Conference Proceedings

IConSES

International Conference on Social and Education Sciences

16 - 19 October 2025
Los Angeles, USA

www.istes.org/event/iconses

Proceedings of International Conference on Social and Education Sciences

Volume: 7

ISBN: 978-1-952092-83-1

Conference: International Conference on Social and Education Sciences (ICONSES)

Conference Dates: 16 - 19 October 2025

Conference Location: Los Angeles, USA

Publication Date: December 30, 2025

Editors

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www.iconses.net October 16-19, 2025 Los Angeles, CA, USA www.istes.org

A Qualitative Case Study of the Impact of Servant Leadership on Graduate Students' Perceptions of their Preparedness to Serve Society after Graduation

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Abstract: The problem addressed in this study was the unpreparedness of students leaving Christian higher education institutions in the United States to engage, serve, and contribute to the common good of society after graduation. Student unpreparedness for life after college is now considered a significant threat to higher education enterprise in the United States. Servant leadership is gaining recognition as a viable model for addressing challenges in higher education. The purpose of this qualitative descriptive single case study was to explore graduate students' perceptions of the impact of servant leadership behaviors of the administrators, staff, and faculty at a private Christian university in the Southeastern region of the United States on their preparedness to engage, serve, and contribute to the common good of society after graduation. Greenleaf's servant leadership theory was utilized as the guiding theoretical framework for this study. Thirteen participants who met the eligibility criteria were recruited for the study through purposive sampling. The thematic analysis of the study's one-on-one interviews and focus group data, using NVivo 14, identified two themes that addressed the research question that guided the study. The study findings showed that graduate students developed servant leadership by observing and learning from campus administrators, faculty, and staff who exhibited servant leadership behaviors and offered them opportunities to practice servant leadership. Also, the findings indicated that graduate students believed their experiences with servant leadership on campus have equipped, prepared, inspired, and motivated them to contribute meaningfully to society after graduation. This qualitative descriptive single case study has contributed to the existing body of knowledge on the appropriateness, applicability, and impact of servant leadership in higher education institutions by examining and providing new insights into graduate students' perceptions of servant leadership, which has been lacking in the literature. Future studies should include quantitative analyses to evaluate the impact of servant leadership from the perspective of graduate students across various colleges and universities nationwide.

Keywords: servant leadership, greenleaf's servant, leadership theory, graduate students, descriptive case study

Citation: Jegede, S. E. (2025). A qualitative case study of the impact of servant leadership on graduate students' perceptions of their preparedness to serve society after graduation. In V. Akerson, H. Polat, & A. Tekin (Eds.), *Proceedings of IConSES 2025—International Conference on Social and Education Sciences* (pp. 1–43). ISTES.

Introduction

The role and effectiveness of higher education institutions in preparing students for real-world engagement after college are under scrutiny in society today (Jensen, 2021; Mann, 2020). Student unpreparedness for life after college is now considered a significant threat to higher education enterprise in the United States (Mann, 2020; PR Newswire, 2023). A recent survey by the Mary Christie Institute and affiliates indicated that nearly 40% of young graduates felt unprepared for the workplace and society by their colleges (American Association of Colleges and Universities, 2023). Another recent survey revealed that 40% of business leaders believed that recent college graduates are unprepared to contribute meaningfully to the workplace and society (PR Newswire, 2023). Further, 94% of the 1,243 business leaders who participated in the survey admitted they would rather avoid hiring recent graduates due to their unpreparedness for the workplace (PR Newswire, 2023). Studies have reported a significant decline in volunteerism among college students and fresh graduates (Lenahan, 2024; Normah & Lukman, 2020).

Higher education institutions now face unprecedented pressure to address student unpreparedness to make meaningful contributions to the workplace and society after college (Mann, 2020). Jensen (2021) warned about impending disruption in the higher education sector and half of higher education institutions in the United States becoming bankrupt in the next 10-15 years. More than one in five higher institutions in the United States are faith-based (National Center for Education Statistics, 2021). Christian higher education institutions contribute distinctively to the landscape of higher education by integrating faith and learning to develop students holistically to engage, serve, and contribute to the common good of society (Mann, 2020; Wallace, 2021). An ongoing scholarly debate exists regarding the capability of Christian higher education institutions to deliver on their primary mission statement of integrating faith and learning to prepare and equip students to contribute to the common good of society and be world-changers after graduation (Fehr, 2024; Lawson & Schreiner, 2021; Mann, 2020).

Mann (2020) argued that Christian higher education institutions in the United States are positioned to positively transform and prepare students to engage and transform local and global communities. However, the results of a survey of 57 member institutions of the Council for Christian Colleges and Universities (CCCU) by Lawson and Schreiner (2021) indicated a lack of institutional infrastructure and support to prepare doctoral students for life after college. Scholars warned that the survival and thriving of Christian higher institutions in the current highly competitive landscape of higher education largely depends on the emergence of new leaders that will redesign traditional hierarchical structures, foster more equitable and inclusive leadership environments, and initiate more collaborative leadership models (Jensen, 2021; Mann, 2020; Wallace, 2021). Christian colleges and universities are now under more significant pressure to thrive in the current challenging and competitive higher education landscape in the United States by producing graduates who can serve and contribute meaningfully to society (Fehr, 2024; Jensen, 2021; Wallace, 2021).

The problem addressed in this study was the unpreparedness of students leaving Christian higher education institutions in the United States to engage, serve, and contribute to the common good of society after graduation (Mann, 2020; Wallace, 2021). The purpose of this qualitative descriptive single case study was to explore graduate students' perceptions of the impact of servant leadership at a private Christian university in the Southeastern region of the United States on their preparedness to engage, serve, and contribute to the common good of society after graduation. There is a growing acceptance of servant leadership as a promising model for solving many problems facing higher institutions, especially student unpreparedness for real-world engagement after college (Cong et al., 2024; Dami et al., 2024; Kainde & Mandagi, 2023). Various studies have been conducted in higher education settings to understand the impact of servant leadership from staff and faculty members' perspectives (Aboramadam et al., 2021; Melinda et al., 2020; Zainab et al., 2022) and undergraduate students' perspectives (Cong et al., 2024; Dami et al., 2024). However, studies have yet to examine the influence of servant leadership from graduate students' perspectives. This qualitative descriptive single case study addresses this gap in the literature by exploring and contributing insights into graduate students' perceptions of the impact of servant leadership on their preparedness to engage, serve, and contribute to the common good of society after graduation.

Literature Review

Since the Great Recession of 2007, the role and effectiveness of higher education institutions in preparing and equipping students for life after college have come under increased scrutiny in the United States (Dockery, 2019; Jensen, 2021; Mann, 2020). Researchers have warned about impending disruption in the higher education sector and half of higher education institutions in the United States becoming bankrupt in the next 10-15 years (Barton, 2019; Jensen, 2021). Christian higher education's values, impacts, challenges, and future in the United States are presently a significant debate among scholars (Barton, 2019; Collins & Clanton, 2018; Guthrie, 2018; Mann, 2020; Schreiner, 2018). This debate is justified because more than one in five higher institutions in the United States are faith-based institutions (Barton, 2019). Also, 5-10% of almost 20 million students in the United States receive their education at Christian higher institutions (Barton, 2019; Collins & Clanton, 2018). Christian higher education institutions contribute distinctively to the landscape of higher education by integrating faith and learning to develop students holistically to engage, serve, and contribute to the common good of society (Mann, 2020). This section highlights the values and economic, social, and community impacts of Christian higher education, the challenges facing Christian higher education, and the future of Christian higher education institutions in the United States.

The Values and Impacts of Christian Higher Education

An ongoing scholarly debate exists regarding the values and impacts of Christian higher education institutions in the United States (Mann, 2020; Lawson & Schreiner, 2021). Some researchers have strongly stated the values and impacts of Christian higher education (Collins & Clanton, 2018; Jagela, 2019; Koonce et al., 2018; Mann, 2020; Otto & Harrington, 2016; Roso, 2019; Savarirajan & Fong, 2019). Collins and Clanton (2018) argued that

Christian higher education institutions contribute significantly to meeting the increased demand for higher education in the United States by providing higher education for about 10% of over 20 million higher-education students. In a study, Jagela (2019) showed that servant leadership in Christian institutions inspired and motivated students to serve their campus community and the surrounding community off-campus. Also, a study by Koonce et al. (2018) indicated that students who attended Christian higher institutions experienced a notable change in their worldview and growth in their leadership skills.

Christian higher education prepares students for more than careers; unlike secular education, it promotes spiritual formation in students and thus prepares their whole beings (Collins & Clanton, 2018; Roso, 2019; Tulung et al., 2024). Mann (2020) argued that Christian higher institutions in the United States can positively transform and prepare students to engage and transform local and global communities. Savarirajan and Fong (2019) reported that integrating faith and learning positively impacted students' development and understanding of the Christian worldview of science. The findings also underscored the significant role of the faculty grounded in the Christian worldview in the effective integration of faith and learning in classes. In a study, Roso (2019) indicated that students in a Christian university perceived they were well-prepared to apply classroom theory to solve real-world problems and practice their Christian faith through service learning.

Though Schreiner (2018) affirmed that Christian higher institutions are developing and producing godly graduates, the researcher argued that the graduates are not actively engaging and transforming the world as claimed by Christian higher institutions. The results of a survey of 57 member institutions of the CCCU by Lawson and Schreiner (2021) supported Schreiner's argument, indicating a lack of institutional infrastructure and support to prepare doctoral students for life after college. Likewise, Guthrie (2018) cast doubt on the effectiveness of the existing Christian higher institution curriculum in adequately preparing students to be good ambassadors of Jesus Christ in their workplaces. However, the Council for Christian Universities and Colleges (2018) presented a compelling case for the value of Christian higher education in the United States in a report highlighting the collective significant economic, social, and community impacts of its 180 member institutions.

Economic Impact of Christian Higher Education

The Council for Christian Universities and Colleges (2018) reported that its 150 member institutions in the United States generate $60 billion annually for the national economy from its institutions' operations and capital investments and the earnings of its graduates. Collins and Clanton (2018) estimated that about 10% of almost 20 million students in the United States receive their education at Christian higher institutions. Christian higher education helps meet the increased demand for higher education in the United States and creates employment for many. The CCCU (2018) claimed that its institutions in the United States are responsible for creating and supporting 134,000 jobs, contributing about $10 billion annually to the federal tax revenue. In addition, CCCU reported that about 2 million students have graduated from its institutions and earn $22.5 billion more annually, generating an additional $7.5 billion in federal tax revenue. Also, CCCU claimed that its graduates are pursuing personal success in their careers and contributing to society in various ways (CCCU, 2018, 2021).

Social Impact of Christian Higher Education

Emphasizing the social impact of Christian higher education, CCCU (2018, 2021) reported that its member institutions prepared and produced godly graduates who bring their Christian worldview to their careers, seek to help others, and transform society. Also, some scholars have emphasized the significant social impacts of Christian higher education in the United States (Collins & Clanton, 2018; Jagela, 2019; Koonce et al., 2018; Mann, 2020; Savarirajan & Fong, 2019). Describing the contribution of Christian higher education to the common good of society, Collins and Clanton (2018) asserted that Christian higher institutions benefited society by producing and disseminating knowledge and preparing and equipping students to pursue the most basic human goods, such as inner peace and religion. The students, in turn, help shape and influence society positively. Unlike secular higher education, Christian higher education focuses not only on educating, preparing, and equipping students for vocations but on students' whole being and thus preparing students for the common good of society (Guthrie, 2018; Mann, 2020). The common good refers to a combination of factors that promote the growth and success of all individuals in the community (Guthrie, 2018).

Studies by Koonce et al. (2018) and Savarirajan and Fong (2019) have been used to bolster the arguments of other researchers in support of the significant contributions of Christian higher education to the common good of society. A study by Koonce et al. (2018) indicated that students who attended Christian higher institutions experienced a notable change in their worldview and growth in their leadership skills to impact society positively. Roso (2019) reported that students in a Christian university perceived they were well-prepared to apply classroom theory to solve real-world problems and practice their Christian faith through service learning. Schreiner (2018) agreed with other scholars that Christian higher education contributes to the common good and the kingdom good by developing students and producing graduates who adhere to Christian values and desire to serve within their churches. However, Schreiner (2018) showed in a study that Christian higher education does not develop and produce students and graduates who desire leadership roles outside their churches or seek to engage the world.

Community Impact of Christian Higher Education

Christian higher institutions integrate faith, learning, and living to prepare students and produce graduates who seek to engage and serve their communities (Mann, 2020). A study by Jagela (2019) indicated that servant leadership in Christian institutions inspired and motivated students to serve their campus community and the surrounding community off-campus. Collins and Clanton (2018) pointed out that Christian higher institutions significantly impact their communities through community outreach, such as students volunteering for community services and offering free medical and legal services. Leaders of Christian higher institutions seek to implement community engagement through various programs such as curricular and co-curricular programs (Mann, 2020). Christian higher institutions can use curricular programs to offer students credits and opportunities to connect their specific course learning objectives with community projects. They can also use co-curricular programs to offer students no credits but aid them in personal moral development and civic responsibility as they engage in voluntary community services (Mann, 2020).

The Council for Christian Universities and Colleges (2018, 2021) reported that many graduates from CCCU institutions play leading roles in many fields and substantially impact their communities. In addition, CCCU claimed that its member institutions offer students opportunities to develop through community service and engagement, resulting in 5.4 million hours of community service yearly. The CCCU (2021) reported that its member institutions invest in a wide range of community engagement, including community service and service learning and making their facilities accessible. They also provide educational, medical, and legal services within their communities, invest in schools and real estate projects, and provide employment opportunities for people in the community. Likewise, Collins and Clanton (2018) affirmed that the mere presence of Christian higher institution facilities, activities, public events, and diverse students contributes to community progress.

The Challenges Facing Christian Higher Education

Researchers have warned about impending disruption in the higher education sector and the possibility of half of higher education institutions in the United States becoming bankrupt in the next 10-15 years (Barton, 2019; Jensen, 2021). More than one in five higher institutions in the United States are faith-based (Barton, 2019). Christian colleges and universities are now under more significant pressure to thrive in the current challenging and competitive higher education landscape in the United States (Barton, 2019; Jensen, 2021; Mann, 2020). Christian higher educational institutions face many challenges threatening their survival and thriving in the highly competitive higher institutions landscape in the United States (Barton, 2019; Guthrie, 2018; Hulme et al., 2016; Schreiner, 2018). Researchers have identified significant challenges facing Christian higher education, including postmodernism, the rising cost of higher education, leadership turnover, and student unpreparedness for life after college (American Association of Colleges and Universities, 2023; Barton, 2019; Hulme et al., 2016; Otto & Harrington, 2016; Wicks, 2019).

Postmodernism

Researchers have argued that a postmodern mindset poses a challenge to the spiritual formation that distinguishes Christian higher education from secular education and gives Christian higher institutions an advantage over secular institutions because postmodernism rejects the Bible as the foundation of truth and the traditional Christian worldview rooted in absolute truth and morals (Daniels et al., 2019; Kretchmar, 2021; Tulung et al., 2024). Collins and Clanton (2018) stressed that the unique function of Christian higher institutions is to "educate students as though the Christian faith were true" (p. 8). Therefore, Christian higher institutions benefit society as a public witness against postmodernism, subjectivism, and relativism (Collins & Clanton, 2018; Tulung et al., 2024). Scholars have warned that if Christian higher institutions fail to respond appropriately to the challenge of postmodernism or the rise of secularization, it will dilute the uniqueness of Christian higher education and reduce its values and impacts (Daniels et al., 2019; Tulung et al., 2024). In addressing the challenges of postmodernism, scholars recommended adopting a balanced approach (Tulung et al., 2024), embracing and staying true to a distinct Christian identity and mission (Daniels et al., 2019), and Christian teachers teaching more classes in secular institutions to engage and influence more students (Roldan Hernandez, 2023).

The Rising Cost of Higher Education

Another significant challenge facing Christian higher education institutions is providing quality education to low-income students despite the rising cost of higher education in the United States (Daniels et al., 2019). Daniels et al. (2019) argued that funding is the most significant challenge facing Christian colleges and universities. They stressed that even tiny drops in enrollment could have substantial financial implications for faith-based institutions. Researchers warned that the increasing pressures of offering quality higher education at an affordable cost to poor or low-income students can shift the focus of a Christian higher institution from its distinctive mission and purpose to mere survival and from its emphasis on the common good to individual good (Collins & Clanton, 2018; Daniels et al., 2019). Therefore, scholars have cautioned against reactive responses to the challenges posed by the rising cost of higher education, such as reducing faculty, increasing tuition, or increasing courses and programs to compete with secular institutions because they may cost Christian higher education its distinctiveness. Instead, they suggested strategically accepting and addressing the challenge and striving to reimagine Christian higher education (Collins & Clanton, 2018; Daniels et al., 2019; Hulme et al., 2016).

Leadership Turnover

Barton (2019) warned of an impending leadership crisis in higher education, citing a projected exodus of senior-level faculty and less attention to adequate succession planning. Consequently, Christian higher institutions have come under pressure to deliver on their mission's promise to produce godly, influential, and transformational leaders (Schreiner, 2018). Barton (2019) recommended that Christian higher institutional leaders deliberately develop a conducive organizational culture to develop and produce new innovative and transformational leaders. The CCCU (2021) posited that Christian colleges and universities are the laboratories for producing the next generation of godly leaders. Therefore, they must prioritize preparing and developing future leaders to reimagine Christian higher education in today's challenging and competitive landscape.

Student Unpreparedness for Life After College

Student unpreparedness for life after college is now considered a significant threat to higher education enterprise in the United States (Wicks, 2019). A recent survey by the Mary Christie Institute and affiliates indicated that nearly 40% of young graduates felt unprepared for the workplace by their colleges (American Association of Colleges and Universities, 2023). Another recent survey revealed that 40% of business leaders believed that recent college graduates are unprepared to contribute meaningfully to the workplace and society (PR Newswire, 2023). Conflicting reports exist in the literature regarding the capability of Christian higher education institutions to adequately prepare students for a life of service after college. Roso (2019) reported that students in a Christian university perceived they were well-prepared to apply classroom theory to solve real-world problems and practice their Christian faith through service learning. Other studies also indicated that students who attended Christian higher institutions experienced a notable change in their worldview and growth in their leadership skills to impact society positively (Koonce et al., 2018; Savarirajan & Fong, 2019). In support, Mann (2020) stated that Christian

higher institutions in the United States can positively transform and prepare students to engage and transform local and global communities. However, the results of a study conducted by Poppinga et al. (2019) suggested that students leaving many Christian higher institutions in the United States are underprepared to constructively engage and serve a post-Christianity society because the demographic compositions of students and staff do not reflect the growing religious diversity of society in the twenty-first century. Likewise, the results of a recent survey of 57 member institutions of the Council for Christian Colleges and Universities by Lawson and Schreiner (2021) indicated a lack of institutional infrastructure and support to prepare doctoral students for life after college. Other studies also cast doubt on the effectiveness of the existing Christian higher institutions curriculum in adequately preparing students to be good ambassadors of Jesus Christ in their workplaces (Guthrie, 2018; Schreiner, 2018). There is a growing acceptance of servant leadership as a promising model for addressing many problems facing higher institutions, especially student unpreparedness for real-world engagement after college (Alshammari et al., 2019; Wicks, 2019).

The Future of Christian Higher Education

Many concerned researchers about the future of Christian higher education have offered some recommendations for its survival and thriving in the highly competitive higher institutions landscape in the United States (Barton, 2019; Collins & Clanton, 2018; Daniels et al., 2019; Gregorutti et al., 2017; Hulme et al., 2018; Jagela, 2019; Roldan Hernandez, 2023). The recommendations include embracing a distinct identity in a postmodern world, effectively integrating faith and learning, and prioritizing producing a new generation of innovative leaders.

Embracing a Distinct Identity in a Postmodern World

Christian higher education institutions are under increasing pressure to change or redefine their unique religious identity and mission to comport with social changes in the postmodern world (Daniels et al., 2019). Christian higher institutions share three fundamental commitments: integrating biblical truth, fostering Christian virtues, and advancing God's kingdom in the world (CCCU, 2018, 2021). Though all higher education institutions produce and disseminate knowledge, engage in various forms of community outreach, and prepare students for careers, the uniqueness of Christian higher education institutions is integrating the Christian faith with learning to transform, develop, prepare, and equip students holistically for the common good of society (Collins & Clanton, 2018; Roso, 2019; Tulung et al., 2024). To survive and thrive in the highly competitive higher education landscape in a post-Christian world, scholars recommended that Christian higher institutions embrace, promote, and defend their unique identity and mission as Christ-centered institutions (Daniels et al., 2019; Tulung et al., 2024).

Additionally, Daniels et al. (2019) suggested that while staying true to their Christian identity and mission, Christian higher education institutions must integrate liberal arts throughout their curriculum to develop student's analytical, critical thinking, and communication skills and must also seek to reinforce the ideals of free speech and academic freedom on their campuses. Other scholars agreed with these recommendations, stressing the need for Christian higher education institutions to promote meaningful dialogues and critical and ethical engagements

among different campus perspectives to bridge gaps between different worldviews (Tulung et al., 2024). Also, Schreiner (2018) suggested that Christian higher institutions intentionally market and promote their distinctiveness and efforts to prepare students for individual good and society's common good.

Effective Integration of Faith and Learning

Christian higher education institutions contribute distinctively to the landscape of higher education by integrating faith and learning to transform and develop students holistically into godly, influential, and transformational leaders who will positively change the world (Mann, 2020; Roso, 2019; Savarirajan & Fong, 2019; Schreiner, 2018). Savarirajan and Fong (2019) indicated that integrating faith and learning positively impacted students' development and understanding of the Christian worldview of science. The findings also underscored the significant role of the faculty grounded in the Christian worldview in the effective integration of faith and learning in classes. Likewise, in a study by Roso (2019), all the students perceived they were equipped and prepared to apply classroom theory to solve real-world problems and practice their Christian faith through service learning (S.L.). Moreover, the results showed the relevance and significance of implementing S.L. in Christian institutions as an effective method for integrating faith and learning and helping students realize the connection between classroom theory and Christian faith. Scholars recommended that Christian higher education institutions should be more creative in integrating faith and learning to thrive in the highly competitive higher education landscape in the United States (Daniels et al., 2019; Tulung et al., 2024).

Prioritizing Producing a New Generation of Innovative Leaders

Barton (2019) warned of an impending leadership crisis in higher education, citing a projected exodus of senior-level faculty and less attention to adequate succession planning. Therefore, Christian higher education institutional leaders must prioritize developing a conducive organizational culture to develop and produce new innovative and transformational leaders (Barton, 2019). The CCCU (2021) posited that Christian colleges and universities are the laboratories for producing the next generation of godly leaders. The survival and thriving of Christian higher institutions in the current highly competitive landscape of higher education largely depends on the emergence of new leaders that will redesign traditional hierarchical structures, foster more equitable and inclusive leadership environments, and initiate more collaborative leadership models (Barton, 2019).

Many researchers have proposed servant leadership as the most promising model for addressing the various challenges facing higher education institutions and preparing students for life after college (Alshammari et al., 2019; Jagela, 2019; Rega & Honen-Delmar, 2022; Wicks, 2019). Researchers argued that today's higher education leaders must become servant leaders to address the problem of student unpreparedness for life after college (Wicks, 2019) and to position higher education institutions to compete in the global market (Alshammari et al., 2019). The literature is replete with various studies conducted in higher education settings to understand the impact of servant leadership on staff and faculty members, such as the effect of servant leadership on faculty job satisfaction (Hashim et al., 2020), work engagement (Zainab et al., 2022), work engagement and affective

commitment (Aboramadam et al., 2021), innovation (Maalouf, 2023), job satisfaction and trust (Zummy et al., 2022).

Limited studies have also been conducted to examine the influence of servant leadership on students in higher education institutions, such as undergraduate students' perceptions of the servant leadership behavior of their professors at a private university (Alshammari et al., 2019) and undergraduate students' perceptions of servant leadership behaviors exhibited by faculty, staff, and students within two Christian denominational campuses (Jagela, 2019). Yue et al. (2024) explored the impact of undergraduates' servant leadership on their self-perception of their employability. Bao-Jian and Hsuan-Po (2024) investigated the influence of undergraduates' perceived servant leadership on their innovative self-efficacy.

Studies have also examined the connection between servant leadership and undergraduate students' cognitive learning and a sense of empowerment (Du et al., 2024). However, research exploring graduate students' perceptions of the impact of servant leadership within Christian higher education settings on student preparedness to serve society after graduation still needs to be included in the literature (Du et al., 2024; Yue et al., 2024). This qualitative descriptive single case study addresses this gap in the literature by exploring graduate students' perceptions of the impact of servant leadership at a private Christian university in the Southeastern region of the United States on student preparedness to engage, serve, and contribute to the common good of society after graduation.

Research Questions

This study explored graduate students' perceptions of the impact of servant leadership at a private Christian university in the Southeastern region of the United States on their preparedness to engage, serve, and contribute to the common good of society after graduation. The following questions were used to guide this exploration:

RQ1: How do graduate students at a private Christian university in the Southeastern region of the United States perceive their preparedness to engage, serve, and contribute to the common good of society after graduation?

RQ2: Which servant leadership behaviors exhibited by administrators, staff, and faculty at a private Christian university in the Southeastern region of the United States do graduate students believe most impact their perception of their preparedness to engage, serve, and contribute to the common good of society after graduation?

Methodology

Researchers have used quantitative and qualitative methodologies to explore the influence of servant leadership in higher education settings. The literature is replete with multiple quantitative studies examining the impact of servant leadership in higher education settings from the perspectives of administrators, staff, and faculty members

(Aboramadam et al., 2021; Hashim et al., 2020; Maalouf, 2023; Melinda et al., 2020; Zainab et al., 2022; Zummy et al., 2022). A few researchers have also conducted qualitative studies to examine the influence of servant leadership in higher education from the perspectives of undergraduate students (Cong et al., 2024; Dami et al., 2024) and graduates (Rega & Honen-Delmar, 2022). This study explored graduate students' perceptions of the impact of servant leadership on their preparedness to engage, serve, and contribute to the common good of society after graduation at a private Christian university in the Southeastern region of the United States.

The qualitative methodology was deemed more appropriate for investigating the central phenomenon of this study and addressing the research questions. The purpose of this study aligns with the selection of a qualitative methodology, as it necessitates interviewing graduate students to understand their perceptions of the impact of servant leadership. The qualitative methodology facilitates direct and close interaction between the researcher and participants. This approach enables an in-depth understanding of the phenomenon under investigation, allowing for a comprehensive analysis and interpretation of the research findings (Merriam et al., 2023). Qualitative methodology emphasizes a detailed examination of a specific concept or phenomenon, incorporates flexibility and adaptability, and relies on inductive reasoning. Also, qualitative methodology involves studying the context within which participants exist and encourages collaboration with those participants (Bloomberg & Volpe, 2023).

A qualitative methodology for this study was suitable, as it would provide detailed descriptions of the participants' experiences, thoughts, emotions, and perceptions (Privitera & Ahlgrim-Delzell, 2019). Stake (1995) stipulated using qualitative methodology when a detailed understanding of a phenomenon is only possible by allowing the participants to voice their opinions. Bloomberg and Volpe (2023) echoed this assertion, stating that qualitative methodology is more appropriate than quantitative methodology for promoting a deep understanding of a phenomenon from the research participants' perspectives. Bloomberg and Volpe (2023) argued that qualitative research gives voice to the research participants. The qualitative methodology allows researchers to study phenomena of interest in their natural or real-world settings to understand them from the participants' perspectives (Merriam et al., 2023). The study phenomenon can only be explored and understood from the research participants' perspectives. Therefore, selecting a qualitative methodology was appropriate for this study. The study's research questions included how and what. Bloomberg and Volpe (2023) and Yin (2018) stated that the qualitative methodology best addresses open-ended questions of how and what.

The study's problem, purpose, and research questions justify using a descriptive single case study as the research design. Yin (2018) stipulated that a case study should be used to explore and understand a contemporary phenomenon in depth within its real-world context, especially when the boundaries between the phenomenon and context may not be evident. Employing a case study will enable a comprehensive understanding of the central phenomenon within its real-world context. A case study is designed to delimit the object (the case), which makes it most appropriate for the study. A case study is an in-depth description and analysis of a bounded system (Merriam et al., 2023). The possibility of excluding all other students and limiting the participants to graduate students at a private Christian university in the Southeastern region of the United States makes the study phenomenon intrinsically bounded.

Population and Sample

The population for this qualitative descriptive single case study consisted of male and female graduate students attending a private Christian university in the Southeastern region of the United States. The study population is not vulnerable or protected, making it feasible to meet the Institutional Review Board (IRB) considerations (Booker-Zorigan & Lloyd, 2021). After obtaining the NU IRB approval letter and site permission from the institution, using the NU IRB approved recruitment letter and flyer, a small purposive sample consisting of 13 participants were recruited who met the study's eligibility criteria—were at least 18 years or older and graduate students at a private Christian university in the Southeastern region of the United States. The participants included nine female and four male participants. The ages of the participants ranged from 23 to 34 years. The participants self-identified as Caucasian, Hispanic, and Black. All participants reported being Christians. Table 1 presents the demographic summary of the participants.

Table 1. Demographics of Participants

Participants	Age	Gender	Race
P1	26	Female	Caucasian
P2	26	Female	Hispanic
P3	27	Male	Black
P4	24	Female	Hispanic
P5	23	Female	Hispanic
P6	23	Female	Black
P7	34	Male	Black
P8	23	Male	Hispanic
P9	26	Female	Black
P10	24	Male	Hispanic
P11	23	Female	Caucasian
P12	24	Female	Caucasian
P13	25	Female	Caucasian

Yin (2018) suggested a sample size of 12-15 to attain data saturation. The small size of the purposive sample made it feasible to complete the study successfully within the timeframe. Purposive sampling is the most time-effective and cost-effective method of selecting sample participants for qualitative case studies (Privitera & Ahlgrim-Delzell, 2019). Purposive sampling is the non-probabilistic sampling technique used in qualitative research that involves intentionally selecting participants with specific required characteristics, knowledge, or experiences (Bloomberg & Volpe, 2023; Privitera & Ahlgrim-Delzell, 2019). Using the purposive sampling technique ensured the selection of sample participants who met the pre-selected criteria to provide rich data relevant to the research problem and purpose (Bloomberg & Volpe, 2023; Privitera & Ahlgrim-Delzell, 2019).

Instrumentation

Qualitative researchers may employ multiple data collection techniques, including interviews, focus groups, observation, document review, and critical incident reports, to gather qualitative data (Bloomberg & Volpe, 2023; Merriam et al., 2023). In this study, I employed two sources of data, one-on-one semi-structured interviews and focus groups, to gain an in-depth understanding of the study phenomenon, achieve data triangulation, and enhance the study's credibility. The study's primary data collection method was a one-on-one semi-structured interview. Semi-structured interviews are a primary source of rich data for qualitative case studies (Bloomberg & Volpe, 2023).

Using semi-structured open-ended interview questions for the qualitative case study allows for the balance between interview questions and interview dynamics (Bloomberg & Volpe, 2023; Merriam et al., 2023). Semi-structured interview protocols enable researchers to pursue a consistent line of inquiry related to the study and some spontaneity to follow new directions emerging during the natural exchange of views (Bloomberg & Volpe, 2023). The interview questions were submitted to a panel of experts for review via email. The interview questions were revised according to the feedback from the panel of experts. The validated interview protocol (see Appendix G) was subsequently used for data collection from the research participants.

Despite the inherent strengths and advantages of interviews, researchers have identified some weaknesses or limitations of interviews as a qualitative data-collection technique, including response bias due to the researcher's presence, inaccuracies due to participants' poor recall, perception, or articulation, and asymmetrical power relations between researchers and participants (Bloomberg & Volpe, 2023; Merriam et al., 2023). Therefore, the interview data collected was corroborated with data from focus groups to achieve data triangulation and enhance the study's credibility because they produce different types of data from one-on-one interviews by fostering interactivity and dialogue among research participants and encouraging a variety of viewpoints on the study phenomenon (Bloomberg & Volpe, 2023). A focus group consisting of seven participants, who had been previously interviewed individually and were available, was interviewed in a group setting using the focus group protocol. A panel of experts reviewed and approved the focus group protocol. The focus group questions differed from those used in the one-on-one interviews to generate new rich, broad, and deep data.

Study Procedures

After obtaining NU IRB approval (see Appendix A) and permission from the research site (see Appendix B), the study participants were recruited by pasting the NU IRB-approved recruitment letter and flyer on bulletin boards and distributing them on the campus. Participants who met the eligibility criteria—are at least 18 years or older and graduate students at a private Christian university in the Southeastern region of the United States—were recruited for the study. A small purposive sample of 13 participants who met the eligibility criteria were emailed the information letter and consent form (see Appendix J) approved by the NU IRB. After obtaining consent, individual interviews and focus groups were scheduled by mutual agreement. The 13 participants were interviewed individually over Zoom using the NU IRB-approved interview protocol for the study. The one-on-one interview sessions lasted approximately 50 minutes on average.

Out of the 13 participants who participated in the one-on-one interview, only seven were available for the focus group session. The seven participants were interviewed over Zoom for 67 minutes using the NU IRB-approved focus group protocol (see Appendix H) for the study. The transcribed interviews were sent to each participant to review, correct, and confirm their accuracy. They reviewed and confirmed the accuracy of the information. Two participants pointed out some spelling mistakes, which were immediately corrected. The verified interview and focus group data were imported into NVivo 14 for comprehensive thematic analysis. The thematic data analytic approach allows researchers to generate codes inductively for thick and detailed descriptions required for case studies (Merriam et al., 2023).

Data Analysis

Data analysis in qualitative research is a complex, non-linear, iterative, and recursive process of bringing order, structure, and meaning to the masses of data collected from multiple sources (Bloomberg & Volpe, 2023). Researchers use data analysis to answer research questions (Merriam et al., 2023). Although numerous methods exist for qualitative data analysis, in this study, I employed thematic analysis utilizing NVivo 14. Thematic analysis was selected for this qualitative case study because it enables the inductive generation of codes for comprehensive and detailed descriptions necessary for case studies (Merriam et al., 2023). Also, thematic analysis allows for examining multiple perspectives of the research participants and highlighting similarities and differences in their perspectives, which are necessary for an in-depth exploration and understanding of a case (Bloomberg & Volpe, 2023; Merriam et al., 2023). Thematic analysis fully embraces the values of qualitative research and the researcher's subjectivity (Bloomberg & Volpe, 2023).

Thematic analysis focuses on uncovering recurring patterns or themes within the masses of raw narrative data collected in the fields by researchers, identifying any relationship among these patterns or themes, and developing a thick description of them (Bloomberg & Volpe, 2023; Merriam et al., 2023). In thematic analysis, researchers may use an inductive approach with themes emerging from the data or predetermined themes based on existing theory or literature in a deductive approach. Data collection and preliminary analysis proceed simultaneously in

thematic data analysis. Data analysis begins immediately after the first raw data is collected and progresses more intensively until the end of the research process (Bloomberg & Volpe, 2023). Therefore, as soon as the first raw data from the one-on-one semi-structured interview were collected, I started to analyze the data following the six steps of thematic analysis (Bloomberg & Volpe, 2023; Merriam et al., 2023).

