelty, and retrievability of the answers, it affects how students learn concepts, build knowledge, and the ways employed to learn them with creativity, efforts, classroom delivery modes, among other factors (Afkari et al., 2024; Jones et al., 2015; Levin-Banchik, 2018). The extent of GenAI use will vary significantly with the teachers and their efforts in the classrooms (Firat, 2023; Huallpa, 2023; Wang et al., 2024); the teachers have a rather exciting and challenging time having to deal with a whole gamut of unknowns and GenAI flaws and shortcomings such as hallucination that result in non-existent source materials, incorrect numerical answers, incipient and equivocal answers, and important ethical issues such as copyright violations. This has created a whole series of questions for the teachers such as inherent biases, falsities, and factually incorrect answers with long term negative impacts such as cheating, plagiarism, and academic dishonesty (Anders, 2023; Chomsky et al., 2023; Lo, 2023; Tyson, 2023)? When students rely too much on ChatGPT and other GenAI software, how does it impact their long-term learning and creative thinking?

GenAI software can even decimate well established older frameworks such as Bloom’s taxonomy by leapfrogging students’ learning beyond the basic concepts and advance to more advanced concepts rather quickly and effectively (Damaševičius, 2023; Spanos, 2024). Does GenAI such as ChatGPT negate the well-established Bloom’s taxonomic principles? That is the primary question we tried to address in this research paper: we

introduced ChatGPT to our students in a diverse set of undergraduate classes – introductory finance (with 28 students), food supply chains management (SCM, 19), and general chemistry II (16); we used the free version 3.5 that was widely made available during 2023 and 2024 (OpenAI, 2023). We document how students approached querying the AI software ChatGPT on these subjects, classify the student questions according to the Bloom’s taxonomic level, classify the nature of student learnings, and the (early/initial) impressions of using such software for long-term sustainable outcomes.

Our results indicate that the students in introductory courses still need to learn the basic concepts and their questions to ChatGPT are at the basic Bloom levels of remembering and understanding for comprehension and basic knowledge (figure 1). The students performed more intense questioning according to their personal interests, but the teachers still need to be present helping students create better prompts and evaluate the GenAI responses. The alignment of the GenAI use with the course objectives and assessments is critical; combined with generating good prompts, the students seek clear instructions on when and how to use AI answers, what is acceptable or not, and how it will be graded. The repeated use of ChatGPT in the classroom instructions resulted in a salient outcome: students queries evolved more quickly into advanced concepts indicating that students employed non-linear, circular learning pathways, that can be situated within the traditional Bloom’s taxonomy.

Research Question and Approach

For this research, we studied our students ChatGPT query questions and how their prompt engineering, that is, honing questions to get better answers (Giray, 2023; Heston & Khun, 2023; Meskó, 2023; Poola, 2023; White et al., 2023). The students were free to query anything of interest to them within the course or subject matter; these responses were classified and categorized according to the Bloom’s taxonomy of thinking and learning – ‘remember, understanding, application, analysis, synthesis, and evaluation’ (Forehand, 2005a, 2005b; Krathwohl, 2002); see figure 1 below.

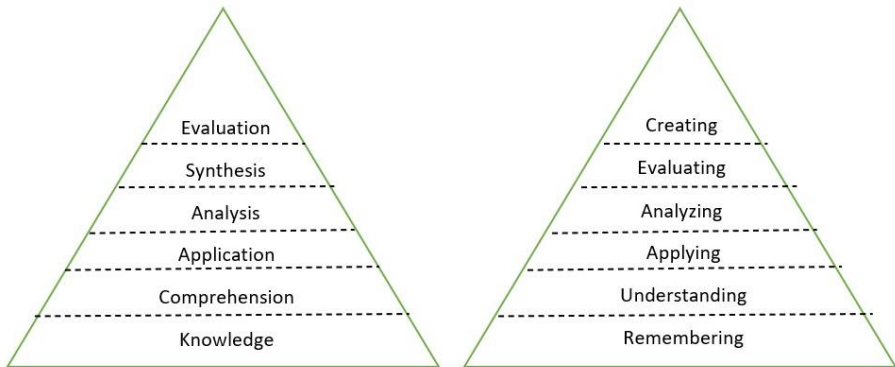


Figure 1. Bloom's Taxonomy – Old (left) and New (right) Versions (reproduced from Forehand, 2005b)

The Bloom's taxonomy is chosen because it has been a bedrock of pedagogical assessments (Nkhoma et al., 2017; Tabrizi & Rideout, 2017). Bloom's taxonomy emphasizes sustainable learning through building a solid foundation (knowledge and comprehension) which can lead to more significant critical thinking skills (synthesis and creation). Besides, Bloom's taxonomy has been extensively studied and expanded: for instance, the Fink's taxonomy emphasizes that students should learn and integrate their knowledge across multiple dimensions and developing a systematic framework to learn how to learn further: 'foundational knowledge, application, integration, human dimension, caring, and learning how to learn' (C. Fallahi, 2011; Fink, 2003). GenAI make it easy 'creating or synthesizing' (an advanced level) with relative ease – hence, there is concern that Bloom's taxonomy might be relegated and become irrelevant with the widespread use of GenAI (Damaševičius, 2023). Indiscriminate or cursory use of GenAI can result in weak foundations of the subject matter resulting in poorer reflection, judgment, and critical thinking skills as given in the additional variations of Bloom's taxonomical categories: 'knowledge/understanding, followed by engagement/motivation, performance/action, reflection/critique, judgment/ design, and commitment/identity' (C. R. Fallahi & LaMonaca Jr, 2009; Shulman & Hutchings, 2004). Our students used only ChatGPT due to its widespread availability and its status as a first mover within the GenAI LLM industry. There are many other alternatives such as Google's Bard, Baidu AI, Microsoft's Copilot, and other software in various stages of development

and deployment (Baidu - AI, 2023; Google - Bard, 2023; Rahsepar et al., 2023; Ram & Pratima Verma, 2023; Rebelo, 2023; Waisberg et al., 2023).

Methods

Demonstration of ChatGPT in the Classroom

The lead author taught the business courses in finance and food supply chains (SCM). In the finance class, the demonstrations included querying the software for concepts such as ‘basic definitions of financial terms, financial systems and institutions, and more advanced concepts and numerical questions involving monthly mortgage payment amounts and interest and principal payment schedules.’ The students were informed which of these answers were reliable (often, the textual content) and which were not reliable (the numerical answers, the citations, equivocal answers, etc.). The numerical errors with ChatGPT (in its version 3.5) is well documented because of its inability to distinguish between the numerical answer that is correct vs. any other number (Amaro et al., 2023; Fergus et al., 2023; Gregorcic & Pendrill, 2023); subsequent improvements to ChatGPT (version 4.0) have enabled better reference sources that can predict correct numerical answers. In the SCM class, the students were shown how to query ChatGPT about the business principles of supply chains. Later, the students completed homework assignments (appendices A through D), that included both open-ended questions and their reflections on the applicability, use, and trust of the ChatGPT.

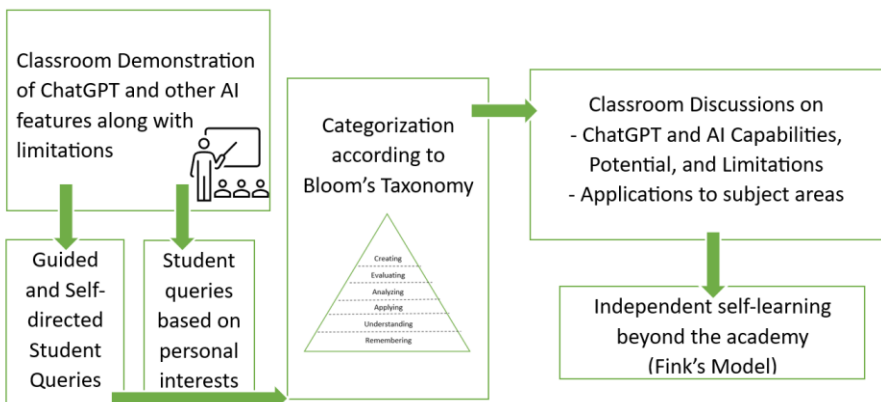


Figure 2. Implementation of ChatGPT in Classroom Instruction

Student Responses by Bloom's Taxonomy

Finance Class

Most of the student questions in the finance class were focused on basic knowledge/understanding type of questions such as *'what is finance/cash flow statement/time value of money/Net Present Value (NPV)/Internal Rate of Return (IRR)/ income statement; should I use NPV or IRR to choose among projects?'* Even without any direction, the students chose to ask questions related to their personal finance *'what is the best time to make a large purchase; suggested monthly deposits for their savings account; tips for (stock market) investing; things to consider while purchasing a car; and should I start investing when I am young?'* Upon repeated questioning, they honed their question prompts to compare two or more concepts (as in analysis or evaluation) *'what is the best way to compare NPV, IRR, and modified IRR; is it smarter to take a loan or purchase it in cash; how to determine the right kind of loan terms; how to payoff student loans right out of college; considerations for a used car vs. new car; and why or how do banks fail?'* It is important to note that these questions were generated by students based on their personal knowledge, experience, and interests.

The student responses were classified by both authors and three different GenAI software (Copilot GPT-5, Gemini 3, and ChatGPT 5.3; see table 1). There is general agreement regarding how human authors and GenAI classified the student responses. According to human author classification, about 60-70% responses fell under Bloom's lower levels of 'knowledge or comprehension' while the same classification was 50-70% according to GenAI software. This shows that students' use of GenAI remains introductory in these finance and supply chains undergraduate classes. Very few questions were rated as higher order 'evaluation and synthesis:' only 6-9% of student responses were rated as higher order questions by human authors, while 5-19% of the responses were rated as higher order questions by GenAI.

The three GenAI rating classifications were different contributing to the wider ranges in GenAI classifications. It also indicates that GenAI classifications may not be taken to be neither objective nor to be taken or trusted independently of each other. Slight differences do exist between the human and GenAI ratings, but it could be due to wideranging differences among the GenAI classifications. The students might have avoided the

analytical questions (only 2% of the queries sought numerical calculations) in the finance class because the students had learned through classroom demonstration that ChatGPT responses could result in numerical errors (with an earlier version of ChatGPT 3). It should be noted that GenAI has rapidly evolved in the recent past and the classroom implications can be very different in the future. Also, the students can be purposely taught how to ask more detailed, higher order questions and use it to improve their overall understanding of the subject matter and develop their expertise.