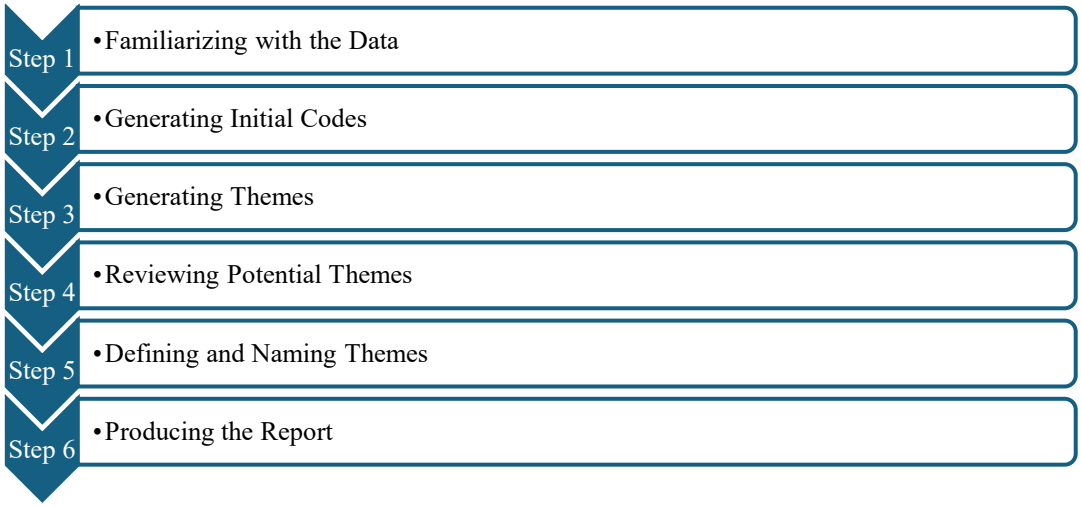

Figure 1.The Six Steps of Thematic Analysis

Figure 1 shows the six steps of thematic analysis used to analyze interview and focus group data with NVivo 14: Familiarizing with the data, generating initial codes, generating themes, reviewing themes, defining and naming themes, and producing the report.

Step 1: Familiarizing with the Data

According to Bloomberg and Volpe (2023), data must be well organized before it can be analyzed thoroughly. Therefore, the first step in the thematic data analysis process is properly organizing and preparing the voluminous raw qualitative data collected from multiple sources. This step involves transcribing interviews, converting the handwritten observation field notes to text files, winnowing, sorting, and arranging the data into different types depending on the data sources, and labeling them accordingly (Bloomberg and Volpe, 2023). After verifying that all information was complete, readable, well-labeled, and securely stored to maintain the confidentiality of research participants, I set about familiarizing myself with the data. The interview and focus group transcripts were retrieved and printed from Zoom for detailed reading and initial manual coding. Each transcript was read thoroughly and multiple times to understand the data and develop insights gained during the data collection. The data were uploaded into NVivo 14 for comprehensive thematic analysis.

Step 2: Generating Initial Codes

After thoroughly reviewing the data multiple times to understand and identify the big ideas, I coded the data and organized the coded segments into categories using NVivo 14. Codes are shorthand (names or identifiers) that

researchers attach to a data segment they deem relevant to the study. Coding is essential to understanding, managing, sorting, and structuring a mass of raw data (Bloomberg & Volpe, 2023). Creswell and Poth (2018) describe coding as winnowing the data collected. According to Saldaña (2021), coding is a cyclical act. The first cycle of coding is rarely perfect. Therefore, researchers must revise codes and add new codes as they emerge.

Coding involves identifying words, phrases, sentences, or paragraphs of interest or significance in a mass of data, segmenting them into categories, and labeling those categories with a term, often based on the actual language of the research participants (Bloomberg & Volpe, 2023; Merriam et al., 2023). Researchers can create codes inductively by deriving codes from the data and deductively using a predetermined set of codes, categories, or themes (Bloomberg & Volpe, 2023). In this study, I utilized an inductive approach by deriving codes directly from the data using the exact words or phrases expressed by the participants. This method is referred to as open coding. The codes were subsequently classified into distinct categories. Categories must be responsive to the purpose of the research, exhaustive, mutually exclusive, sensitizing, and conceptually congruent (Merriam et al., 2023).

Step 3: Generating Themes

Following the coding of all data and the organization of codes into categories, themes were derived from these categorized coded extracts. This step involves developing themes that capture recurring coherent and meaningful patterns across all the data and defining the nature of each theme to the existing literature. Themes are a powerful way to see trends and patterns across the data. Emergent themes inform research findings and are directly tied to the research questions (Bloomberg & Volpe, 2023). Themes are significant findings in qualitative studies, and they must display multiple perspectives of the participants (Bloomberg & Volpe, 2023). Participants' quotations must be included to support the themes generated (Bloomberg & Volpe, 2023; Merriam et al., 2023).

Step 4: Reviewing Potential Themes

This step involved assessing the potential themes identified in relation to the coded data and the overall dataset. Themes that did not effectively serve as meaningful interpretations of the data or provide insights relevant to the research questions were subsequently revised. Each revised theme must be distinct and supported by sufficient data (Bloomberg & Volpe, 2023; Merriam et al., 2023). These themes will be used as headings in the findings section of this study.

Step 5: Defining and Naming Themes

This step involves determining which data items to select as extracts when presenting the analysis results. Defining themes involves thoroughly analyzing the underlying data items (Byrne, 2022). The chosen extracts must clearly and accurately present the arguments made by a specific theme (Byrne, 2022). The themes that emerged in this

study were identified and named through inductive data analysis and deductive application of the theoretical framework underpinning the research.

Step 6: Producing the Report

This final step involves presenting a detailed picture of how the analyzed data adequately addresses the research questions. Qualitative researchers report their findings narratively (Bloomberg & Volpe, 2023; Merriam et al., 2023). The study's findings will be presented to illustrate how each theme was meticulously derived from an in-depth analysis of the data, ensuring they address the research questions comprehensively. The themes will be used as headings in the findings sections of this study, showcasing various perspectives from participants and substantiated with their quotations.

Trustworthiness of the Data

Providing proof of trustworthiness within a study is critical to evaluating its worth, rigor, and credibility (Bloomberg & Volpe, 2023). Trustworthiness in qualitative research entails establishing the credibility, transferability, dependability, and confirmability of the study's findings (Yin, 2018). If a researcher fails to provide proof of trustworthiness, the study is perceived as lacking rigor and credibility, and the findings are worthless or unreliable. Therefore, in this section, I explain how I ensured the four trustworthiness criteria in qualitative research were met in the study.

Credibility

Credibility refers to whether the study's findings accurately represent research participants' perceptions, experiences, emotions, and actions (Bloomberg & Volpe, 2023). In this study, I used triangulation and member checking to establish the credibility of the study's findings. Triangulation is using multiple data sources, data collection or analysis methods, theoretical frameworks, or researchers to test and establish the credibility of the study's findings (Stahl & King, 2020). I employed two data sources in this study, one-on-one interviews and focus groups, to achieve data triangulation and enhance the study's credibility. I also used member checking to establish the credibility of the research findings. Member checking involves taking back the transcribed interviews, preliminary findings, or summaries of the researcher's interpretations to participants to review and check whether they accurately portray their perceptions, experiences, feelings, or actions (Bloomberg & Volpe, 2023; Merriam et al., 2023, Motulsky, 2021). I sent the transcribed interviews to each participant to review, correct, and confirm their accuracy. They reviewed and confirmed the accuracy of the information. Two participants pointed out some spelling mistakes, which were immediately corrected.

Transferability

Transferability in qualitative research measures the extent to which the study's findings are applicable within other contexts and settings. Researchers cannot guarantee the transferability of the study's findings (Bloomberg & Volpe, 2023); however, researchers can demonstrate the transferability of their findings by providing thick descriptions of the research context and process to enable other researchers to evaluate whether they can apply the study's findings to their contexts. Thick description refers to thoroughly describing the research context, participants, related experiences and interactions, data analysis, and findings so that readers can understand the research process and make contextualized meaning (Bloomberg & Volpe, 2023; Stahl & King, 2020). In this study, I provided thick descriptions of the research methodology and design, population and sample, instrumentation, study procedures, data analysis, and findings for readers to determine if the findings are applicable to different situations and settings.

Dependability

Dependability in qualitative research is a measure of the stability and consistency of the study's findings. In other words, dependability concerns whether the study's findings would be compatible with other researchers' findings if replicated with the same participants or in similar contexts (Bloomberg & Volpe, 2023). Researchers can establish the dependability of their studies through triangulation, audit trail, and peer review (Bloomberg & Volpe, 2023; Stahl & King, 2020). Triangulation was developed in this study by using two sources of data, one-on-one interviews and focus groups, to address and support the study's dependability. Additionally, I kept an audit trail throughout the study. An audit trail is a clear and comprehensive record of all the choices, decisions, and steps taken throughout the research and the rationale for them. Using NVivo 14 software for thematic analysis of the data helped to further establish the dependability of the findings by allowing detailed data organization, creating an audit trail of the entire data analysis process, and providing features to track and query themes, patterns, and relationships within the data. The dissertation committee also had access to all the research documents and data to ensure transparency and auditable documentation of the research process.

Confirmability

Confirmability in qualitative research refers to whether the study's findings are derived from the data (Bloomberg & Volpe, 2023). Confirmability is the degree of data neutrality of the study (Stahl & King, 2020). In other words, confirmability is the extent to which the study's findings and interpretations are shown to be the research outcome and not the researcher's biases, assumptions, prejudices, or subjectivities. Using an audit trail and triangulation, researchers can demonstrate the study's confirmability (Bloomberg & Volpe, 2023; Stahl & King, 2020). An audit trail refers to a transparent, detailed, and thorough description of how qualitative research was conducted. Throughout the study, I kept an audit trail including field notes, transcripts, records of raw data, and a reflexive journal to monitor and scrutinize my perspectives, biases, assumptions, values, interests, experiences, and expectations that might influence the research process and findings. I also employed data triangulation, using two data sources in the study, to establish the confirmability of the study's findings.

Assumptions

assumed that all participants in the study willingly provided honest answers to the interview questions and shared their perspectives on the study phenomenon. I assumed the research participants were sincere in their motives for participating. Further, I assumed that the small sample of participants selected through purposive sampling were valid representatives of the study population and would be able to provide rich narrative data to address the research problem and questions and achieve the research purpose— exploring the graduate students' perceptions of the impact of servant leadership at a private Christian university in the Southeastern region of the United States on their preparedness to serve society after graduation for the study.

Limitations

The nature of the research methodology and design and the purposive sample selected for this study impose some limitations on the study. In qualitative research, researchers do not employ instruments designed by other researchers to collect and analyze data. Instead, qualitative researchers are the primary instruments for collecting and analyzing data (Bloomberg & Volpe, 2023; Merriam et al., 2023). The researcher, being at the center of qualitative research, actively participating in the study, observing, interviewing, and engaging research participants may present some limitations to the study (Privitera & Ahlgrim-Delzell, 2019).

The researcher's personal biases, experience, and expertise in data collection and analysis may affect the quality of the research. The closeness between qualitative researchers and participants may cast doubt on the ability of the researchers to collect, analyze, and interpret data in an objective, unbiased manner (Bloomberg & Volpe, 2023; Merriam et al., 2023). I sought to mitigate the limitations that may be imposed on the study due to the researcher's personal biases by keeping a reflexive journal to monitor and clarify any biases brought to the study and how they may impact and influence all aspects and stages of the research process (Bloomberg & Volpe, 2023; Holmes, 2020). Further, I provided a transparent and detailed audit trail, used triangulation (multiple collection methods of data—interviews and focus groups), and member-checking to mitigate the limitations.

The researcher's ability to construct semi-structured interviews and focus group questions related to the study phenomenon that will elicit and generate rich narrative data to explore and understand the phenomenon may present some limitations to the study (Bloomberg & Volpe, 2023). Likewise, the researcher's skills in conducting face-to-face interviews, moderating in focus groups, thematic data analysis, and using NVivo may impose some limitations on the study (Bloomberg & Volpe, 2023). I sought to mitigate these limitations by sending the semi-structured interviews and focus group questions to a panel of experts to review and approve them. Additionally, I endeavored to enhance my competencies in conducting interviews, moderating focus groups, and utilizing NVivo through practical applications.

The limited generality of qualitative research is an unavoidable limitation of this study. Qualitative research aims not to produce findings that can be generalized to other people or settings (Bloomberg & Volpe, 2023). The

inherent weaknesses of interviews as a qualitative data-collection technique, including response bias due to the researcher's presence, inaccuracies due to participants' poor recall, perception, or articulation, and asymmetrical power relations between researchers and participants may also impose some limitations on this study (Bloomberg & Volpe, 2023). The small purposive research sample of 13 graduate students studying at a private Christian university in the Southeastern region of the United States poses an unavoidable potential limitation to the study. The study sample selected through purposive sampling may not represent the demographic diversity of the graduate student population at the university and across the country.

Delimitations

The delimitation of this qualitative case study was precluding other stakeholders of Christian higher education institutions in the United States, such as faculty instructors, administrative staff, college administrators, parents, and church leaders in the study. The literature is replete with various studies that examined the perceptions of multiple stakeholders on the influence of servant leadership in Christian higher education institutions (Aboramadam et al., 2021; Melinda et al., 2020; Zainab et al., 2022). Graduate student perceptions of the influence of servant leadership in Christian higher education settings are still underepresented in the literature. The purpose of this qualitative descriptive single case study was to explore graduate student perceptions of the impact of servant leadership at a private Christian university in the Southeastern region of the United States on their preparedness to engage, serve, and contribute to the common good of society after graduation. The purposive sampling method employed in this study was well-suited to achieving the study's purpose.

Ethical Assurances

When conducting qualitative research, Tolich and Tumilty (2020) asserted that researchers must develop ethics praxis—the ability to plan appropriately upfront and the agility to respond ethically in the field. Bloomberg and Volpe (2023) echoed this assertion, stressing that researchers must show ethical considerations when selecting a research topic and continuing throughout the research process. In this study, I adhered strictly to the fundamental ethical principles of conducting research involving human participants: respect for persons, beneficence, and justice, as stipulated in the Belmont Report (U.S. Department of Health and Human Services, 1979). All participants were well informed about the purpose, the research design, the expected duration, the right to decline or withdraw participation at any time, confidentiality limits, and potential participation risks and benefits.

I obtained approval from the Institutional Review Board (IRB) of National University before commencing data collection. All participants were provided with an informed consent form per the guidelines of the NU IRB. All participants were treated fairly, equitably, and equally respected as autonomous agents. No coercion or undue influence was exerted on any participants. There were no significant anticipated risks to the participants involved in this study. I followed NU IRB and CITI guidelines for data collection. I protected participants' confidentiality throughout the study using pseudonyms instead of real names. In addition, all the signed consent forms, data, and research documents will be securely stored in a password-protected computer to protect the confidentiality of the

participants beyond the study. Throughout the research process, I used reflexive practices to examine, monitor, question, and address the personal views, values, beliefs, expectations, biases, and assumptions brought to the study to mitigate their impact on the research design, conduct, and findings. Adopting a reflexive approach is essential for identifying, articulating, developing, and shaping the researcher's positionality (Holmes, 2020). Also, I employed triangulation, journaling, member checks, and peer review to reduce the impact of potential biases on the research findings.

Results

This qualitative descriptive single case study explored graduate students' perceptions of the impact of servant leadership on their preparedness to engage, serve, and contribute to the common good of society after graduation at a small, private Christian university in the Southeastern region of the United States. According to the information on the institution's website, it is a Christ-centered institution of higher learning committed to equipping the next generation of leaders to enter the world as influential servant leaders in their careers and communities. The institution offers more than 115 degree programs at the associate, bachelor's, master's, and doctoral levels to about 12,000 students. After collecting data from one-on-one interviews and focus groups, I reviewed the interview transcripts from Zoom, correcting punctuation and spelling errors. Subsequently, I sent the interview transcripts to the participants for review and confirmation of accuracy. All participants responded, confirming the transcripts' accuracy. The approved interview transcripts were uploaded into NVivo 14 to develop four themes using the six steps of thematic analysis explained in the methodology section to address the two research questions.

Theme 1: Cultivating Servant Leadership

Table 2 presents the development of theme 1: Cultivating Servant Leadership. This theme addresses the first research question regarding graduate students' perception of their preparedness to serve society after graduation. Through open coding, 46 significant codes were identified based on participants' keywords, phrases, or sentences. These codes were then grouped into two categories: Campus Leaders Demonstrate Servant Leadership and Students Learn and Practice Servant Leadership.

Table 2. Codes, Categories, and Theme 1: Cultivating Servant Leadership

Codes	Categories	Theme
Role Model, Active Listening, A Leader, A Servant Heart, Building and Recognizing Team, Empathy, Cultivate, Examples of Good Leaders, Giving Us the Example, Observing My Professors, Teaching Us, We talked a lot about Leadership, Showing Servant Leadership, Reminder, Servant Leaders, Servant Leadership, Positive Leaders, Professors, Connections, Good Leader, Greatest Leaders	Campus Leaders Demonstrate Servant Leadership	Cultivating Servant Leadership

Codes	Categories	Theme
Read Leadership Books, Learned a lot about Having Empathy, Learning to Become a Servant Leaders, Admire the Leadership, Good Exercise in Servant Leadership, Growing and Pushing Myself, Giving Back to the Community, Put into Practice, Opportunities to Grow, Opportunity to Help, Opportunity to Serve, Incorporate, Serving My Community, Serve Others, Grow, Integrate, Mission Trip, Volunteer, Trying to be a Servant Leader, See the Impact, Legacy, Huge Benefit, Development	Students Learn and Practice Servant Leadership	

All research participants contributed to the development of theme 14: Cultivating Servant Leadership. They reported efforts to cultivate servant leadership by observing and learning from campus administrators, faculty, and staff who demonstrate servant leadership behaviors and provide opportunities to practice servant leadership.

P1 conveyed their willingness to learn and apply servant leadership principles:

> I think it is on you to decide how you will serve if you're going to do it with a servant's heart, or if you're going just to do it for your own gain, you know. So, knowing that, I came into this role with the hope of learning how to become a servant leader in the back of my mind. And so, I look to these opportunities to grow and not just seek to work my way up some kind of leadership ladder. I've also been looking to these people to give me examples of what it means to be a good leader.

P2 articulated that their professor's attendance at their event, providing support, has inspired them to cultivate and practice servant leadership.

> My professor came to the event I organized on campus, and you know, he supported me. So, I feel like the servant leadership that my professor showed me, and my other professors have shown me through all these years, has made me want to be like that. and they listen to me, they try to understand me and be graceful, and that has made me want to aspire to be a good leader.

P3 mentioned that their professors had encouraged them to embrace and practice servant leadership:

> My professors have really inspired me to serve others. In all that I do, or even with my roommates, I try to practice servant leadership on a small scale.

P4 stated their intention to be a servant leader, inspired by observing servant leadership demonstrated by their mother and faculty:

> The biggest servant leader that I have as a role model will be my mom. Since I was a little kid, my mom owns a company. So, she's the highest in the position of a company, of course, so she was a person who lived by example, but not only by that, but she also took care of everyone like in other positions. Seeing that since I was a little kid and continuing to see that in my university, it's something that I'm also trying to aim to excel at in my life every day. I'm trying to be a servant leader every day because I think that's how we can meet people's needs. I think it's the best way.

P5 discussed how servant leadership by campus leaders inspired their community involvement:

> Our department has a social work Advocacy Club. We go out and give out food for the unhoused people

groups in the community dream center and pick up trash. And so, they have a whole club for that, and I try to go to, and then I also volunteer at my church which they have like a center, where they give out food to the unhoused people. We host events where people can get clothes. So yes, I am involved in giving back to the community.

P6 mentioned learning empathy by observing their professors demonstrating it:

I was inspired by my professor to become a leader and get more involved on campus. And I just admire the leadership and the way they go about things. I learned a lot about empathy for others, observing my professors truly putting yourself in someone's shoes, and going out of your way to figure out what they need and what I can do to help them.

P7 stated their commitment to contribute to society after graduation, inspired by their campus leaders:

After graduation, we have, as international students, one year to opt. So, I told myself that while doing the opt, I could channel whatever I've learned or have been taught in the university to help people in society by giving back, teaching people, influencing, and imparting my knowledge.

P8 shared that their professors taught them to seek God's guidance in their plans:

I have learned from my professors that if you surrender your life to God, you don't know what to do. And it's okay. But God will guide you step by step; even if you don't see the whole picture at the end of the day, you will see that God is guiding you through the things and places you are supposed to go.

P9 discussed how volunteering highlighted the needs of underprivileged children in the impoverished area of the community:

I volunteered at the Dream Center with children in impoverished areas of this community. I really enjoyed the volunteering I did with the Dream Center. We would go on Saturdays, play with the kids, and then teach them a Bible lesson. And then we would give them snacks, and I really enjoyed that because it opened my eyes to the need of these children to have someone to look up to because it was a very, very rough neighborhood that you shouldn't go in at all. And these children were living there. They were living in circumstances that I was privileged enough not to have to live in, and it was something that really opened my eyes.

P10 mentioned that campus leaders are helping students develop servant leadership:

They're actively teaching us or giving us examples of what it will look like, telling us the right thing, guiding us, and giving us wisdom and advice to be great leaders.

P11 reported significant growth and essential leadership skills development:

I think one of the biggest things I have developed is my soft skills and maybe my people skills, as well as being able to understand others, be empathetic, be humble, and implement different types of leadership, especially as an executive leadership major. I've learned so many different leadership theories, frameworks, and types of leadership. And so, I think I have grown a lot as a person, and being able to engage with others, both in a personal and professional setting, and just practice some of the things I learned here to have more meaningful relationships, to have a good career, and just to have a good life in general.

P12 expressed confidence in their ability to embody servant leadership in any future endeavors:

I don't know what my plans are. I know something about music, whether that's me being a singer or

songwriter or working in the music industry from the business side. But I've been able to see it done, you know, from all areas. You can still be a servant leader wherever you are and go. Yeah, that's good. That's a great plan.

P13 felt they should contribute more to the community:

I've volunteered with our Super Kids Ministry, which is our ministry for children with special needs. Honestly, I feel like I'm not pouring in as much as I think I actually need to. Outside of the church and my workplace, I don't know how much community service I actually do, which was a little convicting on my part.

Theme 2: Cultivating Servant Leadership

Table 3 presents the development of theme 2: Ready and Eager to Serve Society. This theme emerged from 30 codes identified through open coding of individual interviews and focus group data from the research participants. These codes were then consolidated into two categories: Students Feel Equipped and Prepared to Contribute to Society and Students Feel Inspired and Motivated to Serve Society.

Table 3. Codes, Categories, and Theme 2: Ready and Eager to Serve Society

Codes	Categories	Theme
A Completely Changed Person, Changed, Changing My Perception, Perception Shift, Impacted My Life, Choose to Serve, Confidence Level, Confident in My Skills, Gained More Confidence, I Do Feel I'm Prepared, I Feel Empowered, I Feel I have been Equipped, My Way of Thinking has Changed, Ready and Prepared, Prepared, People Skills, Practical Skills, Ready to Contribute to Society, Find Ways to Serve People, Graduate, Soft Skills, Practicing Skills, Preparedness	Students Feel Equipped and Prepared to Contribute to Society	Ready and Eager to Serve Society
Aspire to be a Good Leader, Influenced and Inspired Me, Inspired, Motivating, Motivating Factor, Encouraging, I Love Serving	Students Feel Inspired and Motivated to Serve Society	

All research participants contributed to developing theme 15: Ready and Eager to Serve Society. Participants expressed, with enthusiasm, that their experiences with servant leadership on campus have equipped, prepared, inspired, and motivated them to make meaningful contributions to society after graduation.

P1 expressed their readiness and motivation to continue the legacy of their campus leaders, who have exemplified servant leadership:

It's certainly obviously encouraging to know that there are servant leaders in higher positions, such as the ones I've mentioned. It's also motivating to want to be their student who carries on this legacy they have shown me. So, it's a motivating factor. And I think it has prepared me more for what I'll do after

graduation. I think seeing how they integrate all of these different facets of their work, their life, their spirituality, and their servant leadership in this atmosphere has given me more of a context or framework of how I can cultivate that when I graduate.

P2 articulated confidence in their preparedness and possession of the necessary leadership tools to serve as a servant leader following graduation:

> You know I am doing the executive leadership. So, I have had some leadership courses, and in addition to all that my professors have taught me, I have read and researched. And I'm like, oh, wow! That's true; leaders should do these things. Oh, wow, like, I do want to follow these. But for sure, that has given me the tools and prepared me to be the leader that I should be and the leader that God wants me to be. I have seen that through my professors and some of the staff, and yes, so I will say yes, it has prepared me to be that.

P3 conveyed their readiness and commitment to serving their community, demonstrating exemplary servant leadership:

> I feel I'm ready and prepared to go over and beyond in serving my community and in showing servant leadership. I'm doing this on a small scale in the house, going the extra mile, cleaning the house, and making sure the tables are all well set. When I go back to the village. I want to continue serving my community as a servant leader.

P4 expressed their love and enjoyment in serving their community:

> Coming to this university was a mind-changing experience because I learned about servant leadership. I love serving. Serving is part of who I am. It's something that just comes out of me. I don't know how else to explain it. I'm always available to help people, especially if I hold a leadership position.

P5 stated that the school had prepared her to contribute to the community:

> I definitely think they do prepare you through those serving opportunities, such as mission trips. They definitely promote it, even in chapel, like to get out of the bubbles because Jesus hangs out with sinners. And that's something that's pushed to give back to our community. So yes, I feel prepared with that firm foundation to serve my community.

P6 stated that they had gained more confidence as a leader and acquired practical leadership skills to use in their future career:

> I do feel like I'm prepared. But you always could learn along the way. But I'm prepared to serve my society. I've honestly gained more confidence as a leader, especially with those mandatory leadership classes at the beginning of my freshman year. We talked a lot about leadership. We read leadership books. We learned how to be a selfless leader. They were very intentional about us developing practical skills, like empathy, active listening, and teamwork, which I now integrate into my job or my internship in my master's program. As a social worker, I plan to use it in my future career. So, I feel like I have been equipped and have become more confident in my skills.

P7 described how the college transformed their thinking and approaches, preparing them to contribute meaningfully to the world:

> I'm ready to contribute to society, not even my society, but to the entire world. I'm ready to give back. I'm ready to help. I'm prepared to do whatever is within my means to go out there and do what the Lord

has told me to do. This school has had a lot of impact on me. So, it has shaped me. The way they interact and the way they treat people has really shaped me. My way of thinking has changed, and the way I even approach matters has also changed.

P8 attested to the esteemed reputation of the institution within the community, attributing this to the high caliber of students that the school produces:

When you go to any place in this community and you say, oh, I'm from this campus, most of the time, it is easy to connect with people in the community because they know the quality of students who have been doing internships there or helping in the community.

P9 articulated a clear intention and plan to contribute to the community following graduation:

I do want to do something to give back to the community. I'm looking into a women's house where they help women who are pregnant out of wedlock or teenagers. There is another place here that helps women who are homeless, and they do fitness with them, and I love doing fitness. I go to the gym, and that's something that I thought would be really cool to do with these women so they can still stay active. But that's something, of course, I will do after I'm done with my graduate studies.

P10 mentioned a perception shift in school that has made them a better person for society:

One of the things that I've noticed changing is my perception, change. I have learned about forgetting myself, you know, and thinking about others a little more, not taking decisions that are selfish but are for the good of others. I'm not thinking so much about what I'm going to gain. But what is everybody going to gain? I think that that perception shift was, you know, given to me here. I feel like ever since I came here, I've been a different person for the better.

P11 expressed confidence in their servant leadership abilities, drawing from skills gained and examples set by campus leaders:

I think I've seen great examples of servant leaders who have shown me how to be a servant leader and incorporate that in the future, no matter what job I do or what part of the community I engage with. I think I'm pretty confident I can use those skills I've learned from my experience here to serve.

P12 felt confident and prepared to serve society, with plans to continue developing their servant leadership qualities:

I feel confident. Yes, I'm being prepared to do them now, you know, starting to work those qualities now and then, after graduation, just continue to work that you know. It's like working out, you know, to be in great shape or to have strong muscles; you got to keep working at them every day. It's just not going to happen one time, or you sit here and do nothing. You just have to keep working at it, and then, once it becomes a great habit, it just comes naturally. So, I think, with some of those qualities, I've been working at them now and just have to be more diligent and keep working at them even after graduation.

P13 expressed that their confidence has increased as a result of observing the campus leaders exemplify servant leadership on campus:

Before I came to the college, I was not as confident as I am now. I definitely thought I had a long way to go to become a servant leader. And now that I'm a year in, I'm seeing how they've modeled things and just how they run the college. I'm like, oh, I actually feel empowered to be a servant leader, and I honestly think back to what I was saying. Just seeing them model it so well, I feel pretty confident about it now.

There's so much I still need to learn and need to grow. And we're all still learning and growing. But I would say, like 8 out of 10, I probably feel like an 8 with my confidence level.

Theme 3: Emotional Healing

Table 4 presents the development of theme 3: Emotional Healing. This theme was derived from 23 codes identified through open coding of research participants' responses to individual interviews and focus group questions about the servant leadership behaviors of campus leaders that most influenced their perception of their preparedness to serve society after graduation. The codes were organized into two categories: Supporting and Caring for Students and Demonstrating Empathy Towards Students.

Table 4. Codes, Categories, and Theme 3: Emotional Healing

Codes	Categories	Theme
Care about Me, Caring, Love, Listen, Intentional, Meet the Needs of the People, Willing to See You, Willing to Greet You, Willing to Make Time for You, Grace with her Time, Stewards her Time, Stewardship, Interested in Knowing Students, Remembering Details, Friendship Element	Supporting and Caring for Students	Emotional Healing
Empathetic, Empathy, Grace, Connection, Willingness to Help Students, Wanting Students to Graduate Well, Compassion, Kindness	Demonstrating Empathy Towards Students	

All research participants contributed to the development of this theme. The participants expressed that experiencing emotional healing through the support, care, and empathy demonstrated by their campus leaders is one of the most influential servant leadership behaviors on their perception of their readiness to serve society after graduation.

P1, a graduate assistant, shared that their boss, the Dean, showed care by remembering details from their past conversations, which had a significant impact on them:

I would say the greatest impact has been from my boss, the Dean. Well, quite a few individuals, but her specifically the way she stewards her time to meet the needs of all people. And she's very intentional and remembering details. I'm always shocked because she doesn't need to remember the details of my life. I'm always shocked when she comes in and asks about something I talked to her about a month ago, and it's very specific to whatever that situation was. So, her grace with time and her grace with her remembering details are both things that I think have always amazed me.

P2 articulated that the empathy shown by their professor during their participation in a tournament had the most significant impact on them:

When I'm in a tournament, I'll say, hey, Professor, I'm in a tournament. My professor always says it's

> okay. Just let me know if you need extra days after you come from the tournament to complete your homework because I know you'll be tired. Let's schedule the test you missed when you are available and feel comfortable to take the test.

P3 explained that their professors demonstrated understanding when they were contacted on weekends:

> So, it's a Sunday when I reach out to our professor today. Most of them will get back to you. First, you may get a message that I'm unable to talk now, and then they call you back almost immediately that, hey, I missed your call, or hey, I miss your email. What can I do for you? They always say that we understand that things happen. You have things coming up. You're an adult. Let me know if you need me to create a schedule that works for you.

P4 mentioned that the kindness from campus leaders greatly influenced their choice to be kind to others:

> I've seen the impact of servant leadership on my life. And I'm truly amazed at how a small act of kindness can make a great, very big deal in someone's life, and since experiencing that, it's something that I'm trying to be and do for others.

P5 described how observing their professors' leadership and service in the classroom influenced their decision to assist and serve other students:

> Their leadership has definitely impacted me 100 percent. How they just lead the classroom has definitely impacted my life in many ways, how I view the class and other people. And how I can step out of my way and serve others as well just as they serve. If they have given me a resource, I can share with other students just the way they teach and help in and out of the classroom.

P6 expressed how the thoughtful care from their professor after their grandfather's death had a significant impact on them:

> I'll say the way they show they care. For example, I had a grandfather who passed away, and I reached out to my professor, and I was like, hey, my grandfather passed away. I'm not going to be in the class, I'm traveling home to go to the funeral. And in about 5 minutes, I got an email from the SOS (Students Outreach Services) team, and they said, hey, we heard about your grandfather. I'm like. Dang! That was fast, like, how did you all hear about that? So, my professor reached out to them, obviously, and they reached out. So, I felt like that was intentional.

P7 mentioned that their professors' compassion, empathy, and willingness to assist significantly influenced them:

> It is the compassion, empathy, and willingness to help that has really had a huge impact on me. I've met people who have gone out of their way to do things for me, and I've seen this not only in one person but also in almost every leader I come across. They really want to help more and even extend to your family. They want to know more about your family.

P8 noted that their professors' efforts to understand people's contexts and backgrounds significantly impacted them.

> It is easy to access and connect with my professors. They are interested in understanding people's context and backgrounds. And I don't know, I think these are great qualities.

P9, a graduate assistant, described the significant impact of their boss, the Dean of the college, demonstrating empathy toward students facing difficulties:

> Yes, and I would use my boss again as an example. The way he has gone above and beyond for students

has influenced me to do as much as I can. The way he's more empathetic towards the students and gives students multiple chances. How do I explain it? For example, if a student is failing something, he's not just going to say, oh, the student is failing because they are not paying attention. He's going to find the source of why the student is failing, talk to the student, and see how he can help the student.

P10 noted that their professors' love, kindness, and care profoundly impacted them:

> It's that love, kindness, and care for others that they exemplify that have really stuck with me. I think everything else just stems from that heart.

P11 described how the empathy they received on campus during a rough time recently significantly impacted them:

> To get a little bit personal. I had a little bit of a rough patch, maybe a week or two ago, just in my personal life, and my peers and my boss noticed that. And because they're so empathetic, they just picked up the slack for me in some areas. They tried not to overwork me or give me too much at one time so that I wouldn't get even more overwhelmed with the things I was going through, and I could handle my personal life and then get back to normal without having to be almost pushed over the edge, you know. And I think that's a big thing shown all across the board.

P12 mentioned that they observed the willingness of their faculty to help and serve others:

> They genuinely want to help other people and meet them where they're at, and just genuinely want to serve them in any shape or form, whether that, you know, is from a practical standpoint or a spiritual standpoint.

P13 was significantly impacted by observing their team caring for someone's well-being:

> I've seen that within the team I've been on, it's caring first and foremost about the person, like their well-being and relationship with God, and everything else is secondary to that. I remember an example. One morning, one of our bass players woke up, completely sick and throwing up. It was the day that we had chapel. And it's like, I guess we're just not going to have a bass player. But it wasn't like, oh, my gosh! This is terrible, like the set's going to go bad. I've never experienced that before. Here, it was more like caring about the person.

Theme 4: Helping Students Grow and Succeed

Table 5 outlines the development of theme 4: Helping Students Grow and Succeed. This theme was derived from identifying 28 codes through open coding of all individual interviews and focus group data from the research participants. These codes were subsequently integrated into two categories: Modeling Servant Leadership to Students and Developing Servant Leadership in Students.

Table 5. Codes, Categories, and Theme 4: Helping Students Grow and Succeed

Codes	Categories	Theme
Role Model, They Do What They Preach, They Teach through Examples, Lead the Way, Sacrifice, Sacrificing, Servanthood,	Modeling Servant Leadership to Students	Helping Students Grow

Teamwork, My Boss, Old Provost, Accountability, Honest, Authentic, Authenticity, Respect, Humble, Humility, Spirit of Humility, Looking Beyond Oneself Mission Trips, Opportunities to Grow, Opportunities to Serve, Graceful, Communication, Influenced, Inspired, Teach and Help, Mentoring	Developing Servant Leadership in Students	and Succeed

All research participants contributed to developing theme 13: Helping Students Grow and Succeed. They described how campus administrators, faculty, and staff exemplified servant leadership to students and promoted the cultivation of servant leadership within the student body.