Table 1a. Classification of Students’ GenAI Queries according to Bloom’s Taxonomy in the Finance class

	Human Authors		GenAI classification*			Average Score	
	Author 1	Author 2	Copilot (GPT-5)	Gemini 3	ChatGPT 5.3	Human Authors	GenAI
Knowledge	44%	27%	27%	40%	26%	36%	31%
Understanding	29%	42%	20%	27%	14%	36%	20%
Application	15%	7%	18%	18%	12%	11%	16%
Analysis	2%	12%	18%	9%	14%	7%	14%
Synthesis	3%	0%	17%	6%	34%	2%	19%
Evaluation	7%	7%	0%	0%	0%	7%	0%

1b. Classification of Students’ GenAI Queries according to Bloom’s Taxonomy in the Food Supply Chains class

	Human Authors		GenAI classification*			Average Score	
	Author 1	Author 2	Copilot (GPT-5)	Gemini 3	ChatGPT 5.3	Human Authors	GenAI
Knowledge	30%	36%	59%	54%	60%	33%	58%
Understanding	24%	36%	14%	20%	23%	30%	19%
Application	12%	0%	1%	16%	4%	6%	7%
Analysis	26%	26%	16%	7%	9%	26%	11%
Synthesis	2%	1%	9%	3%	4%	2%	5%
Evaluation	6%	1%	1%	0%	0%	4%	0%

* There are slight variations in the GenAI classifications and calculations depending on the free or paid versions

The students' reflective comments indicated the perception of ChatGPT to be *'efficient and quick; ability to generate quick summary; help study for exams; learning some new things beyond things discussed in the classroom; a way to confirm that classroom lessons are relevant for their learnings, being able to ask insightful questions; and the ability to obtain the perspectives of another 'person'.*' Some students expressed concerns about the *'non-reliability due to numerical errors; ChatGPT answers being convoluted and difficulty to use it for understanding; and the necessity or inability to cross-verify the ChatGPT answers in some cases.'*

Student Reflections on GenAI

In the final exam for the finance class, the students reflected on how they could employ ChatGPT and AI software for their careers and farming profession. There was near-unanimous recognition that AI software could help improve their knowledge, ability to process and assimilate information, improve their creativity, higher order thinking, and expand their overall knowledge. The students also emphasized the importance of adapting and learning new AI tools to become more marketable in their careers. Nonetheless, a few student responses highlighted the falsities and potential pitfalls in trusting ChatGPT information in its current form; those students also indicated a preference for simpler, traditional online search engine tools that are already available.

Knowledge vs. Effort

While the students generally agreed with the relevance of ChatGPT for their learnings, they displayed different levels of interest and effort while employing ChatGPT to generate their queries and write reflective answers. We computed correlation coefficients (r) between the final exam grades with the extent of their explanations for the query to ChatGPT (number of words), explanation of their understanding (number of words), and their reflective essays (number of words). Particularly, these correlations can explain whether the traditionally low performing students gained more interest in using GenAI software, that is easy to use and implement, improve their knowledge and eventually lower the efforts to fill their knowledge gap. The corresponding null hypothesis would be $H_0: r \leq 0$ indicating that the correlation coefficients (r) would indicate no or negative

relationship between the students’ final grades and their efforts on GenAI assignments. The corresponding alternative hypothesis would be H1: $r > 0$ indicating that the high performers continue to benefit the most from the GenAI software usage. The t-test statistics were computed as $t = r \sqrt{\frac{n-2}{1-r^2}}$ with (n-2) degrees of freedom where r is the correlation coefficient and n is the number of observations (Webb, 2023). The test results and statistical significance calculated based on 1-tail t-test are given tables 2 and 3 for the finance classes in 2023 and 2024 spring semesters, respectively.

Table 2a. Summary statistics of student responses on ChatGPT assignments in Finance class – 2023

	Range		Did not attempt (# of students)	Average
	Minimum	Maximum		
Course Grade	37%	100%	0	83.30 %
Query Extent (# words)	15	42	8	17.4
Explanation words (#)	44	218	9	102.5
Final Reflective Essay (#)	98	333	4	173.5

Table 2b. Correlation Matrix for Finance Class Assignments and Grades - 2023

	Final Grade	Query Words	Explanation Words	Final Reflective Essay
Final Grade	1	0.715***	0.591***	0.535***
Query Words		1	0.603***	0.233
Explanation Words			1	0.136
Final Reflective Essay				1

***, **, and * indicates statistical significance at 1%, 5%, 10% levels.

The correlation values ranged from +0.136 to +0.715 during 2023 and +0.120 to +0.705 during 2024. All positive values indicate that the high

performing students continued to show more interest in using and reflecting upon the ChatGPT assignments. The students continued to view the ChatGPT as an assignment rather than a tool that can contribute to their long-term professional successes. The final grade correlations with the assignment and reflective questions were all statistically significant at 1% level during 2023 and at 1% and 5% levels in 2024. It is noteworthy that the statistical results were consistent across the two terms during 2023 and 2024.

Table 3a. Summary statistics of student responses on ChatGPT assignments in Finance class – 2023

	Range		Did not attempt (# of students)	Average
	Minimum	Maximum		
Course Grade	63.69%	100%	0	83.78 %
Query Extent (# words)	18	62	8	23.5
Explanation words (#)	98	190	10	65.3
Final Reflective Essay (#)	90	314	0	156.5

Table 3b. Correlation Matrix for Finance Class Assignments and Grades - 2024

	Final Grade	Query Words	Explanation Words	Final Reflective Essay
Final Grade	1	0.454**	0.572***	0.522**
Query Words		1	0.705***	0.120
Explanation Words			1	0.382*
Final Reflective Essay				1

***, **, and * indicates statistical significance at 1%, 5%, 10% levels.

Supply Chains Class:

The taxonomical composition of student queries in the SCM class were very similar to that of the finance class with most of the queries being

at the lower orders of thinking (knowledge and understanding) and fewer queries at the higher levels of thinking (synthesis and evaluation). One marked difference was (table 1b) the slightly higher proportion of analysis questions in the SCM class where the students wanted to know what critical factors would determine better prices and profits for their products. The answers in the supply chains class generally did not contain any numerical values for the student queries; while some students continued to query more to get numerical values, there was a tendency for the students to trust those values blindly without further verifications.

Chemistry Class:

The coauthor taught the general chemistry class and followed a similar approach: ChatGPT was introduced by demonstrating the query process using questions such as *'what is pH/buffer/strong acid/pH of 0.1M HCl/pH of 0.01M NH₃; differences between acids and bases; what is the resulting of pH of mixing two solutions of different molarity, etc.'* Less than half of the students had heard about ChatGPT in the chemistry class in 2023. During the demonstration, the students indicated that answers to simpler questions were easy to understand and were more trusting of those answers, while the responses to more complex questions were viewed with skepticism or difficulties in comprehending and verifying those answers. The chemistry classroom demonstration showed that some of the explanations given by ChatGPT were neither simple nor straight forward, but highly convoluted. In some cases, the explanations were so complicated, that students vehemently rejected ChatGPT to learn scientific concepts that require numerical calculations further; a total of nine out of 16 students rejected or expressed distrust in using ChatGPT for understanding advanced chemistry concepts.

The student responses in the chemistry class (survey in appendix C) were generally introductory and could be classified mostly as basic at the levels of 'knowledge or understanding' in Bloom's taxonomy. The student queries to ChatGPT included questions such as *'what is the electron configuration for Ni²⁺; percentage of sulfur in iron sulphate; second law of thermodynamics; calculate entropy for heat released from a system; number of electrons in 2p orbital of calcium;'* and some analytical questions such as *'conversion of 0.2 grams of calcium into moles of calcium, concentration of salt in a solution after dilution, etc.'* Like the finance class, the chemistry students were unable to confirm ChatGPT responses for more advanced

questions primarily due to lacking of prior knowledge. Many students merely expressed skepticism reading through the voluminous textual output from ChatGPT and suggested minimal use of ChatGPT; the students even commented that ChatGPT would be more useful in courses such as English and History, rather than science courses such as chemistry. These outcomes may be limited to this set of students and there was not enough data.

Key Observations

This exercise uncovered three main aspects of using AI in the classroom instruction:

(i) students' interest in ChatGPT queries focused on topics of personal interest to them; they lacked the knowledge to verify the authenticity, reliability, and subsequently interpret the results to improve their knowledge and understanding of the subject matter. Most of the questions were at basic level; while the advanced level queries such as 'evaluations or synthesis' may not occur immediately, but they may appear at the end of a series of repeatedly honed queries. These observations indicate that the student learnings occur in a non-linear, circular manner as given in a conceptual model – see figure 3 – as opposed to the linear, pyramid structures used to depict Bloom's taxonomy (figure 1). *The most value with the use of GenAI software lies not in a single instance of querying but in continuous repetition of the querying process with GenAI software; the students can learn and direct their own self-guided learning for sustainable learning outside of the educational institutions after their graduation.*

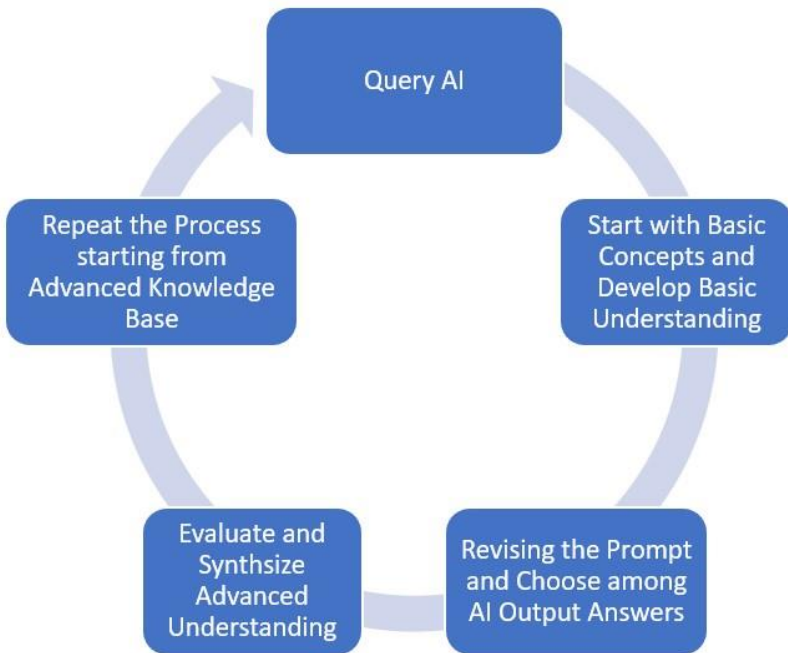


Figure 3. A Conceptual Model of Accelerated Non-linear, Circular Learning Approach with Bloom’s Taxonomic Categories (Source: Authors)