P1 detailed the opportunities they were provided to develop and practice servant leadership:

> Our college is constantly connecting with people from all over the world. We have people always coming and visiting us to establish networking and connections and whatnot. So, part of what I took on for myself was to serve those people as well as I could, so that has given me opportunities to meet people and to find ways to serve people, kind of practicing skills that will be used throughout the rest of my life. I'm thinking about the mission trips again. That would probably be another example. I was able to go on a mission trip this past spring, and choosing to do that was a good exercise in servant leadership regarding team building and recognizing team unity is dependent upon being servant-hearted toward one another. So yeah, that's another opportunity.

P2 mentioned encountering great leaders on campus who cared for students and served as role models:

> There are many greatest leaders that I have come across on campus who have made me say, okay, I want to be like that. I want to be graceful like that. I want to care for those who I'm leading. I want to give, you know, be able to give the best that I can for those who I'm leading.

P3 felt motivated after seeing a professor help keep the campus clean:

> I saw one of our professors just when we were walking downstairs, and he saw a piece of paper and a piece of another paper, and then he kept picking them and then making sure that they were in the right place in the trash. That is not what he's supposed to do because he has his job. I saw him going beyond the job description to ensure the whole community was cared for. So, that has really influenced and inspired me that it doesn't take anything from me, but it only makes me a role model as well as an asset to the community just going beyond and doing that little thing that doesn't count, and I mean, that nobody cares about.

P4 noted that the authenticity of their campus leaders had a significant impact on them:

> I think for me, the highlight will be that they do what they preach. So, it's very, very important to be authentic. As for who you are and whatever you're saying and proclaiming to be, you're also living to do that. I think that's very key, especially when we talk about religion.

P5 said their professors' emphasis on accountability motivated them:

> Accountability has been the most inspirational for me because it's the most practical, like, hey, did you

> get that homework done? Hey, did you call that doctor? Hey, were you able to get your car fixed? So, when I go out and serve my community, I tell a child, hey, did you do your homework? I'm making sure to keep them accountable but not condemning them for not doing it, and if they did, I'm definitely congratulating them.

P6 mentioned that their leaders regularly seek input from the staff, and this is significant for them:

> They also show respect, you know, and teamwork. That is a big thing I've seen amongst the leaders on this campus. No matter how big or small their position is, I've seen them get their staff's input.

P7 mentioned that their professors prepared them for the job market, which means a lot to them:

> They have taught me a lot. How to live with people here. They have also taught me how to build relationships here in America and make friends. They've also taught me how to be ready for the job market. So, once I'm done with school, then I will just go and start my work. So, the kind of training they give you here gives you that preparedness for the outside world. That is one thing that is huge for me.

P8, a student working on campus, described how their supervisor and faculty lead by example:

> Servant leaders don't only show the way. They lead the way. So, I remember one of my supervisors, who was working in the grounds department on campus, would come and teach me how to use the shovel and equipment, and he was not scared to get dirty. So, I think it's important to teach through example, and a lot of our faculty members do it through example.

P9, a graduate assistant, described how their boss helped improve their communication and service to rude and disrespectful students:

> I work a lot with the students, and the communication with the students has really helped me to understand that sometimes the students are freaking out because they don't understand what's going on, and they might come across very rudely. At first, I would get really upset and annoyed. Why would someone speak to me like that in such a rude manner? Through the guidance of my boss and my professor, I understood how to better respond to it and still be respectful, but also talk to the student or express to the student that they can't talk to you like that but still help them.

P10 stated that being a graduate assistant helped them discover themselves:

> As a graduate assistant, which is my first real job, I found it is in me to want to help my professors with anything to do, regardless of whether I'm feeling tired or not, you know. I want to do my job to the best of my ability.

P11 explained the influence of campus leaders demonstrating humility on them:

> I think they've all impacted me and inspired me to be better. But I think one of the most important qualities is humility, just because I've seen people throughout the organization who have titles and experience and have these things that could be typically a divider between two different people become a tool for them to serve you better. They're able to use what they have to serve others and help instead of maybe keeping that division and keeping that kind of line that you can't cross and that boundary.

P12 mentioned that they have observed humility from various role models on campus:

> I've had opportunities to learn from and be close to some of the best leaders, role models, and mentors on the campus. They lead from a spirit of humility, and I think that's something really admirable because they're not looking for you. How can this benefit me? Or looking to be the center of attention, but they're

genuinely humble and want to help others genuinely.

P13 attributed their campus's health to intentional student care by the leaders:

> I would just say overall, we have a very emotionally intelligent and healthy campus, but I think that just stems down from our leaders being so intentional about it.

Discussion

The problem addressed in this study was the unpreparedness of students leaving Christian higher education institutions in the United States to engage, serve, and contribute to the common good of society after graduation (American Association of Colleges and Universities, 2023; Lenahan, 2024; Mann, 2020; Normah & Lukman, 2020; Wallace, 2021). Student unpreparedness for life after college is now considered a significant threat to higher education enterprise in the United States (Fehr, 2024; Wallace, 2021). This qualitative descriptive single case study explored graduate students' perceptions of the impact of servant leadership on their preparedness to engage, serve, and contribute to the common good of society after graduation at a private Christian university in the Southeastern region of the United States.

For the study, I explored the perceptions of 13 graduate students attending a private Christian university in the Southeastern region of the United States regarding the servant leadership behaviors exhibited by their campus administrators, staff, and faculty and how these behaviors impacted their perceptions of their preparedness to serve society after graduation. I utilized Greenleaf's servant leadership theory, as developed by Liden et al. (2008, 2014). The servant leadership model developed by Liden and his team consists of three main components: antecedent conditions, servant leadership behaviors, and leadership outcomes (Liden et al., 2014; Northouse, 2016). The central focus of this model of servant leadership is the seven servant leadership behaviors: conceptualizing, emotional healing, putting followers first, helping followers grow and succeed, behaving ethically, empowering, and creating value for the community. These servant leadership behaviors are influenced by three antecedent factors: context and culture, the leader's attributes, and the follower's receptivity.

According to the servant leadership model, a leader exhibiting the seven servant leadership behaviors will result in these three possible outcomes: follower performance and growth, organizational performance, and societal impact (Liden et al., 2014; Northouse, 2016). Greenleaf also highlighted these servant leadership outcomes in his original work. In Greenleaf's conceptualization of servant leadership, when leaders put followers first, listen to them, attend to their personal concerns, nurture and support them, and help them grow and succeed, their organizations become healthier, ultimately impacting society positively (Greenleaf, 1970). Based on this postulation, I explored how servant leadership practices at a private Christian university in the Southeastern region of the United States impacted graduate students' perception of their preparedness to engage, serve, and contribute meaningfully to society after graduation. The study's sample comprised 13 participants who met the eligibility criteria. Triangulation was achieved using two data sources: one-on-one interviews and focus groups. Data from

individual interviews and focus groups were analyzed using NVivo 14 to develop codes, categories, and themes to address the research questions. In this section, the findings are discussed in relation to each research question.

Research Question 1

How do graduate students at a private Christian university in the Southeastern region of the United States perceive their preparedness to engage, serve, and contribute to the common good of society after graduation?

The interviews and focus group data analysis from research participants revealed two themes related to this research question: Cultivating Servant Leadership and Ready and Eager to Serve Society. The study findings indicated that students cultivate servant leadership by observing and learning from campus administrators, faculty, and staff who demonstrate servant leadership behaviors and provide opportunities to practice servant leadership. P1, a graduate student and assistant, states, "I came into this role with the hope of learning how to become a servant leader in the back of my mind. And so, I look to these opportunities to grow and not just seek to work my way up some kind of leadership ladder." P3 commented, "My professors have really inspired me to serve others. In all that I do, or even with my roommates, I try to practice servant leadership on a small scale." P6 mentioned, "I learned a lot about empathy for others, observing my professors truly putting yourself in someone's shoes, and going out of your way to figure out what they need and what I can do to help them." The finding supports Greenleaf's (1970) postulation that servant leaders will produce more servant leaders.

The findings also suggested that students perceived that their experiences with servant leadership on campus have equipped, prepared, inspired, and motivated them to make meaningful contributions to society after graduation. All participants expressed their readiness and eagerness to serve society after graduation. P3 stated, "I feel I'm ready and prepared to go over and beyond in serving my community." P5 expressed," I definitely feel prepared with that firm foundation to serve my community." P7 announced, "I'm ready to contribute to the society, not even my society, but the entire world. I'm ready to give back. I'm ready to help." These findings were anticipated, aligning with the outcomes predicted by Greenleaf's servant leadership theory, which served as the theoretical framework for this study. According to this study's servant leadership model, a leader demonstrating the seven servant-leader behaviors will result in these outcomes: follower performance and growth, organizational performance, and societal impact (Liden et al., 2014; Northouse, 2016). In Greenleaf's conceptualization of servant leadership, when leaders put followers first, listen to them, attend to their personal concerns, nurture and support them, and help them grow and succeed, their organizations become healthier, ultimately impacting society positively (Greenleaf, 1970).

Theoretical Implications

The study's results corroborate Greenleaf's servant leadership theory, as expanded by Liden et al. (2008, 2014). Liden et al. (2014) posited that leaders demonstrating the seven servant leadership behaviors integral to the servant leadership model can achieve three primary outcomes: follower performance and growth, organizational

performance, and societal impact. This study contributes to the literature on servant leadership outcomes in higher education by examining the effects of servant leadership behaviors exhibited by campus leaders at a private Christian university in the Southeastern United States. The outcomes of servant leadership in higher education institutions have been sparsely covered from graduate students' perspectives in the existing literature.

Practical Implications

According to the study's results, graduate students cultivated servant leadership skills through observing and learning from campus administrators, faculty, and staff who demonstrated servant leadership behaviors and provided the students with opportunities to practice servant leadership. The implication is that students at institutions where campus leaders exemplify servant leadership and opportunities are provided for students to practice servant leadership are more likely to develop servant leadership skills. Consequently, these students may become effective servant leaders in society after graduation. Based on the results, implementing servant leadership within higher education institutions is appropriate and effective in preparing and motivating students to participate, serve, and contribute meaningfully to society. All the participants conveyed their willingness and enthusiasm to contribute to society after graduation, attributing this aspiration to their experience with servant leadership. The implication is that students who experience servant leadership on campus are more likely to demonstrate a willingness and enthusiasm to engage, serve, and contribute meaningfully to society after graduation.

Research Question 2

Which servant leadership behaviors exhibited by administrators, staff, and faculty at a private Christian university in the Southeastern region of the United States do graduate students believe most impact their perception of their preparedness to engage, serve, and contribute to the common good of society after graduation?

Two themes emerged from the thematic analysis of the interviews and focus group data: Emotional Healing and Helping Students Grow and Succeed, addressing this research question. The research findings revealed that emotional healing and helping students grow and succeed are the most significant servant leadership behaviors influencing graduate students' perceptions of their readiness to serve society post-graduation. The literature review reveals a scarcity of studies on the impact of servant leadership in higher education from students' perspectives. Alshammari et al. (2019) found that undergraduate students at a private university rated their professors highly on *Agapao* loving behaviors (which include effective listening, valuing people, and equality), empowerment, and serving in servant leadership behaviors.

Theoretical Implications

The research participants identified and described emotional healing and helping students grow and succeed as the most influential servant leadership behaviors on their perceptions of their preparedness to serve society after

graduation. The findings significantly enhance the understanding of the impact of servant leadership behaviors within the servant leadership model used as this study's theoretical framework. The existing literature lacks sufficient coverage of graduate students' views on the effects of servant leadership behaviors. This study fills this gap by offering insights into graduate students' perceptions of the effects of servant leadership behaviors, particularly emotional healing, and helping students grow and succeed.

Practical Implications

According to the study, graduate students perceived emotional healing and helping students grow and succeed as the most influential servant leadership behaviors on their perceptions of their preparedness to serve society after graduation. The implication is that graduate students who receive emotional support from campus leaders are more likely to feel prepared to serve society after graduation. Also, when students receive support for their spiritual development and professional growth, they are more likely to feel ready, confident, and motivated to contribute meaningfully to society. When followers receive caring, nurturing, empowerment, and support from servant leaders, they, in turn, will possibly become servant leaders and begin treating others in this way (Greenleaf, 1970).

Recommendations for Practice

Researchers have examined the effects of servant leadership in higher education from the perspectives of staff and faculty (Aboramadam et al., 2021; Dami et al., 2024; Hashim et al., 2020; Maalouf, 2023) and undergraduate students (Alshammari et al., 2019; Bao-Jian & Hsuan-Po, 2024; Du et al., 2024; Jagela, 2019; Yue et al., 2024). Nevertheless, the perspectives of graduate students regarding the applicability and impact of servant leadership in higher education are insufficiently represented in the existing literature. This qualitative descriptive single case study fills this gap in the literature. This study expands current knowledge on the appropriateness, applications, and implications of servant leadership in higher education by exploring graduate students' perceptions of the impact of servant leadership on their preparedness to engage, serve, and contribute to society after graduation from a private university in the Southeastern region of the United States. Based on the findings of this study, I propose the following recommendations for practice and future research.

Exemplify Servant Leadership

According to the results of this study, servant leadership is relevant, applicable, and positively affects the campus climate. Researchers have studied and shown the applicability and benefits of servant leadership in higher education settings (Alshammari et al., 2019; Bao-Jian and Hsuan-Po, 2024; Du et al., 2024; Jagela, 2019; Yue et al., 2024). All research participants indicated that servant leadership positively influenced the campus climate by promoting an inclusive environment where each community member felt valued, welcomed, and accepted. The graduate students developed servant leadership by observing and learning from campus administrators, faculty, and staff who exhibited servant leadership behaviors. The results demonstrated the significant impact campus leaders who exhibit servant leadership behaviors can have. Participants expected their campus leaders to

exemplify servant leadership through their actions and behaviors. Based on these findings, I recommend that colleges and universities promote the principles of servant leadership and encourage administrators, staff, and faculty to cultivate and exemplify servant leadership behaviors.

The graduate students perceived their campus experiences with servant leadership had equipped, prepared, inspired, and motivated them to make meaningful contributions to society after graduation. These findings align with Greenleaf's (1970) theory that servant leaders tend to cultivate more servant leaders. According to Greenleaf (1970), when followers experience caring, nurturing, empowerment, and support from servant leaders, they are likely to adopt similar behaviors and treat others similarly. All the participants articulated their commitment and enthusiasm to contribute to society after graduation. Based on the findings, campus leaders should continually reflect on their attitudes and behaviors to set an example for students. They should demonstrate servant leadership behaviors more intentionally when engaging with students and community members.

Provide Students with Opportunities to Develop and Practice Servant Leadership

According to the study findings, graduate students cultivate servant leadership when provided opportunities to serve and practice it. Participants in the study described the servant leadership behaviors of their administrators, faculty, and staff as fostering student leadership and providing opportunities for students to practice servant leadership. They described their experiences with servant leadership and its influence on their leadership development. Based on these findings, higher education institutions should intentionally and innovatively support students in developing servant leadership mindsets and behaviors while offering opportunities to practice servant leadership.

Promote Student Involvement in Community Service

There is an indication developed from this study's results that campus leaders create value for the community by promoting a sense of belonging and motivating students to give back to the community. Sharp (2023) reported a positive correlation between servant leadership and creating value for the community. The finding also aligns with Greenleaf's (2003) assertion that a servant leader is responsible for supporting the less privileged. Although all participants acknowledged that the institution provides students with opportunities to engage in community service, more than half indicated that they are not currently involved in community service or volunteering activities. Studies have reported a significant decline in volunteerism among college students and fresh graduates (Lenahan, 2024; Normah & Lukman, 2020). These findings can be applied to call upon colleges and universities to develop innovative strategies for encouraging students to participate in community service, integrate community service into the curriculum, and actively promote and recognize student involvement in such activities.

Recommendations for Future Research

This qualitative descriptive single case study has contributed to the existing body of knowledge on the

appropriateness, applicability, and impact of servant leadership in higher education institutions by examining and providing new insights into graduate students' perceptions of servant leadership, which has been lacking in the available literature. Future research should broaden the sample to include graduate students from Christian colleges and universities nationwide, overcoming the limitations of a small purposive sample. Also, future research should compare the graduate students' perceptions of the impact of servant leadership in faith-based private higher institutions with those in non-faith-based public higher institutions.

According to the results from this study, graduate students identified emotional healing and helping students grow and succeed as the most influential servant leadership behaviors affecting their perceptions of their preparedness to serve society after graduation. Future qualitative studies should explore and understand how and why graduate students perceive these behaviors as the most impactful. Moreover, given the limitations inherent in the research methodology and design, future studies should include quantitative analyses to evaluate the impact of servant leadership from the perspective of graduate students across various colleges and universities nationwide. These studies should also examine their awareness of campus leaders' servant leadership behaviors and their perceived development in servant leadership.

Conclusion

The problem addressed in this study is the unpreparedness of students leaving Christian higher education institutions in the United States to engage, serve, and contribute to the common good of society after graduation (Mann, 2020; Wallace, 2021). Student unpreparedness for life after college is now considered a significant threat to higher education enterprise in the United States (Mann, 2020; PR Newswire, 2023). Higher education institutions are currently under significant pressure to address the issue of student unpreparedness in making meaningful contributions to both the workplace and society following their graduation (Mann, 2020). Servant leadership is increasingly being recognized as a potential model for addressing various issues in higher education institutions, particularly the challenge of student preparedness for real-world engagement after college (Cong et al., 2024; Dami et al., 2024; Kainde & Mandagi, 2023). This qualitative descriptive single case study explored 13 graduate students' perceptions of the impact of servant leadership on their preparedness to engage, serve, and contribute to the common good of society after graduation at a private Christian university in the Southeastern region of the United States.

The existing literature was extensively explored to analyze servant leadership's application, implementation, and impact in higher education institutions from the viewpoints of staff, faculty, and undergraduate students. However, the perspectives of graduate students remain underrepresented in the current body of research. This study was developed to address this gap by examining graduate students' perceptions of the impact of servant leadership. The study's results confirm the applicability and efficiency of servant leadership in higher education institutions. The findings support Greenleaf's (1970) assertion that servant leaders tend to cultivate more servant leaders. When followers experience care, nurturing, empowerment, and support from servant leaders, they are likely to adopt

these leadership qualities themselves and treat others similarly. The results from this study highlight the need for campus leaders to exhibit servant leadership behaviors deliberately. It also suggests supporting students in developing servant leadership mindsets and behaviors, as well as encouraging and acknowledging student participation in community volunteering services.

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The Use of Technology, Projects and Fun Games in Teaching Mathematics

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Abstract: Mathematics is a challenging subject especially for students in lower-division mathematics classes. Mathematics instructors apply significant effort towards developing students' mathematics knowledge and skills. One of the efforts is to increase students' motivation in mathematics learning. Motivation is a crucial factor for influencing student performance in the mathematics learning process. This study aims to utilize different strategies to enhance student motivation in learning mathematics and to enhance the enthusiasm in the classroom. We focus on two of the strategies in this study -- the use of technology and a project-oriented approach, and the injection of fun mathematics games in the classroom. First, the use of technology in teaching mathematics has changed how mathematical concepts are presented and taught. The project-oriented approach enhances students' ability to apply the knowledge they learned in the classroom to solve real-life problems, and fosters student engagement and active learning. Second, the daily fun mathematics games make mathematics classes more fun and significantly boost student motivation. The fun mathematics games promote a more positive and engaging learning experience, which lead to increased interest, improved understanding, and have created a better retention ration and higher academic achievement. This paper provides a basis for redesigning the mathematics curriculum to address the specific needs of mathematics students and promote the role of technology, project, and fun in mathematics education in this digital age. While the study primarily focuses on lower-division mathematics students, we also describe how a project-oriented approach can be beneficial for upper-division students.

Keywords: technology, mathematics games, project-oriented teaching study

Citation: Wang, H., & Presho, M. (2025). The use of technology, projects and fun games in teaching mathematics. In V. Akerson, H. Polat, & A. Tekin (Eds.), *Proceedings of IConSES 2025—International Conference on Social and Education Sciences* (pp. 44–55). ISTES.

Introduction

Education enables students to acquire the knowledge and skills that will help them become successful members of society and prepare them for a wide range of professions. The inventions and implementations of new technologies have signifcant impacts on our education. In particular, technology provides instant accessibility to information. For example, smartphones facilitate easy communication, provide instant access to information, and

allow users to work, learn, and entertain themselves anywhere and anytime as they wish. Correspondingly, utilizing different types of technology such as smartphones, computers and tablets in the classroom is a vital component ot students' learning. Online education continues to grow across disciplines at institutions of higher learning (Glass & Sue, 2008; Olesova et al., 2011; Wagner et al., 2011). Instructors have been exploring how to create meaningful learning experiences to meet the unique needs of students in both in-person and online learning settings. "These digital technologies have made a paradigm shift in the entire education system" (Haleem et al., 2022). Technology in the classroom offers numerous benefits, for instance, the use of technologies has increased student engagement and enhanced collaboration in addition to the improved access to resources. It better prepares and equips the students' with the abilities for the future in a digitally-driven world (Brown, 2002).

One of the crucial factors that influences student performance in mathematics is motivation. When students are motivated, they are more likely to persevere through challenges, engage deeply with concepts, and develop a positive attitude towards the subject. This, in turn, leads to better understanding, retention, and overall achievement in mathematics. Many research papers (Rahayu et al., 2024; Saadati et al., 2023) aim to identify strategies to enhance student motivation in learning mathematics, to address the common issue of low enthusiasm and reduced classroom activity, and to develop effective teaching methods that increase student perseverance and independent learning in mathematics. Among many teaching methods, project-oriented teaching and learning is a method where students acquire knowledge and skills by working on complex and real-world problems. Project-based teaching is a dynamic approach that encourages active learning, collaboration, and the application of knowledge to authentic situations. The results of the study (Guo et al., 2020) on project-based learning indicate this approach has a more positive impact on students' academic achievement than direct instruction did. In addition, game-based learning is one of the modern trends in education in the 21st century. The study (Hui et al., 2023) shows that game-based learning has a positive effect on students when they are learning mathematics. This approach improves students' knowledge and mathematical skills and positively influences their mathematics achievement, attitude, motivation, interest, and engagement. The study (Orhani, 2025) examines the effects of using technology-based gamification on mathematics acquisition in elementary and secondary schools. The results show a significant improvement in student motivation and acquisition of mathematics concepts in addition to the increased social interaction and teamwork skills.

Striving to accommodate students' needs, increase their mathematics learning motivation, improve their academic performance, and enhance their professional skills, a variety of technology, projects and fun games were introduced into our lower-division mathematics classes. In addition, a project for the computation of integrals was introduced into an upper-level mathematics classes. In the lower-divison mathematics classes, the types of technology include graphing calculators, and computer software packages such as Mathematica. In the upper-divsion mathematics classes, the students use the Python programming language combined with existing techniques for integral calculations. We carefully integrate the best-known educational practices in technologies to create innovation curriculums, to provides engaging and cross-discipline projects, and to reduce math anxiety and boost academic resilience by making learning mathematics more fun via games. Our goal is to inspire students

from diverse backgrounds and abilities, and to assist students in acquiring the knowledge and skills necessary to compete in a global economy.

In this study, we apply mixed methods, combining illustrative examples with technologies, projects, and fun games in teaching our lower division mathematics classes. We explain how our strategies were implemented, why they have improved students' mathematics motivation levels and engaged their learning. Student performance data in several lower-division mathematics courses was collected, and statistical analysis was used to identify significant factors affecting students' mathematical performance. Specifically, the final course grades of the students enrolled in those courses were analyzed to determine the effectiveness of the use of the technology, projects and fun games. While less extensive, student performance data in an upper-level mathematics course spanning two semesters was also collected and used to reinforce the positive effects of project-based learning in these classes. The results provide insights into effective teaching practices in undergraduate mathematics. In particular, the results of this study indicate that our strategies significantly boost student motivation, provide higher engagement, better retention, and improve academic performance.

Method

Technologies and Projects

"Technology is essential in teaching and learning mathematics; it influences the mathematics that is taught and enhances students' learning." (National Council of Teachers of Mathematics, 2000). Electronic technologies such as calculators and computers are essential tools for teaching, learning, and doing mathematics. They furnish visual images of mathematical ideas and improve students' conceptual understanding of mathematics. They compute efficiently and accurately, reduce time consuming repetitious computations, and allow students allocate more time in understanding and learning mathematics concepts.

Lower-Division Mathematics

We first share a couple of examples to illustrate the type of techonologies and how they are implemented in the our lower-division mathematics classes. Graphing calculators are used in our mathematics classes, and they are recommended by national standards in mathematics (National Council of Teachers of Mathematics, 2000). Many topics such as the basic operations concerning percentage, radicals, decimals, solving equations, trig function computations, basic statistical computations, and graphs of functions in Intermediate Algebra, or College Algebra ,or Trignomitry, or Elementry Statistics, or Calculus classes, can be taught by graphing calculators. For instance, the graphs of linear equations can be demonstrated by using graphing calculators. Students can experiment with changing parameters such as the slope and the y-intercept in a linear equation to observe the impact on the graph. In addition, students can find the intersection(s) of two linear equations. Through manipulating the slopes of the two lines, students are able to draw conclusions on the conditions on when two linear equations have no solution, a unique solution, or infinitely many solutions. Graphing calculators should be used to promote students' number

sense, to eliminate tedious computation, to support concept development, to facilitate students' search for patterns, to encourage students mathematics exploration, and to guide students to analyze information and draw logical conclusions.

Second, computer softwares such as Mathematica and Excel are used in our lower-division mathematics classes. These tools offer many benefits including increased efficiency in calculations, enhanced visualization, and deeper conceptual understanding. For example, in Calculus classes, Mathematica can help visualize functions, especially 3-dimensional graphs, and allows students to better understand the functions' behavior and properties. Topics such as limits of functions, sequences, and multivariate functions, derivatives, integrals, parametric equations, solving differential equations or optimization problems that are usually challenging to calculate by hand can be managed easily via Mathematica. Similarly, Excel is also a helpful tool in calculus courses. Tasks like visualizing functions, approximating integrals, and exploring limits can be successfully completed using Excel. For example, an instructor can create tables of values for various of functions, graph them using Excel's charting features, and then numerically approximate integrals of these functions using Excel via methods like Riemann summation. In addition, Excel can be used for automating tasks and managing large datasets in Statistics classes. We want to emphasize that students' ability of hand computation in these mathematics classes is important, and is in fact considered as foundational skills. Computer software should be used to shed the load of tedious and error-prone computations, and to energize students' desire to learn the numerous and intricately connected concepts. Furthermore, it is important for students to learn how to use Excel and Mathematica, because these tools are valuable in many fields, including academia and professional careers. For example, Mathematica is a powerful tool for STEM fields like engineering, physics, and computer science, while Excel is a widely used for data analysis, reporting, and various administrative tasks in many industries, including finance, marketing, and healthcare. Teaching students how to use these computer software will equip them with skills that will enhance their employability across various fields.

Finally, combining project-based teaching with technologies in our mathematics classes is one of our efforts to stimulate students' interest in mathematics. Hands-on activities are implemented to expose students to a variety of means for exploring mathematics career options, and the projects are designed to build students' mathematics curiosity and drive to discover mathematics in their daily life, foster a positive attitude and confidence regarding mathematics, and encourage students to become promoters and ambassadors for mathematics among their peers. For example, a project such as creating a piece of artwork using mathematics and computer software was assigned to students. Students had the freedom to choose any software and create any craft as long as they apply mathematics to generate the artwork. Figure 1 illustrates three final products from students. The photo on the left of Figure 1 shows a cat generated by using Desmos where the left panel contains various mathematics equations that create the head, the body, and the tail of the cat. The picture in the middle of Figure 1 exhibits a 3D printed rose, where various mathematical principles were used to create digital models that were then translated into a physical rose. The image on the right of Figure 1 depicts the CAM design of a bicycle handlebar. The mathematics in the areas of geometry, trigonometry, calculus, linear algebra, and topology, are all used to define and produce these artworks. These projects provide students with great experience of productive struggle and practice their

preseverance, promote their creativity and innovation, and enhance their abilities of applying mathematics in their daily life. Furthermore, students learn to use a variety of technologies. In particular, making designs using computer software such as CAM is extremely beneficial to the students. These computer skills together with their mathematics background are highly valuable in today's job market.

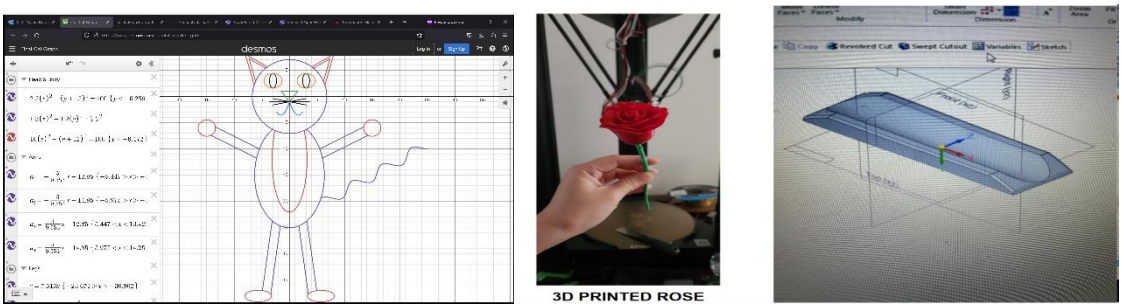

Figure 1. Art Projects: (Left: Cat via Desmos; Middle: 3D Printed Rose; Right: Bicycle Handlebar via CAM)

Upper-Division Mathematics

In addition to the projects that have been implemented in our lower-division mathematics courses, we also describe a project that is being used in higher-division mathematics course. This project hinges on the computation of integrals using both Calculus-based techniques and introductory numerical methods. Some integrals may be analytically obtained via Calculus methods, whereas some may not be analytically available. Furthermore, even integrals that are analytically available may be daunting to compute. For this project, we ask students to focus on an example of the latter that arises in Calculus II (Stewart et al., 2021). In particular, we ask students to find the length of the curve $y = 1 - e^x$ from $0 \leq x \leq 2$. The formula for the length of a curve is given by the integral

$$L = \int_a^b \sqrt{1 + \left(\frac{dy}{dx}\right)^2}\, dx \tag{1}$$

(Stewart et al., 2021). Substituting our function into Eq. (1) yields the integral

$$L = \int_0^2 \sqrt{1 + e^{-2x}}\, dx. \tag{2}$$

An exact solution to Eq. (2) is available and hinges on the clever u-substitution $u = \sqrt{1 + e^{-2x}}$ or $u^2 = 1 + e^{-2x}$. After constructing the differential, transforming the integrand, and updating the limit values, the students may then rewrite the integral as

$$L = \int_{\sqrt{1+e^{-4}}}^{\sqrt{2}} \frac{u^2}{u^2 - 1}\, du. \tag{3}$$

The form in Eq. (3) then requires the method of partial fraction decomposition (Stewart et al., 2021) in which we

may rewrite the integral as

$$L = \int_{\sqrt{1+e^{-4}}}^{\sqrt{2}} \left(1 - \frac{1}{2}\frac{1}{u+1} + \frac{1}{2}\frac{1}{u-1}\right) du \tag{4}$$
$$= \left[u - \frac{1}{2}\ln(u+1) + \frac{1}{2}\ln(u-1)\right]_{\sqrt{1+e^{-4}}}^{\sqrt{2}}.$$

The form in Eq. (4) finally yields an exact solution of

$$L = \sqrt{2} - \sqrt{1+e^{-4}} + \frac{1}{2}\ln\left(\frac{\sqrt{2}-1}{\sqrt{2}+1}\right) - \frac{1}{2}\ln\left(\frac{\sqrt{1+e^{-4}}-1}{\sqrt{1+e^{-4}}+1}\right). \tag{5}$$

There are a few important topics for students to consider in regard to the process for deriving the exact solution in Eq. (5). It should be noted that the tools used in this integration are standard tools of Calculus II students, and their importance cannot be overlooked. However, it should also be noted that this particular integral is fairly detailed and a bit tedious to compute. Additionally, the exact solution is a long expression involving irrational numbers, and it must be rounded if a numeric value is desired. As a result, this problem can be used as a motivational tool for the use of Simpson's Rule (Faires & Burden, 2013) as an integral approximation method. By embracing this method, the students can simultaneously use the exact solution and approximate solutions to cross-validate their Simpson's Rule implementation.

Simpson's Rule may be stated as follows:

$$\int_a^b f(x)\,dx \approx \frac{\Delta x}{3}(f(x_0) + 4f(x_1) + 2f(x_2) + 4f(x_3) + 2f(x_4) + \cdots + 4f(x_{n-1}) + f(x_n)), \tag{6}$$

where $\Delta x = \frac{b-a}{n}$ and $x_i = a + i\,\Delta x$. The rule in Eq. (6) only requires evaluating the integrand at a set of specified values and is relatively easy to implement. Figure 2 illustrates the moderate task (~20 lines of code) of implementing Simpson's Rule using the Python coding language (Sedgewick et al., 2015). For this project, students are required to write their own code "from the ground up" and incorporate it into a Python module.

```
36  def simpsons( f, a, b, N ):
37      #---Define x-values
38      dx = (b-a) / N
39      x = np.linspace( a, b, N+1 )
40
41      approx = 0
42
43      #---Internal even indices
44      for i in range(1, int(N/2)):
45          ind = 2*i
46          #print(ind)
47          approx += 2*f( x[ind] )
48
49      #---Odd indices
50      for i in range(1, int(N/2)+1):
51          ind = 2*i - 1
52          #print(ind)
53          approx += 4*f( x[ind] )
54
55      #---Endpoints
56      approx += f( x[0] )
57      approx += f( x[N] )
58
59      approx *= dx/3
60
61      return approx
62
```

Figure 2. Basic Implementation of Simpson's Rule in Python

In order to compare the approximate solutions from Simpson's Rule from Eq. (6) with the exact solution in Eq.

(5) (recall the goal of both is to solve Eq. (2)) the students then create a table of values as seen in Table 1. In particular, we see that a moderate value of n = 128 yields a Simpson's Rule approximation with 9 decimals of precision.

Table 1. Simpson's Rule Results

n	Approximation (up to 9 digits)	"Exact" Value (up to 9 digits)	Absolute Error
8	2.221444033	2.221418666	2.54E-5
16	2.221420249	2.221418666	1.58E-6
32	2.221418765	2.221418666	9.90E-8
64	2.221418672	2.221418666	6.00E-9
128	2.221418666	2.221418666	0.00 (9 digits)

The construction of the numerical values from Table 1 is beneficial for students for a variety of reasons. First, it allows higher-level mathematics students to review some fundamental Calculus techniques for integral calculations. In addition, it exposes students to numerical approximation techniques which are typically not covered in detail in Calculus. The project ultimately builds a bridge between the respective techniques, and the students can personally construct and visualize the results in a hands-on setting. In doing so, they simultaneously use exact and approximate solutions to cross-validate their Simpson's Rule implementation. As a result, their implementation may be used for a large variety of other integrals where an exact solution may or may not be available. Furthermore, this type of project prompts student ideas and questions that foreshadow more detailed error analysis that they may see later in their mathematical ventures.