(ii) Another major advantage with GenAI software is in learning that occurs at a much faster scale, that may differ in content and dimension based on the individual student’s queries. Incorporating the traditional Bloom’s framework (for example, analyze, evaluate, and synthesize) itself can result in more advanced knowledge (Das et al., 2022; Newton et al., 2020; Stanny, 2016). *The teachers should anticipate and be prepared for rapid pace of learning and a broader understanding of the subject matter.*

(iii) The student queries resulted in slightly different answers; their follow-up queries gradually diverged and the student comprehension varied based on what answers they received. Sometimes, the in-class querying exercise resulted in widely varying answers and outcomes and can even become intractable. This provides both an opportunity and a challenge for the instructors, where they would need to impart a collective overall understanding for all the students in the class. Some of the ChatGPT responses created an awareness for topics and discussions that would

otherwise not have been covered in traditional classroom settings. *The teachers must recognize the challenges with diverse GenAI responses, the necessity to create an integrated understanding, and the unique opportunity to cover supplementary topics, often at a much rapid pace.*

Difficulties

The students that participated in these exercises were unable to verify the correctness of ChatGPT answers, especially in the science classes and questions related to numerical calculations. Such intractability led to quickly waning interest among the students who eventually lost trust and interest. Coupled with the unreliability of numerical answers (Amaro et al., 2023), some explanations were unnecessarily complex and verbose that a human being could teach it better than GenAI software. ChatGPT is often trained to answer in a generic way without giving specific answers which reduces the usefulness of it beyond a certain point. Once the novelty of the AI software wears off, the adept users will recognize that GenAI software is simply repeating the information from various databases it was pre-trained on.

Various other shortcomings and limitations are documented by the researchers as well (Azaria, 2022; Tyson, 2023), such as biases – natural or built-in (Roose, 2023); plagiarism, exhibiting apathy and obviation (Chomsky et al., 2023). Recently, the authors faced with a situation in one of our classes where the student had used it unauthorized for a classroom assignment despite its being prohibited for that particular assignment, as given in the syllabus. Such instances can lead to confusions and academic misconduct investigations by the departments, colleges, and universities. Hence, with the widespread growth of GenAI software, the educators are increasingly facing pressures to ensure their academic integrity while also providing superior learning environment by adopting these high-tech software resources (Azoulay et al., 2023; Cotton et al., 2023; Currie, 2023).

Conclusions

The students used the artificial intelligence (AI) software ChatGPT in undergraduate business (finance, supply chain management) and chemistry classes to query and learn the subject matter. The student queries were classified according to Bloom's taxonomy; most of the student queries were basic and introductory asking for definitions and explanations. While some students asked more advanced analytical questions, they were unable to

verify the correctness of those responses due to lack of knowledge and the general mistrust with the ChatGPT provided answers for numerical calculations. With consistent practice, the students showed improvements in their querying capabilities. A non-linear, circular learning process is identified that encapsulates the accelerated learning potential presented by the AI software. Overall, this exercise using ChatGPT queries add credence to the fact that students should learn the basics (understanding, remembering) before the advanced levels (creating/synthesizing, evaluating). Incorporation of ChatGPT indeed markedly improve the pace of learning in the classrooms. With careful planning and clear guidance, the students can certainly benefit with the use of GenAI software for their long-term self-learning. Given that ChatGPT and other AI software are still in their early stages of development, the future improvements will create considerably more pedagogical opportunities and implications. But in the very long term, the philosophical and societal questions of the implications of AI for human lives remain.

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Appendix A: Finance Class Homework Question

What can you reliably learn from ChatGPT? Higher Education is all about 'Solving Problems by Asking the Right Questions.' In this assignment, you can ask any finance related question such as

Sample Basic Questions: What is _____ in finance? what does _____ do? what are the important topics or issues in _____ area of finance?

More Advanced Questions: how to take action to improve the company's financial prospects for this set of balance sheet / income statement numbers? which project to choose given the Cash Flows when the projects are mutually exclusive for these numbers? what things should I consider while buying _____ vs _____?

ASSIGNMENT

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1. Ask any THREE questions of your interest. Copy-Paste the three questions and ChatGPT answers for your questions (no word limit)
 2. Do you consider the answers RELIABLE? are the NUMERICAL calculations reliable? How will you verify if these answers are reliable? Did you ask follow-up questions to clarify?
 3. How can you sharpen your skills in asking the right questions?
- Was this assignment helpful to improve your understanding of finance and how to get additional info about finance? You can ask any question based on any finance concept that we have discussed so far (various chapter titles)

Appendix B: Finance Class – Final Exam Question

- A) Artificial intelligence software can provide more reliable calculations and numerical results soon. If they can be improved, what do you see as applications in Business Finance? in your farming business operations?
- B) What skills can you learn to position yourself and your business finances to succeed in a world that is increasingly taken over by the technology?

Appendix C: Supply Chains Management Class – Homework Assignment

Creating Better Prompts through Artificial Intelligence Software: Choose any agricultural product of your interest. Open a new chat and ask a series of questions. Here are some examples: what are the critical components of corn (*or a product of your interest*) supply chain? what is high quality corn that is eligible for price premium? what is the ideal moisture content for corn for premium pricing, etc.

Prompt using a series of queries for a product of your interest to delve deep inside the supply chain features and characteristics (consumer demand, producers, industry, costs, prices, globalization, etc.). Try to find numerical values in terms of units, prices, quality specifications.

1. In your own words, give a summary of what you learned about your product and its supply chains! What can you do to make your supply chain successful based on what you learned?
2. Copy-paste all the answers from ChatGPT.

Appendix D: Chemistry Class – Survey Questionnaire

1. Have you heard of the artificial intelligence software called **ChatGPT**? Yes / No

2. Log into ChatGPT; type a few questions related to our class content (atomic structure, pH concepts, thermodynamics, chemical equilibrium, etc.) and copy-paste your conversation with ChatGPT. Ask a few follow-up questions to ChatGPT, raise doubts that its answers are confusing or wrong, or ask it to explain more or give you a reliable source.

3. What do you think about the power of ChatGPT to help you find answers? Is this a resource you would use for chemistry? Do you trust these answers?

4. If not for chemistry, what other courses can you use ChatGPT for? Do you consider using ChatGPT as academic plagiarism? Should the instructors in your classes adopt or prohibit artificial intelligence software such as ChatGPT?

Based on your experience so far, how does ChatGPT compare with search engines such as Google? What issues do you anticipate with using ChatGPT rather than traditional internet search engines?

Building Community Through Inclusive, Interdisciplinary, and Cross-Campus Undergraduate Research

Nisreen Nusair

Miami University Regionals, Middletown Campus

Undergraduate research is a high-impact educational practice that enriches student learning, fosters faculty engagement, and strengthens the academic mission of regional campuses. This paper highlights the development and impact of a distinctive undergraduate research initiative in chemistry and biochemistry at Miami University Regionals. Designed to address disparities in research access between main and regional campuses, the program emphasizes inclusive, interdisciplinary, and cross-campus collaboration. It offers students early and meaningful research experiences through independent study, faculty mentorship, and strategic partnerships while equipping them with essential scientific inquiry and communication skills. The initiative also supports faculty development and contributes to a vibrant scholarly community. Through student testimonials, structural insights, and institutional alignment with best practices, this study underscores the transformative potential of undergraduate research in teaching-focused settings. Future directions include program expansion, institutional recognition, and external funding to sustain and scale its impact across disciplines and campuses.

Introduction

Undergraduate research is a high-impact educational practice that substantially benefits students, faculty, and regional campuses of large universities (Guo et al.; Adebisi). For students, participating in research fosters meaningful mentoring relationships with faculty while enhancing essential skills such as critical thinking, problem-solving, communication, and collaboration. These experiences help clarify academic and career goals, build confidence, and strengthen students' preparation for graduate studies, careers, and workforce entry, particularly in STEM fields. The transferable skills developed through research broadly apply across disciplines, increasing students' competitiveness in academic, professional, and employment arenas (*How Undergraduates Benefit From Doing Research | Best Colleges | U.S. News*).

Through hands-on inquiry, students gain technical expertise, practice data analysis, and collaborate in team settings, skills highly valued in today's workforce and that make students more competitive applicants to professional and graduate schools (Petrella and Jung). Furthermore, opportunities to present at conferences and engage in scholarly dialogue foster professional networking, boost motivation, and enhance a sense of academic belonging. When institutions prioritize equitable access to research, students from diverse backgrounds gain valuable exposure and experience, contributing to a more inclusive and representative academic community. Interdisciplinary collaborations across departments further enrich the educational experience, promoting a dynamic and integrated research culture.

The literature on undergraduate research not only demonstrates positive outcomes associated with these experiences but also suggests that the magnitude of effects varies by outcome domain. Studies consistently report moderate to strong impacts on student persistence in STEM, scientific identity formation, self-efficacy, and clarity of career or graduate school goals, while gains in traditional academic metrics such as course grades or standardized exam performance tend to be more modest or context dependent. These findings indicate that undergraduate research may be particularly effective as a developmental and motivational intervention rather than as a direct substitute for content-focused instructional reforms.

Faculty members likewise benefit from mentoring undergraduate researchers. These collaborations invigorate teaching, support scholarly productivity, and often lead to innovative lines of inquiry. Faculty gain recognition for their mentorship and research contributions while cultivating a more engaged and interactive educational environment. For smaller, teaching-focused regional campuses, supporting undergraduate research strengthens institutional identity, enhances academic reputation, and serves as a powerful tool for student recruitment and retention. It fosters a vibrant intellectual community, attracts external funding, and promotes campus-wide engagement. Ultimately, undergraduate research contributes to a more dynamic, supportive, and enriching educational environment for all members of the academic community.