Fun Games

The ultimate goals of mathematics instruction are students understanding the material presented, applying the skills, and recalling the concepts in the future. There is little benefit in students recalling a formula or procedure to prepare for an assessment tomorrow only to forget the core concept by next week. Mathematics can be considered as a game or mindful activity that increases our intelligence and focus. Students often do not realize they are learning when they play math games. Transforming tricky questions into fun math problems and injecting a short brainstorming period into a regular math class can be entertaining and delightful, and spark students' interest and engagement. Below, we provide a couple of fun mathematics games that we played in our lower-division mathematics classes. These fun games spark students' interest and intrinsically motivate them to seek knowledge and proactively solve problems. Both examples show how fun games can help students translate word problems into mathematics sentences, and how to analyze the mathematics expressions and draw logical conclusions.

(1) I can tell your age using your shoe size! *Start with your shoe size, if you are a half size, for example, size 8.5 round up to 9; Multiply your shoe size by 5, then add 50; Multiply that number by 20; Add 1025; Subtract the*

year you were born, for example, 1991; Add 1 if you already had your birthday this year. The first digit(s) are your shoe size, and the last two digits are your age. After following the procedures, students were usually amazed by the correct answer and wondered about the reasons behind this game. This is a fantastic opportunity to teach students how to translate word problems into mathematical sentences, identify the operations such as addition, subtraction, multiplication, division, and the unknown variables described in the problem, then express the relationship between these elements using mathematical symbols. As students relalize that by setting X as the variable for the shoe size, Y as the year one was born, then the procedure is expressed as the mathematics expression: (5X+50)*20+1025-Y=100X+1000+1025-Y=100X+(2025-Y), where 2005-Y is the age (+1 if you already had your birthday this year) and 100X=X00 yields the shoe size. In addition, the students could observe the importance of the number 1025 and noticed that it would be different to provide the correct age should the game be played another year. This shows that the students improved their number sense by playing the game.

(2) What are the ages of the children? *The woman said: "I have 3 daughters, their ages are hole numbers, and the product of the ages is 36"; "It is not useful to tell you the sum of their ages"; "My oldest daughter likes dogs."* The initial reaction from the students upon reading the game was extremely puzzling, and they did not know how to approach the problem. Again, this example reiterates the importance of replacing words with mathematical expressions that accurately reflect the relationship described in the problem. Listing all the possibilities of three positive integers whose product is thirty-six and their sums:

(1,1, 36)	(1,2,18)	(1, 3, 12)	(1, 4, 9)	(1, 6, 6)	(2,2,9)	(2, 3, 6)	(3,3,4)
38	21	16	14	13	13	11	10

Realizing that the sentence "It is not useful to tell you the sum of their ages" implies the ages are either (1,6,6) or (2,2,9); and the sentence "My oldest daughter likes dogs" means that there is an oldest; thus, the ages are (2,2,9). Again, this fun game illustrate how to convert the words and phrases into mathematical expression, and how to derive an answer using logical reasoning based on the given information.

Results

The primary purpose of the study was to better understand the effect of the use of technology, projects and fun games in lower-division mathematics classes on student motivation in learning mathematics and their academic performance. However, the effect of a technology-based project for the numerical calculation of integrals in upper-division mathematics classes was also assessed.

Lower-Division Mathematics

In order to assess students' perception of technology, projects, and fun games in our lower-division mathematics classes, we administered an online survey toward the end of the semester for the students (enrolled in Applied Calculus and Calculus I classes that implemented these components). As seen in Table 2 below, students in general had a positive experience with the technology, projects, and fun games used in their classes.

Table 2. Student Experience in Lower-Division Mathematics

Media	Strongly agree	Agree	Neutral	Disagree	Strongly disagree	Total
Technology	76	5	-	-	-	81
Projects	70	11	-	-	-	81
Fun Games	81	-	-	-	-	81

Below is some feedback from students concerning the use of technology, projects, and fun games in these classes:

"*Graphing calculator really helped me understand the concepts of polar curves, and I can see the area inclosed by the given curves. I now know how to apply the formula to solve problems. I feel good about math for the first time.*"

"*I enjoyed spending hours on one project. I didn't know that I can do something I like with mathematics before.*"

"I gave credit to the instructor who encouraged me to learn how to design and do 3D printing. I didn't know there are so many math involved. It is not easy, but it is quite fun to learn the new stuff and use math. Great."

"I like the games we played in class. I would never thought they are math problems. They are hard, but I learned a lot."

Based on these comments, it is obvious that students appreciated the use of technology, projects, and fun games in these classes. It also appears that these approaches boosted students' interest and confidence in mathematics, and motivated them to learn more mathematics.

In addition, we collected the final course grades for the students who enrolled in the classes that implemented these components in their classes in Spring 2024. We tabulate the number of students who earned a letter grade "C" or above and the number of students who earned a letter grade "D" or below in Table 3. Among a total of 97 students, 93 students (96%) successfully completed their course with a letter grade "C" or above. Among the 4 students (4%) who failed to earn a letter grade "C" or above, two students completed their course with a letter grade "D", and two students with a letter grade "F". Furthermore, all 97 students who registered for their courses remained in their perspective courses without dropping out during the semester. Hence, the retention is at 100% for the courses that implemented technology, projects, and fun games in our lower-division mathematics courses.

Table 3. Final Course Grades in Lower-Division Mathematics

Number of students whose course grade is "C" or above	Number of students whose course grade is "D" or below	N
94	4	97

In summary, the results of the lower-division mathematics study clearly indicate that technologies, projects and fun games provide a more engaging learning environment, boost their interest toward mathematics, motivated them to learn, and improved their academic performance, and increased the retention rate.

Upper-Division Mathematics

In addition to the results that are offered for our lower-division mathematics courses, we also offer a set of results corresponding to the upper-level mathematics integration project. All results included herein were taken from a Mathematical Programming course (which has a prerequisite of Calculus II) from the Spring 2023 and Spring 2025 semesters. Due to the frequency in which this course is offered, and the smaller class sizes, the results are less robust than those for the lower-level mathematics courses. Nonetheless, the results offer insight into the effectiveness of the aforementioned projects. An online survey was offered toward the end of the semester for the students, and the results may be seen in Table 4. The results suggest that the students had a generally positive experience with the projects and that their knowledge in the subject increased.

Table 4. Student Experience in Upper-Division Mathematics

Evaluation Questions	Strongly agree	Agree	Neutral	Disagree	Strongly disagree	Total
(i) Assignments helped understanding	9	2	1	1	-	13
(ii) Knowledge/abilities in subject increased	9	2	1	1	-	13
(iii) Instructor responsive to student questions/ideas	8	4	-	1	-	13

As a counterpart to the results in Table 4, we also offer a comparison between the Spring 2023 and Spring 2025 semesters in Table 5. The rating values in the table are the average response values from the students in each respective semester. The values range from 1 (Strongly disagree) to 5 (Strongly agree). Table 5 shows that the average values never fall below 4, and also illustrates that the rating values from the Spring 2025 semester were larger than those from the Spring 2023 semester. This is likely due to the continued refinement of the project details and discussions from one semester to the next.

Table 5. Semester Comparison for Upper-Division Mathematics

Semester	Evaluation Questions	Rating
Spring 2023	(i) Assignments helped understanding	4.25 / 5
	(ii) Knowledge/abilities in subject increased	4.38 / 5
	(iii) Instructor responsive to student questions/ideas	4.38 / 5
Spring 2025	(i) Assignments helped understanding	4.8 / 5
	(ii) Knowledge/abilities in subject increased	4.6 / 5
	(iii) Instructor responsive to student questions/ideas	4.6 / 5

As a final set of results, we offer the upper-division students' final grades in Table 6. In particular, we tabulate the number of students who earned a letter grade "C" or above and the number of students who earned a letter

grade "D" or below in Table 6. Among a total of 28 students, 26 students (93%) successfully completed their course with a letter grade "C" or above. Among the 2 students (7%) who failed to earn a letter grade "C" or above, both remaining students earned a letter grade "F". Correspondingly, in those upper-division classes in which the integration project is offered, the student success rates are quite high.

Table 6. Final Course Grades in Lower-Division Mathematics

Number of students whose course grade is "C" or above	Number of students whose course grade is "D" or below	N
26	2	28

In summary, the results of the upper-division mathematics study clearly indicate that the integration-based projects have a positive effect on the students' understanding and knowledge of the material. While student motivation is of arguably less concern for upper-division mathematics students, the results also suggest that these students tend to maintain their motivation throughout the duration of the course.

There are many factors that impact students' interest, motivation, and academic performance. One of the most important factors is the mathematics background. The data collected consists of a diverse student body with differences in race, ethnicity, culture, socioeconomic status, learning abilities, gender, sexual orientation, and more. It would be interesting to conduct research to different subgroups, compare the effect of the use of these approaches on each of those subgroups, and identify the subgroup that benefits the most from these approaches.

Conclusion

Technology, projects and fun games seem to have made a big difference on student performance as both qualitative and quantitative data have showed. Various factors may have contributed to these positive results, and further studies may reveal whether the demographics of student also contribute to student performance. Our hope is that with the passage of time, as students became more proficient in mathematics and the use of technology, they will be able to use both skills to enhance their contribution to the society.

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Using AI to Build Confidence and Support Student Learning

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Abstract: Research has shown that learning is enhanced when students prepare and present lessons to their classmates. Students are often fearful of being judged by their classmates or using terminology incorrectly. Having students create video presentations affords them the opportunity to exhibit an understanding of the materials without the anxiety that may be associated with presenting live in front of a classroom. We can further reduce this anxiety by allowing the use of AI to create a presentation script. The benefits of using AI in this capacity are two-fold. Using a resource like ChatGPT can help to relieve anxiety related to the fear of giving an incorrect explanation or using the discipline specific terminology incorrectly. ChatGPT can also serve as a beneficial learning and engagement tool in that students would be required to review and analyze the validity of the AI generated writing. In this project, students enrolled in a Survey of Calculus course were divided into groups and asked to create a video presentation on a topic of their choice with the aid of ChatGPT. Most students enrolled in this course are non-STEM majors with a fair amount of self-reported anxiety toward mathematics. Using mathematical terminology and notation correctly can be difficult, especially during a presentation. It is our belief that allowing the use of ChatGPT to aid in the creation of a presentation script will help to reduce this anxiety. This, in turn, will allow our students to engage with the course material in a less stressful way. We also believe that working with the AI generated script will help students to become more comfortable with mathematical notation and terminology, allowing them to use discipline specific terms in a more natural way.

Keywords: Empowerment, Mathematics Education, AI, Retention, Engagement

Citation: Hood, S., & Namakshi, N. (2025). Using AI to build confidence and support student learning. In V. Akerson, H. Polat, & A. Tekin (Eds.), *Proceedings of IConSES 2025—International Conference on Social and Education Sciences* (pp. 56–66). ISTES.

Introduction

We began this project when AI was initially gaining momentum in academic settings. Will AI hinder learning and pose a threat to academic integrity? This is still the biggest question that many educators grapple with everyday. While we were concerned about how the use of AI would play out in classrooms, we also recognized that our students would continue to use AI (just as they have been using other forms of technology) even if we prohibited its use entirely. After discussing this issue, we decided using AI as a learning tool in our math classrooms. We

can guide students in using AI ethically in a way that would benefit their learning, reduce their anxiety towards mathematics, and promote engagement with the course content.

Many students find Survey of Calculus to be a challenging course, particularly those students who are non-STEM majors. Learning math vocabulary and notation in the context of calculus is the first bridge students must cross to engage with the material in a meaningful way. Therefore, we decided to create an assignment that required students to use AI to create video presentations on an assigned topic in calculus. Our rationale behind this assignment was that AI can serve as a beneficial learning and engagement tool for the students. Students would be required to review and analyze the validity of the AI generated script thereby engaging with the content is a meaningful way that enhances their own understanding of concepts in the process. And creating a video presentation would relieve anxiety related to the fear of giving an incorrect explanation or using the discipline specific terminology incorrectly when presenting live in front of their peers. The figure below depicts the model of our study.

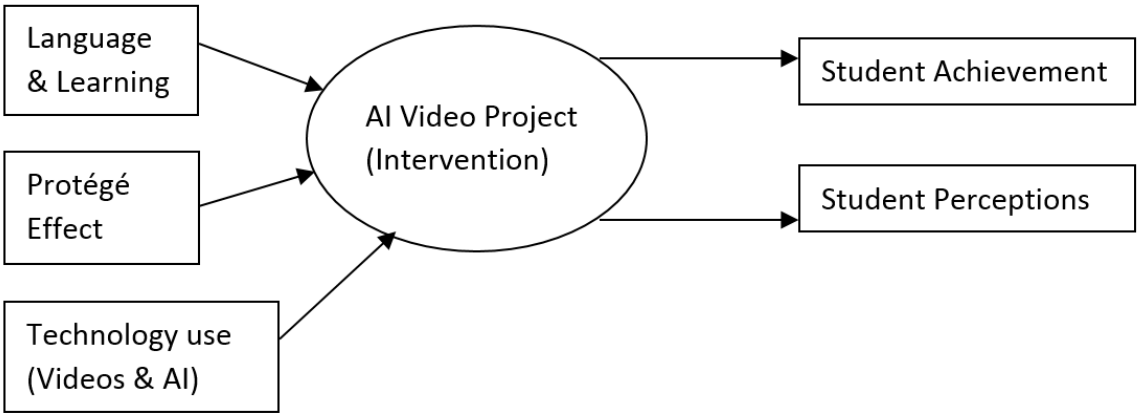

Figure 1. Model for the Study

Our study is guided by the following research questions:

1) How did the AI Video Project intervention impact the student achievement as measured through students' term exam scores that was administered after the intervention?
2) How did the students describe their experiences engaging with the AI Video Project with respect to the comfort level in using mathematical terminology and their understanding of the concepts addressed in the project?

As represented in our model in Figure 1, our AI Video Project intervention is informed by three large bodies of research in education – languange and learning, the protégé effect, and the use of technology in learning (in particular video presentations and AI). In the following section we provide a brief review of the literature of the aforementioned constructs and how they inform our study.

Literature Review

Language and Learning

The connection between discipline specific language and its impact on learning has been a long-researched area in mathematics education. There have been several studies throughout decades (e.g. NCTM, 1991, Cobb et al., 1997; Boulet, 2007; Mulwa, 2015; Riccomini et al., 2015) that provide evidence of how important mathematical discourse in a classroom is to build student understanding of the concepts and facilitate learning. In order to understand definitions, carry out procedures, read notation, and to even articulate difficulties, students must first need to get familiar with using mathematical terminology and language. For example, before students can solve a problem such as finding the derivative of the function $f(x) = \sin x \cos x$, students need understand the definition of a derivative, a function, be able to read the notation and make sense of it among other things. Furthermore, they need to use the correct mathematical vocabulary and terminology to even communicate the difficulty they are experiencing in solving the problem. Therefore, informed by the research in this area of mathematics education we included in our 'AI Video Project' intervention the aspects of reading, writing, and communicating a mathematical concept using the correct mathematical notation, vocabulary, terminology, and language. Our assumption was that by expending effort in understanding the vocabulary and notation associated with a concept, the students can build a deeper overall understanding of the concept.

The Protégé Effect: Learning Through Teaching

There has been much research supporting the benefits of learning through teaching. The Protégé Effect is the name for the observance that people tend to learn more effectively and gain a deeper understanding of material when teaching or explaining to others. When we are preparing to teach a lesson or explain a concept to someone else, we put more effort into organizing our thoughts. We pay more attention to potential gaps in our own knowledge so that we can provide a better explanation. After all, nobody wants to provide incorrect information or give the impression that they don't know what they are talking about.

The method of having students teach their peers to foster learning in classrooms has been around for a very long in different parts of the world. This time tested method was systematically developed by the French language teacher Jean Pol-Martin in early 1980s when he was teaching in Germany. The learning by teaching or in German the "Lernen durch Lehren," abbriviated as the LdL method "sees students in the role of the teacher, and enhances their learning experience by encouraging them to teach other students..." (Stollhans, 2016, p.161).

More recently building on Martin's (1985) work the researchers Chase et al. (2009) at Stanford University provided empirical evidence for the protégé effect. Chase et al. (2009) conducted two studies with a group of 8th graders and 5th graders. Students in both studies were divided into experimental and control groups where they were learning through a computer-based learning environment called Betty's Brain - a software that capitalizes on the social aspects of learning. In Betty's Brain, students can instruct a character called a Teachable Agent (TA)

which can reason based on how it is taught. The students in the experimental group were asked to *teach* their TA while the students in the control group operated under the assumption that they were using the software to learn the material for themselves. In both studies the researchers found the existence of a prote´ge´ effect. The first study "...revealed that students who taught TAs spent more time on learning behaviors and ultimately learned more than students who learned for themselves..." (Chase et al., 2009, p. 348). Furthermore the authors note that the "...prote´ge´ effect was particularly beneficial for low-achieving students who, through increased effort, developed an understanding of the complex biology content that was on par with the high-achieving students who did not use TAs" (Chase et al., 2009, p. 348).

Therefore, informed by the research in this area, we made 'learning by teaching' the core component of our 'AI Video Project' intervention. Our assumption was that when students are giving a presentation or explaining a concept to their classmates, they need to be able to verbalize the concepts in a way that makes sense. It is important that they can use the correct mathematical terminology and language when doing so thereby building a deeper understanding of the material.

Studies (e.g. Deslauriers et al., 2019; Hoogerheide et al., 2016; Denancé et al., 2015) on active learning strategies (such as our intervention) have shown that students in classrooms that employ active learning strategies are more engaged, motivated, and tend to learn more.

Technology and Learning

There have been several studies (e.g. Swidan & Fried, 2021; Yimar, 2020; Hargis et al. 2014) that have offered evidence regarding the use of technology when teaching mathematics in general and Calculus in particular. More recently several educators are now integrating AI tools in classrooms to increase student motivation, engagement, and learning. For example, Zhou and Li (2023) investigated the impact of using ChatGPT as a learning aid on student motivation and found that there was a negative correlation between tension-pressure and interest-enjoyment. Though the research on using AI tools to reduce anxiety and increase student motivation in math classrooms is still new and limited, however through our study we hope to make some contribution by adding to the growing body of literature in this area.

We integrated technology into our 'AI Video Project' intervention to facilitate the core concepts of - *learning by teaching* and *using correct mathematical language*. Our assumption was that by assigning students a topic to teach to their peers through a pre-recorded video presentation would be far less stressful than if they were to teach their topic in a live presentation during class. This format would allow students to plan, revise, practice, and re-record their presentation. In this way the students' video presentation still affords them the opportunity to present knowledge and take ownership of learning. We also allowed students to use AI tools such as ChatGPT to generate scripts for their video lesson. Such tools can help students get feedback on their explanations and tone. AI can further reduce anxiety associated with creating presentations by providing a starting point. And more importantly,

AI can encourage interaction with the course material to promote a deeper understanding of concepts since students have to make sure that the AI generated script is mathematically correct.

Method

Setting and Participants

MATH 22003 Survey of Calculus is a one-semester course for students who need to understand the basic ideas of Calculus but don't necessarily need the same rigor or depth required for students entering STEM fields. Most students who enroll in this course are majoring in business or social sciences. For many of these students, mathematics is a challenge. They may experience higher levels of math anxiety or struggle with confidence in their abilities to be successful in a mathematics course. For this reason, instructional strategies are often aimed at building self-efficacy and creating a sense of belonging.

In Spring 2025, there were sixteen different sections of MATH 22003 with a total enrollment of 941 students. The course is highly coordinated, so students in all sections cover material at a similar pace, are assigned the same homework sets, and take part in common exams. Students from two sections, 005 and 006, with total enrollment of 128 participated in this study. These two sections met two days each week, Tuesdays and Thursdays, each for 75-minutes and were taught by the same instructor.

The AI Video Project

Content for MATH 22003 is divided into four units: Limits, Derivatives, Applications of the Derivative, and Integrals. Historically, Unit 3: Applications of the Derivative is the unit which students tend to struggle the most. This is evident when reviewing exam scores for previous semesters. The overall average for the Unit 3 exam is consistently lower than the other three-unit exams. This is likely due to the perceived complexity of the unit combined with the negative feelings regarding mathematics experienced by many of the students. For this reason, Unit 3 was selected for this project.

Students were given a choice to work individually or in groups of up to four members. They were allowed to select a Unit 3 topic on which they were to create a video presentation. This presentation would be posted in the class LMS and, hence, could be viewed by other class members. While students were given creative freedom in the creation of the video presentation, they were asked to use ChatGPT to assist in the creation of the script for this video. Students could ask ChatGPT to revise and clarify components of the script as needed.

The decision to allow the use of AI for this purpose was based on several reasons. Students tend to struggle with where to start when asked to give a mathematical presentation. The ability to use ChatGPT provided a low stress way to help the students brainstorm ideas and relevant examples. Additionally, many students struggle with using correct notation and terminology when it comes to mathematics. By allowing the use of this tool to help generate

a presentation script, students were encouraged to read through and verbalize their explanations using correct mathematical language. The idea was that practicing the use of correct terminology would lead to more confidence and a greater understanding of the concepts as well as an increased ability to effectively communicate mathematical ideas to others. Finally, students would have to actively engage with the course material, and the AI generated content to ensure that all explanations were correct, and all appropriate details were included.

To help ensure that students were conversing with ChatGPT and working through the content in advance of the deadline, the project was scaffolded so that various components were due on different dates. Students were given time during a Thursday class meeting to review a list of potential Unit 3 topics and to select their preferred topic. Students were provided with instructions and a grading rubric for the project. They were also given time to begin creating a script for their presentation using ChatGPT. To ensure that time was taken to review the content, necessary follow up-questions were asked, and revisions were made, groups/individuals were required to submit copies of their conversations with ChatGPT on the following day. The actual video presentation was due at the end of the following Tuesday. This was to ensure that students had one more class meeting in which to seek help and to make sure that video presentations could be reviewed by others prior to the Unit 3 Exam. Groups/Individuals were also asked to complete a project evaluation form with questions related to their experience using ChatGPT and any effect it may have had on their understanding. While the majority of students opted to complete the form individually, many chose to complete the form as a group. Project components and due dates are listed in Table 1.

Table 2. Component Due Dates

Project Component	Deadline
Topic Due	Thursday, March 13, 2025
Chat GPT Conversation	Friday, March 14, 2025
Video Presentation Due	Tuesday, March 18, 2025
Project Evaluation Form	Tuesday, March 18

The purpose of the Project Evaluation form was to gain some insight into the students' experience with using ChatGPT and to gauge any perceived impact on understanding. On the evaluation form, students were asked to respond to open response questions which allowed them discuss how AI may have affected their understanding of the necessary mathematical language and content and whether or not using AI served to reduce any anxiety related to presenting the material. The open response questions used in the evaluation form are included in Table 2.

Table 3. Evaluation Form - Open Response Questions

Open Response Questions
Do you believe that participating in the creating of a video presentation affected your comfort level with using mathematical terminology?

Open Response Questions
In your opinion, was ChatGPT helpful in generating a script for your video?
Did the creation of a script using ChatGPT have any influence on your comfort level in using the mathematical terminology required for your topic? Please explain.
Do you believe that using ChatGPT to create your script had any influence on your understanding of the topic you were presenting? Please explain.
What, if any, were the benefits to using ChatGPT to create your video script?
What, if any, were the drawbacks to using ChatGPT in creating a video script?

Findings

Research Question 1

Our first research question asked how the 'AI Video Project' intervention impacted student achivement achievement as measured through students' term exam 3 scores that was administered after the intervention. As mentioned earlier we implemented the intervention in two sections in Spring 2025 (N = 128). We were interested to see how the students' exam scores changed from term Exam 2 (before the intervention) to term Exam 3 (after the intervention). Typically, the data in the past has shown that scores on Exam 3 tend to be lower than the scores Exam 2 by 6-7 percentage points on average. We were hoping that after the intervention the scores on Exam 3 would have a positive impact in the sense that the intervention may lower the gap between the two term exam scores. However, as noted in Table 3 below, the intervention did not lower this gap which remained the same in accordance with the past data within 6-7 percentage points.

Table 4. Average student exam scores - Spring 2025.

	Section 005	Section 006	Overall
Exam 1	92.3	90.3	83.6
Exam 2	79.4	78.1	74.2
Exam 3	73	72.4	73.1

Research Question 2

We now report our findings for our second research question in which the students describe their experiences engaging with the AI Video Project with respect to the comfort level in using mathematical terminology and their understanding of the concepts addressed in the project. The consensus of the students was to note the benefits that they gained when creating the video presentation using ChatGPT included an increased level of comfort and confidence in using mathematical terminology and language, and a better understanding of the material. We present our findings from the project evaluation survey characterizing the students' experience with the 'AI Video Project'.

Video presentation - impact on comfort level with using mathematical terminology/language

As shown in the figure below, 81% of the students reported an increased level of comfort and confidence in using mathematical terminology and language when creating the video presentation, 5% reported a minor impact on the comfort level, while 14% reported that creating the video presentation had no impact on their comfort level when using mathematical terminology/language.

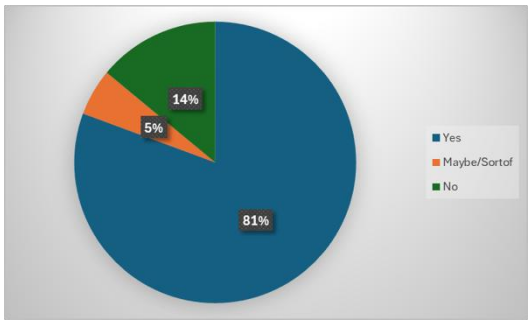

Figure 2. Do you believe that participating in the creation of a video presentation affected your comfort level with using mathematical terminology?

ChatGPT – impact on comfort level with using mathematical terminology/language

As shown in the figure below, 74% of the students reported an increased level of comfort and confidence with the mathematical terminology/language when using ChatGPT to generate a script for their video presentation, 5% reported a minor impact on the comfort level, while 21% reported that using ChatGPT to help create the video presentation had no impact on their comfort level with mathematical terminology/language.

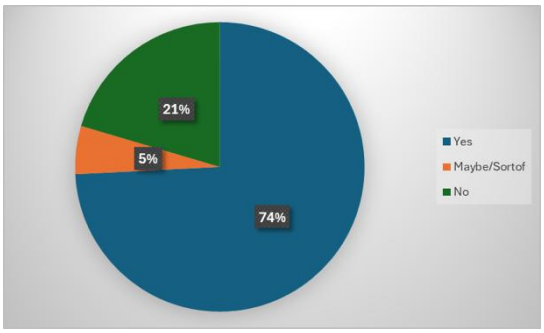

Figure 3. Did the creation of a script using ChatGPT have any influence on your comfort level in using the mathematical terminology required for your topic?

AI Video Project – overall impact on understanding the assigned topic content

As shown in the figure below, 82% of the students reported an increased level of understanding of the content in their assigned topic for the project when creating the video presentation with the help of ChatGPT, while 18%

reported that creating the video presentation using ChatGPT had no impact on their understanding of the material in their assigned topic.

Figures 1-3 illustrate that the majority of students believed that creating a video presentation and using ChatGPT to aid in the creation of the script was beneficial. The table below provides a sample of student comments from the survey.

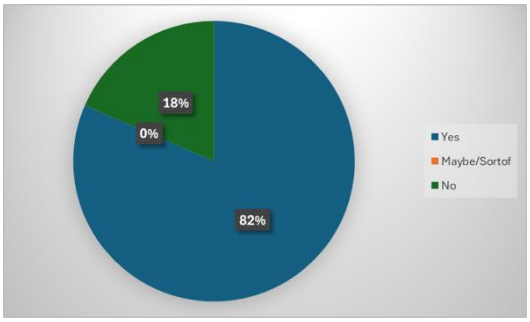

Figure 4. Do you believe that using ChatGPT to create your script had any influence on your understanding of the topic you were presenting?

Table 4. Student Comments from Project Evaluation Survey Spring 2025

Comments: impact on comfort level using mathematical terminology/language	*"Yes actually, The amount of trials it took for me to make this video I noticed the further I got into the tries the more comfortable I was using the words I was saying."* *"It did. It helped me learn not only how to teach others, but it also helped me learn the terminology that is used in the problems."* *"Yes, we would agree that it was helpful because it gave us a place to start, and it made us feel more confident that we knew what we were speaking about."* *"Yes. It made me more sure of what I was talking about."* *"It did, because hearing what ChatGPT was saying, it made me more confident in understanding how to word different things."* *"No, we think we were comfortable using the terminology after doing the lesson in class, but we think doing this project just helped us practice using the terminology and ensured we knew how to use it correctly."*
Comments: impact on understanding content	*"Yes, I dug into the topic to check the accuracy, and it made me understand it better."* *"Yes, it helped me create a more simple and visual approach to understanding the material, but I did need to know what I was doing previously so I knew it was right."* *"Yes, it allowed teamwork and collaboration."* *"Yes, I think ChatGPT was useful in helping with words or parts of the problem that I was unfamiliar with."* *No, we don't think it really helped us much. Maybe the one way it did was by us checking the math to make sure it was right. This helped instill what we already knew and apply it.*

Conclusion

Although we did not find a change in the student achievement that we were hoping for, student comments reveal a boost in confidence when using math terminology/language and the level of understanding the material as a result of participating in the AI Video Project. Although no measure of anxiety was included in the survey, the numerous comments related to the fact that the AI tool helped students to "get started" with the project and that it helped students to "feel more confident" do point toward an experience which reduced negative feelings.

Additionally, we saw several comments which indicated students felt the need to really understand the material in order to verify that the AI tool was providing correct information. This suggests that using ChatGPT encouraged students to engage more deeply with the course content and to critically think about the responses they received to their own prompts. Anecdotally, the video presentation project encouraged collaboration between students and interaction between students and the instructor. Students were more likely to attend office hours to ask questions about their presentations which led to discussion of the course material. For these reasons, we will likely continue to make use of this project.

For future iterations of this project, we plan to make adjustments to the Project Evaluation Survey to incorporate questions related to math anxiety and/or anxiety related to giving presentations. This would provide an opportunity for students to self-report any influence this project may have had on reducing said anxiety. We might include a pre/post questionnaire with Likert-scale questions related to feelings involving mathematical tasks or open-ended questions allowing students to describe coping strategies.

Reviewing the data, project design, and our findings, we believe we can make improvements to the project design moving forward. Using a more scaffolded approach, we can encourage students to meet with the instructor to review content, ask more questions, and perhaps spend more time practicing with the correct terminology. We did notice that students tended to pick the easiest topics or choose content they feel more familiar with already which defeats the purpose of this intervention. While all topics were aligned with course materials, we believe it could be beneficial for the instructor to assign specific presentation topics to ensure a more balanced and comprehensive coverage of Unit 3 material.

Furthermore, the project could include more guided instruction on how to create the video that is more inline with teaching a lesson to the class instead of just presenting the material. We could include examples of sample video lessons from instructors as exemplars for students to follow. With the correct permission and with identifying information removed, we might also consider providing examples of previous student work.

In the next few years, we believe that the use of AI tools will increasingly become part of classrooms and offer new and innovative teaching and learning opportunities for teachers and students alike. Encouraged by our students' comments, we plan to continue research in this area exploring different ways in which AI tools can

increase student motivation, engagement, and above all learning.

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Evidence-based Behavior Support Programs and Interventions for Individuals with Disabilities

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Abstract: The author shares evidence-based interventions and behavior support strategies for individuals with disabilities to empower teachers, staff, students, and parents in school and classroom settings. The goal is to assist teachers, staff, and students to increase appropriate behaviors for individuals with disabilities. Highlighted programs include: Positive Behavior Intervention and Support (PBIS), Social and Emotional Learning (SEL) and the Collaborative for Academic, Social, and Emotional Learning (CASEL) Framework, Restorative Practices and SEL Alignment, and Multi-Systemic Therapy (MST). All interventions discussed in this article are evidence-based. Each of the programs, strategies, and techniques were vetted and are supported with research. Each of these systems of interventions will be detailed individually, and discussed holistically as to how they work in conjunction with each other. In addition, each of the evidence-based behavior support programs discussed in this article have been systematically implemented, in Pre-K through 12th grade classrooms, with validity in a large school district in the Southeastern United States. The team approach used in this school district will be shared in this article and includes the collaboration and coordination of a behavior liaison, behavior support teachers, behavior support assistants, special education teachers, general education teachers, students, and other resources. Throughout implementation of these programs, positive district data have been collected to track improvements in disciplinary referrals, teacher satisfaction, and annual student test scores.

Keywords: education, individuals with disabilities, classroom management, behavior management, social emotional learning

Citation: Voytecki, K. S. (2025). Evidence-based behavior support programs and interventions for individuals with disabilities. In V. Akerson, H. Polat, & A. Tekin (Eds.), *Proceedings of IConSES 2025—International Conference on Social and Education Sciences* (pp. 67–76). ISTES.

Introduction

It is critical for educators, both pre-service and in-service, to be effectively prepared with classroom and behavior management techniques. Negative and inappropriate student behaviors have increased during the post-COVID timeframe (Akomodi, 2025; Lane et al. 2025; Sun et al., 2022). Student behavior impacts the learning of that particular student and the learning of her/his peers around them (Akomodi, 2025). In addition to cognitive development, there is currently an emphasis placed on students' social and emotional well-being (Bai et al., 2024). Social-emotional learning is critical to foster students' academic and personal growth (Belay & Dejene, 2024).

Oftentimes, beginning teachers leave the profession due to classroom management and student behavior issues (Brandenburg et al., 2025; Reinke et al., 2025). In addition, educators with high self-efficacy in classroom management report lower rates of teacher burnout (Reinke et al., 2025). It is imperative for education professionals, who are required to foster student learning and social emotional well-being in students, to lead with social emotional competence (Gimbert et al., 2023). Parents are often seeking advice for how to reduce inappropriate behaviors with their children with disabilities. Community members are frequently caught off guard and are unsure how to react when an individual with a disability displays unexpected behaviors in public. The author will share evidence-based interventions and behavior support strategies to empower teachers, staff, and administrators in classroom and school settings. One goal is to increase appropriate behaviors for individuals with disabilities. Other goals are to maintain positive, appropriate behaviors to keep students in the classroom and prevent out-of-school suspensions.

The main evidence-based behavioral support interventions to be focused on include: Positive Behavior Intervention and Support (PBIS), Social and Emotional Learning (SEL) and the Collaborative for Academic, Social, and Emotional Learning (CASEL) Framework, Restorative Practices and SEL Alignment, and Multi-Systemic Therapy (MST). PBIS creates a positive learning environment through defining, teaching, and reinforcing appropriate behaviors. SEL assists individuals with obtaining knowledge, skills, and attitude for living a mentally healthy lifestyle. CASEL framework emphasizes five core competencies: self-awareness, self-management, social awareness, relationship skills, and responsible decision-making. Restorative Practices fosters accountability and self-discipline, while building trust and positive relationships. MST takes into account family, peers, school, and community to address the root causes of delinquent and antisocial behavior for long-lasting change. Each of the programs, strategies, and techniques were vetted and supported with research.

These evidence-based programs have been implemented, in Pre-K through 12th grade classrooms, in a large school district in the Southeastern United States. District data have been collected to track improvements in disciplinary referrals, teacher satisfaction and annual student test scores. The author will share multiple evidence-based practices to assist with reducing inappropriate behaviors for individuals with disabilities. Furthermore, the author will provide information to allow for analysis of current situations and settings for the reader to transfer the information and determine which behavior support strategy(ies) to employ. Finally, the author will explain validated implementation for behavior support practices to ensure preparedness to enact strategies.

Evidence-based Interventions and Behavior Support Strategies

Evidence-based class management interventions and behavior support strategies are shared to empower teachers, staff, and administrators in classroom and school settings. The use of evidence-based class management interventions and behavior support programs accomplish many goals. These strategies have demonstrated effectiveness in promoting appropriate behaviors among individuals with disabilities. By fostering the consistent maintenance of these positive behaviors, the programs help ensure students remain in the classroom and reduce

the likelihood of out-of-school suspensions.

Featured Programs

It is essential to utilize programming that promotes social emotional well-being. This article will focus on five evidence-based programs known to promote social emotional health in students with disabilities, students from marginalized populations, and general education students. These programs include: Positive Behavior Intervention and Support (PBIS); Social and Emotional Learning (SEL) and the Collaborative for Academic, Social, and Emotional Learning (CASEL) Framework; Restorative Practices; Social Emotional Learning (SEL) Alignment; and Multi-Systemic Therapy (MST).

Positive Behavior Intervention and Support (PBIS)

Positive Behavior Intervention and Support (PBIS) creates a positive learning environment through defining, teaching, and reinforcing appropriate behaviors. PBIS is implemented school-wide. When applied consistently and with fidelity, PBIS leads to notable improvements in school climate and disciplinary practices. Schools that implement PBIS experience environments that are positive, welcoming, and motivating. Discipline procedures become more uniform, and there is a storng focus on acknowledging and reinforcing appropriate student behaviors (Lawrence et al., 2022). PBIS has been shown to be effective with significantly improving students' prosocial behaviors and the overall climate of the school (Karlberg et al., 2024). When implemented simultaneously with validity and fidelity, Multi-tiered System of Support (MTSS) and Positive Behavior Intervention and Support (PBIS) prove to have positive outcomes for students, educational professionals, and school systems (Turner, 2023).

Utilizing a menu of evidence-based supports, PBIS is based on a tiered pyramid system of needs. At the bottom base of the pyramid, serving 75 – 90% of all students, the focus is on universal supports. It is implemented school/class-wide using equitable, culturally response systems of support. The approach emphasizes fostering peer relationships and applying progressive strategies to address behavioral challenges. At this level, the second phase of Social and Emotional Learning (SEL) is implemented, alongside the use of evidence-based classroom management techniques and the integration of Restorative Practices. The middle portion of the pyramid is utilized for selected students with more advanced challenges and needs, including at-risk students being served in this tier. 10 – 25% of students respond favorably in this system tier.

A range of classroom and small group strategies are utilized. These include targeted social skills instruction in small groups, the use of behavior contracts, specific academic interventions tailored to student needs, and the implementation of restorative dialogues. The top tier is reserved for the high-risk students who require the most intensive individual interventions. 3 – 5% of students need this most intense level. Behavior plans, based on Functional Behavior Assessments (FBA), are implemented and individual counseling is provided. It is important

to note that students may transition between tiers depending on their evolving needs and challenges.

Special considerations may need to be applied when using PBIS with students with disabilities. To ensure inclusive practices, modifications may be required. For instance, it may be essential to utilize individualized strategies with Tier 1 supports. Also, it may be necessary to employ data-driven decision-making in order to promote equity in behavior support systems (Meyer et al., 2021).

Social and Emotional Learning (SEL)

Social and Emotional Learning (SEL) assists individuals with obtaining knowledge, skills, and attitude for living a mentally healthy lifestyle. Research has shown that SEL positively influences academic performance in general education settings (Bai et al., 2024). It enhances students' academic outcomes, emotional well-being, and engagement in classroom activities. SEL contributes to the development of students' social emotional skills, attitudes, prosocial behaviors, peer relationships, school climate, and overall academic success. Additionally, effective implementation of SEL is associated with reductions in emotional distress and externalizing behaviors. Universal social and emotional learning have been found to be beneficial across diverse student subgroups, indeed even proving greater results for some racially marginalized subgroups. This may be a potential solution to utilize evidence-based programs, such as this one, to promote equity in student outcomes and reduce existing subgroup discipline and social and emotional learning growth disparities (Lee et al., 2023).

Social and Emotional Learning (SEL) is centralized around five competence cluster categories. The focus of SEL circles around the core of these competencies: self-management, self-awareness, responsible decision-making, relationship skills, and social awareness. All of these competency clusters work independently of each other, as well as influence each other.

Another aspect of SEL is a focus on transformative social and emotional learning. This perspective places an emphasis on equity, community issues, and social justice. In order to achieve transformative social and emotional learning, educators can focus on five key areas: connecting through language, connecting to students' social identities, addressing social issues, encouraging civil engagement, and activism (McGovern et al., 2023).

In order to properly implement SEL, barriers must be overcome and addressed, including: educators' resistance to change, allocation of resources, and the need for training and professional development in the area of SEL (Martinez et al., 2024). There continues to be a need for students with disabilities to have more targeted interventions and additional professional developments and trainings for teachers who work with students with disabilities (Nanda et al., 2025). Imperetive in SEL utilization are the use of direct instruction for teaching relationship skills, responsible decision-making, and emotional regulation. To foster inclusivity for students with disabilities, it is essential to have program fidelity and contextual adaptation (Shi & Cheung, 2024). There remains a crucial need for inclusive and culturally responsive social emotional learning implementation, particularly for students with disabilities and marginalized populations (Cipriano et al., 2023).

Collaborative for Academic, Social, and Emotional Learning (CASEL)

The Collabortive for Academic, Social, and Emotional Learning (CASEL) is one of the most widely recognized social and emotional learning (SEL) frameworks (Frye et al., 2022). CASEL emphasizes five core competencies: self-awareness, self-management, social awareness, relationship skills, and responsible decision-making. Each of these five core competencies influence, and are influenced by, the individual, the classroom, the school, their families and caregivers, and their community. With proper implementation, CASEL can increase students' psychological and physiological well-being and assist with the needs and challenges experienced by at-risk youth, resulting in increased academic and life success outcomes of adolescents (Simmon, 2024). CASEL is employed to inform state Social and Emotional Learning (SEL) standards. CASEL is also utilized to facilitate educators' social and emotional learning methods (Frye et al., 2022). With CASEL, there is interrelatedness of social and emotional learning components, with social awareness at times rising as the most significant indicator (Belay & Dejene, 2024).

It is important to note that many of the current instruments utilized to implement CASEL lack accessibility and cultural responsiveness. Therefore, there is a need for inclusive tools that can assess the social emotional learning of students with disabilities, based on the CASEL framework (Martinez-Yarxa et al., 2023). It is essential to adapt CASEL social and emotional learning frameworks to match the cultural and educational realities of students' environments (Belay & Dejen, 2024).

The CASEL framework is used to assess educators' social and emotional learning competence. As a direct result, with understanding their own social and emotional learning, educators can thereby improve their educational practices and support of school-wide social and emotional learning initiatives to attain positive school improvement outcomes (Gimbert et al., 2023). There are notable gaps in social and emotional learning training, in relation to the CASEL framework. Professional development for education professionals utilizing CASEL is recommended to focus on the guiding principles of modeling positive behaviors, sustaining healthy relationships, and engaging in reflective practice (Gimbert et al., 2023).

Restorative Practices

Restorative Practices foster accountability and self-discipline while building trust and positive relationships. Restorative Practices are guided by six core principles: building strong relationships between educators and students; reducing, preventing, and addressing harmful behaviors; repairing harm and restoring positive connections; resolving conflicts constructively; promoting accountability among individuals and groups; and identifying and addressing the needs of the school community. Goals of Restorative Practices include: building peer relationships, promoting prosocial skills, developing appropriate behavior skills, and utilizing conflict resolution to enact dramatic culture changes within educational systems (Moran et al., 2024).

Implementing Restorative Practices has been shown to enhance students' empathy, self-awreness, and

relationship-building skills (Garnett et al., 2022). Positive outcomes include improved classroom climate and increased student voice. These practices have demonstrated effectiveness in improving disciplinary outcomes, school climate, and academic performance (Proctor-Legg, 2025). Schools that adopt Restorative Practices report statistically significant reductions in disciplinary incidents (Gregory et al., 2022), along with notable decreases in out-of school suspension rates for students with prior suspensions (Huang et al., 2023). Many urban districts use Restorative Practices to reduce suspensions and address disparities in racial discipline procedures (Dhaliwal et al., 2023).

There are many factors that contribute to educators' successful implementation of Restorative Practices. These include having adequate time, maintaining a positive attitude, and possessing successful beliefs about the practice and potential outcomes (Dhaliwal et al., 2023). Other key consideration include the symbiotic relationships between teachers, students, and school staff; school context; educators' experience levels; school policies; and available support structures being the impetus for creating an environment to promote Restorative Practices (Moran et al., 2024).

Notable challenges of Restorative Practices implmentation include initiative fatigue and equitable participation for students with disabilities and English as a second language learners (Garnett et al., 2022). Due to the complexity of valid Restorative Practices implementation and follow-through, there is a need for the use of multifaceted support approaches for educators and plans for overcoming the challenges and barriers with the innate daily time-consuming details of Restorative Practices (Joseph-McCatty & Hnilica, 2023). This may require changes in attitudes and school expectations, since facilitating restorative culture within school systems requires leadership support (Moran et al., 2024).

Multi-Systemic Therapy (MST)

Multi-Systemic Therapy (MST) addresses the underlying causes of delinquent and antisocial behavior by considering the interconnected influences of family, peers, school, and community. As a social ecological model, MST recognizes that each of the child's systems, including the child, caregivers, siblings, extended family, peers, neighborhood, school, provider agency, and broader community, interact and impact one another.

As an intensive systematic intervention, MST is employed to increase students' engagement in education (Clayton, 2024). Research results indicate that MST can result in significantly more mature outcomes of teenagers and young adults (Conroy et al., 2023). This leads to mature, positive future viewpoints and life accomplishments during the transition into adulthood (Conroy et al., 2023). MST has been shown to have effectiveness in reducing psychiatric hospitalizations and improving family functioning.

It is imperative that MST be implemented with fidelity amongst all groups of students. This includes students with disabiities and those from marginalized populations. Therefore, there is an essential need for MST's strategies to incorporate tools to promote diversity, equity, and inclusion (Lee, 2023).

Systematic Program Implementation

Each of the evidence-based behavior support programs discussed in this article have been systematically implemented, with validity, in Pre-K through 12th grade classrooms. Program utilization occurred in a large school district in the Southeastern United States. The team approach used in this school district included the collaboration and coordination of a behavior liaison, behavior support teachers, behavior support assistants, special education teachers, general education teachers, students and other resources.

District Data Collection

Throughout implementation of these programs, district data have been collected. The purpose of data collection and analysis is to track improvements in disciplinary referrals, teacher satisfaction, and annual student test scores. Although in its beginning stages of data collection and analysis, positive trends are being noted in all three data collection categories.

Conclusion

It is essential to foster social and emotional learning constructs by utilizing evidence-based educational strategies that factor in cultural and contextual considerations (Belay & Dejene, 2024). There is a critical necessity for social and emotional learning research to include the impacts of program design and implementation and its effects on marginalized and minoritized students (Cipriano & McCarthy, 2023). This study aims to fill in some of the research gaps related to social emotional learning and students with disabilities.

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Beyond the Algorithm: Predictive Learning Analytics in Higher Education

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Abstract: Predictive learning analytics (PLA) has been grounded as a tool for forecasting student performance, identifying at-risk learners, and supporting institutional decision-making processes in higher education. PLA enables universities to create early identification systems personalized for individual students so that failure can be prevented and timely support and interventions can be provided to those students. This study aims to explore influential PLA studies in higher education published since 2020 regarding research focus, methodological approaches, and reported outcomes. A scoping review was conducted using the databases of Scopus and Web of Science. At the initial screening, 1,853 records were obtained, and the criteria for inclusion and exclusion based on the research design narrowed the dataset to 112 studies. To reveal the influential PLA studies in higher education since 2020, a citation threshold was applied, and 21 studies were included to explore research questions. The results indicated that PLA studies generally relied on demographic and behavioral data, with an increasing focus on machine learning models. Beyond the algorithms used for PLA, pedagogical integration should be designed within predictive systems. Notably, PLA can move beyond technical accuracy and data mining towards evidence-based and student-centered learning and teaching practices in higher education.

Keywords: predictive learning analytics, predictive models, learning analytics, artificial intelligence, higher education

Citation: Fayda-Kinik, F. S. (2025). Beyond the algorithm: Predictive learning analytics in higher education. In V. Akerson, H. Polat, & A. Tekin (Eds.), *Proceedings of IConSES 2025—International Conference on Social and Education Sciences* (pp. 77–88). ISTES.

Introduction

Emerged as a transformative approach in higher education (HE), predictive learning analytics (PLA) uses data analytics and machine learning (ML) to forecast student outcomes, identify at-risk individuals, detect distinct learning and engagement patterns, and guide timely interventions (Dwivedi et al., 2024; Herodotou, Naydenova et al., 2020). Since PLA offers a data-driven solution to personalized support and evidence-based decision-making (Al-Tameemi et al., 2020; Howell et al., 2018), it can help institutions face increasing pressure to improve student retention, learning outcomes, and equity. It can serve as a diagnostic tool and a mechanism for advancing proactive academic strategies. By detecting risks earlier, universities can design customized support measures, optimize learning environments, and allocate resources effectively. Therefore, PLA can contribute to a broader shift towards accountability and transparency in HE, where evidence derived from analytics can increasingly guide teaching practices, student support systems, and institutional governance (Ifenthaler & Yau, 2020).

PLA is widely recognized for its benefits in the HE literature. Predictive models can accurately identify patterns of student engagement and performance, thereby offering opportunities for early intervention (Bertolini et al., 2021; Riestra-Gonzalez et al., 2021). Through dashboards and automated alerts on learning management systems (LMS), PLA enables instructors to track learner progress in real time, which facilitates adaptive teaching strategies and personalized feedback (Kokoc & Altun, 2021; Susnjak et al., 2022). At the institutional level, predictive systems can guide administrators to allocate resources more effectively, monitor program quality, and improve retention rates (Herodotou, Rienties et al., 2020). By linking student data to strategic actions, PLA can enhance both the efficiency of teaching and the equity of outcomes, particularly when it is holistically embedded within student support services (Bulut et al., 2023; Howell et al., 2018).

Despite these benefits, the widespread adoption of PLA into HE systems may be limited due to some significant challenges. For instance, building effective predictive models can be technically complex in terms of balancing accuracy with interpretability (Bird et al., 2021). Ethical considerations can be regarded as another challenge, including issues of privacy, consent, and algorithmic bias, which may disproportionately affect vulnerable student groups (Jones et al., 2020; Li et al., 2022). Besides, many institutions have difficulties in turning predictive outputs into meaningful pedagogical practices due to a lack of faculty training and institutional readiness (Herodotou et al., 2021). Algorithms used for PLA have also limited interpretability and transparency in nature, which may weaken students' confidence in the institution (Marachi & Quill, 2020; Whitman, 2020). Such challenges can be overcome through the models combining technical innovation with pedagogical, ethical, and organizational considerations.

To design effective PLA in HE, it is essential to synthesize findings from recent influential studies. In the relevant literature, the potential of learning analytics has been mapped broadly regarding either technical aspects of modeling or ethical concerns; however, there is limited systematic evidence on how PLA research has progressed since 2020 in terms of focus, methodologies, and outcomes. This study contributes to addressing this gap by conducting a scoping review of highly cited PLA studies in HE published between 2020 and 2025. Specifically, it aims to explore the main research foci of influential PLA studies, the methodological approaches employed, and the outcomes reported. By mapping these dimensions, the study contributes to a more comprehensive understanding of PLA's role in HE and provides recommendations for future research and practice.

Methodology

Research Design

This study aims to explore influential PLA studies in HE published since 2020 regarding research focus, methodological approaches, and reported outcomes. A scoping review was conducted to investigate the following research questions (RQs):

RQ1. What are the main research foci of influential PLA studies in HE published since 2020?

RQ2. What methodological approaches are employed in these PLA studies?

RQ3. What outcomes are reported regarding the implications of PLA in HE contexts?

A scoping review aims to reveal an overview of a body of literature about a broad topic, including the stages of identifying RQs, selecting the relevant studies published, and summarizing the results (Arksey & O'Malley, 2005). Accordingly, the data sources were identified, and the relevant PLA studies were selected to investigate the RQs in terms of their research focus (RQ1), methodological approaches (RQ2), and research outcomes (RQ3).

Data Collection

To identify the eligible PLA studies in HE, the keywords for PLA and HE were specified, along with their equivalent meanings. A search string was formulated by using the Boolean operators. Scopus and Web of Science (WoS) were selected as the databases because of their range of quality papers indexed to obtain PLA studies in HE. The dataset was extracted in August 2025 from the databases. The process of identification and selection of PLA studies is depicted in Table 1.

Table 1. Identification and Selection Process of PLA Studies in HE

Stages	Scopus (n)	WoS (n)	Excluded (n)	Total Retained (n)
Initial screening	1,182	671	-	1,853
C1: Education research	367	87	1,399	454
C2: Publication range (2020-2025)	246	62	146	308
C3: Document type (journal articles)	140	58	110	198
C4: Language (English)	137	58	3	195
C5: Removal of duplicates (studies merged)	-	-	50	145
C6: Content check (relevance screening)	-	-	33	112
C7: Citation threshold (≥20 citations)	-	-	91	21

As presented in Table 1, 1,182 records were retrieved from Scopus and 671 records from WoS, resulting in a total of 1,853 studies at the initial screening stage. To refine the dataset, the inclusion criteria were applied. First, the studies were limited to the field of education and educational research (C1), which reduced the dataset to 367 studies in Scopus and 87 in WoS. Next, the publication date range was restricted to 2020-2025 (C2), which revealed 246 studies in Scopus and 62 in WoS. Applying the criterion of document type as journal articles (C3) further reduced the number of documents to 140 in Scopus and 58 in WoS. Limiting the language to English only (C4) resulted in 137 studies from Scopus and 58 studies from WoS. Then, the two databases were merged, 50 duplicates were removed (C5), and a content check for relevance was conducted (C6). 112 eligible studies remained in total. Finally, a citation threshold of 20 citations was applied to identify the most influential works (C7), and 21 studies were included in the final analysis.

Data Analysis

The studies retrieved from the databases were systematically analyzed through the screening and evaluation processes based on the inclusion criteria. After the duplicates were removed, a decision matrix was applied to evaluate each study to address the RQs. Each study was assessed for its scope, including the components of the HE context, predictive purpose, study designs, and outcome relevance. Then, citation counts were used as an indicator of influence, and only studies with more than 20 citations were retained in eligibility. After the final dataset was obtained (n=21), each study was analyzed and categorized to investigate the RQs in terms of research foci (RQ1), methodological approaches (RQ2), and research outcomes (RQ3). In this respect, the influential PLA studies in HE were comprehensively mapped within the thematic synthesis of this scoping review.

Results

Research Foci in PLA Studies in HE

To address RQ1, the eligible studies were categorized according to their main thematic foci. This classification revealed the diverse purposes for which PLA has been employed in HE, ranging from predictive accuracy of student outcomes to broader institutional and pedagogical applications. Table 2 summarizes the research foci, along with corresponding descriptions and representative studies.

Table 2. Research Foci of Influential PLA Studies in HE

Thematic Focus	Description	Representative Studies
Student performance	Predicting academic achievement, grades, or course success with demographic, behavioral, or engagement data	Al-Azawei & Al-Masoudy, 2020; Bertolini et al., 2021; Bulut et al., 2023; Chen & Cui, 2020; Okoye et al., 2024; Riestra-Gonzalez et al., 2021; Yakubu & Abubakar, 2022
Dropout and retention	Factors influencing student attrition, withdrawal risk, and retention through predictive modeling	Baneres et al., 2023; Bird et al., 2021; Herodotou, Naydenova et al. 2020; Herodotou et al., 2021
Engagement and learning behaviors	Patterns of student interaction and engagement in online or blended learning contexts, including behavioral traces (e.g., time-on-task, clicks, forum activity, dashboard use/design), as well as motivational and affective dimensions (e.g., task-value, anxiety, self-regulation)	Crawford et al., 2024; Herodotou, Rienties et al., 2020; Kokoc & Altun, 2021; Susnjak et al., 2022; Valle et al., 2021
Equity, access, and student agency	Identifying vulnerable learners or addressing digital inequalities in	Jones et al., 2020; Kezar et al., 2023; Li et al., 2022

Thematic Focus	Description	Representative Studies
	predictive systems	
Pedagogical and institutional applications	Integrating PLA into decision-making, course design, teaching practices, or policy implications	Bird et al., 2021; Bulut et al., 2023; Herodotou, Rienties et al., 2020; Jones et al., 2020; Kezar et al., 2023; Marachi & Quill, 2020; Susnjak et al., 2022; Whitman, 2020

As shown in Table 2, most studies focused on predicting student performance (e.g., Al-Azawei & Al-Masoudy, 2020; Bertolini et al., 2021; Chen & Cui, 2020; Yakubu & Abubakar, 2022) and dropout risk (e.g., Baneres et al., 2023; Bird et al., 2021; Herodotou et al., 2021) through behavioral and demographic data to estimate grades or course success, which reflects the central role of PLA in supporting academic achievement and retention. A smaller but notable group of studies investigated engagement and learning behaviors, using trace data to capture interaction patterns and motivational factors influencing online settings (Crawford et al., 2024; Herodotou, Rienties et al., 2020; Kokoc & Altun, 2021; Susnjak et al., 2022; Valle et al., 2021). More recent research has extended PLA to equity and agency issues, addressing disparities in data use and access (e.g., Kezar et al., 2023; Li et al., 2022). Finally, several studies examined pedagogical and institutional applications, emphasizing the use of predictive insights to guide teaching practices, course design, and policy development (e.g., Bulut et al., 2023; Jones et al., 2020; Marachi & Quill, 2020; Whitman, 2020).

Methodological Approaches in PLA Studies in HE

The methodological designs were analyzed across the influential studies to investigate RQ2. Accordingly, the results ranged from ML models to traditional statistical techniques, as well as qualitative and mixed-methods designs. A structured overview of these methodological approaches is organized in Table 3 along with sample sizes and representative studies.

Table 3. Methodological Approaches in Influential PLA Studies in HE

Approach	Description	Sample Size / Type	Representative Studies
Quantitative: ML models	Use of advanced predictive algorithms (e.g., classification, decision trees, neural networks, random forests, ensemble models) applied to educational datasets such as LMS logs, clickstream data, institutional records, or assessment results	Ranges from small (100+ students, single-course) to very large (5,000+ students, multi-course/ institutional) datasets	Al-Azawei & Al-Masoudy, 2020; Bertolini et al., 2021; Bird et al., 2021; Chen & Cui, 2020; Crawford et al., 2024; Kokoc & Altun, 2021; Okoye et al., 2024; Riestra-Gonzalez et al., 2021; Yakubu & Abubakar, 2022
Quantitative:	Logistic regression, correlation,	Small to medium	Bulut et al., 2023; Herodotou,

Approach	Description	Sample Size / Type	Representative Studies
Statistical models	experimental/quasi-experimental designs, and other traditional statistical models distinct from advanced ML	datasets (200-1,000 students)	Naydenova et al., 2020; Valle et al., 2021
Qualitative approaches	Conceptual, theoretical, or policy-oriented analyses of PLA adoption and implementation, including system design, ethical and institutional critiques, teacher and student perceptions, and evaluations of governance and policy frameworks	Institutional documents, program reports, faculty interviews, focus groups, and critical discourse analyses, critical ethnography	Jones et al., 2020; Susnjak et al., 2022; Marachi & Quill, 2020; Whitman, 2020
Approach	Description	Sample Size / Type	Representative Studies
Mixed-methods	Combined predictive modeling or other quantitative analyses with qualitative insights from interviews or open-ended survey responses, or case studies	100 to several thousand students; surveys, institutional data, interviews, observations	Baneres et al., 2023; Herodotou, Rienties et al., 2020; Herodotou et al., 2021; Kezar et al., 2023; Li et al., 2022

As presented in Table 3, ML methods dominated recent PLA research, which shows the field's reliance on advanced predictive algorithms for analyzing large-scale institutional and LMS data (e.g., Al-Azawei & Al-Masoudy, 2020; Chen & Cui, 2020; Riestra-Gonzalez et al., 2021). However, statistical models remained common, especially in medium-sized studies where interpretability is prioritized (e.g., Bulut et al., 2023; Herodotou, Naydenova et al., 2020). Mixed-methods designs have become increasingly visible, which combine predictive models with qualitative inquiry to better contextualize findings (e.g., Herodotou, Rienties et al., 2020; Kezar et al., 2023; Li et al., 2022). In contrast, qualitative studies played a critical role in scrutinizing ethical, social, and policy implications, often problematizing data use in HE (e.g., Jones et al., 2020; Susnjak et al., 2022; Marachi & Quill, 2020; Whitman, 2020).

Research Outcomes in PLA Studies in HE

The reported outcomes of PLA studies were analyzed to explore RQ3. The categorization of outcomes demonstrated both technical and pedagogical contributions of PLA in HE. These categories are listed in Table 4 with their descriptions and representative studies. Table 4 illustrates a consistent pattern across the studies, including four main outcomes revealed from the 21 eligible PLA studies in HE. First, many studies reported solid

model performance, typically high accuracy, and supported the practicality of early risk detection in course and program contexts (Al-Azawei & Al-Masoudy, 2020; Bertolini et al., 2021; Bird et al., 2021; Bulut et al., 2023; Chen & Cui, 2020; Kokoc & Altun, 2021; Okoye et al., 2024; Riestra-Gonzalez et al., 2021; Yakubu & Abubakar, 2022). Second, multiple studies moved beyond scores to illuminate how students learn, such as time-use, interaction patterns, and dashboard engagement routinely emerging as meaningful predictors, and several works tied these traces to motivation and anxiety (Crawford et al., 2024; Herodotou, Naydenova et al., 2020; Herodotou et al., 2021; Kokoc & Altun, 2021; Valle et al., 2021). Third, only a subset of research was directly evaluated who were at risk and when, but those demonstrated actionable identification windows for targeted support (Baneres et al., 2023; Chen & Cui, 2020). Finally, the implications for teaching and governance, including formative assessment design, student-support practices, staff engagement, and institutional policy, were found as recurrent themes, alongside warnings about consent, fairness, and oversight (Bird et al., 2021; Bulut et al., 2023; Herodotou, Rienties et al., 2020; Jones et al., 2020; Kezar et al., 2023; Li et al., 2022; Marachi & Quill, 2020; Susnjak et al., 2022; Whitman, 2020; Valle et al., 2021).

Table 4. Main Outcomes of Influential PLA Studies in HE

Outcome Category	Description	Representative Studies
Accuracy and effectiveness of models	Reporting strong predictive performance (accuracy, precision, recall) and showing feasibility of early identification	Al-Azawei & Al-Masoudy, 2020; Bertolini et al., 2021; Bird et al., 2021; Bulut et al., 2023; Chen & Cui, 2020; Kokoc & Altun, 2021; Okoye et al., 2024; Riestra-Gonzalez et al., 2021; Yakubu & Abubakar, 2022
Insights into student behaviors	Providing evidence of engagement patterns, time, use, and activity types as significant predictors of success	Crawford et al., 2024; Herodotou, Naydenova et al., 2020; Herodotou et al., 2021; Kokoc & Altun, 2021; Valle et al., 2021
Identification of at-risk learners	Highlighting predictive indicators for vulnerable students and enabling targeted support strategies	Baneres et al., 2023; Chen & Cui, 2020
Outcome Category	Description	Representative Studies
Pedagogical and institutional implications	Demonstrating how PLA can support teaching practices, curriculum design, student support services, and faculty engagement, whereas shaping broader institutional strategies, governance, policy-making, and ethical guidelines for data use	Bird et al., 2021; Bulut et al., 2023; Herodotou, Rienties et al., 2020; Jones et al., 2020; Kezar et al., 2023; Li et al., 2022; Marachi & Quill, 2020; Susnjak et al., 2022; Whitman, 2020; Valle et al., 2021

Discussion

In this scoping review, the influential PLA studies were investigated within the HE context since 2020 in terms of their thematic foci, methodological designs, and research outcomes. Regarding the research themes, prediction of academic performance and persistence still dominated the field, with models estimating grades or completion from demographic and behavioral traces (e.g., Al-Azawei & Al-Masoudy, 2020; Bertolini et al., 2021; Bird et al., 2021). Besides, engagement studies examined how students use digital environments, how often they consult dashboards, the rhythm of their clicks, and when they access materials, and related these behaviors to achievement (Kokoc & Altun, 2021) and to affective outcomes such as statistics anxiety (Valle et al., 2021). In parallel, equity and student agency were explored by documenting uneven consent to analytics and differential trust in institutions (Li et al., 2022) and by describing program designs that tailor support for minoritized students (Kezar et al., 2023). These shifts reflect longstanding arguments that learning analytics should advance inclusive, ethical practice rather than only prediction (Ifenthaler & Schumacher, 2016).

Methodologically, ML approaches were frequently adopted by exploiting large LMS and institutional datasets (e.g., Chen & Cui, 2020; Okoye et al., 2024; Riestra-Gonzalez et al., 2021). Even though these models performed well, comparative evidence showed that rankings and risk labels can vary across modeling choices, which underlines the need for transparency and stability checks (Bird et al., 2021). Traditionally designed statistical models were prominently selected where interpretability and smaller samples matter, particularly in regression studies that combine predictive factors with course or program context (Bulut et al., 2023; Herodotou, Naydenova et al., 2020). Mixed-methods approaches were increasingly used to contextualize predictions within educational practices by combining modeling with surveys or interviews to understand why patterns occur and how staff act on them (Herodotou, Rienties et al., 2020; Kezar et al., 2023; Li et al., 2022). Notably, the variety of methodological designs employed in the influential PLA studies in HE suggests a growing field that balances performance with explanation and use.

Regarding the reported outcomes across the influential PLA studies, predictive accuracy was generally strong, which supports the feasibility of early identification in HE settings (e.g., Al-Azawei & Al-Masoudy, 2020; Yakubu & Abubakar, 2022). However, the conversion of predictive signals into action was uneven. Only a subset of research explicitly tested intervention timing or impact (Baneres et al., 2023) and designed features with unintended effects; for example, task-value scaffolds embedded in dashboards had detrimental effects on learners and did not consistently improve outcomes (Valle et al., 2021). At the institutional level, beyond individual courses, PLA supported decision-making and staff engagement through large-scale deployments (Herodotou, Rienties et al., 2020). At the same time, governance-focused studies indicated obligations around consent, data sharing, and the risks of surveillance (Jones et al., 2020; Marachi & Quill, 2020).

Overall, PLA in HE has established technical feasibility and is moving toward questions of use, impact, and responsibility. The literature points to the priorities in combining predictive models with designs that specify who

acts, when, and with what evidence; preferring transparent, auditable modeling, particularly when predictions guide the allocation of student support; and embedding equity and privacy considerations from the outset, which acknowledges institutional responsibilities to students (Ifenthaler & Schumacher, 2016; Jones et al., 2020). In this respect, striking a balance between technical complexity and educational purpose is decisive for whether PLA meaningfully improves teaching practices and learning outcomes.

Conclusion

In this study, 21 influential PLA studies were synthesized within the HE context, published between 2020 and 2025. The results were categorized into their research foci, methodological approaches, and reported outcomes. Accordingly, although performance prediction and dropout analysis were found dominant, PLA research has progressively diversified into engagement, equity, and institutional applications. Methodologically, ML models predominated, but were increasingly complemented by statistical and mixed-methods designs. The overall outcomes indicated that PLA is technically viable and carries significant pedagogical and institutional implications. All these results contribute to a more comprehensive understanding of where PLA adds value, where its limits exist, and how future work should be organized.

In particular, designs combining effective prediction with timely, transparent action and governance frameworks that can protect equity and privacy while supporting effective instructional decision-making should be adopted in the HE context. Practically, tutoring protocols should be embedded into pedagogical implementations of PLA through interpretable indicators. Beyond algorithmic outputs, curriculum and assessment design should be aligned with PLA findings. Staff development should be provided on reading and acting on model outputs. Student dashboards within the LMS should preserve agency and consent. Institutions should run routine equity audits and error monitoring across subgroups, and impact evaluations that track whether predicted risks turn into improved learning and retention in HE.

This review has several limitations that shape its implications and recommendations. First, the corpus was restricted to journal articles indexed in Scopus and WoS, published in English, and filtered by a citation threshold. These choices can favor well-established works, English-speaking contexts, and earlier publications, and may underrepresent recent, lower-visibility, non-English, or practice-based studies. Moreover, several highly cited implementations originated from a small set of institutions, which may limit transferability to residential or hybrid settings. In light of these boundaries, future PLA studies should combine predictive modeling with explicit, theory-based actions and evaluate impacts using experimental, quasi-experimental, or strong observational designs, incorporate participatory methods with students and instructors to reveal contextual constraints and support adoption, conduct equity audits, including subgroup performance and consent dynamics, and compare interpretable statistical baselines with complex ML to justify added complexity relative to cost, governance demands, and instructional usefulness. These steps would improve rigor, ethical governance, and the practical value of PLA for teaching, student support, and institutional decision-making.

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Blueprint for AI-Powered, Code-Free Software Development: A Formula for Non-Technical Subject Matter Experts

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Abstract: This paper will present a simple walkthrough process for non-technical developers to develop the competence and confidence to build software in their respective fields to solve discipline-related problems. Experts in the human and social sciences often have unique ideas for software needed in their respective fields that would make their work easier and their time use more efficient. They have ideas that would make processes more streamlined, automated, easily replicable, and adaptable, with the ability to manage data at scale. This software could also increase interactivity, personalization, and visualization, with better and more interesting user experiences. However, these experts often lack the technical skills to bring these ideas to life because of their limitations in programming and writing software code. They often lack the resources it takes in terms of time and will in writing code or the dollars it takes to hire developers to transform their ideas into usable software products. There are also bureaucratic and institutional holdbacks to this. Thus, many are often disillusioned and challenged with how to bring their software build to life. The tendency is to abandon their unique idea and to assume that all is lost. At best, they often have to compromise their ideas, dropping aspects that they consider important, leaving in only what the "technicians" tell them is possible to build. With the technologies available today, and with the help of no-code platforms and AI technologies, it is now possible to realize ideas in our heads that were once thought impossible to execute in real life. The paper also discusses ways to increase software findability and trustability with ideas on marketing and distribution. The paper concludes that building software is absolutely doable by scholars in the human and social sciences.

Keywords: no code, low code, citizen developer, artificial intelligence, humanities

Citation: Epwene, B. (2025). Blueprint for AI-powered, code-free software development: A formula for non-technical subject matter experts. In V. Akerson, H. Polat, & A. Tekin (Eds.), *Proceedings of IConSES 2025—International Conference on Social and Education Sciences* (pp. 89–101). ISTES.

Background and Introduction

This paper will present a simple walkthrough process for non-technical Subject Matter Experts (SMEs) to develop the competence and confidence to build software for solving discipline-related problems in their respective fields. Subject Matter Experts in the human and social sciences often have unique ideas for software needed in their domains that could streamline and automate processes, making work easier and time use more efficient. Ideas for software that others in other disciplines might not know about or think much of in terms of importance.

Unfortunately, these subject matter experts cannot bring these ideas to life because they lack the technical knowledge in coding and programming know-how to transform those ideas into usable software products.

Often also, human and social science scholars find their software needs and ideas undermined in establishments, in favor of needs for those in areas considered more technical such as computer science or engineering. Sometimes, human and social science researchers have to go through lengthy processes and meetings with administrators and colleagues from technical departments before their ideas could see the light of day. To add, they often lack the money and budget to hire developers. For these reasons, they may never realize their ideas for software development.