A cross-sectional survey of medical students at the Michael G. DeGroote School of Medicine in Ontario, Canada, identified key barriers to undergraduate research participation, particularly in an undergraduate

medical program within regional campuses (Jennifer Leigh et al.). Nearly half of the students (44.5%) reported difficulty securing research opportunities, and 43.6% noted the need to conduct research outside their home regional campus. These findings underscore the importance of institutional support to improve research accessibility and integration across campuses.

Undergraduate research is widely recognized as a powerful tool for enhancing student learning, engagement, and professional development, particularly in the sciences. However, research opportunities are often more readily available to students on main campuses in large universities, where most research facilities and core academic programs are concentrated. In contrast, regional campuses affiliated with the main university, which serve smaller student populations through open enrollment in specific geographical areas, typically have more limited access to research resources. The primary mission of regional campuses is focused on teaching in small-class settings, which can further limit opportunities for research engagement. Miami University's main campus in Oxford, OH, houses most of the university's research infrastructure and academic programs. Meanwhile, the university's two regional campuses in Hamilton and Middletown, OH, have traditionally offered fewer research opportunities, creating a gap in access to valuable hands-on learning experiences.

At the same time, undergraduate research is a labor-intensive educational practice, requiring sustained faculty mentorship, individualized project design, and ongoing supervision. This level of investment raises legitimate questions about scalability and cost-effectiveness, particularly at teaching-focused or regional campuses with high instructional loads. Understanding undergraduate research as one component within a broader portfolio of high-impact practices is, therefore, essential when evaluating its role in institutional educational strategy.

Given its labor-intensive nature, undergraduate research is most effective when implemented as a targeted, high-impact intervention rather than a universally applied instructional model. In teaching-focused environments, such initiatives are often designed to serve a limited number of motivated students at key transition points in their academic pathways, thereby maximizing depth of engagement and developmental impact while remaining feasible within existing faculty workload and institutional constraints.

The following section translates these national recommendations and best practices into a concrete, institution-specific implementation at Miami University Regionals

Applications of Best Practices: Undergraduate Research Implementation at Miami University Regionals

Within this context, a distinctive undergraduate research initiative in chemistry and biochemistry was launched in 2022 at Miami University Regionals to address disparities in access and promote a more inclusive, interdisciplinary, and cross-campus research culture. This initiative was intentionally structured to balance educational impact with faculty capacity and student readiness while embodying the transformative potential of undergraduate research highlighted throughout this introduction. By offering hands-on, inquiry-based research opportunities across diverse science disciplines and facilitating collaboration between regional and main campuses, the program fosters critical skill development, professional growth, and sustained faculty–student mentorships, contributing to a more vibrant, engaged, and inclusive academic community across Miami University’s campuses.

The Undergraduate Research Model: Independent Study versus Course-Based Undergraduate Research Experiences (CUREs).

Undergraduate research can take many forms, but two of the most common models are Independent Study and Course-Based Undergraduate Research Experiences (CUREs). Each offers unique advantages and poses different challenges, particularly when implemented at smaller institutions like Miami University Regionals.

Independent Study is a flexible, mentorship-driven model where a student collaborates closely with a faculty member outside the traditional classroom setting. These experiences are highly personalized, allowing students to contribute to existing research projects or explore new ideas aligned with their interests. At small campuses, the lower student-to-faculty ratio enables more meaningful one-on-one mentorship. Faculty can devote more time to nurturing student development, making independent study an especially valuable opportunity for upper-level students who have completed key foundational coursework.

In contrast, large campuses often offer a wider variety of research projects and specialized facilities. However, the volume of students and

reliance on graduate students or postdoctoral fellows for mentorship can lead to less individualized faculty-student engagement. Independent study at such institutions may require students to be more proactive and self-directed to navigate the available opportunities.

CUREs, on the other hand, embed research into the structure of a credit-bearing academic course (Duboue ER et al.; Vance-Chalcraft et al.). All students enrolled in the course work on a common research project, often in teams. This model lowers many of the barriers associated with traditional independent study, such as the need to seek out a mentor or possess prior research experience. CUREs are especially effective in broadening access to research, supporting early engagement, and developing scientific thinking across diverse student populations.

CUREs have gained significant traction in recent years. According to a review of 68 articles published between 2016 and 2022 (Field M. Watts and Jon-Marc G. Rodriguez), 82% of CURE implementations in chemistry occurred at doctoral- or master-granting institutions, with only 26% taking place at baccalaureate institutions. Most of these implementations are integrated into upper-level coursework, particularly in biochemistry, with far fewer incorporated into foundational courses like general or organic chemistry laboratories.

At Miami University Regionals, these national trends present both challenges and opportunities. The regional campuses do not offer bachelor's degrees in chemistry or biochemistry. Students in these majors complete their first two years at the regional campuses before transferring to the main campus. However, a bachelor's degree in applied biology is offered at the regionals, which allows biology majors to participate in independent research or CURE-based experiences offered locally. Still, students majoring in chemistry, biology, or pursuing pre-health tracks have limited access to chemistry- or biochemistry-related research opportunities while at the regional campuses, often delaying their involvement in research until they transfer in their junior year.

Implementing CUREs into foundational chemistry courses at the regional campuses could significantly enhance early research exposure for students. However, several barriers must first be addressed. A major challenge is the wide variation in student preparedness in these entry-level courses, with many students struggling in key areas such as math skills, laboratory techniques, time management, maturity, and even clarity in selecting a major. Additionally, standardized course delivery across all

Miami University campuses requires strict coordination and consistency. Any modification to the curriculum, such as the integration of a CURE, requires formal approval and alignment with the Department of Chemistry and Biochemistry at the main campus to ensure uniformity in learning outcomes and academic standards. This makes it difficult to implement CURE-based content exclusively at the regional campuses. Finally, infrastructure limitations further complicate the process, as both the main and regional campuses often face constraints in teaching staff, laboratory space, and budgetary resources.

For these reasons, independent study has become the primary research model for chemistry and biochemistry at Miami University Regionals. This approach allows for greater flexibility in adapting to local resources, student readiness, and mentorship capacity. Faculty can carefully select and train motivated students to work on research projects tailored to the regional campus environment. While this model may not reach as many students as a CURE would, it enables sustained, in-depth experiences that build technical skills, confidence, and long-term mentor-mentee relationships, key components of successful undergraduate research. Compared with CURE or large-scale pedagogical reforms that can reach hundreds of students with relatively low per-student faculty investment, independent undergraduate research reaches fewer participants but offers greater depth, personalization, and continuity of mentorship. While broader strategies may be more efficient for improving aggregate learning outcomes, undergraduate research provides distinctive benefits that are difficult to replicate in classroom-based settings, particularly in fostering scientific identity, confidence, and long-term persistence in STEM.

Balancing Student-Centered and Outcome-Oriented Undergraduate Research

In efforts to define undergraduate research, a key issue identified is whether its primary purpose is student development or outcome production (Beckman and Hensel). When the focus is on fostering student learning, undergraduate research is considered student-centered. In contrast, when the emphasis is on producing tangible outcomes, such as presentations or publishable work, it becomes product-centered. The definition and focus of undergraduate research often vary by department and discipline, reflecting differing expectations. Additionally, a student's academic level may influence the orientation: research for first-year

students is typically more process- and learning-oriented, while senior students may be expected to engage in more outcome-driven projects. The undergraduate research initiative in chemistry and biochemistry described here was launched by a first-year tenure-track faculty member at a regional campus, where faculty are required to produce scholarly work for tenure and promotion. While the program's primary aim was student-centered, in alignment with the regional campus's teaching-focused mission, it also placed intentional emphasis on producing scholarly outcomes, balancing the dual goals of enhancing student development and supporting faculty advancement.

Scaffolding Undergraduate Research: From Recruitment to Readiness

- **Recruitment and Selection Process**

A key mentoring trait highlighted in *“How to Mentor Undergraduate Researchers”* is the mentor's approachability and initiative, especially when fostering collaborative work with students (Merkel). The book notes that many students may feel hesitant to express interest in research opportunities. Aware of their limited experience, they may fear rejection or feel unqualified to contribute to scholarly work. However, in undergraduate research, faculty have the opportunity and responsibility to lead. Mentors can actively recruit students who show a spark of curiosity and enthusiasm in the classroom, even if they haven't yet found the confidence to approach us. By taking the initiative to reach out, mentors can create inclusive and supportive environments that draw out potential in students who might otherwise remain on the sidelines.

At Miami University Regionals, the chemistry mentor uses a structured yet inclusive process to introduce students to undergraduate research opportunities. At the start of each semester, a brief presentation is delivered during the first day of General Chemistry I and II classes, highlighting the research focus, its relevance, and opportunities for student involvement.

Beckman and Hensel (2009) raise an important question: should undergraduate research be available to all students, or should it be reserved for high-achieving or honors students? Given limited institutional resources, some universities choose to invest in a smaller group of students, guiding them toward advanced levels of scholarly development with the expectation of producing tangible outcomes such as presentations or

publications. This selective approach is often intended to prepare students more effectively for graduate school and competitive career pathways. Therefore, later in the semester, an invitation is sent via the course's learning management system, encouraging selected students to attend an informational research session. This session outlines the project objectives, research methods, and campus locations for conducting research, and communicates expectations regarding commitment, skill requirements, and participation standards.

Students who express interest and meet the selection criteria are eligible to begin their research involvement after completing either General Chemistry I or General Chemistry II. The majority of students enrolled in these courses are freshmen, though some sophomores also participate. According to (Merkel), mentors are often hesitant to involve first- or second-year students in research due to their limited coursework and academic maturity. However, an important recommendation in effective mentorship is for mentors to intentionally design sub-projects that are more accessible to early-stage students. These projects should align with the mentor's broader research goals but require less prior knowledge and training. When early engagement is paired with strong mentorship, students are more likely to remain involved in research over multiple years. As a result, they gain deeper experience and become significantly more capable and independent researchers by the time they reach their junior and senior years.

It is important to note that the regional campuses offer a bachelor's degree only in Applied Biology. Students pursuing other science majors, such as Chemistry or Biochemistry, are required to transfer to the main campus after completing their sophomore year. Additionally, some students choose to transfer to the main campus even when their intended degree is available at the regional level. Given these dynamics, it is essential to offer undergraduate research opportunities to science majors at the regional campuses as early as their first year. Because the regional campuses operate under an open enrollment policy, a selection process is necessary to identify and recruit motivated students for research participation. Mentors should intentionally *select students and set clear expectations*. Mentors should look for key qualities in prospective undergraduate researchers, including scientific inquisitiveness, the ability to work independently, and a range of previous experiences (Merkel).