The tendency at best is to listen to their technical colleagues tell them what's possible to build and then queue up in an endless timeline of waiting. Sometimes, they are forced to compromise by dropping aspects of their plan which they considered important, leaving in only what the "technicians" tell them is possible to build. Or, they rely on off the shelf solutions which may not adequately address their needs (Morgan, 2018). A study by Sage Publishing (n.d.) reveals that even though more than three quarters of humanities scholars and social science respondents to a survey agreed to have used software in their research and believe software is important or critical in their research, only 10% have developed their own (Duca, n.d.), most likely from lack of skills on how to develop software products. At worst, researchers abandon their ideas completely and never bring the build to life.

For these reasons, practitioners in the non-technical disciplines need to take matters into their own hands and build exactly the ideas that are in their heads to meet the needs that they have in their disciplines. This paper, therefore, suggests a streamlined approach to software development for scholars in the human and social sciences. It discusses and describes a simple and doable formula for non-technical developers to realize their software development dreams. The paper provides steps to consider in the build process, showing how it could take less time, money, and frustration to develop software with available tools and technologies today.

Technologies and Advantages Available Today

Fortunately, with the technologies available today, it has become possible and easy to bring ideas to life if practitioners know what to do. Specifically, the existence of no code-low code application development platforms powered by Artificial Intelligence technologies present tremendous opportunities for non technical, citizen developers to confidently enter the field of software development. It is now possible for subject matter experts to realize their ideas for software applications in forms that were once thought impossible to execute. With no code-low code platforms with Artificial Intelligence integrations, the lack of skills in coding and programming are no longer a barrier to one's ability to bring sophisticated software into existence, without writing a single line of code (Swinhoe, 2017; Waszkowski, 2019; Woo, 2020). Thus, this paper challenges humanities and social science scholars to imagine ways in which the content in their field and research materials they engage with could be prepared, codified, and reduced to forms that invite automation and application development, aligning practices

in the human and social sciences with the technological leap forward.

No Code-Low Code Platforms Defined

According to Elshan and Dickhaut (2023), low code and no code development platforms enable users to develop applications based on a graphical user interface without having to demonstrate competence with hard-coded programming techniques. The code, which is usually generated automatically, runs in the background (Elshan & Dickhaut, 2023). Rokis and Kirikova, 2022) elaborate that low-code platforms enable rapid translation of business requirements and development into applications and provide possibilities for quick adjustments as there is no need for extensive manual coding. This also leads to cost reductions and savings due to reduced time spent on the development cycle. Sahay et al. (2020) offer another perspective, "low-code development platforms (LCDPs) are easy to use visual environments that are being increasingly introduced and promoted by major IT players to permit citizen developers to build their software systems even if they lack a programming background. The advantages of no code builds have been discussed in several studies (Zavery, 2020; Waszkowski, 2019; Sahinaslan et al., 2021).

Subject Matter Experts (SMEs) as Citizen Developers

Subject Matter Experts engaged in building software on no code-low code platforms fit the designation of citizen developers. Binzer and Winkler (2022) describe citizen developers as non-IT employees who have no formal IT education, but possess great skills and in-depth knowledge in particular domains. Rokis and Kirikova (2022) and Waszkowski, (2019) further explain that this phenomenon of citizen software development on No code-low code platforms has already transformed software building in several fields. Rokis and Kirikova (2022) provide a catalogue of specialty fields where no code-low code has been used to transform work such as in agriculture, human resource management, ecommerce, social media, customer relationship management and entertainment among others, while Waszkowski (2019), describes the application of citizen development in automating business processes in manufacturing.

Yet even though the adoption of no code build and software use have flourished in other domains, it is still lagging in the human and social sciences. Collins et al., (2011) note that automation and upskilling in new technologies, particularly software development, is still not a foreground issue to many in the humanities and social sciences. While Struck (2018), echoes a similar sentiment observing that writing software has been and is increasingly a large part of scientific research but this has not been the case for research in the humanities and social sciences. To add, Chang (2017) laments that "in most other academic fields from physics to genetics, researchers rely on computers for everything from data analysis to modeling. But one area of scholarship that has gone largely untouched is the humanities" (Chang, 2017, Computational Tools). Thus software use and computation have been a mainstay in other domains but the use in the humanities and social sciences has been lagging. This paper makes the case that software development and use can also flourish in the human and social sciences too. It is time for

the human and social sciences to catch up and that responsibility falls on experts in these fields to lead that process.

A Cursory Literature Assessment

A review of selected literature in the no code-low code space concerning software development shows that discussions have mostly focused on the use of these platforms in building software applications for managing business processes such as project management, time and task tracking among other business uses (Waszkowski, 2019; Guthardt et al., 2024). Other discussions focus on the perceived limitations of the no code-low code platforms for software building, referring to challenges relating to interoperability, extensibility, and scalability issues (Rokis & Kirikova 2022). Other most discussed aspects concern security of the no code-low code platforms and potential problems for organizations as shadow IT departments may emerge across establishments with accompanying risks to systems that this might pose from a security stand point (Elshan & Dickhaut, 2023).

The literature also largely discusses the fact that low code-no code builds might only be good for single and specific tasks, for instance project management, time and task tracking or administration of devices (Guthardt et al., 2024). Little is found in the literature specific on code builds for use within the humanities and social sciences. Duca and Metzler (2019, 2020) catalog software use in the human and social sciences, in general but not specific about no code builds or at least that is not explicit in their study. Lastly, the literature mostly presents no code build steps strictly from a technical point of view beginning with design, development, testing, deployment and maintenance (Rokis and Kirikova, 2020). Instead of beginning with this typical build process which speaks more to technical elements, this paper takes a different approach, discussing the needs of the field first as the beginning phase of software development in the human and social sciences.

Step 1: Problem Identification

In considering developing software in the human and social sciences, it is important to spend time identifying a vexing problem which a software application can help resolve. Subject matter experts who are citizen developers are drawn to solution-seeking for a burning problem in their domain which they believe a computerized solution, automation and big data queries can help resolve. They know the field, they are experts. They know what is lacking and understand the pain points in their domain. Therefore, their software idea should help resolve a substantial problem in an area of expertise or introduce a new and better methodology of doing work. This step is crucial for development.

Education and experience in the subject matter area should serve experts well for this step. They have the knowledge and interest in the field and they want to see progress and advancement in their knowledge domain. It is thus important that they are clear about their software idea and the problem it will help resolve. Some pertinent questions to ask include: What discipline problem is the builder trying to solve? There is no point developing an application if it will not solve a particular humanistic or social science problem in a way that only software can

and for which no other software currently available does. Considering this question will also enhance adoption in the field because the necessity for the software tool will be obvious and essential.

Problem identification-Problem Solution also speaks to problems for which solutions would otherwise be too manual, too time consuming or too hard and repetitive, or too costly to investigate if done otherwise without the help of computation in the technological age. Or, it could be a problem for which there is just too much data to process otherwise. It could also be a problem which has been hard or difficult to solve with traditional research means. Some guiding questions here could be the following: What is it about your job or your field that entails manual, hard, time consuming, repetitive or complex tasks that software can resolve by automation? Is this a substantial problem you want to help resolve in your field?

According to Binzer & Winkler (2022), citizen developers can realize a multitude of advantages…first and foremost is that citizen developers are empowered to cut down routine work and tackle frequent pain points of daily work in their respective fields. Thus, think of creating software that tackles a pain point in your field, cutting down routine work. Gentzkow and Shapiro (2014), opine that software helps the researcher by introducing better ways to work so they spend less time wrestling with code and more time on the research problem. Today, there are several humanistic problems that software, powered by artificial intelligence can help resolve and it is up to researchers in those fields to find and explore those questions.

Whereas technical developers think design first (Rokis & Kirikova, 2022), subject matter experts in the human and social sciences think problem-solution first before technology. As experts they go first to the questions or problem to be solved instead of thinking design first, which would be the approach most technical builders will follow. Instead of asking “how do I design this platform,” human and social sciences researchers think first “how can I solve this problem” then “what would be the best approach or best tool to use for this.” Several researchers have listed the steps for no code tool creation. For strictly technical builders they look at a 5-6 step process starting with design, development, testing, deployment, and maintenance (ElBatanony & Succi, 2021; Rokis & Kirikova 2022). A human and social sciences researcher should start with problem-solution first before technology or platform in consonance with human centered design.

Critics of no code builds, erroneously, always point to the lack of ability of no code-low code builds to handle challenging and complex issues because of limitations in how they are configured. They also say that, given their backgrounds, citizen developers are mainly equipped for creating applications of low complexity for simple solutions and for personal use but not for solutions for use by others, organization-wide (Binzer & Winkler (2022, Guthardt et al., 2024). On the contrary, “interestingly…firms perceive application development on low code development platforms (LCDPs) still as complex tasks that require specialized skills (Binzer & Winkler, 2022). However, this argument of support for no code-low code builds, is not a call for developers to be abstruse for the sake of it but to really aim at solving a hard problem in their discipline. In fact, most software Minimum Viable Products (MVPs) focus on doing just one thing well. So developers in the human and social sciences should be serious about that one pain point they are trying to solve with their software build before they start.

Step 2: Identify Data Elements

The second step is also indispensable to application creation in the human and social sciences. The crucial issue for this step is to identify data elements in the problem you are trying to solve. What exactly are the types of data concerned? Images, text, audio files, videos etc.? Determine what you are trying to study or measure, the variables you want to observe or manipulate. Find elements that could be reduced to quantifiable data. What will the application track, save, multiply, keep? What can be added, counted, classified, grouped or listed. What is it that can be automated or analyzed etc.? These will be the elements to enter into the rows, columns, tables and databases of your software. They are data elements you or your software users input or which you will input via integrations, libraries, SDKs, tables and files from other sources. Most especially, think about how you can track and quantify, to make real those normative questions and qualitative, hard to quantify elements such as sentiments, ideas and feelings that are often tracked in the social and human sciences. This is tricky at times in the humanities and social sciences where things are hard to pin down with numbers. Your aim will be to set your application up for automation so there are replicative, repeatable patterns that a machine can learn to handle.

In the human and social sciences we mostly deal with unstructured data requiring extra processing to make it stable and usable for extracting insights. We deal with data at scale and we look at large quantities of information such as interview transcripts, social media posts and comments, whole novels, newspaper articles or material collected through oral research. One way to categorize such data is to draw from how humanistic research was done in the period before automation or computation. To help with identifying data elements for your software build, it may be helpful to think as a traditional researcher. Questions such as what elements would one study while doing traditional research should come to mind here. The developer must find a way to bring order in some sense to the data they intend to use. In short, you have to find ways to structure unstructured data. Find elements you can list, quantify, showcase and visualize etc. In poetry you can count verses, stanzas and meters, in writing we can count word classes, sentences, paragraphs. In literature we can list and count classes, themes, traits, words, chapters, pages, characteristics, categories of things and in interviews we can count themes, instances or measure time intervals.

The challenge then is to find ways to structure the data so it fits into rows, columns and tables to be machine readable and be capable for the application of elements of natural language processing (NLP). This is important because it starts to streamline the types of data to study, helping the builder to start narrowing down and focusing on elements that could be isolated and identified into categories, lists, themes, groups etc. before the design phase of the build. Data perception and creation in the humanities and social sciences is not as easy nor straightforward as it is in the hard sciences and this is where the next step, data codification comes in.

Step 3: Codify Your Data

Once data to be tracked is identified, it needs to be codified to make sense of it. Reduce your information to data

that makes sense. Create lists, pages categories, themes, numbers, patterns or some other recognizable structures or containers to hold data elements that a computer can recognize. Gentzkow and Shapiro (2014) shed some light on what data looks like in software creation. They say data is stored in rectangular arrays called tables and they refer to rows of tables as elements, and columns of tables as variables, in their study. The other consideration at the codification stage is to think about what laws, formulas, reasoning patterns or logic rules that can be created to bring order to the elements and variables chosen. Create those rules and relations for your data elements and apply formulas to create repeatable, recognizable patterns.

Be sure the data will be amenable to take simple logic structures and commands such as Booleans, And/Not, True/False elements and If/then/Else statements (Morrish, 2017) and be ready for relations and lookups which will eventually come in your build process. These will be helpful in creating the logic and relations for the application. It is also important to isolate and simplify these elements so responses, inputs and interactions are in the form of check boxes, radio buttons, Boolean choices and likert scale options. This will enhance your User Interface (UI) and the User Experience (UX) for the potential users. Designing this way also works well for the drag and drop, visual and graphical interfaces which permeate the low code-no code ecosystem.

Structuring your data this way also prepares your build to accept prepackaged and prebuilt systems and components such as libraries and AIPs through integrations. ElBatanony and Succi (2021) describe the basic building blocks of software tools. They write that the building blocks of software tools are made up of "systems" or "components" available in the form of libraries, integrations, APIs, SDKs, which other designers and developers can tap in to build and design what they want. Knowing that these packages exist eases up concerns about the learning curve for low code no code builders as these elements provide resources for building various elements within applications. Also, these days, with low code no code builds, you can write all the instructions in simple, direct and clear everyday English Language with absolutely no need to write code. Some guiding questions as you consider data elements for codification could be the following: Can data elements be reduced to lists, counts, categories, pages, lines etc.? It is important to also keep in mind that there are multiple ways that information could be reduced to data for quantification (Gentzkow & Shapiro, 2014).

Step 4: Choose Your Build Platform

Once all the above information is known and ready, build your software. Choose a platform to build on. Build an interactive, usable, and inviting user-friendly interface. Choose a no-code-low code build platform that will be best for the kind of software you want to build. In the no code space, there are a lot of options one can appropriate. It is up to the builder to find the best one for their build. (Rokis and Kirikova (2022) present 35 features that could help in comparing and selecting an appropriate build platform. The features cover such issues as graphical user interfaces, support of interoperability, security, opportunities for collaborative development, reusability possibilities, scalability, mechanisms to specify business logic among others. While Sahay et al. (2020), conscious of the conundrum that decision-makers have to choose among hundreds of heterogeneous platforms which are

difficult to evaluate without dedicated support, their study classifies no code low code systems to facilitate understanding and comparison of the platforms that can best accommodate a user's requirements. Rokis & Kirikova, (2022) also recommend that you automate all processes that can be automated so the platform needs as little maintenance as possible and runs almost on autopilot once launched. ElBatanony and Succi (2021) also endorse this idea with their "write once, run anywhere" approach.

Some no-code-low code platforms are basic, easy to learn and not powerful enough to do the types of computations that may be needed. One thing to consider before choosing a platform is the purpose of the build. Is it to build a quick MVP to prove a point or model an idea? If that is the immediate need, then a basic tool could be helpful to just brainstorm, prototype or model an idea. Sometimes a criticism of no code builds is that they are limiting in their flexibility of what you can build but that is also what gives them their power of speed in modeling ideas quickly. Quick builds to test ideas and MVPs for proof of concept could be an advantage sometimes. Rokis and Kirikova (2022) agree that nowadays agile methodology is a widely used approach, and its adoption is increasing. Also, applications that will do just basic tasks, say chat, categorize things or track just one thing, easy to build, simple applications could be the way to go (Guthardt et al., 2024). Therefore, though such platforms may not be computationally powerful, they still have a place for agile prototyping.

On the other hand, some other platforms are really hard to learn and may even require the ability to understand and be able to write pieces of code to achieve full functionality with them. These platforms are also powerful in computing, but the learning curve is steep to get really proficient in using them. However, once you start adding computations and relations and other elements to your build, you will realize that a basic platform is just that, basic. According to Pinho et al. (2022), Model-Driven Development (MDD) is a software development methodology that uses models as its primary development artefacts, raising abstraction levels, thereby enabling more sophisticated builds. These types of no code builds can handle complex relations, accept APIs, libraries and SDK packages. For this reason, Binzer & Winkler (2022) report that low code no code vendors vouch that creating applications on low code development platforms is still a complex task that requires specialized skills. That is the dilemma. If a platform is too basic, you could lose computing power and if too advanced the non-technical builder could get discouraged in the build process. Morgan (2018) writes that technology, even off the shelf, prepackaged tools are not always easy to use by default. Some take considerable time and effort to master.

There is a third category of no code-low code tools, perfectly midway between computing power and a more friendly learning curve. These offer stronger and adaptable performance as your future needs change. This higher tier no code-low code build platforms have the ability to adapt and integrate through the use of APIs, packages, libraries etc. for more complex applications. With these you can perform powerful relations within pages, columns and lookups to produce powerful results and account for those intricate variables studied within the human and social sciences. In these cases, the balance between learning curve and the power to execute higher end builds are matched. The tendency will be for you to want to do more things with your application in future. So, it is best to invest the time, the energy and even the money upfront and that returns dividends down the road. The downside is that if the platform is too complex for a start, the non-technical builder may be discouraged and not finish the

build assuming that it cannot be done.

Also, read reviews on user experiences since it can be hard for you to determine upfront how easy or hard a platform could be, and you do not want to spend time learning to use a platform which ends up not being suitable for your needs. Another helpful tip in the build process is to pay attention and work in the database area and get that to work smoothly before trying all the fancy things in the layout of the application interface. It will save countless hours of build headaches and frustrations. A word of caution to builders is that No coders must start by mastering one tool well, but oversimplification in tool selection and build can lend credence to the erroneous criticism that no code low code tools are only good for less complex builds (Guthardt et al., 2024). So, keep balance in mind.

The Power of AI Integration in No Code-Low Code Builds

Fortunately, these days with the power of AI integrations now, even basic platforms can become more powerful. You can query the AI algorithms to write prompts, create code, fetch meta data, create columns and relations, do mathematical computations and output results from input or even be agentic or predictive, things that were hard to do before by hand even on no code-low code platforms. Today, AI can even output code that you may edit and deploy, if you have the know-how. A technique known as vibe coding is on the rise, where you literally write or speak what you want, and the AI writes the code or even predesigns your output. Also, with the ability to integrate third party software and APIs to do parts that no single no code-low code platform can do, broadens the usefulness of no code tools and expands the reach of what they can do today. So, build an interactive and user-friendly interface with visual and graphical drag and drop components and automate, and your tool is ready for use today.

Step 5: Usability Testing, Feedback and Iteration

At this stage if you are satisfied with your build, then it is time to deploy the first trial version on a small scale. It is time to test whether the software meets users' expectations and is performing as expected. Gather feedback, learn, adjust and iterate. Next, send out a beta version to a small group of actual users for continuous testing. Find that segment of the population who will actually be using your software and watch them interact with it. Ask for a genuine assessment of the work you have done and if they believe they could actually adopt or even pay for your software in real life. Collect data, take feedback and iterate. Include features suggested if pertinent, implement lessons learned from observation, fix bugs, learn and improve. In case you get some negative feedback do not be discouraged. Consider it a learning process and ask the crucial follow up question to know why or what the platform would need to include or be able to do for users that could prompt adoption. After that, it is then time to conduct massive usability testing with an enlarged version of the primary target audience. This is no time to only ask your friends and well-wishers. Pinho et al, 2022, discusses the process of continuous refinement in the software development process by the continuous iteration of models of the desired application until the models become more refined…and the result starts taking the desired shape. Update, fix, retest and then redeploy.

Step 6: Plan for Discoverability, Adoption and Trustability

Prepare your tool for discoverability and findability. According to Barker et al. (2022), software discoverability and findability have been identified as problematic. They point out that there are "significant challenges to discoverability, productivity, quality, reproducibility, and sustainability" when it comes to software. They suggest that software built for discoverability should be searchable, indexable and have a plurality of accurate and relevant attributes with a globally unique identifier. They set some guidelines on what builders should do to make their software discoverable and findable. They are also clear that it is the developer's responsibility to make sure their software is findable and discoverable but also call for scholarly infrastructures to enable findability, Barker et al (2022).

Therefore, a group of SAGE researchers have taken up the task of indexing research software in the social sciences, mapping out the existing landscape for software discovery (Duca & Metzler, 2019, 2020). Their goal is to improve our knowledge about software in human and social science research, offering a classification system and providing guidance on how to make software discoverable by including specifications that could help in identifying existing solutions such as license numbers and also to also help avoid duplication. They comment that the lack of established repositories for research software makes it difficult to find existing software solutions, potentially resulting in the unnecessary duplication of development work. They also note that even when a tool (software tool) exists that could be suitable for a certain aspect of a social science research project, it can be difficult and time-consuming to find it. Many researchers don't know where to look, and some research papers don't provide details of the technical packages used Duca & Metzler, 2019, 2020. Their work identifies challenges, risks and new opportunities in research software publication and discovery.

As far as reliability, trustability and transparency goes researchers recommend that software builders be transparent and provide the ability to examine the source code so others can inspect it or even adapt it for their own builds (Schindler, 2020). Gruenpeter et al. (as cited in Barker et al., 2022) also add that software is a fundamental and vital part of research, especially when it provides the source code, files, algorithms, scripts, computational workflows, and executables that were created during the research process or for a research purpose. The ability to access these elements increase transparency and build trust for software build and enhances their adoption. Using software in research enhances transparency, believability, reproducibility and replication, all elements needed for veritable research and scientific work.

Step 7: Publishing, Distributing and Marketing Your Software

Once you ascertain with enough data that there are little to no fixes and no bugs on your software system, it is time to massively launch and deploy the first official version of your tool. Now that you have proffered a solution to a discipline-related problem, it is still not time to sit back satisfied yet. A full-blown marketing campaign should accompany your launch, not just listing on an app store, for instance. Go to where your target audiences are and

educate them about the availability and functionality of your application, what it costs, what it does, where to get or download it, share magic links etc. Be Ready to be entrepreneurial in your distribution and marketing plan. Think about scalability, the ability to massively amplify your tool adoption in the marketplace. This step needs you to pivot from being a researcher to embracing entrepreneurship. Promote the use of your tool. Seek commercialization opportunities at your university or other outlets and institutions which support entrepreneurship and entertain ideas of offering software as a service. Market and share your tool and even create a business around your platform.

Other Build Options: What Else Can You Do Today to Get the Software You Need?

Also, today, even if you cannot finally build the whole application yourself, there are agencies and consultants who can work with you for a small fee to finish and perfect your build or build the complete tool for a small investment. They can help with checking your connections, your relations, actions and columns and can help with AI integration or whatever part of your build is getting you stuck. So, with a little help you can still build your software idea. You only have to be really clear about what you are trying to build, figure out your data, your variables, your categories and lists and still produce your own software at a comfortable cost for any small or big scale business, personal budget or research project. At the very least, you can build an MVP to have something tangible to use as you discuss your ideas with potential collaborators or even investors. Have something that you can show, tell and test. This then can advance to the next stage where either funders give you money to run with your idea or just test your idea to see if it is viable and if you can get users to adopt it or even accept to pay for it before you make a bigger investment in time and money.

Conclusion

With patience and a little creativity and hard work these days, it is absolutely possible for subject matter experts in the human and social sciences to build the software tools they need for the work they do. By identifying a problem, isolating variables and trackable data, codifying their data and selecting a build platform, they can produce the tool they need, proceed to test it, iterate and distribute it by tapping into their entrepreneurial abilities, being conscious of building for discovery. They can also take advantage of newer methods such as vibe coding and artificial intelligence or hire freelance builders cheaply after producing MVPs (minimum viable products to illustrate their idea. It is totally possible today to accomplish no code or low code builds and release them into the world.

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Causation Pedagogy for Student Projects Using Molecular Dynamics and Finite Element Analysis Software Packages in Post-COVID Era

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Abstract: Cause and effect in causation theory is a center pillar in physics pedagogy in terms of understanding with the promotion of memory, especially in an open-admission community college with the DEI focus. The YouTube tutorial videos posted by Educational Centers as a delivery modality during the COVID Lockdown was found to be very helpful. For instance, the use of molecular dynamics and finite element analysis software packages was found to be a vital resource to support a variety of student projects in the context of biophysics and aerodynamics. The software packages of NAMD with CHARAM-GUI, LAMMPS, FEBio, ANSYS, OpenVSP, and OpenFOAM have been used as project contents at the level of operation steps in terms of skill learning in a specific topic. It is important to keep track of the various pedagogical aspects at different levels of cognition. On the one hand, a most obvious pedagogy would be the asking of students to use the shadowing pedagogy to analyze the result of a simulation posted by an expert role model on YouTube video to mimic an acquisition of an authentic analysis experience. On the other hand, a simulation objective relying on the what-if perspective would satisfy the critical thinking pedagogy. The verification of the simulation result by the experimental data could remain solely in the engineering realm with creativity as an objectivity in a pedagogy. The engineering verification examples could include protein folding data, wind tunnel data, etc. A straightforward extension to include a science perspective could be conducted in terms of causation in the understanding of the equations, without an absolute requirement of an understanding of the detailed math derivations used in the construction of a software package. Molecular dynamics and finite element analysis examples are illustrated with assessments. The online delivery and sustainability strategies in the post-COVID era are also discussed. Recommendations are presented.

Keywords: Cause and effect, molecular dynamics, finite element analysis, shadowing pedagogy, skill learning threshold

Citation: Dehipawala, S., Holden, T., & Cheung, T. (2025). Causation pedagogy for student projects using molecular dynamics and finite element analysis software packages in post-COVID era. In V. Akerson, H. Polat, & A. Tekin (Eds.), *Proceedings of IConSES 2025—International Conference on Social and Education Sciences* (pp. 102–113). ISTES.

Introduction

Current Situation Explanation

We are faculty members in Queensborough Community College (QCC) in New Your City. Our QCC College Now Program has been recruiting high school students to enroll in the physics research project class. We have been developing a pedagogy in molecular dynamics and finite element analysis to fulfill the demand of the high school students in research project class and community college students interested in the learning of computational skills.

Cause and effect in causation theory is a center pillar in physics pedagogy in terms of understanding with the promotion of memory. Learning would rewire the brain to encode the memory (Huganir, 2011). After another 10 years of further research, Huganir concluded that memory is all about the connections (Hopkins Medicine, 2021). A knowledge of the first semester physics in mechanics can be the first step for student projects in Queensborough Community College (QCC) with DEI focus and Outreach mission for high school students. The YouTube tutorial videos posted by Educational Centers as a delivery modality during the COVID Lockdown was found to be very helpful. For instance, the use of molecular dynamics and finite element analysis software packages was found to be a vital resource to support a variety of student projects in the context of biophysics and aerodynamics. The software packages of NAMD with CHARAM-GUI (NAMD, 2020), LAMMPS (LAMMPS, 2018), FEBio (FEBio, 2021), ANSYS (ANSYS, 2024), NASA Open Vehicle Sketch Pad OpenVSP (OpenVSP, 2024), and OpenFOAM (OpenFOAM, 2024) have been used as contents at the level of operation steps in terms of skill learning in a specific topic. We found that students with exact college goals usually would select specific-software focused projects with clear continuation opportunities in their perceived transfers to the senior college programs.

How to set the learning objectives? A set of clear objectives is needed in software package focused projects. Besides the first objective of the learning of a software package, there is an additional need for a science or engineering objective in a student research project. On the one hand, the study of complexity in a system would fit into a science objectivity in our experience. For instance, Shannon entropy in bioinformatics and molecular dynamics, Tsallis entropy in high energy scattering cross section data, etc. have been calculated in our student projects. Other measures of complexity such as fractal dimension calculation have been used as well. On the other hand, finite element analysis packages in biophysics and aerodynamics work on macroscopic objects. The functionality affected by parametric modification is an obvious engineering perspective. For instance, fluid throwing through a flap in FEBio, turbulence effect in the boundary layer of an airfoil using OpenFOAM, etc. beyond an explanation of the consistent Bernoulli's principle have been studied as student projects.

The two tiers, (1) parametric change investigation in skill learning and (2) complexity investigation in science or functionality modification in engineering would also satisfy the research project requirement of NYC Science Research Mentorship NYCSRM for high school students in our community college outreach mission. The

BrainWaves curriculum from UCONN uses EEG-based data to delivery an authentic research experience for high school students (UCONN 2022). They assess the positive results of authentic research experience in terms of self-efficacy in research, content knowledge strengthening, etc.

A transformation to course pedagogy is productivity. Short duration projects such as 2-week projects for extra credit in a calculus physics course have been found to be successful when using coupled differential equations in Brusselator investigation, profile extraction in Synchrotron Radiation data, MRI (magnetic resonance imaging) data, EEG (electroencephalogram) data, etc. Similarly, with the help of online molecular dynamics and finite element analysis tools without download can be delivered as short duration 2-week projects, especially for those knowing the FreeCAD software from their technology courses already (FreeCAD, 2024).

It is important to keep track of the various pedagogical aspects at different cognition levels. On the one hand, a most obvious pedagogy would be the asking of students to analyze the result of a simulation to mimic an authentic analysis experience. For instance, the result of a galaxy simulation could be treated as a given galaxy with real observational data for a correlation study of stellar mass and interstellar dust, without necessarily knowing the simulation procedure in detail. Similarly, the result of a molecular dynamics simulation would be used to study the diffusion across a cell membrane, without necessarily knowing the programming of a molecular dynamics software package in detail.

On the other hand, a simulation objective relying on the what-if perspective would satisfy the critical thinking pedagogy. The verification of the simulation result by the experimental data could remain solely in the engineering realm with creativity as an objectivity in a pedagogy. The engineering verification examples could include protein folding data, wind tunnel data, etc. A straightforward extension to include a science perspective could be conducted in terms of causation in the understanding of the equations, without an absolute requirement of an understanding of the detailed math derivations used in the construction of a software package. Molecular dynamics examples in protein folding and material phase transition, and finite element analysis examples in aerodynamics and biophysics are illustrated with assessments. The online delivery and sustainability strategies in the post-COVID era are also discussed. The rise of Causal AI would enhance the causation pedagogy when students are operators on software simulations as the basic learning deliverables.

Method

The Method Section first presents the shadowing pedagogy, in which the in-person modality and online modality were set at the same education values during the COVID Lockdown. In other words, the shadowing of a role model, either represented by an instructor in an in-person situation or by a respectable expert on YouTube video situation, is acceptable as a learning method. Then the Single-panel pedagogy for concise information delivery is discussed, follows by a presentation of the Tribunal discussion pedagogy for a group of three members, namely, a student, an instructor, and an expert. Last but not the least, the causation method is presented.

Method-1 Shadowing pedagogy

Shadowing pedagogy basically is the asking of a student to follow a role model in terms of software download and installation, simulation operation, and result interpretation. The what-if critical thinking can be implemented by tweaking a parameter value by 10%, for instance, with guidance from a faculty mentor to acquire an authentic research experience. As examples, QwikMD and Discovery Studio can be used to modify the input file as a research objective in molecular dynamics projects, while a numerical value of shift of 10% in the distance information in the pdb-format files can be used to guide the robustness of the simulation without further knowledge in the detailed residue interaction (QwikMD 2024). Matlab finite element analysis videos are good resources before diving into specific software packages like OpenFOAM, ANYST, FEBio, etc. The FreeCAD can be used to generate the stl-format files for Matlab PDE toolbox to solve partial differential equations numerically. Some YouTube links are listed in the Appendix for the interested readers,

Method-2 Single-panel pedagogy

A faculty has the duty of delivering inspiration and it is not easy to estimate the success rate when presenting a potential student project in Molecular Dynamics, Finite element analysis, etc. to potential students (such as New York State CSTEP students). Following the success of The New Yorker One/Single Panel Comics strategy, a faculty can abbreviate every video used in the shadowing pedagogy into a single panel for concise information delivery. The issue of a stuffed-curriculum has been tackled with a focus on threshold concepts in a less-is-more approach (Cousin, 2006, Nicola-Richmond et al., 2017). Similarly, a project could be stuffed with a vast amount of knowledge from a community college student perspective and a threshold of the skills to operate a software could be formulated and used to determine the assessment deliverables.

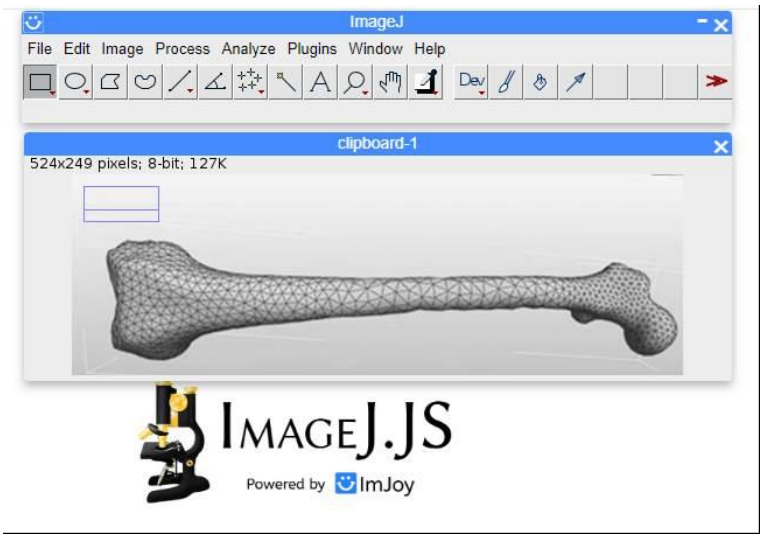

Figure 1. A single panel showing the mesh grid in finite element analysis of a bone structure, with boundary condition matches. The content was adapted from FEBio, Nonlinear finite element analysis in biomechanics and biophysics of Columbia University, using online ImageJ (https://www.youtube.com/watch?v=I3_PKL4x45g)

The single panel pedagogy would facilitate a quick determination of whether there is a reasonable success rate of aspiration induction. This is a crucial technique in our setting as there is only a few physics majors, compared to 500 students taking technology courses and 2,000 students taking biology course, and the learning skill threshold built on a single-panel (shown in Figure 1) was set at the mesh-grid manipulation in finite element analysis.

Method-3 Tribunal discussion pedagogy or AI assisted discussion pedagogy

The shadowing pedagogy could be transformed to a discussion based on three perspectives, namely, student, faculty mentor, and the expert role model. Another faculty member is asked to be the role model expert. AI could be used to represent the selected role model in a discussion with planned queries. An example follows. In a standard discussion of the MKS measurement system, a discussion of kilogram between a student and a faculty could include that of a faculty mentor saying "The kilogram in comparison is similar to a calibration-focused pedagogy in the delivery of the concept of mass for technician education". A third expert role model, YouTube authors or another faculty, could add that "The Newton's law of motion at the nano-gram molecular dynamics level, such as the blocking of vibration propagation of a protein structure using a drug molecule, is being scaled down from macroscopic vibration. The scaling down of kilogram to pico-gram level was shown to be correct in simulation confirmed by cryo- microscopy data". The tribunal discussion pedagogy is student focused with two professionals, an instructor, and a respectable role model represented by another faculty member or an AI. An instructor must be different from the role model to emphasize that plagiarism is not allowed.

Method-4 Causation pedagogy (with online tools without any downloads)

Molecular Dynamics /Finite Element analysis (MD/FEA) projects show cause and effect when parameter changes in the simulation steps.