Selection in this chemistry undergraduate research initiative at MU Regionals is based on a combination of strong academic performance, classroom engagement, and personal attributes such as enthusiasm, initiative, and a solid work ethic. In addition, students are expected to demonstrate foundational laboratory skills, the ability to work collaboratively in a team setting, and competence in scientific communication, including report writing. This intentional screening process ensures that participants are not only academically prepared but also equipped with the practical and interpersonal skills necessary to contribute meaningfully to the research experience.

- **Developing Independent Study and Safety Training**

A collaboration was initiated by the chemistry faculty with the Department of Chemistry & Biochemistry at the main campus, the Department of Math and Physical Sciences at the Regionals, and the Registrar's Office to establish independent study courses in chemistry at the Regionals. These courses mirror the independent study offerings at the main campus but carry a regional designation, providing students with a formal pathway to earn academic credit for research. Students are enrolled in an online safety training course provided by the Department of Chemistry and Biochemistry at the main campus, ensuring they complete the required safety protocols before beginning lab work.

- **Research Kick-Off Meeting and Planning**

At the beginning of each research semester, a kick-off meeting is held where students introduce themselves, discuss their schedules, and clarify their roles. The Department Chair is invited to this meeting to reinforce the importance of the initiative and foster a sense of community among the research team.

Research is conducted at both the main and regional campuses. Experiments requiring specialized instrumentation are performed at the main campus, while other aspects are carried out at the regional campus. Students have the flexibility to conduct research at either or both campuses, depending on their interests and logistical needs.

Weekly meetings provide students with ongoing guidance and support, allowing them to review progress, address challenges, and plan

next steps. This structured approach helps students stay focused and fosters a collaborative research environment.

Expanding Opportunities Through Cross-Campus and Interdisciplinary Collaborations

A strong university mission and culture is one of the key best practices that support and sustains highly effective undergraduate research environments (Hensel). Institutions committed to undergraduate research excellence prioritize high-quality research experiences for students, promote broad disciplinary participation, and ensure that opportunities are equitable, accessible to a diverse student population, and aligned with essential career readiness competencies. In addition, research infrastructure that provides appropriate space, equipment, and resources is essential to facilitate meaningful student engagement in research. A strategic cross-campus collaboration with the Department of Chemistry and Biochemistry at the main campus has significantly enriched the research experience for students at the regional campuses. Through this partnership, regional students gain access to advanced instrumentation and dedicated laboratory space, allowing them to engage in more sophisticated and technically demanding experiments that would otherwise be beyond the scope of regional resources.

In addition to cross-campus cooperation, connections with other STEM faculty at the regional campuses have fostered meaningful interdisciplinary research. One ongoing project, for instance, integrates biochemistry and physics, enabling students to work on complementary aspects of the research. This model promotes collaborative problem-solving, encourages diverse scientific perspectives, and enhances student learning by exposing them to methodologies and concepts beyond their primary discipline.

Moreover, the initiative has attracted participation from main campus students, who now actively contribute to joint research efforts. Their involvement helps create a dynamic academic bridge between campuses, facilitating the exchange of ideas and strengthening both peer and faculty relationships. This interconnected framework not only broadens the scope of scientific inquiry but also cultivates a more cohesive and inclusive research culture across the university.

Impact: Student Development and Showcasing Student Research

Dissemination of research through peer-reviewed publications, presentations at professional meetings, and on-campus symposia is a critical best practice for supporting and sustaining highly effective undergraduate research environments, as highlighted in (Hensel).

The undergraduate research initiative plays a transformative role in student development by equipping participants with essential scientific and professional skills through hands-on training in sample preparation, data collection and analysis, instrumentation, scientific software, manuscript writing, and poster preparation, thereby fostering both technical proficiency and analytical competence that support future academic and professional pursuits.

Beyond laboratory skills, the program emphasizes scientific communication and public engagement. Students have presented their work at prominent venues, including the Annual Undergraduate Research Forum at Miami University and a variety of regional and national conferences. These experiences allow students to share their findings with wider audiences, receive valuable feedback from experts, and build professional networks early in their careers. To remove financial barriers, the regional Dean's Office has committed annual funding to support travel and conference registration costs, making participation accessible to all qualified students.

Since its inception, the program has seen robust student interest and participation. Many students have submitted and presented abstracts at conferences, demonstrating the program's effectiveness in nurturing independent research capabilities, critical thinking, and scientific communication. Students of the program often report increased confidence, improved academic performance, and a clearer sense of direction for graduate studies or careers in STEM fields.

The initiative has advanced institutional goals of equity and inclusion by offering regional campus students research opportunities on par with those at the main campus. The cross-campus nature of the program has fostered stronger student-faculty mentoring relationships and encouraged interdisciplinary collaboration. As a result, the program contributes not only to individual student success but also to a more cohesive, inclusive, and vibrant undergraduate research culture across campuses.

Students' Feedback

Student J.R.

I began undergraduate research during the spring semester of my freshman year at the Miami Regionals. I started by working with Dr. N.N. to study the effects of various cancer drugs on synthetic lipid bilayers. While our research did not yield usable results, the experience deepened my understanding of the research process and taught me that research doesn't always go as planned. Since then, I have worked with Dr. M.B. and Dr. N.N. on carbon nanodot research. These experiences have been extremely valuable, allowing me to develop essential lab skills and gain a deeper understanding of chemistry, biochemistry, physics, and laboratory techniques. These experiences have also allowed me to build important connections with faculty at Miami and fueled my enthusiasm for learning. Furthermore, these experiences have shaped my future career. I have decided to pursue a career in biochemistry, specifically focusing on drug and treatment development in a bio lab. The technical knowledge and experience I've gained have prepared me for success in this field in a way that neither lectures nor labs could. I strongly encourage Miami University to expand research opportunities for students on the Regionals by increasing faculty support, funding, equipment, and lab space. Doing so would not only benefit current students but could also attract more students to the Regionals.

Student E.H.

Over the past year, I have had the wonderful opportunity to work alongside faculty members and participate in undergraduate research through Miami University Regionals. During this time, I have experienced so much growth both as a student and professional as well as growth as a person as I have been challenged both in the lab and outside of it. I have been given opportunities to hone skills such as critical thinking when a procedure in the lab goes awry and doesn't follow the "textbook" version of a lab that might be done in a classroom setting, and I have been given the opportunity to formulate new skills such as operating new equipment and understanding new concepts and analytical information. Having started this research in my freshman year, I have had a unique opportunity to experience and learn in a way that many students have not, which I believe

has set me up for success within the courses I take and concepts that I face as I continue my classes and education.

Having transferred from another university to Miami Regionals, I knew early on that I wanted to participate in research, but I was hesitant as to whether there would be opportunities that suited my interests and qualifications. Upon connecting with Dr. N.N. and having the opportunity to conduct research under her guidance, I have been more and more thankful to have found a place in the lab, especially when there are currently limited undergraduate research opportunities in the biochemistry department for regional students. As I continue down this path with research, I would also urge other students to become involved as more opportunities become available because there is nothing, in my opinion, that better prepares you for classes, a future career, and grad school than research does.

Student P.M.

My research experience at Miami Regionals was truly life-changing, both academically and personally. One of the most impactful aspects was having Dr. N.N. as one of my first professional mentors, her guidance and support helped shape not only my academic journey but also my confidence in myself. I always dreamed of becoming a researcher, but this was the first time I truly felt like I belonged in that world. Being in the lab allowed me to develop critical thinking skills and gave me hands-on experience with techniques that many of my peers hadn't yet encountered. More than that, it gave me a sense of direction and purpose during a time when I really needed it. This experience reminded me that I am capable of achieving great things and helped me realize I am meant for more than what I had once settled for. It inspired me, motivated me, and gave me the confidence to pursue my goals with a new level of determination.

Excellence in Mentoring Undergraduate Research

Excellence in mentoring undergraduate research is a high-impact educational practice. Research studies consistently highlight that faculty mentorship plays a central role in student development, research success, and fostering a positive research environment (Vandermaas-Peeler et al.). Effective mentorship is characterized by several key practices. Faculty mentors should maintain open and consistent communication with their students, provide clear expectations and timely feedback, and offer encouragement throughout the research process. They should guide

students through essential aspects of research, including experimental design, data analysis, literature review, and scientific writing. Importantly, mentors should cultivate a supportive environment by being approachable, encouraging student independence, and recognizing and celebrating student achievements.

To support this vital role, universities should offer structured mentoring programs that include training, resources, and professional development opportunities. Faculty, especially those new to mentoring, often need support to mentor effectively. Institutional investment in mentorship not only enhances student outcomes but also strengthens faculty engagement and research culture.

A Challenge to Effective Mentoring is Faculty Workload

A major barrier to effective undergraduate research mentorship at small, primarily undergraduate institutions is the heavy teaching load faculty often carry, which limits time for meaningful research engagement (Straffin). The short duration of most student-faculty research interactions, usually just one or two semesters, further complicates efforts to mentor students substantially. Integrating research into the curriculum can help address these constraints, as demonstrated by Edinboro University, where short-term, inquiry-based undergraduate research projects have been incorporated into a long-term faculty research program to balance teaching and research productivity.

In a different study, scholars suggest that the most meaningful undergraduate research experiences occur when students are involved in every stage of the research process, from identifying the research question to publicly disseminating their findings, while working closely with faculty mentors in collaborative, supportive relationships (Tugman et al.). This level of engagement requires a high degree of faculty involvement and a strong commitment to mentorship.

At Miami University Regionals, faculty mentorship in undergraduate research is not formally recognized in workload evaluations, making it even more difficult to sustain. Effective mentoring requires time and commitment, including designing projects, supervising students, coordinating across campuses, and often managing the use of specialized instrumentation. Without institutional acknowledgment in the form of workload credit, faculty involvement remains limited, and expansion of the program is hindered.

To strengthen interdisciplinary research and attract more faculty mentors, undergraduate research mentorship must be formally counted as part of faculty workload. This would also support efforts to increase student participation, especially from diverse scientific backgrounds, and enhance cross-campus collaboration. While seeking external funding could provide additional resources, this too presents a challenge, as faculty at regional campuses are primarily teaching-focused and are not typically expected to secure research grants. Addressing these workload-related barriers is critical to sustaining and growing a high-impact undergraduate research culture.

Administration Support and Professional Development to Sustain Undergraduate Research

Drawing on over 30 years of experience from members of the Council on Undergraduate Research (CUR), the Characteristics of Excellence in Undergraduate Research (COEUR) provides a comprehensive framework outlining best practices for initiating, developing, evaluating, and sustaining high-quality undergraduate research programs (Hensel). This framework is organized into sections corresponding to various functions and units within a college or university. It begins with establishing a supportive campus mission and culture where undergraduate research is highly valued and involves commitment from leaders, faculty, and various campus units. Crucially, it requires strong administrative support, encompassing not only internal budgetary resources for materials, personnel, and equipment but also recognition and compensation for faculty through workload credit or reassigned time for research-related tasks and mentoring. A robust research infrastructure is deemed essential, necessitating adequate dedicated space (like labs and meeting rooms), appropriate instrumentation and equipment, and sufficient library resources. To maintain effective scholarship and mentoring, professional development opportunities for faculty (like research leaves and training workshops). Recognizing the importance of contributions, the framework highlights the need for recognition of both faculty and students through avenues like promotion and tenure considerations, salary reviews, campus awards, and prominent publicity for accomplishments.

The Office of Research for Undergraduates at Miami University is committed to supporting and sustaining high-quality undergraduate research programs. Many of the elements outlined in the COEUR framework are already in place at Miami, including access to research infrastructure,

professional development opportunities for faculty, and recognition of research contributions. However, greater attention should be directed toward enhancing undergraduate research opportunities on the Regional campuses, where faculty serve as the primary mentors, unlike the main campus, where undergraduate students often work under the guidance of graduate students or postdoctoral fellows. To ensure equity and effectiveness, increased administrative support is essential, including compensation for faculty through workload credit or reassigned time for research-related tasks and mentoring.

Future Directions and Conclusion

This work does not attempt to quantify effect sizes or directly compare undergraduate research with alternative educational investments such as course redesigns or large-scale active-learning initiatives. Instead, it presents a descriptive and reflective account of a programmatic model situated within a specific institutional context. While student testimonials, participation outcomes, and dissemination activities suggest educational impact, future research employing mixed-methods or longitudinal designs would be valuable for more precisely assessing the relative costs and benefits of undergraduate research within broader institutional strategies. Looking ahead, the undergraduate research initiative at Miami University Regionals aims to expand its reach and impact by becoming more inclusive, interdisciplinary, and cross-campus. Broadening access to students from diverse academic and demographic backgrounds will ensure equity and representation in research participation. Increasing interdisciplinary collaboration with faculty across STEM and non-STEM fields can further enrich the student experience and promote innovation. Strengthening cross-campus partnerships, particularly with the main campus, will facilitate shared resources, joint projects, and a more unified institutional research culture.

For this initiative to grow sustainably, it must be formally recognized and supported. This includes providing faculty with workload credit for mentorship, investing in infrastructure, and integrating undergraduate research into the broader curriculum. Securing external funding will be critical to scaling the program, enabling the purchase of specialized equipment, supporting student travel to conferences, and offering research stipends to promote broader participation.

In conclusion, undergraduate research is a transformative experience that empowers students, enhances faculty engagement, and elevates the academic profile of regional campuses. By continuing to invest in inclusive, interdisciplinary, and cross-campus research opportunities, Miami University Regionals can serve as a model for integrating high-impact practices into teaching-focused institutions and fostering a vibrant scholarly community.

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**“The Devil Made Me Do It”: Re-examining the Salem Witch Trials
Assignment Through a Modern Point of View**

Allison Schottenstein
University of Cincinnati

“Satan’s design was to set up his own worship, abolish all the churches in the land, to fall next upon Salem and go through the country,” testified the accused William Barker Sr. during the 1692 Salem Witch Trials.ⁱ The fear of the devil in early America was beyond reason because in the Puritan world, even mere mortals were not protected from Satan’s wrath. In twenty-first-century mainstream America, the notion of the devil walking the earth would hardly make the news—but would be relegated to TV series such as *Lucifer*. However, at one point, books like the *Malleus Maleficarum* offered deep insight into witches in Europe and what would become the United States.ⁱⁱ Throughout my teaching career, I have struggled to help students relate to the witch craze, whether in Europe or America. Part of the challenge is that educators have marginalized this history as a metaphor for the fear of McCarthyism, as seen through Arthur Miller’s *The Crucible*.ⁱⁱⁱ As educators, we hope students grasp not only the dangers of mass hysteria but also the problems posed by Religion becoming fanatical in American history. Despite the separation of Church and state, it has shaped the nation’s moral and political life. However, throughout its history, America struggled to delineate the line between Religion and public life, prompting Americans to go to court to clarify this boundary.

Although the European Witch craze claimed more lives—from 35,000 to as high as 45,000—colonial America is guilty of twenty-four lost lives.^{iv} They have blood on their hands—nineteen were hanged and one was pressed to death.^v However, we often reduce this event to a historical footnote—or, worse, to a fun Halloween activity.^{vi} In my effort to bring attention to this colonial American tragedy, I have experimented with various assignments in my United States History 1 course from the Colonial period to end of Reconstruction.

My first assignment drew inspiration from the *Choose Your Own Adventure series*, popular from 1979 to 1998. To remain compliant with the US Copyright Law, I digitized and shared only a limited excerpt from *Salem Witch Trials: An Interactive History Adventure*, so students could have a

framework to help them imagine themselves in Salem and choose their own adventure. Using this excerpt as a starting point, I asked students, “What Would You Do?” Students choose one of three scenarios: 1) a friend has accused a young girl of being a witch, 2) your mother is accused of witchcraft, 3) or you think someone put a spell on you. After choosing a scenario, students had to decide how they would act if they were living in Salem in the 1690s.

Because students had access only to a small portion of the text, they were required to rely on their historical knowledge and creativity. I encouraged them to weigh their decisions in the context of historical time period. However, many students used this opportunity to create superficial fan fiction rather than critically engage with the historical realities of the period. While I appreciated the creativity, students took historical liberties to make their stories more interesting.

My second teaching concept was the “Salem Witch Trials Justice Paper.” For this assignment, students would watch “What Really Happened During Salem Witch Trials” and “America’s Hidden Stories: Salem’s Secrets.” My goal was to have students decide whether justice had been served for the victims of the Salem Witch Trials. Students were asked if they had been alive during that period, if they would have succumbed to the witch hysteria, or if they would have had a different approach that might excuse or condemn the behavior of the accusers. Finally, they were to reflect on how we should remember those who perished in this trial. However, the main obstacle with this assignment was that students struggled to connect modern concepts of social justice with the world of colonial America. After this project, I came to an important realization. Students recognized from a historical perspective that what happened in Salem was wrong and justice should prevail, but they could not relate. They were psychologically distant from the events. They were not personally connected to it and had no reference point in their lives

For instance, one student wrote “It is really sad to think about all the people that suffered during this time because of a justice system that put their religious values over everything else.” The student clearly feels remorse, but also knows this was tied to a specific date and time in history. She points out that it was “sad,” because the justice system in Salem failed, but at the same time frames individuals as “victims” of an “authoritarian system,” and simply “products of their time.”

When the students completed the created-your-own adventure assignment, it was a similar issue. They made their stories more creative because the time period was too distant for them to place themselves in a similar situation or think more deeply about the torture or injustice the accused faced. These two assignments helped me come to the conclusion that there are two ways to teach history. We can have students learn history so they know the historical facts and can interpret them as moral failures of the past, or we can create opportunities for students to connect the past to situations that feels familiar to them, allowing them to recognize that the same human behaviors still exist today. While there is a fine line so as not to make anything ahistorical, it is important to think outside of the box so that history becomes real and relatable.

My third teaching project was titled "Salem Witch Trials Reflection: History of Scapegoating." In this assignment, I chose archival material so students could read the victims voices. I asked students to think more deeply about the townspeople's reactions during the trials. Why did they quickly blame their friends and condemn them to torture and death? I explained that throughout history, a select group of people has always been singled out and blamed for the woes of the majority. In their essay, students were to include what they learned about the Salem Witch Trials and about scapegoating, and to consider whether the Salem Witch Trials were a meaningful and relevant lesson for today. To support their analysis, students were encouraged to use details from the National Geographic's "Salem Witch Trials" and from the online Salem Witch Trial Archives.

When asked to reflect on the concept of scapegoating, many students struggled. Some did not think it was a significant part of American history; others chose not to address the question directly, and some produced a general statement about the unfairness of the trial. A few students had difficulty comprehending the meaning of the term "scapegoat." These assignments prompted me to reconsider my lesson—but I did not want to give up on it. I recognized that Salem was not an isolated event in history, but was part of a long chain of violence directed towards marginalized individuals.

I turned to Jack Mezirow's *Transformation Dimensions in Adult Learning*. My goal was to prevent students from recycling information they had previously learned in high school or potentially during school field trips to Salem. Mezirow argues that adult learners do not learn effectively by memorizing facts or attending additional lectures.^{vii} Instead, meaningful

learning occurs when adults experience a “disorienting dilemma”^{viii}— an event or idea that challenges their “existing frames of reference.”^{ix} In other words, educators must help adult learners dismantle their prior assumptions so they can critically assess why they believe what they do. Only through this process can genuine transformation take place. In the case of the Salem Witch Trials, I needed to devise a plan to allow for this “transformation”^x— one that would move students to empathy for those accused and executed during the Salem Witch Trials and deepen their understanding of the socio-political atmosphere that provoked the persecutions.

The one area I never thought to tap into was centering the discussion on the danger of Puritanism and how it easily influenced the townspeople. The solution to this problem arrived unexpectedly. Inspired by the *Conjuring* film franchise, which centers on demonic possession and faith, my *transformation* as an educator began. I was mesmerized by how the *Conjuring Universe* had successfully marketed faith without a clear conversion goal, earning a record-breaking of over 2 billion worldwide.^{xi} This observation led me to ask a new question: Why do films with strong religious undertones, like the *Conjuring* universe, dominate the silver screen?

As with many superhero films, *The Conjuring* franchise encourages the main characters, Ed and Lorraine, to courageously face the unimaginable. Ed and Lorraine appear as almost *Marvel-like* spiritual superheroes who save the day from demons. In all *four Conjurings*, Ed and Lorraine save innocent, non-spiritual families in Western countries (America and England alike). As Captain America has a shield, Lorraine and Ed carry Catholic symbols—rosaries, crucifixes, and holy water—as their weapons against evil and to help coordinate an exorcism.