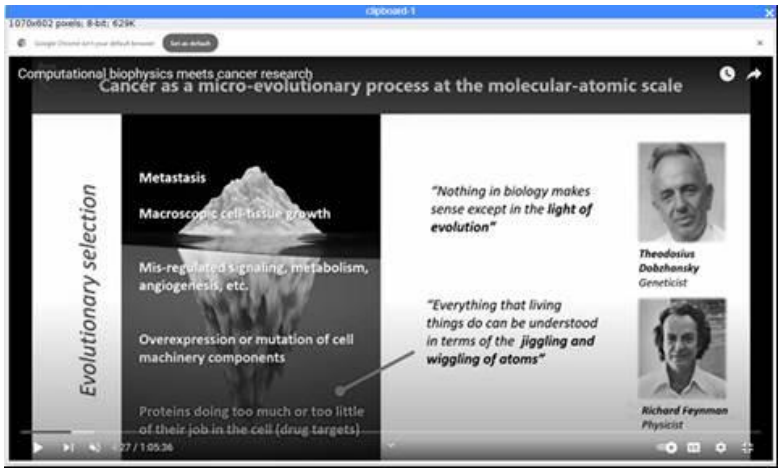

Figure 2. A single panel showing the protein cause at the tip of a funnel structure and the cell-tissue growth effect at the mouth pf the funnel structure. The context of Computational physics meets cancer research. 2024 was adapted using ImageJ. https://m.youtube.com/watch?v=CWO_3T8LGvo

Cause and effect would represent the mechanism of a simulation. The MD/FEA cause and effect examination is more demanding than just an examination of correlation effect between 2 data columns using a single parameter such as the coefficient of determination R-sq = 1 for perfect correlation. A single panel pedagogy showed the cause and effect concisely as the jigging and wiggling of atoms, according to Feynman, shown in Figure 2.

A single-panel pedagogy showed the analysis of the results of a simulation of a cell membrane. Cause from a force and effect of glycerol passage through membrane, shown in Figure 3.

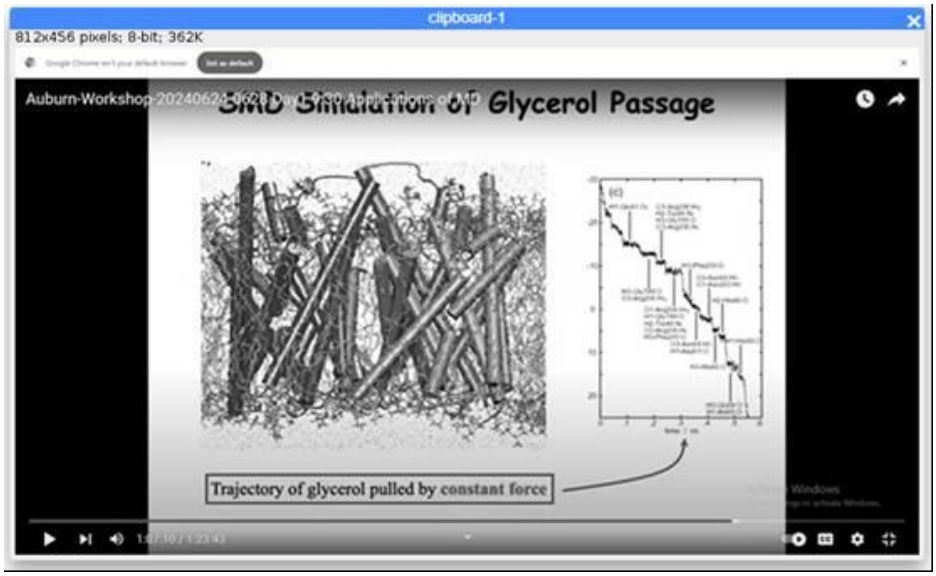

Figure 3. A single panel showing the result of a simulation with force as the cause and cell membrane crossing as the effect. The context of Auburn-Workshop-20240624-0628 Day1 9:30 Applications of MD was adapted using ImageJ. https://m.youtube.com/watch?v=lTvpLDHWGFY

Molecular dynamics simulations on petroleum science were also of interest to those students thinking about energy related careers. Some links on force filed formulas and software comparison are listed in the Appendix for the interested readers.

Online tools without any downloads were found to be suitable for the causation pedagogy when working in the short 2-week project situation. The traditional WebGro says that "(It) is a fully automated online tool for performing molecular dynamics simulation of macromolecules (proteins) alone or in complex with ligands (small molecules) University of Arkansas for Medical Sciences. https://simlab.uams.edu/index.php) The Molecular Dynamics on Web IRB Barcelona is also another popular online tool (https://mmb.irbbarcelona.org/MDWeb/). However, we used the more recent Visual Dynamics online tool with "A new approach in molecular dynamics simulations automation with GROMACS" (https://visualdynamics.fiocruz.br/en-US), explained in a publication (Vieira, et al. 2023). The best instructional tool for the first learning of a particle simulator was found to be the online simulator tool provided by Weber State University in our teaching experience (Schroeder, 2022).

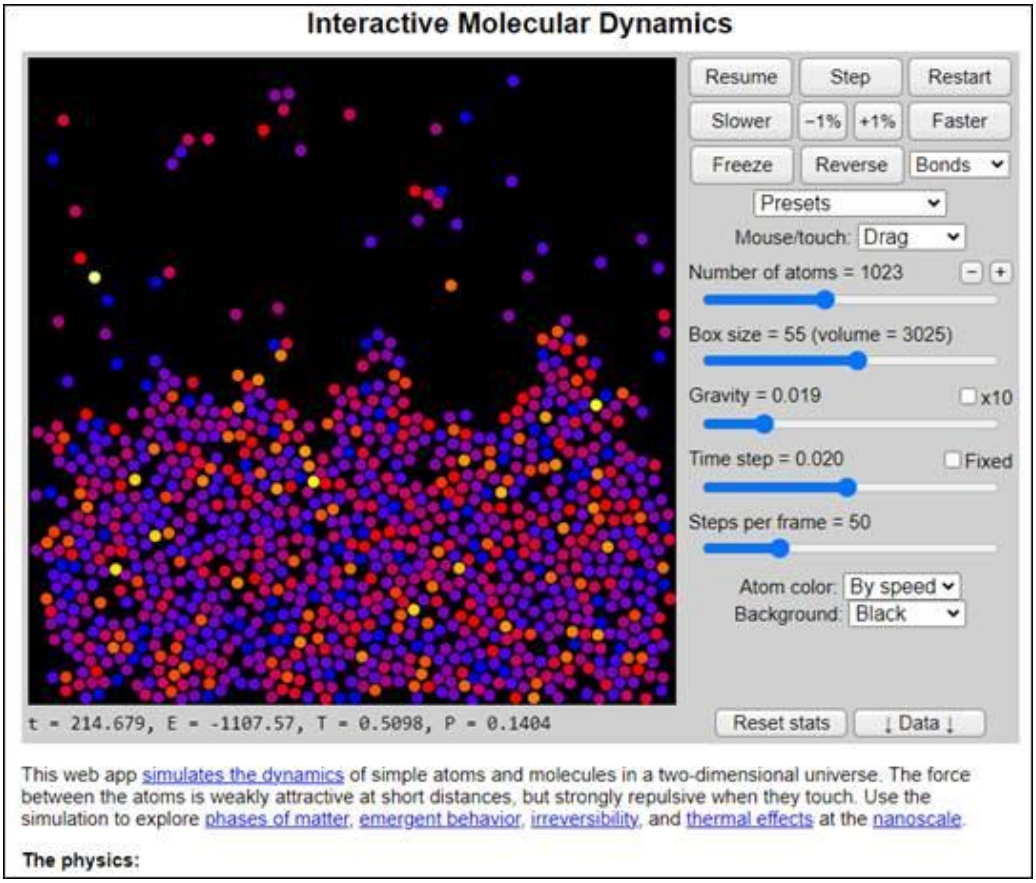

Figure 4. The Interactive Molecular Dynamics Simulator from Weber State University running at the displayed parameter values (https://physics.weber.edu/schroeder/md/).

The Matlab finite element analysis "Try this example" also have been used as online tool without any downloads. An illustration of a Poisson's equation example is shown in Figure 5, and of a MEMS device example is shown in Figure 6. The cause from using two different mesh grid sizes would result in two different simulation results (see Figure 6).

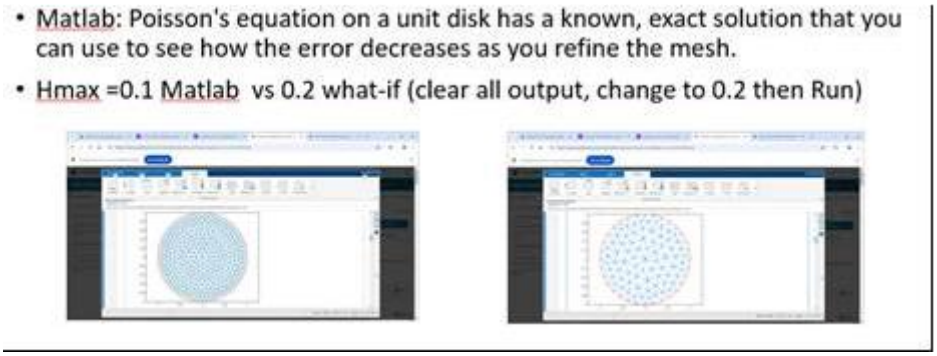

Figure 5. An illustration of the Matlab finite element analysis of a Poisson's equation example using two different mesh grid sizes, the results are too lengthy to be displayed here. Interested readers could perform the "do it yourself" actions at the website without download (https://www.mathworks.com/help/pde/ug/solve-poissons-equation-on-a-unit-disk.html).

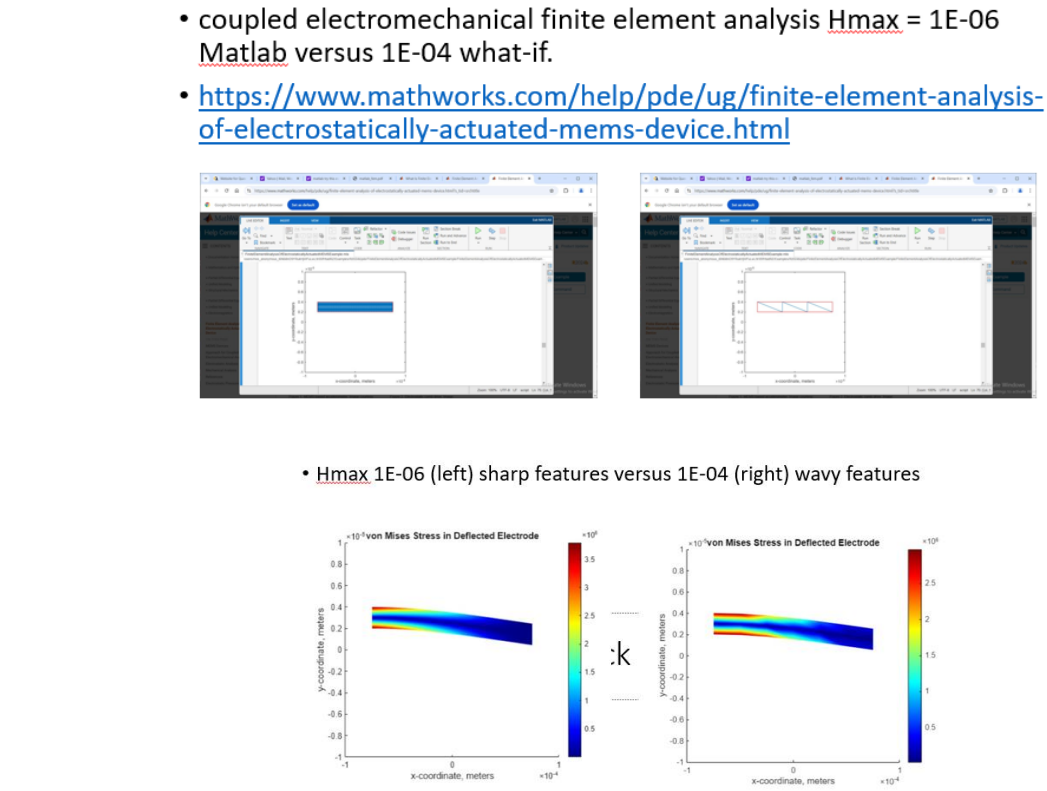

Figure 6. An illustration of the Matlab finite element analysis of a MEMS device example using two different mesh grid sizes shown in the top display. The results are shown in the bottom display. (https://www.mathworks.com/help/pde/ug/finite-element-analysis-of-electrostatically-actuated-mems-device.html).

A method to assess the understanding of causation follows. The free tutorial narration of a commercial product, FEATool Multiphysics Finite Element Analysis Toolbox, was used to generate the causation questions on the assessment of the finite element analysis related projects (https://www.featool.com/doc/tutorials). Although we cannot afford the subscription fee of $500 per FEATool Multiphysics user ($250 for only the Computational Fluid Dynamics Tool) in out pedagogy, the excellent organization of the free tutorial gives easy access to a mini review of the causation relationships in terms of physics laws. For instance, the narration of the Poison Equation with a Point Source section relates to the computation steps in the mesh grid to the physical laws and boundary values constraints (https://www.featool.com/doc/Classic_PDE_01b_poisson_point1)

Similarly, the tutorial narration of the UIUC Biophysics QwikMD Gateway for Easy Simulation was used to generate the causation questions in the assessment of molecular dynamics related projects. For instance, the sections on solvent models and protein structure utilize the Coulomb Electric force and quantum bonding (https://www.ks.uiuc.edu/Research/qwikmd/). For instance, a recent report on the allosteric signal mechanism of controlling the receptor-binding domain in SARS-CoV-2 (Boonserm, et al. 2024) was illustrated by a YouTube video. The classification of the Electric Dipoles effect and van der Waals effect as separated from the fundamental

Coulomb force (shown in Figure 7) could utilize the causation pedagogy to understand that some initial steps in a simulation may not be built from basic principles due to the lack of computer simulation capacity.

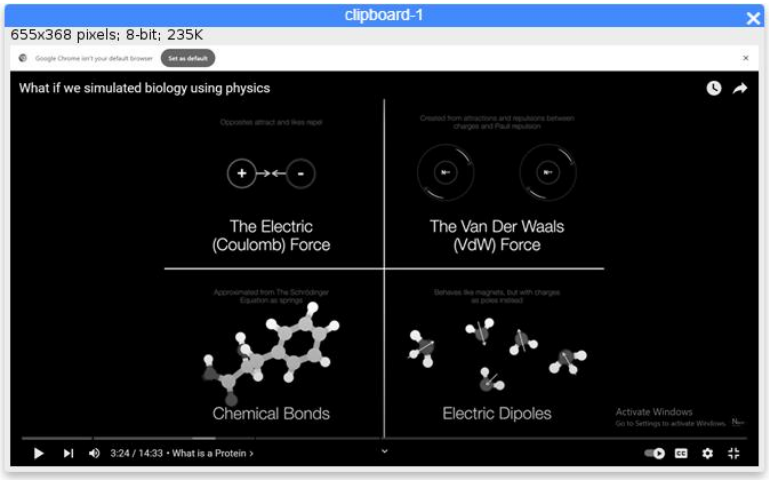

Figure 7. Forces in a molecular dynamics simulation to illustrate the effect of a drug in the blocking the vibration of a COVID receptor. The content was adapted from "What if we simulated biology using physics. NanoRooms" using ImageJ (https://www.youtube.com/watch?v=ncC-GMzF9RY)

Results of the Pedagogy

The causation pedagogy recruited 2 students on molecular dynamics projects. The pedagogy recruited zero student on finite element analysis project. The pedagogy recruited 3 assembling/building project students to add the finite element analysis as a supplemental learning objective.

The causation pedagogy of molecular dynamics was assessed to be useful for 4 pre-med students doing 2-week projects for extra credit in the Physics One Mechanics course.

The causation pedagogy of finite element analysis was assessed to be useful for 8 technology students doing short projects for extra credit in the Physics One Mechanics course.

One of the important results is the "peace of mind" for a faculty member when asked by students on extra credit opportunities. These opportunities include applications for the stipends in our scholarship research project program sponsored by the Queensborough Community College Administration. The implementation of projects with skill- learning is the very first step, and the molecular dynamics and finite element analysis simulations are among the most elementary projects in terms of operation of the software. The variety of topics offer the "peace of mind of a faculty mentor" because there is always a straight forward project to learn some computational skills for a student interested in software and its operation.

For the high school students recruited in the Outreach College Now research project class, the following patterns

were observed. We found that the demand of the high school students interested in life science shifted to medical physics projects when given a choice between medical physics imaging projects using ImageJ-Excel analysis or biophysics projects using molecular dynamics with software at the national level. The finite element analysis in aerodynamics projects were found to be of lesser interest when compared to the assembling/building projects among the high school students interested in engineering.

A "peace of mind" for a faculty member would be the fulfillment of serving as a community college professor in an R-1 university, classified by the Chancellor Office of City University of New York (CUNY). The offering of software packages calibrated at the national level would offer the status of "peace of mind" to the faculty members, when the ImageJ-Excel analysis of medical images on webpage commercials might not be accepted as research project class activity by other R-1 universities. We did develop research projects for the research class medical physics students in terms of matRad radiation therapy software written in Matlab (Wieser, et al. 2017) and Fréchet Inception distance (computed in Matlab or Python) in machine learning of medical image analysis (Deshpande, et al. 2024). However, only one high school student was recruited, so ImageJ and Excel were used as medical physics research project tools to meet the demand of the high school life science students. The availability of software projects in biophysics with relationship to medicine would offer "peace of mind" to us the faculty members in R-1 City University of New York, regardless of the choices of the high school life science students for medical physics or biophysics research projects.

The fulfillment of the DEI mission with causation pedagogy is obvious because of the ease of running a selected simulation software as an operator for every student with a high school diploma, similar to the requirement of being an operator when playing a selected computer game by an individual. The causation pedagogy starts the academic standards, and with some diligence and/or luck, a student may discover an unexpected simulation result and can advance the project to a research level, beyond the authentic experience in computational skill learning.

The "peace of mind of a mentor" also includes the stability factor in which the online delivery and mentorship are readily available when the Administration announces that there is a need for a lockdown. Although the "peace of mind of a mentor" was not substantiated with psychological data, we believe that our subjective observation of the causation pedagogy result is worthy of sharing with the interested readers.

Discussion and Conclusion

The transition of "a community college being a continuation from high school" to "a community college being a continuation to senior college" is an important mindset for the faculty mentors in a DEI focused community college for those students NOT in the AAS Degree Programs. Faculty members can offer authentic research experience to every interested student including the AAS Degree technology students. Therefore, there is a need to have a software learning objective when an assembling/building project fails due to the lack of time, unexpected budget increase, schedule changes, etc.

For instance, the finite element analysis of computational fluid dynamics can serve as a learning objective in a project of wind tunnel construction. In such a situation, an airfoil computational analysis could be an appropriate complementary learning objective using 15% time of the allocated project timeslots.

The causation pedagogy could be extended to AI driven simulation projects in the future, especially with the expected rise of Causal AI to accompany the current Large Language Model AI. The failure of the current AI on mathematical reasoning (using basic arithmetic steps) reported by Apple would further support the importance of using the causation pedagogy discussed above (Mirzadeh, et al. 2024)

The molecular dynamics and finite element analysis steps in research or skill learning projects could be made relatively simple for extra credit assignments in physics classes. The causation mechanism becomes an important pedagogy in the delivery of a higher cognition when compared to the pedagogy of using R-sq value in a correlational study of 2 data columns

Recommendations

Transformation of research project pedagogy to classroom pedagogy is a good practice in terms of molecular dynamics and finite element analysis projects being transformed to classroom-homework exercises.

Streamline a student research or skill-learning project for classroom pedagogy delivery would enhance the content knowledge and inspire students to initiate aspiration, especially with the free molecular dynamics and finite element analysis software packages.

The demand of the high school life science students for medical physics research projects could be replaced with biophysics research projects in the context of medical applications. The software packages in terms of the causation pedagogy are readily available for online delivery in the post-COVID era.

Acknowledgements

We thank those authors sharing their works on YouTube. We thank Alexei Kisselev and Arkadiy Portnoy for computer support. Partial support of NSF-REU is gratefully acknowledged.

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New York Election of 1808

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Abstract: From 1793 to 1815 France and Great Britain fought for global supremacy. Both nations seized American ships and cargoes enroute to each other's ports. Also, the British took American seamen off American vessels and forced them to serve in the British Navy. Many Americans perceived the British assault on American neutral rights as an attack on American sovereignty and independence. Americans were further angered in June 1807 when a British warship fired on an American warship, Chesapeake, off the Virginia Capes killing three and wounding eighteen. While the British government apologized it refused to stop impressment or seizing cargoes and ships. Negotiations failed and President Thomas Jefferson asked Congress to declare an embargo to pressure the British into respecting American neutral rights. The embargo devastated the economy of New York, and it had a political impact. Republicans dominated New York since 1801, and Federalists reached their nadir in the 1807 elections. The embargo made foreign policy the major issue in state and congressional elections in 1808. While New York Republicans campaigned on support for the embargo and President Jefferson, Federalists attacked the embargo leading to significant gains in 1808 creating a political resurrection of the Federalists. Renewed political competition and the embargo brought voters to the polls increasing voter turnout. Foreign policy dominated New York politics from 1807 to 1815 and rearranged New York politics.

Keywords: embargo, New York, federalists, Jefferson, election

Citation: Strum, J. H. (2025). New York Election of 1808. In V. Akerson, H. Polat, & A. Tekin (Eds.), *Proceedings of IConSES 2025—International Conference on Social and Education Sciences* (pp. 114–123). ISTES.

Introduction

On April 19, 1808, President Thomas Jefferson declared the Lake Champlain region of New York and Vermont in the state of insurrection and authorized the use of troops to enforce the embargo law. Jefferson requested fellow Republican Governor Daniel Tompkins to call out the state's militia to stop the widespread smuggling in the North Country. President Jefferson planned to announce a second proclamation of insurrection to cover the region from the St. Lawrence River to Buffalo. Governor Tompkins persuaded Jefferson not to issue a second proclamation of insurrection because of the negative consequences implementation of the embargo had on New York. The embargo, starting in December 1807, led to an economic depression in New York City. Thousands of seamen, skilled mechanics, and unskilled laborers could not find work. By February, 5000 residents of the city received shelter in the Alms House or received daily rations form outdoor relief. Forty mercantile firms collapsed due to lack of foreign trade. Upstate farmers lost their foreign markets and resorted to widespread smuggling of farm

produce, cattle, sheep, potash, and pearl ash up Lake Champlain to Montreal, Similarly, in western New York from St. Lawrence County to Buffalo farmers smuggled their agricultural produce across Lake Ontario, St. Lawrence River, and Niagara River to Montreal. The embargo's impact emerged as the major issue in the 1808 state, local, and congressional elections. Out of loyalty to President Jefferson Republicans defended the embargo. Federalists used the embargo to appeal to the disaffected farmers and city residents suffering from the embargo to regain political relevance. A recharged Federalist Party became better organized in 1808 creating a competitive political environment that brought voters to the polls.

Campaign

Governor Daniel Tompkins kicked off the campaign in late January with a pro-embargo speech to the state legislature. Before presenting his address, the governor sent a draft to De Witt Clinton urging the New York City mayor to suggest any changes. (Tompkins to Clinton, 24 January 1808, Clinton Papers) Clinton recommended no changes. Tompkins condemned the British violations of American neutral rights. Replying to the pro-embargo speech, the Clintonian Republicancontrolled Assembly and State Senate gave their total support to the measures adopted by President Jefferson. Rejecting Federalist charges of French influence they rejected the charges of foreign influence. All Republicans, whether Lewisite (supporters of former Governor Morgan Lewis) or Clintonians voted for the pro-embargo resolution. (Assembly, 1808, 45-47)

During the 1808 campaign Republicans held public meetings throughout the state to mobilize public support for the embargo. Tammany, a New York City Republican organization, condemned European belligerents, but especially the British for trying to reduce the United States to colonial humiliation. At ward meetings and at a citywide Republican meeting at Martling's Tavern (home of Tammany) in April, New York City Republicans endorsed the embargo. Realizing the hostility of the residents of Columbia County to the embargo, Kinderhook Republicans shifted the responsibility to the belligerent behavior of the nations of Europe.

On 11 April, delegates from the Columbia County towns met at Hudson to nominate candidates for the Assembly, State Senate, and Congress. Columbia County Republicans emphasized one issue in their election address---foreign policy, evidence that foreign policy issues dominated state and local issues in New York from 1807-1815. Threatened by foreign and domestic foes, the national administration needed the support of all New Yorkers proclaimed Columbia County Republicans. Local Republicans stated their willingness to endure the difficulties of the embargo in order to support President Jefferson. Federalists who sought to undermine faith in the government were guilty of treason. Any form of dissent bordered on treason. All New Yorkers should show their unity and patriotism by supporting the embargo whatever the economic sacrifices it entailed. (Hudson *Bee*, 13-20 April 1808).

Equating republicanism with Republicanism, the party faithful in Columbia County denounced the enemies of republicanism who "aided the foreign invaders of our rights." (*Bee*, 13-20 April 1808) Denying the charge of French influence, Republicans attacked Great Britan for denying American neutral rights and undermining

American sovereignty. Coinciding with statewide Republican strategy, Columbia Republicans argued that the embargo remained the only alternative to war. Republican members of the state legislature made the same arguments to the voters. De Witt Clinton signed the appeal. Although Clintonians and Lewisites continued to contend for control of the state party, both factions publicly endorsed Jeffersonian foreign policy. (Samuel Mitchell to Catherine Mitchell, 9, 20 March, 29 April 1808, Mitchell Papers).

Fearing he embargo would lead to war Barent Gardenier urged the Federalists to create a public outcry against war in the state legislature. "to catch the public ear." (Gardenier to Rufus King, 28 January 1808, King Papers) Federalists introduced an amendment to the Assembly's reply to Governor Daniel Tompkins's speech assailing the embargo and Jefferson' s handling of Franco-American relations. Then on 28 March at an Albany meeting of the state's Federalists, the party adopted an election address extremely critical of the embargo. (*Address*, 1808) Only on one issue did the Federalists agree with the Republicans---American government was founded on public opinion. Underlying the bitter antagonism between Federalists and Republicans lay one shared belief---that the American government derived its powers from the people. The people in exercising their rights must meet in public to express their sentiments upon the conduct of their rulers.

The Federalist meeting adopted a state election address dealing almost solely with foreign policy. They warned "*our country is in danger.'* (Federal *Address.* 1808) They felt a moral duty to save the nation from the misery of the embargo and Republican misrule. "As soldiers of the Constitution," Federalists would remain alert "Centinels at their posts." (*Address)* The concept of declension dominated their thoughts and rhetoric. A once prosperous nation now stood "reduced to dull subsistence."(*Address)* A moral and economic decline took place under Jeffersonian rule. New York Federalists saw themselves as Jeremiahs trying to cleanse the nation of its political sins and return the New Israel to the path of political righteousness.

A meeting of Schenectady Federalists adopted resolutions and a report with the same themes as the state electoral address. They articulated in far greater detail the rights of citizens to dissent and throw out office holders who violated the public trust. The American government "was formed for the people, not the people for the government." When a government ceases to maintain the "safety, honor and welfare of the people," it loses its mandate to rule, and the people have the right to elect men who will fulfill these obligations. In the United States "all power emanates from the people." (*A Report.* 1808. 3-14) The Schenectady Federalist pamphlet represents the best example of Federalist Party rhetoric during the 1808 election campaign.

Schenectady's Federalists articulated a vision of the people's role in government remarkably similar to the Republicans. Many of the older Federalists clung to the concept of a speaking aristocracy and a silent democracy---deferential politics. Schenectady Federalists expressed a commitment to popular will and veneration of popular sovereignty. Older Federalists, especially John Jay and Gouverneur Morris, complained of the Republican tendency to court public opinion and flatter the multitude. Schenectady Federalists appeared just as willing to court public opinion suggesting a partial ideological difference between a new generation of Federalists and their older contemporaries. By encouraging the public to criticize government, participate in the political process, and

vote, Federalists speeded the democratization of New York's political structure. Federalist appeals contained a moralistic streak missing from Republican pronouncements. Schenectady Federalists should support '*able men---men of truth---who fear God and hate covetousness'."* (*A Report.* 1808) Their conception of the right to vote emphasized that God entrusted each citizen with the right to determine their rulers. This required voters to choose wisely because for he would eventually account to God. Turning Republican rhetoric on its head, Schenectady Federalists warned the odium of the embargo "would discredit the republican form of government" and drive the people into supporting the "first desperate adventurer to establish despotism" (*A Report.* 1808).

Reminding voters of the economic consequences of the embargo, Federalists claimed the law would ruin farmers by lowering the prices for agricultural goods. Dutchess and Ulster County Federalists approved resolutions condemning the embargo because it left farmers with "their hard earned produce a burthen on their hands." (*Kingston Ulster Gazette,* 5 January 1808) The embargo turned "smiling fields into deserts" (*Hudson Balance,* 5 January 1808) and brought economic ruin to the nation. "In the complaints and murmurs of our hardy seamen, our labouring poor, and their suffering families," Federalists charged, "we hear the evidence of dismay and alarm." (New York *Evening Post,* 11 April 1808).

Federalists viewed Jefferson as a visionary. Washington Iving emerged as the most humorous critic of President Jefferson. Irving, who campaigned for the Federalists in 1807, immortalized the President in his *History of New York.* William the Testy bears a stirring resemblance to Jefferson. In his work, Irving described as fond of 'philosophical and political experiments and prone to running the government of New York as he did the windmills---"by mere wind." (Irving, I, 194-198, 217) Taking a similar approach, Ulster County Federalists reminded voters that they suffered from the embargo because Jefferson sought "to test executive experiments." While Ulster Federalists lacked the wit of Irving, they stressed the same point---Jefferson made the people of the country endure the embargo because he wanted to play philosopher king (New York *Evening Post,* 26 March 1808).

During a speech before thousands of Federalists at Mechanic's Hall in New York City on 25th March, David B. Ogden, explained that Federalists perceived themselves as a persecuted minority in Republican controlled New York, "proscribed and trodden under foot by the Republicans." (New York *Evening Post,* 26 March 1808). Republicans treated Federalists worse than aliens, and showed more consideration for Irish immigrants than long time patriots and native-born Americans who formed the Federalist Party,

Political emotions ran high in Columbia County in April. Federalist Elisha Williams challenged future president Martin Van Buren to debate the embargo. To ensure a sympathetic audience Van Buren assembled party members from Claverack and Hudson to hear the debate. When Van Buren arrived with the Republican legion, Williams denied offering to debate Van Buren Then, Van Buren and his allies took control of meeting hall. Federalists regrouped in another part of the meeting hall and rejected Van Buren's call for a debate. Boasting about this minor confrontation, Van Buren told Republican political leader De Witt Clinton it proved "the Federalists feared a debate." (Van Buren to Clinton, 16 April 1808, Clinton Papers). During the first party system Federalists and

Republicans rarely met in a direct debate, and political meetings remained confined to the party faithful Members of the opposition came only to heckle or break up the meeting.

A typical incident took place on New York City in late April 1808 in a donnybrook between pro-Federalists sailors and Republicans. When Cadwallader Colden started an anti-embargo speech, Republican sailors drowned him out. In reaction to the "tumult and confusion" some Federalist sailors left the meeting hall, and the Republicans took it over passing pro-embargo resolutions. In retaliation, a mob of Federalists marched into the heavily Republican Sixth Ward carrying an American flag shouting "no Republicans, down with Jacobins.' (New York *Evening Post,* 26 April 1808; New York *American Citizen,* 28 April 1808).

Clearly the embargo dominated the campaign, and no local issue emerged. However, the embargo was a unique foreign policy issue with a direct impact on large numbers of voters. In spite of the divisions within Republican ranks and Vice-President George Clinton's dislike for the law, Republicans went into the election united in support of the President's policies. Seeing an opportunity, Federalists warned voters the embargo would lead to the imprisonment of farmers for debt "after seeing their property bid off for little…at sheriff's sale." (New York *Evening Post,* 20, 27 April 1808). Not only did Federalists seek to benefit from the discontent of voters, but they also blamed the President for seeking "to revenge on industrious farmers the insults [the administration]…had drawn on themselves by their partiality, their vain boasting and their arrogance." (Utica *Patriot,* 26 April 1808). Federalists bitterly attacked the embargo and President Jefferson, while picturing themselves as the champions of farmers, mechanics, and merchants. Going into the last weeks of the campaign Federalists optimistically predicted success. They hoped the embargo would lead to a resurrection of the Federalists. They believed the public rejected the embargo. "Time and the continued inconvenience, which all will feel, must and will work a change, "Federalist leader Rufus King believed in public sentiment. (King to Timothy Picke ring, 12 April 1808, Rufus King Papers). As the campaign drew to a close, Federalists expressed the same righteousness as they had at the start of the campaign. Even in private, Federalists justified their exertions, as John Wadsworth phrased it, "the reward is noble---the honor and respectability of our country." (Wadsworth to Wadsworth Wadsworth, 18 April 1808, Wadsworth Family Papers). Convinced of their righteousness, Federalists went to the polls in late April hoping voters kwould share their vision of political salvation.

Outcome and Results

The embargo proved the catalyst for a major change in the politics of New York leading to the re-emergence of the Federalist Party as the opposition political force in the state. Ever since their defeats in 1800-1801 the Federalists were reduced to a pale third force forced to choose between warring Republican factions. As a result of the 1808 election, Federalists jumped from twenty-four to forty-seven seats in the Assembly. After the 1806 elections, Federalists held only two of the state's seventeen Congressional seats. They picked up six additional seats in 1808.

Federalist majorities in the Assembly races in Albany and Oneida counties increased from 600 in 1807 to 1,300 in 1808 and from 150 in 1807 to 600 in 1808, respectively. Rensselaer, Madison, Greene, Kings, and Queens went Federalist. Schoharie County elected Federalists for the first time since 1799, and Montgomery elected Federalists for the first time in ten years. Several Republican counties reported sharp drop in Republican majorities. In Herkimer, Republicans dropped from a majority of 624 in 1807 to 204 in 1808. Otsego's Republican majority plummeted from 800 in 1807 to 200 in 1808. Alarmed at the results in Otsego, a county thought as safely Republican as Suffolk, led New York City Republican newspaper editor James Cheetham to wonder, "where will the mania stop." (New York *American Citizen,* 1 May 1808).

Contemporary observers attributed the Federalist gains to opposition to the embargo. Former Governor Morgan Lewis wrote to James Madison that he considered the "uncandid representations" of the embargo by Federalists as solely responsible for their increased representation in the Assembly. (Lewis to Madison, 16 May 1808). "The embargo and the idea of French influence produced a most extraordinary effect, " noted Martin Van Buren in his analysis to De Witt Clinton. (Van Buren to Clinton, 16 May 1808). Republicans in Columbia County voted Federalist hoping to obtain relief from the economic distress of the embargo according to Van Buren. The drop in Republican vote in Otsego and Washington counties, James Cheetham, argued came principally from the embargo. Solomon Southwick, another Republican leader and editor of the Albany *Register*, believed that the dislike for the embargo produced the Federalist gains in Montgomery, Rensselaer, and Herkimer counties.

While the sudden doubling of Federalist strength in the Assembly pleased Federalists, they expressed dismay at their failure to carry New York City. Comparing the votes for the state Senate and Assembly, editor William Coleman blamed the Irish. (New York *Evening Post,* 28 April-14 May 1808). An Albany Federalist editor reminded upstate voters of more than 10,000 Irish immigrants in the city. Federalists pinned their hopes in 1809 on farmers who would save the country from Jefferson and the embargo.

Two days of post-election rioting in New York City further incensed Federalists against the Irish. On 28 April 1808, a mob of six hundred Irish marched down the streets of the Sixth Ward chanting, "Kill the Federal scoundrel." Rioting on the night of 28 April led to the deaths of two men. Incensed, William Coleman attacked recently re-appointed Mayor De Witt Clinton for infectively dealing with the "mobs and murders in the city." Placing the responsibility for the riots on the Irish, Coleman criticized the Republicans for catering to "the tribe fresh from the bogs of Ireland." (New York *American Citizen,* 28 April to 14 May 1808). Hostility to the Irish immigrants to New York had been expressed by Federalists since the 1790s and by segments of the Republicans in New York City who despised the new immigrants. De Witt Clinton, however, became the first American politician to appeal and understand these new voters. A majority of the Irish voted for the Clintonian faction of the Republican Party as Clinton successfully channeled the Irish into local and state politics.