Ed and Lorraine can save the vulnerable from possession without fault as their faith is unshakeable. Only they can “make hell pay” before “all hell breaks loose,” and they succeed every time because God empowers them to do so. This realization prompted me to question: Are Americans attracted to these films because of faith or because of the power of cinematic storytelling? Once I figured this out, I finally found new ways to teach my students about Salem. Just as Americans believed in Ed and Lorraine’s divine mission, the Puritans of Salem were convinced that the devil dwelt among them. Both demonstrate a struggle against good and evil—whether grounded in faith, fear, greed, or post-traumatic stress

syndrome—that continues to shape the mindset of the American moviegoer despite a general decline in religiosity.

Pew has conducted several studies on Americans' religious practices, offering insight into how religion take shape in the United States today. It is a far cry from the cultural memory of Irving Berlin's "God Bless America," but America has not yet fallen from grace. Instead, religion remains part of America's cultural framework — but it shows up in different ways. In 2022, Pew published *Modeling the Future of Religion in America*, which found a significant decline in Americans practicing Christianity: "As recently as the early 1990s, about 90% of U.S. adults identified as Christians. However, today, about two-thirds of adults [are] Christians."^{xii} Americans born after 1992 tended to move away from their faith. Most significantly, surveys have also been conducted on Americans' reactions to the supernatural.

Jacob Ausubel related in his Pew Study, "Christians, religiously unaffiliated differ on whether most things in society can be divided into good, evil." Ausubel revealed Americans had different conceptions of evil. Most remarkable is that almost half of Americans—around 48%—believed that "most things in society can be clearly divided into good and evil."^{xiii} Although the other half believes that "society [is] too complicated to be categorized that way," this demonstrates that a significant portion of the United States believes in the existence of evil.^{xiv} Strikingly, Americans have a solid connection to the afterlife. Around 75% of Americans believe in heaven.^{xv} Sixty-two percent of Americans acknowledge hell's existence. Of the Americans who accepted hell's existence, 44% believed there was a Satan.^{xvi} Americans have, in greater numbers, believed in ghosts, a trend higher than in an earlier modern period. However, belief in the supernatural has always been part of American DNA, as early as the 18th and 19th century, with the New England Vampire Panic and the Bell Witch Haunting.^{xvii} According to the Ipsos study, around 46 % believed in ghosts, a figure that is significant given the decline in organized Religions' involvement.^{xviii} During the COVID-19 pandemic, there was greater interest in the paranormal as a means of coping with the uncertainty. This juxtaposition between people's opposition towards organized Religion and their embracement of the supernatural world reveals why Americans gravitated towards demonic films. After all, the heroes are Catholics, and the victims are generic non-practicing Christians who come to acknowledge that hell does exist on earth.

Religious scholar Colleen McDannell explains, “Religion is not merely learned in synagogues, mosques, and churches. The common admission— ‘everything I know about religion I learned from the movies’ — is true for believers as much as for unbelievers.”^{xxix} Movies are not scripture, and you cannot do communion with popcorn, yet American theatergoers have made assumptions about the religious-based films, as though Hollywood itself wrote the Gospels. Though no resurrection has occurred at an AMC, Christ has still led more than a few disciples to the theater in search of meaning. Christianity, specifically, possessed the silver screen. In particular, Catholic-infused possession films became more than a quest to stop lurking demons from ripping apart innocent souls. Instead, they reflected on how Americans could believe in the impossible and the supernatural in a specific time and place. Early to mid-twentieth-century Americans still viewed the nation through a largely Christian lens, a perspective reflected in possession-based cinema.^{xx}

As a history professor, I understood one of the most striking aspects of American life was how the film industry influenced Americans’ views on Religion, regardless of their personal faith. In particular, Catholicism played a significant role in shaping Americans’ understanding of religious themes, especially the struggle between good and evil. By examining how Catholicism helped shape the film industry—and how its influence persisted after the Church’s direct control declined—I could develop a stronger framework for understanding my students, who are themselves consumers of pop culture.

Catholicism truly gained control over the production of films due to the fear of immorality consuming Hollywood in the 1930s.^{xxi} To sell more tickets, especially during the Depression, American motion pictures lost touch with *decency*.^{xxii} Jews, Protestants, and Catholics feared how the soul of America would become tarnished by the film industry. The chairman of the Motion Picture Association, William Hays, tried to create what is known as the “Hays Morality Code” and promised that “he would allow no dirt in pictures and failed to keep his promises—and failed miserably.”^{xxiii} The National Legion of Decency, primarily composed of Catholics, also had Jews and Protestants join.^{xxiv} The Legion instituted strict policies on film and rated the movies themselves. They were a force to be reckoned with: “The Legion dominated so much control over the films that a reviewer of *Picture of the Week* stated, ‘Whenever a drama with a religious background is used, almost invariably the hero has turned out to be a Catholic priest. Not that

we have anything against having our Roman brethren well depicted...it is just that in a land predominantly protestant, it seems a bit out of balance to have religious pictures go Catholic by ten to one."^{xxv} Not only did Catholics boycott films, but they also would take pledges to protest " 'unwholesome movie pictures'" and "'to arouse public opinion against' the portrayal of vice as a normal condition of affairs."^{xxvi} The boycotts made such an impact that Hollywood hired Catholic Joseph Breen, director of the Production Code Administration, to save itself from destruction and to bring God back to the movies. As Andrew Quickie explained, Breen decreed that "every film had to show moral compensating values for any evil that might be shown amounted to an attempt at Catholic social engineering."^{xxvii} Breen altered any screenplay that did not fit into his moral sensibility.

Catholicism inundated American films. Catholicism entered mainstream popular culture, and American filmgoers began associating Americanism with Catholicism, an ironic historical turn considering anti-Catholicism in America:

As the religion of many immigrants, Catholic characters represent outsider status as well as the 'American way of life.' Rather than being marginal to American popular culture, Catholic people, places, and rituals are central. At the movies, Catholicism—rather than Protestantism—is *the* American religion.^{xxviii}

In other words, it did not matter if one was Protestant or Catholic; the film industry made them believe in the power of the Catholic faith. Americans had described their nation as Christian, with the apex of such revelation manifesting during the Cold War Era. Religiously inclined Americans perpetuated the mythology that the Founding Fathers desired a nation under God. In the early Cold War, America became a Christian nation in response to the "godless communists" whom fierce anti-communists feared secretly possessed the nation.^{xxix} Under President Dwight D. Eisenhower, America became the quintessential nation entrusted by God. Historian Kevin Kruse explained that the Pledge of Allegiance was rewritten in 1953 to include the phrase "under God," and even "'In God, We Trust' was added to a postage stamp for the first time in 1954 and then to paper money the next year."^{xxx} Though the film world and the real world aligned

with American religious beliefs, this did not always hold for American personal faith; however, it did remain true in the films.

Catholicism did not become exorcised from the screen. In fact, it evolved significantly in the horror genre, in which it was the one area where Catholicism could emerge as the embodiment of the heroes against evil. Though there were early horror films like *Nosferatu* (1922) that showed the power of Christianity, and confirmed, as scholar Craig Detweiler said, “horror films remain a robust genre for combining Christianity and cinema,”^{xxxix}—*Rosemary's Baby*, in the 1960s, after the end of Breen’s reign, paved the way for the *Exorcist*. Perceptions of America as a religious nation, albeit Christian, have also influenced the American horror genre, especially possession films, which came of age in the 1970s with the phenomenon known as *The Exorcist*. *The Power of Christ* may not have compelled Americans to faith in the 1970s, when *The Exorcist* came out; however, it did provoke visceral reactions. Because of the *Exorcist*, people began associating the devil with pea soup, possession, and priests—specifically, Catholicism. Catholicism dominated possession. Such a film made a lasting religious impact on the American population; regardless of Americans’ spiritual practice, Catholicism became the savior from the devil. The *Exorcist* evolved into more than just a horror film. Film critic Pauline Kael said, “The *Exorcist* was ‘the biggest recruiting poster the Catholic Church had since the sunnier days of *Going My Way* and *The Bells of St. Mary*.”^{xxxix} Clergy even felt connected to *The Exorcist*, as it made the battle between good and evil real, allowing films like *The Conjuring* to bring faith to horror. The *Exorcist* secured Catholics’ place in exorcism history through the character Clinical Director Dr. Barringer, who made the following statement to Chris, Reagan’s mom, in the film. Unable to find a reason for Reagan’s peculiar, disturbing, unnatural behavior, Dr. Barringer said:

Have you ever heard of an exorcism? It’s a stylized ritual in which rabbis or priests try to drive out the so-called invading spirit. It’s pretty much discarded these days, except by the Catholics who keep it in the closet as a sort of embarrassment. It has worked, in fact, although not for the reason they think, of course. It was purely the force of suggestion. The victim’s belief in possession helped cause it. And just in the same way, this belief in the power of exorcism can make it disappear.^{xxxix}

The short film *The Cultural Impact of the Exorcist* captured Americans' over-the-top reaction to the film. Indeed, Americans were so captivated by this film that they were willing to drive hours to the movie theater to find a showing of *The Exorcist*, even waiting in line for hours in the cold to attend one of the showings. Americans were so convinced of the reality of *the Exorcist* that, mentally, some viewers had difficulty watching the entire film in one sitting. They would vomit, faint, or scream in terror while watching the movie. Some people had mental breakdowns and had to seek further care in the hospital; ambulances waited in some theaters in anticipation of medical emergencies. There were even people who had to be committed for psychiatric counseling.

The documentary emphasized that Americans did not have to believe in a higher power to be impacted by this film. Regardless of a person's faith background, *The Exorcist* shaped public perception, enabling Americans to believe that demonic possession was real. Even as practice in the United States declined, Americans remained intrigued by religious-based films, particularly horror. More importantly, movies like *The Exorcist* had such an influence that they could cause filmgoers to experience hysteria.

This phenomenon led me to view the Salem Witch Trials from a new perspective. I realized the students could better understand the Salem Witch Trials if they could relate them to a modern example. Considering America's long history of engaging with film—which even continued after the Hays Code era, as seen in the fascination with *The Conjuring Universe*—I recognized the potential to link the Salem Witch Trials to the world of cinema. Following in the footsteps of Mezirow, I sought to create a “transformative” learning experience for the students by providing them with an accessible framework, such as *The Exorcist*, so they could explore the multilayers of Salem, hysteria, belief, and fear.^{xxxiv}

I realized that students would not relate to Salem by simply watching a horror film like *The Conjuring*, but that they needed to tap into the phenomenon of *The Exorcist*. Whether or not they had seen the film was unimportant, as I knew they were familiar with demonic possession because of the popularity of *The Conjuring Universe*. By observing how individuals from the 1970s overreacted to *The Exorcist*, students would be able to understand the hysteria in Salem. Unlike colonial America, students would most likely have relatives or friends who remember the release of

The Exorcist, providing them an accessible connection to an event rooted in fear and belief.

I completely recreated the Salem Witch Trials into a radio program rather than a formal academic paper. Aligning my approach with Peter Felten’s “Principles of Good Practice in the Scholarship of Teaching and Learning,” I decided to incorporate podcasts into my curriculum. Many students consume and create content on social media platforms such as Instagram and YouTube.^{xxxv} Also, many aspire to become “influencers” and are drawn to expressing themselves openly in environments where they feel in control.^{xxxvi} In the classroom, students may hesitate to speak out of fear of peer judgment. As educators, we must remain connected to the next generation of students and the ways they engage with learning materials—especially in the age of social media. I asked myself how my students learn most effectively and how I came to this understanding. Online, they often feel freer to express their thoughts authentically.^{xxxvii}

As a result of this revised assignment, students began, for the first time, to see how the human mind can believe in witches, vampires, and even Sasquatch when emotion outweighs reason. In Salem, belief was shaped by the way townspeople were taught; in contemporary America, belief can be shaped by the power of visual persuasion. Once students realized this, they began to see why Salem was so significant because it reveals a timeless human vulnerability. From those willing to join new religious movements or follow a radical leader without protest, humanity reveals its cruelest truth: people can commit the most heinous acts when they are convinced they are acting in righteousness. Indeed, the students observed that just as some Americans in the 1970s, Reagan was truly possessed; they could now understand how individuals during the Salem Witch Trials could accept false accusations of demonic witchcraft based on spectral evidence.

The Salem townspeople were inundated with a fear so powerful it could cut like a blade through the human heart. The Salem Witch Trials show us why hysteria was able to penetrate through Salem and neighboring areas because they genuinely believed the devil could turn anyone into a witch. Such a figure embodied Salem’s worst nightmare, showing how even the most rational could succumb to fictitious belief in Satan’s power. Though, as a historian, I can still hear the cries of the innocent placed in the dark dungeons, my students’ comprehension of Salem’s story—on the other hand—was reduced to a bunch of figures and facts without a soul. This

epiphany helped me to refocus my Salem Witch Trials project into a more transformative experience. *The Exorcist* also proved that fear and faith can still provoke even the most secular. By pointing out to my students the parallels between the events that led to Salem and the hysteria caused by *The Exorcist*, I was able to instill a modern framework for how belief, fear, and authority can alter a person's perspective on the world.

I finally realized that I had been missing *the forest for the trees*. I needed to create a path that would transform my students from passive observers to active learners. Through film and podcasts, my students began to understand that the witch trials were not simply superstitious tales, but part of a large narrative about Americans' inability to confront the unknown without suspicion of something darker. The intense reactions of moviegoers to *The Exorcist* helped my students grasp why the villagers of Salem so readily accepted the words of the preacher, leaders, and teenagers— they, too, were struggling to make sense of irrational behavior for which they could find no rational explanation.

After completing this new project, I went back to review whether this experiment was effective. Did students learn, and were they engaged? From a data perspective, all twenty-seven students completed the assignment. The minimum requirement was to complete a five-minute podcast. Students were asked to watch one lecture by Dr. Justin Sledge, a National Geographic documentary on the Salem Witch Trials, and a short documentary on *The Exorcist* phenomenon, entitled *The Cultural Impact of The Exorcist*.

The data were as follows: 1 out of 27 students (3.7%) fell below the requirement; 6 out of 27 (22.2%) met the requirement; and 20 out of 27 (74.1%) exceeded the five-minute minimum. In total, 96.3% of the class met or exceeded the requirement. This suggests that the method was successful and that the students were willing to go beyond expectations, likely because the assignment was relatable.

In addition, from a qualitative perspective, I observed a high level of creativity. Some students created original podcast show names, incorporated visuals, designed a game-show format, used sound effects and character voices, and, in some cases, integrated PowerPoint presentations to enhance their shows.

Student reflections further reinforced their engagement, particularly in how they connected both time periods. Many students saw the parallel between the Salem Witch Trials and *The Exorcist*. As one

student explained: “It is interesting to see how we can go back to the 1600s and see similarities of people reacting to the movie and people reacting to the witch trials.” He also observed that people “flocked” to see the Salem executions, in ways similar to audiences were drawn to *The Exorcist*.

Others emphasized how fear extends beyond the present moment. One student noted that she was struck by how *The Exorcist* “hysteria spilled out beyond the theater into everyday life... so to tie it all together from early colonial witch trials to the madness of Salem to a horror movie that people were falling the same pattern.” She further reflected that the “real horror story here is not witches or demons but the way fear itself can be contagious over and over again...the scariest monster might just be our history how we fear it.”

Across multiple responses, students identified similar emotional responses to both events. One student remarked that *The Exorcist* “mirrors the earlier patterns of hysteria seen in Salem and other colonies, with the girl in the movie being possessed also mirroring the ‘bewitched’ girls from Salem, the people reacted with similar emotions. Fear, hysteria, psychological distress.” Another student emphasized that Salem was not an “isolated event, it was part of a bigger story that shows how fear can shape communities, destroy lives, and still echo modern times...the real worry isn’t the witches, demons, or monsters it just how people react to itself.” Although this is only a sample, I was intrigued by how students had an easier time understanding, relating to, and empathizing with the horrors of Salem when I utilized popular culture.

By applying Mezirow’s idea of pushing students “out of the box” to help them become genuine learners, I have come to recognize that twenty-first-century students will only become better students if we try other means to connect them with the past. As educators, we must look beyond our traditional methods to create transformative experiences. By asking students to explore this topic through a new lens, I am inviting them to think critically and discover empathy. Salem’s story may have a beginning and end, but the lessons will never be buried like its human victims.

My pedagogical experiment has shown me the power of transformative learning. Indeed, the colloquial saying “the Devil Made Me Do it”—part of the title of *Conjuring 3*—appears to have more relevance in society today, tomorrow, and the future than one would have expected. The devil may live only in our imagination. However, whether real or not, he has the power to persuade even the unbeliever to believe in the

impossible—an unimaginable truth that even the Lord’s Prayer could not protect. From Salem to *The Exorcist*, the two worlds are more intertwined than different. For as William Faulkner says, the “past is never dead. It’s not even past.”

ⁱ Qtd in Benjamin Ray, “Introduction to the Salem Witch Trials Digital Archive: How and Why.” The Salem Witch Trials Digital Archives, University of Virginia, last modified 2002, <https://salem.lib.virginia.edu/intro.html>.

ⁱⁱ Susan Phelps, “Reading the Fire: 17th Century Witchcraft Books That Shaped a Hysteria,” *Salem Witch Museum* (blog), June 10, 2025, <https://salemwitchmuseum.com/2025/06/10/reading-the-fire-17th-century-witchcraft-books-that-shaped-a-hysteria/#:~:text=Translated%20as%20The%20Hammer%20of,Church%20and%20ocular%20courts%20alike>.

ⁱⁱⁱ Melanie Shoffner and Richard St. Peter, eds., *Introduction to Teacher Representations in Dramatic Text and Performance: Portraying the Teacher on Stage* (New York: Routledge, 2020), 3.

^{iv} Brian P. Levack, *The Witch Hunt in Early Modern Europe* (New York: Routledge, 2015), 21.

^v Bryan F. Le Beau, *The Story of the Salem Witch Trials* (New York: Taylor & Francis, 2016), ix.

^{vi} Georgene Lockwood, *The Complete Idiot’s Guide to Crafts With Kids* (New York: DK Publishing, 1988), 258.

^{vii} Jake Mezirow, *Transformative Dimensions of Adult Learning* (San Francisco: Jossey-Bass, 1991), 3-7, 75-86, 351-354.

^{viii} Mezirow, *Transformative Dimensions of Adult Learning*, 94-96; 168-170.

^{ix} Mezirow, *Transformative Dimensions of Adult Learning*, 14-15, 42.

^x Mezirow, *Transformative Dimensions of Adult Learning*, 14.

^{xi} Anthony D’Alessandro, “Conjuring’ Box-Office Franchise Passes \$2 Billion Worldwide,” *Deadline*, July 20, 2021, <https://deadline.com/2021/07/conjuring-box-office-franchise-2-billion-1234806930/>.

^{xii} Pew Research Center, *Modeling the Future of Religion in America* (Washington, D.C.: Pew Research Center, September 13, 2022), <https://www.pewresearch.org/religion/2022/09/13/modeling-the-future-of-religion-in-america/>.

^{xiii} Pew Research Center, “Christians, religiously Unaffiliated Differ on Whether Most Things in Society Can be Divided into Good and Evil,” December 21, 2021, <https://www.pewresearch.org/short-reads/2021/12/21/christians-religiously-unaffiliated-differ-on-whether-most-things-in-society-can-be-divided-into-good-evil/>.

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- xv Pew Research Center, *Views on the Afterlife among U.S. Adults*.
- xvi Pew Research Center, *Views on the Afterlife among U.S. Adults*.
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- xix Colleen McDannell, "Why the Movies? Why Religion," in *Catholics in the Movies*, ed. Colleen McDannell (New York: Oxford University Press, 2008), 8.
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- xxi Gregory Black, *The Catholic Crusade Against the Movies, 1940-1975* (Cambridge: Cambridge University Press, 1998), chap. one.
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- xxiv Doherty, *Hollywood's Censor: Joseph I. Breen and the Production Code Administration*, 56.
- xxv Andrew Quicke, "The Era of Censorship (1930-1967)," in *The Routledge Companion to Religion and Film*, ed. John Lyden (New York: Routledge, 2009), 42.
- xxvi Quicke, "The Era of Censorship (1930-1967)," 36.
- xxvii Quicke, "The Era of Censorship (1930-1967)," 35.
- xxviii McDannell, "Why the Movies? Why Religion," 14.
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- xxx Kruse, *One Nation Under God: How Corporate America Invented Christian America*, xiii.
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