In the wake of the 1808 election, Federalists charged the Republicans with prostituting the electoral process by resorting to the use of illegal alien Irish votes. To substantiate the charge, editor William Coleman cited several instances of illegal Irish voting in the First and Eight Wards. Questioning how vigorously Republicans enforced

the state's election laws Federalist editors noted anyone could vote if they swore an oath, but this did not mean they produced evidence of their qualifications to vote. Also, Federalists accused Republicans of buying votes. Reports from Otsego County suggested that Jedediah Peck, the county loan officer and leader of the local Republicans, offered $1,000 loans to farmers for their votes. (Cooperstown *Otsego Herald,* 21 May 1808).

James Cheetham denied the charge of bribing voters but acknowledged the importance of the Irish vote for Republican victory in New York City. Counterattacking Cheetham accused the Federalists of buying the free African American vote. Cheetham denominated the Federalist ticket as the "African ticket," since free African Americans tended to vote Federalist, The ability of the Federalists to win over African Americans angered Republicans as much as Clinton's success with the Irish incensed Federalists. (New York *American Citizen,* 9 May, 1, 6 June 1808).

The results of the Congressional races also indicated the impact of the embargo upon the voters. Federalists reelected Barent Gardinier in the Ulster-Greene district and Killian K. Van Rensselaer won reelection with 65 percent of the vote in Albany-Schenectady. Previously Republican Dutchess provided a landslide for Federalist James Emott over his Republican rival Robert Johnson. The double district of Columbia, Rensselaer, and Washington counties elected Federalists Robert Le Roy Livingston and Herman Knickerbacker The Livingstons were a prominent landowning and political family split between Federalist and Republican leaders. In 1806 both Columbia and Rensselaer voted Republican, but both went 57 percent Federalist in 1808.

Schoharie and Montgomery counties voted Republican in 1806-07, but the embargo shifted voting behavior. Both counties voted Federalist for the Assembly, State Senate, and Congress electing Thomas Sammons to Congress over his Republican opponent John Herkimer, nephew if General Herkimer of Revolutionary War fame. The state named Herkimer County after him. Displeasure with the embargo proved more important in 1808 than relationship to a famous Revolutionary figure. Similarly, Thomas Gold, Federalist, defeated Republican Joshua Hathaway in the Madison-Oneida district. A Republican donnybrook in the southwestern district of Seneca-Cayuga—Steuben--Tioga counties between three Republicans allowed Federalist Vincent Matthews. a lawyer for the Holland Land Company, to win with a plurality of 41 percent (Albany *Gazette,* May-June 1808).

Republicans retained nine of the seventeen seats. In the Suffolk-Queens-King district Republicans almost threw away victory by nominating two candidates. However, physician Ebenezer Sage squeaked by with 39 percent to 38 percent for his Federalist challenger. To the surprise of the Federalists two Republicans Gurdon S. Mumford and Nathan Denning carried the New York-Richmond-Rockland district defeating Federalists Barent Gardenier and William Henderson. Internecine warfare within the Republican Party between different factions failed to aid the Federalists, While Federalists won a significant majority in Westchester, the Republican lead in Orange County enabled Republican Jonathan Fisk to win. In a by-election in Washington County to fill an unexpired seat, Republican Nathan Wilson won.

While Clinton and Franklin counties in the North Country near the Quebec border were in a virtual state of

insurrection against the embargo Republican John Thompson defeated Federalist William Bailey in the Saratoga-Essex-Clinton-Franklin district. Support for Republicans in Saratoga accounted for the Republican victory. Moss Kent won his home county St. Lawrence due to widespread smuggling across border, but Republican John Nicholson won the three other counties, Jefferson, Herkimer, and Lewis. In Brome County Federalists won 53 percent but Republican Uri Tracy received 84 percent in Onondaga and 82 percent in Chenango, two strongly Republican counties. In the westernmost district—Ontario-Allegany-Niagara-Genesee, Peter Porter, a prominent local Republican, easily won over Federalist Nathaniel Howell. By nominating two candidates in Otsego-Delaware, Federalists permitted Republican Erastus Root to defeat Gabriel North and Ebenezer Foote. None of the four Republicans who voted against the embargo in Congress were nominated by the Republicans to run again since party unity and support for the President demanded unanimous party loyalty.

In a few strongly Republican counties the embargo did not aid the Federalists in 1808. Every town in Rockland, Chenango, and Suffolk voted Republican. Even though the embargo hurt the economy of New York City, Republicans won 55 percent of the vote for Assembly and 56 percent for Congress. Only the upper middle class and middle class First, Second, and Third Wards went Federalist. Mechanics, artisans, and lower-class laborers clung to the Republicans. They carried two thirds of lower income voters who could only vote legally for Congress and Assembly, because New York electoral laws required higher property ownership to vote for Governor and State Senate. Public works sponsored by the city eased the effects of the embargo. New York's mechanics, artisans, and laborers had a history of nationalism dating to the Revolution that Republicans successfully tapped. Once again, the Anglo-American crisis led to their rallying around the national government. However, in parts of the Hudson Valley and Mohawk Valley farmers showed the greatest disposition to swing over to the Federalists because of their dependence on foreign markets for their surplus agricultural produce.

The embargo and political competition brought citizens to the polls. In the State Senate races, 57,000 (80 percent). Returns from New York City, western New York, and northern New York suggest flouting of the election laws for gubernatorial and senatorial voters. Over 100% of eligible voters cast ballots in New York City, Oneida, Genesee, Allegany, Jefferson and Ontario counties. Five of New York City's ten wards reported over 100% turnout. About 67 percent of the eligible Congressional voters went to the polls. There was not much difference in the voting behavior of gubernatorial voters and voters only eligible to vote for the Assembly and Congress. The significant exception was New York City where Federalists carried the Senate race but lost in the Assembly contests. If the Federalists had won the city they would have won control of the Assembly. This is why Federalists were so enraged against the Irish who they blamed for their loss.

Conclusion

Election returns indicate wide variation in voting not only between neighboring counties but also between towns in the same county. In Columbia County, for example, Hillsdale, the most solidly Republican town and center for anti-landlord agitation voted consistently against Livingston Manor. In Rensselaer County, the Patroon of the

Manor Stephn Van Rensselaer found his tenants in Petersburgh voted Republican while he led the Federalists in his county. This suggests in some counties older differences played a role in voting behavior. However, the counties with the highest voter turnout were those where the Federalists either won or put up a stiff challenge to the Republicans. The embargo restored political competition as Federalists grabbed for an opportunity to regain political power.

The results of the elections suggested to Federalist Henry Van Schaack of Kinderhook that New Yorkers had finally begun "to distinguish between their real friends and the harpies who have so long preyed upon their credulity." (Henry Van Schaack to Stephen Van Rensselaer, 2 May 1808). Another Federalist, Dirck Ten Broeck anticipated driving the Republicans from power, and placing "true American federal Patriots…in their stead." (Dirck Ten Broeck to Abraham Ten Broeck, 9 September 1808). While Republicans retained a majority in the Assembly and State Senate and won a majority of Congressional seats, they could no longer dismiss the Federalists as politically unimportant. Due to public opposition to the embargo, Federalists doubled their Assembly seats from twenty-four to forty-seven and increased their Congressional seats from two to eight. For the first time since 1800 Federalists won a State Senate seat. Even in many counties they did not win, especially Jefferson, Oswego, Herkimer, and Washington, Federalists seriously reduced the Republican majorities. They emerged from their political oblivion to establish a two-party system once again in New York.

What happened in New York was not unique. Hostility to the embargo boosted the Federalists in New Jersey, Delaware, Maryland, and New England. Federalist partially misunderstood their political comeback in New York. New Yorkers did not embrace Federalism; they cast their ballots against the embargo. Looking forward to 1809 Hency Van Schaack predicted we "shall do much better than we have now done." (Van Schaack to Van Rensselaer, 2 May 1808). The continuance of the embargo into 1809 proved his prediction true as the Federalists finally won control of the Assembly in 1809. Foreign policy dominated New York politics in 1808 because the embargo had a direct impact on many voters, especially farmers in upstate.

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Robotic Telescope Data Collection for Facilitation of Astronomy General Education Learning Outcomes in Fine-tuning and Consciousness Inquires in Post-COVID Era

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Abstract: The learning of the fine-tuning concept in Astronomy depends very much on the understanding of comparative magnitude in General Education (Gen-Ed), with a quantitative assessment of the uncertainty in a measurement. A robotic telescope with cooled camera technology inside an observatory is a versatile tool for learning Astronomy and Astrophysics in classroom environment with or without research projects. Our Community College, located in New York City, has an Outreach mission to include local high school student participants in our College Now program, with Observatory open evenings for parents and children in the community. An assessment discovered that the learning of the robustness concept could be a better alternative for the learning of the Astronomy fine-tuning concept, which is rooted in Astrophysics as a specific selection from infinite numeric possibilities using the content of Calculus. In other words, without the use of Calculus, what can we learn from the question of "Were the initial conditions of the Big Bang robust enough for life to emerge at high probability without further inputs along the multiple billion years of evolution?" The recent inquiry of consciousness in Astronomy and AI offers a natural extension of the fine-tuning contents. The pedagogy of the robotic telescope data collection on our campus in the post-COVID era has been supplemented with YouTube materials authored by the top universities and research centers, consistent with the shadowing pedagogy. The phenomenon-based pedagogy delivers the inspirational contents, while the model-based pedagogy enables those aspired students to continue Astronomy and/or Astrophysics in senior colleges. For instance, the multi-messenger astronomy proof of gold production mainly from the mergers of two neutron stars using the LIGO Gravitational Wave data, Fermi Spacecraft Gamma Ray Burst data and Skynet Robotic Telescope DLT40 Supernova data in

combination together has been delivered successfully to a group of Astronomy students in a cohort. The assessment of students' understanding with and without AI-assisted writing, application skills, and analysis software knowledge is presented in the context of Gen-Ed learning outcomes. The extensions to Astronomy and Astrophysics learning using Astrophotography, important in the Outreach mission and for the engineering physics majors, are discussed. Recommendations are presented.

Keywords: Robotic telescope, Multi-messenger Astronomy, Fine-tuning, Initial conditions robustness for life

Citation: Kisselev, A., Portnoy, A., Dehipawala, S., Holden, T. & Cheung, T. (2025). Robotic telescope data collection facilitation of Astronomy General Education learning outcomes in fine-tuning and consciousness inquires in post-COVID era. In V. Akerson, H. Polat, & A. Tekin (Eds.), *Proceedings of IConSES 2025—International Conference on Social and Education Sciences* (pp. 124–138). ISTES.

Introduction

Description of Current Situation

The introductory description consists of two parts, namely, the concepts of fine-tuning and consciousness in Astronomy, and the traditional pedagogies without the newly acquired robotic telescope. Interested high school teacher readers could go to the Recommendation section directly to determine the applicability in their local districts.

Fine-tuning and Consciousness concepts in Astronomy

The learning of the fine-tuning concept in Astronomy depends very much on the understanding of comparative magnitude in General Education (Gen-Ed), with a quantitative assessment of the uncertainty in a measurement. The learning of uncertainty in a data collection process is a fundamental Gen-ED outcome. It is a well-known fact that a robotic telescope with cooled camera technology inside an observatory is a versatile tool for learning Astronomy and Astrophysics in classroom environment with or without research projects. Our Community College, located in New York City, has an Outreach mission to include local high school student participants in our College Now program, with Observatory open evenings for parents and children and adults in the community.

From our assessment data, we discovered that the learning of the robustness concept could be a better alternative for the learning of the Astronomy fine-tuning concept, which is rooted in Astrophysics as a specific selection from the infinite numeric possibilities using the content of Calculus. In other words, without the use of Calculus, we can focus on what can we learn from the question of "Were the initial conditions of the Big Bang robust enough for life to emerge at high probability without further inputs along the multiple billion years of evolution?" The assessment results suggested that the studied students did not fully understand the application of uncertainty to the concept of range in physics, and thus misunderstood the fine-tuning issue in Astronomy.

The recent inquiry of consciousness in Astronomy and AI, posted as YouTube materials by respectable experts, offers a natural extension of the fine-tuning contents. The pedagogy of the robotic telescope data collection on our campus in the post-COVID era has been supplemented with YouTube materials authored by the top universities and research centers, consistent with the shadowing pedagogy we used in student projects, mirroring the shadowing of physicians for college students applying for medical schools in United States.

The phenomenon-based pedagogy delivers the inspirational contents, while the model-based pedagogy enables those aspired students to continue Astronomy and/or Astrophysics in senior colleges. For instance, the multi-messenger astronomy proof of gold production mainly from the mergers of two neutron stars using the LIGO Gravitational Wave data, Fermi Spacecraft Gamma Ray Burst data and Skynet Robotic Telescope DLT40 Supernova data in combination together has been delivered successfully to a group of Astronomy students in a cohort. The Skynet Robotic Telescope Network was able to connect the DLT40 Survey with GW 170817 (Reichart, 2019).

Traditional pedagogies

We use the MKS pedagogy to conceptualize the fine-tuning and consciousness inquires with numeric content, the Feedback mechanism pedagogy to quantify complexity in galactic evolution and the MMA pedagogy to demonstrate the current trend in Astronomy. The pedagogy to use single-panel as information tab organizer is also presented.

The MKS pedagogy basically deliver a fundamental description of the MKS measuring system. Meter in operation is for the in-between numeric representation. There are space separation, Big Bang event, and multiverse possibility which echoes the Leibniz saying of “we are in the best world of all possible worlds”, not that we use the Leibniz calculus method to replace the Newton calculus with graphic representation in physics classes.

Kilogram must be measured as in comparison, we do not know what inertia mass is in essence, but we have Mach's Principle that internal frame is affected by galaxy mass billion of light years away. There is no need to involve entanglement to hide our ignorance in classical physics, not to mention the mass gap problem in the 1 million dollars challenge together with the Naiver-Stokes equation and others.

Second is for time interval, about 14 billion years since the Big Bang event. We avoid the discussion of Father Time and not Mother Time and keep physics away from philosophy.

Together with a basic understanding of the MKS units in terms of astronomy issues, the standard pedagogy includes the topic of feedback mechanism in astronomy. A galactic ecosystem depends very much on the feedback mechanism, illustrated in Figure 1.

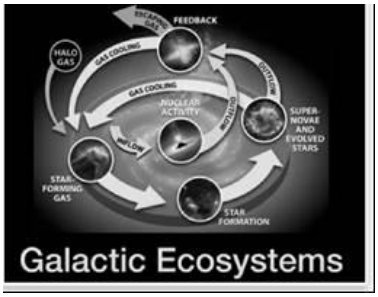

Figure 1. An illustration of the Galactic Ecosystems, adapted from Vivian U "Black Hole Feedback in Galaxy Mergers", https://www.youtube.com/watch?app=desktop&v=zcY5ufcPVpo , using ImageJ

With the wide usage of YouTube vides in the post COVID era, we found that the single-panel pedagogy, in which a single video frame is selected to represent the essence of a video, has been gaining importance in the helping of students to recall the content. For instance, a video explaining that the fast cold gas fuels star formation readily when compared to the turbulent slow cold gas can be summarized in a single panel, illustrated in Figure 2 (Kocjan, 2024).

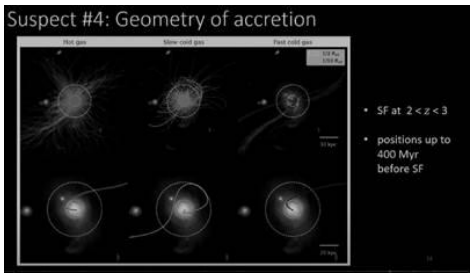

Figure 2. An illustration of the single panel pedagogy that hot gas fueled stars faster than cold gas, adapted from Harvard Zuzanna Kocjan's video, https://www.youtube.com/watch?app=desktop&v=xH76pFGgB8w, using ImageJ.

The Multi-Messenger Astronomy MMA pedagogy is consistent with the advances in robotic telescope equipped with spectral measurement. The MMA using the multi-wavelegth data to study the spectrum of gravitational eaves can be captured as a single panel for our students to recall the content, shown in Figure 3 (Liu, 2024)

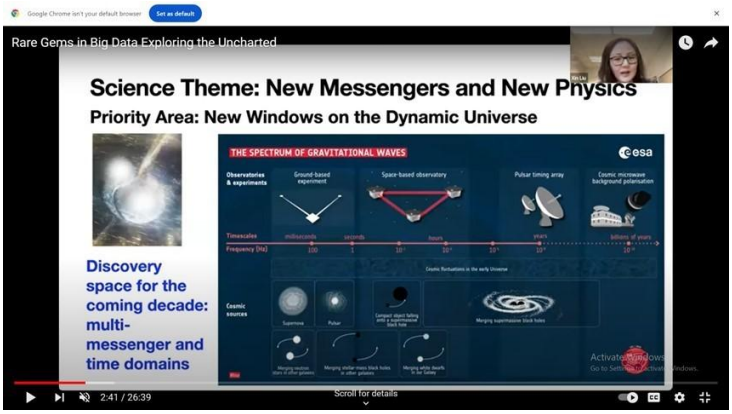

Figure 3. A single panel illustration of Multi-Messenger Astronomy, Rare Gems in Big Data Exploring the Uncharted, NSF NOIRLab Science. https://www.youtube.com/watch?app=desktop&v=3PxAgz6W8iY

Method

The Method Section first describes a pedagogy for the learning of numeracy in astrophotography beyond the artistic appreciation of images, then describes a pedagogy for an understanding of cosmology with numeracy, follows by a description of a pedagogy for the learning of what AI can do in astronomy in terms of numeracy. The combined three pedagogies provide a numeracy understanding of fine-tuning and consciousness in astronomy. Note that the popular image formats such as JPEG are used for teaching with calibration to the standard FITS mage format used in the research community in the analysis of NASA data, ESA data, etc.

Method-1 Astrophotography solar data pedagogy with data fluctuation and fine-tuning stability

The use astrophotography data for initial engagement was implemented. Phenomenon-based pedagogy was the first teaching principle. The data from (https://stellarium-web.org/) are compared with the robotic telescope images using numeracy of altitude in degrees, suitable for Outreach program observations with children, parents, etc.

At the college level, the astrophotography pedagogy consists of Image J analysis using the Solar Dynamics Observatory SDO image data to study a profile across a diameter, a histogram of a selected region, etc. The cross-correlation study of the solar brightness fluctuation with neutron monitoring station of solar particle effects (for instance the Neutron Monitoring Station in Athens) are included as exercises. The uncertainty of the imaging data in terms of arc-second resolution and Poisson counting error are also part of the exercises.

There is a need to prepare the students to go from uncertainty concept to fluctuation concept and then fine-tuning concept. The logical flow can be summarized as the following sequential concepts, namely, uncertainty, smallness, two nearly equal numbers, and fine tuning. A graph showing the solar half-diameter as a function of time relative to apparent noon has been used (Sofia, et al. 2013)

The following narration has been used to compliment the astrophotography pedagogy. First, a general narration was explained. (Start) A group of Fifth Graders were asked to plan for a birthday party at a budget level of 49 to 50 dollars. The budget fluctuation among the plans should be within 1 dollar such that the spending must be robust at (1 – 1/50) *100% = 98 % level. We can say that the spending must be fine-tuned at 98 % level, that is, the two numbers, spending amount and limit amount, are 98% equal in the fine-tuning of the expense. In other words, when X is asked to cancel Y, then X must be fine-tuned to match Y to a high percentage for a successful cancellation. Students using noise cancelling headphones would know that the cancelling mechanism using phase-shift and amplitude-match must be fine-tuned to the ambient noise at a high percentage for effective noise reduction. (End) Second, an astronomy specific narration wad explained, (Start) It was reported that the Sun's half-diameter values have a range from 959.4 to 959.9 arcsec over several hours of observation. The fluctuation percent = (difference / average) * 100 % = 0.05%. A stability of within 99.95 would be indicative of interior

regulated processes to maintain the robustness of the Sun's diameter within a duration of several hours in time. The Sun's diameter perhaps is an important parameter as a proxy for the Sun's stable energy output within a duration of several hours to support life stability on Earth (End). The above narration has been adapted with fill-in-blanks and delivered as a cloze test.

Another more advanced example of fine tuning using the concept of friction was offered to students interested in real life application. An object on an incline would be sliding down due the weight component along the incline. A robotic arm could be used to pull the object up along the incline. The friction could be in either up or down direction such that the robotic arm has a range of applied force values. The following narration has been used to build a cloze test test. (Start) For a slippery slope, let friction = 0.000001-Newton for an object at rest. Let the incline generate a weight component of 10-Newton downward along the incline. Therefore, a robotic arm must generate a 10-Newton plus or minus 0.000001-Newton, margin of error = 0.000001-Newton, one micro-Newton to keep the object at rest. A robotic arm supplying that applied force must be accurate at (1-0.000001/10) *100% = 99.99999%, that is 10-Newton at 99.99999% stability. The robotic arm must be fine-tuned to an accuracy level of 99.99999% to balance the 10-Newton Earth pulling (weight) when friction = 0.000001-Newton (End).

Two vastly different numbers can generate a small number when using the ratio concept of (x – y) / (x + y) for positive x and positive y. In other words, we are using the concept of "difference / average" in Physics 101 and Astronomy labs. Whether it is the sum or sum/2 (average) in the denominator is irrelevant in the application. If matter density was calculated to be x and the experiment showed y, then there must be a z somewhere to cancel the x to get y (x – z = y) for whatever z might be.

Let the matter density = ρ. The value of (ρ-expected minus ρ–cancelling)/(ρ-expected plus ρ–cancelling) is very small.

So, the fine-tuning is the near equality requirement that the ρ-expected must almost equal to the ρ-cancelling of an unknown mechanism (Helbig, 2023). The cancelling perspective triumphed at the success of the renormalization theory in quantum electrodynamics, and continues in the mindset of physicists.

The matter density calculated from experimental data using arithmetic steps, showed a value of about 10^-11 unit. However, the matter density calculated from quantum physics showed a value of 10^112 unit. Therefore, the canceling mechanism, details unknown at the moment, must be very precise to cancel the calculated 10^112 unit to get the experimental value of 10^-11 unit. The cancellation mechanism must be fine-tuned to a magnitude of 10^123. The infinite numeric possibilities in Calculus tell us that a value of 0.000…. 001 (122 zeros in total) is still not zero. Professor Haber had provided a plug-in arithmetic calculation in his PH 117 General Relativity class (Haber, 2015). As Nobel Laureate Weinberg pointed out a few months before his passing, this huge cancellation demand became a bone in the throats of theoretical physicists (Weinberg, 2022).

Method-2 Cosmology understanding with numeracy

The QCC Robotic Telescope from PlaneWave, 0.4 meter aperture with single photon detection capability to monitor supernova SN explosions and changing-look AGN situations (López-Navas, E., et al. 2022), (Komossa, et al. 2023), (Wu et al. 2024), (Zeltyn, G. et al. 2024).

The data processing in ImageJ (or in the download required AstroimageJ) for difference image analysis is useful for variability studies. Supernova detection procedure could be just a "yes or no" answer, when comparing two images at two different time stamps. A light-curve could be studied when combining many sequential images. Most students understood the result of the relativistic stretch-factor correction to merge several light-curves from various redshift values into a universal light-curve, shown in a Caltech education video, Figure 4 (Djorgovski, 2024). The stretch factor correction content was adapted by us for an online exercise during Lockdown using the phenomenon-based pedagogy, and constitute as a numeracy exercise in cosmology study at the Gen Ed level. ImageJ was used to estimate the stretching and to understanding the use of the supernova standard candle model in cosmology.

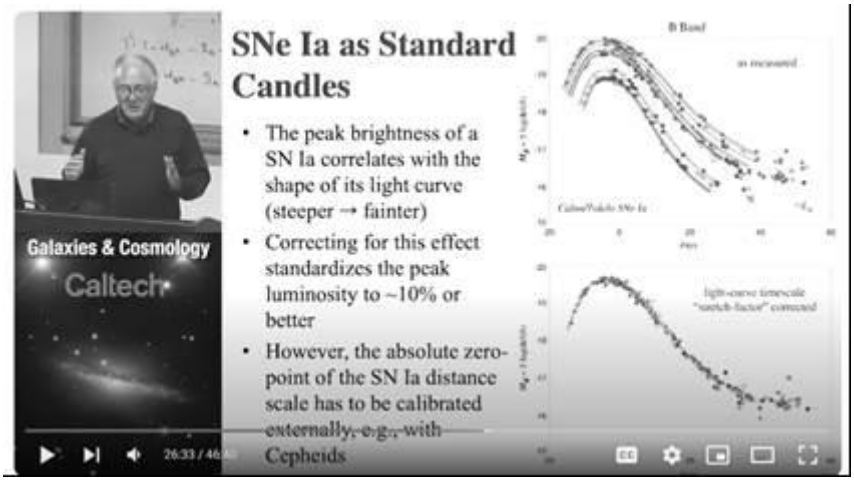

Figure 4. An illustration of the stretch-factor correction, adapted from Caltech Galaxies and Cosmology Lecture 4 - Cosmological Distance Scale 2024, https://www.youtube.com/watch?v=Gjku9EJe-Fg, using ImageJ. The associated pdf file is available https://sites.astro.caltech.edu/~george/ay21/Ay21_Lec04.pdf

With the advances in computer technology, we can add more numeracy in the post COVID era at the Gen Ed level. A combination of GW, Fermi spacecraft, robotic telescope data for supernova SN study has been put forward and documented on YouTube, Figure 5 (Valenti, 2024). The DLT40 Survey and GW 170817 was illustrated. The Distance Less Than 40 Mpc (DLT40) is a supernova (SN) search led by David Sand (U. Arizona) and Stefano Valenti (UC Davis). The YouTube video enhances the authentic experience for our students in the difference-image analysis technique. A data collection from our own robotic telescope supplies a real experience on how the light-curve animation was performed.

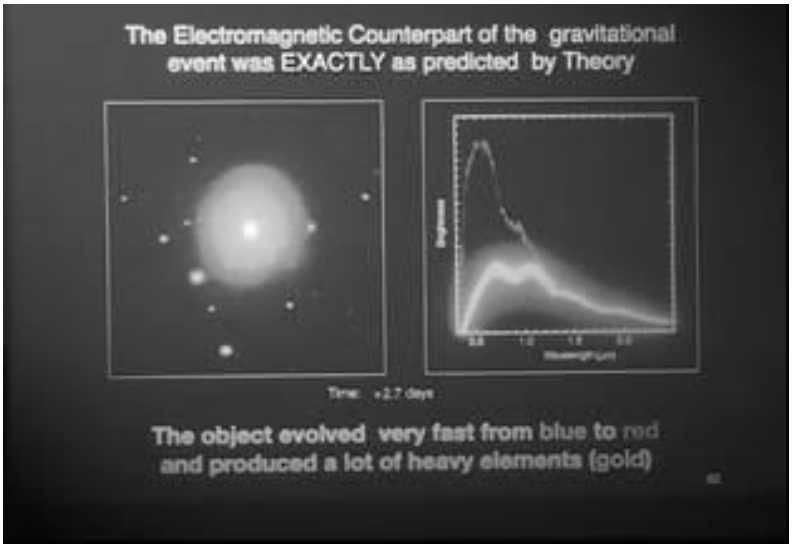

Figure 5: An illustration of light-curve changes in time, adapted from Lick Observatory: The Golden Era of Time Domain Astrophysics: New Explosions and their Origins, https://www.youtube.com/watch?app=desktop&v=Wkggx8tK3lI, using ImageJ.

Another YouTube video on black hole has been used in an application of the log graph. Figure 6 shows a log graph. Students were asked to use ImageJ to estimate the distance in the < 30 Myr displayed figure, log-graph understanding of the 0.1 pc to 0.0001 pc scale (Liu, 2024).

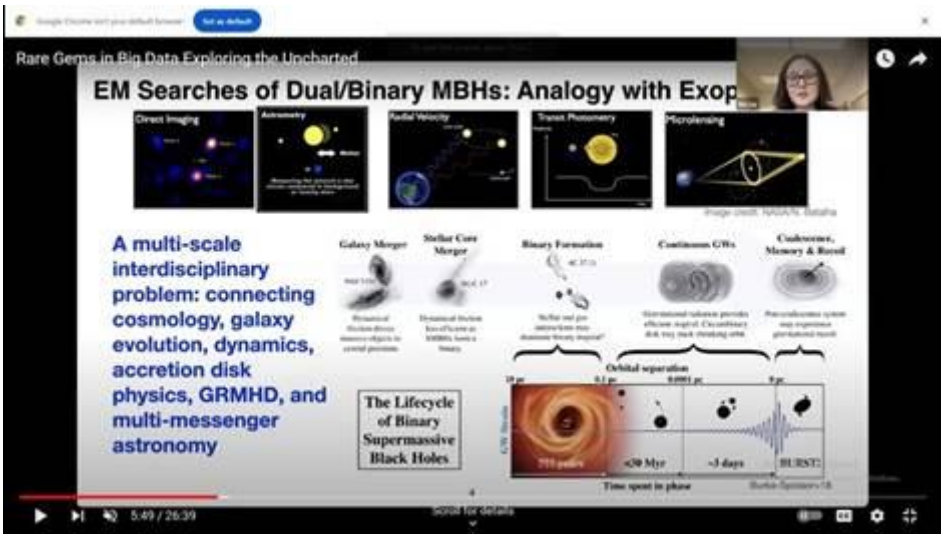

Figure 6: An illustration of the log graph exercise, Rare Gems in Big Data Exploring the Uncharted, NSF NOIRLab Science. https://www.youtube.com/watch?app=desktop&v=3PxAgz6W8iY

Students were also asked to test the arrival time of light particles (photons) in a Gamma Ray Burst GRB event. The Earth based telescope needed the RA and DEC information of the GRB Object, provided by the Space based telescope which detected the GRB signal initially (Cao, et al. 2024). Data shown in Figure 7.

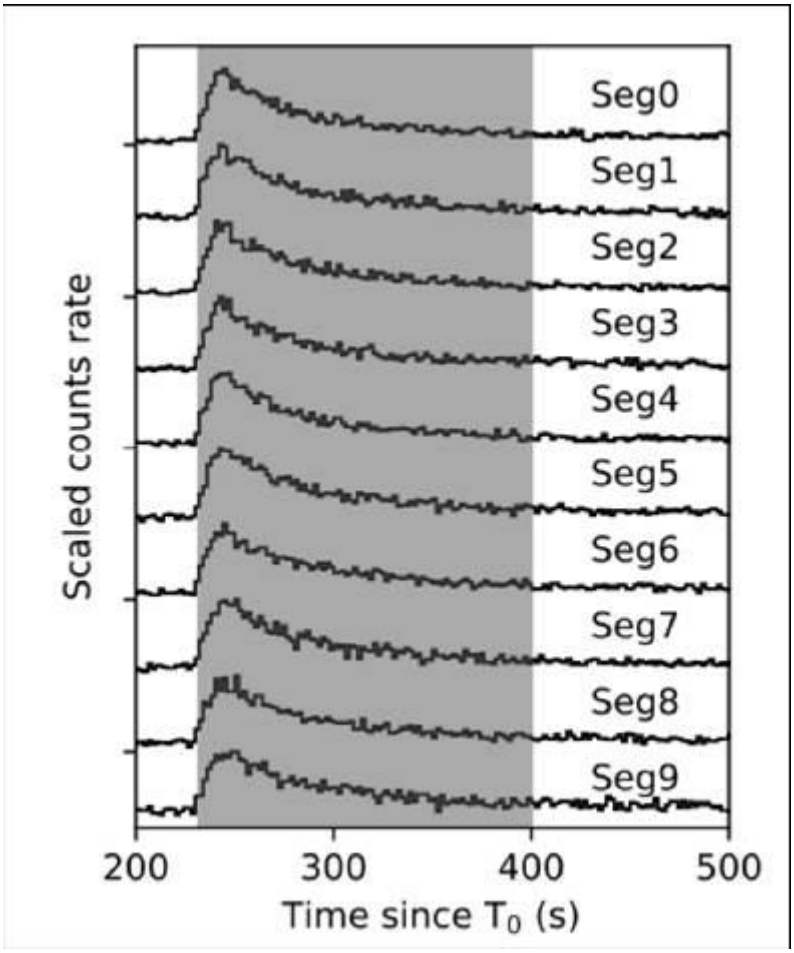

Figure 7 GRB signal time profile, adapted from Figure 1 of the preprint, https://arxiv.org/pdf/2402.06009.

Exercise is described as the following steps. (1) Pick any two peaks and show that the x-coordinate values are within 5% uncertainty of each other. (2) Uncertainty fraction = Absolute value of (Peak1-Peak2) / (0.5*Peak1 + 0.5*peak2). (3) Uncertainty percent = 100% * {Absolute value of (Peak1-Peak2) / (0.5*Peak1 + 0.5*peak2)}. (4) Peak 1 time using x-value proxy = _____. (5) Peak 2 time using x-value proxy = _____. (6) Uncertainty percent = _____ (7) The GRB data tested the theory of "same speed for different photon energies" to an uncertainty of ___ percent, and future experiments are expected to test the theory at an even lower uncertainty.

The feedback mechanism for star stability used exercises based on ImageJ. Students were asked to use ImageJ brightness profile as proxy for mass distribution, following the pedagogy shown in the U of Northern Texas video in which a 4-in telescope with CCD was used in the observation of M51 in a student parking lot (Zahedy, 2024). The circum-galactic medium CGM study is an active topic in cosmology in the quest of "Where are the missing 90% of protons" (Silich, 2024). The ImageJ profile feature is suitable for our students to participate in CGM analysis exercises. For the introduction to the feedback mechanism in the language of simulation modeling, we have used the narration found on the Harvard webpage (Whitehead, 2022). As far as a star is studied, the feedback to the stellar environment consists of radiation, culminated outflows and stellar wind since it is the environment that started the accretion to form that star, a self-regulating process (experimental language) to reduce the accretion

of more matter onto a star. On the one hand, there are many structures revealed in MMA multi-messenger astronomy data, with feedback for stability highlight the robustness concept or the multiverse concept. On the other hand, small change can cause big difference in Chaos study, therefore, we need robustness to avoid instability, and fine-tuning for stability.

Method-3 What AI can do in astronomy in terms of Gen Ed numeracy

The use of sigmoid function in Neural Network AI regardless of either in Excel or Python environment is beyond the Gen Ed learning objectives of a regular community college in United States, although we had used Excel-VBA neural network for data classification in student research projects. Professor Freedman of NYU published a comparison between the Excel neural network back-propagation solution and Python Tensorflow solution (Freedman, 2019). Such neural network tutorial information is useful for us the faculty to help students wanting to transfer to NYU, our neighbor in the City of New York.

Using numeracy without Calculus, what can we learn from the question of "Were the initial conditions of the Big Bang robust enough for life to emerge at high probability without further inputs along the multiple billion years of evolution?" The recent inquiry of consciousness in Astronomy and AI offers a natural extension of the fine-tuning contents. What is numeracy in programming, machine learning, and AI?

The IBM video on AI vs Machine Learning 2023 has a concise statement "Frame 2:04 When we program a system, I have to come up with all the codes… In Machine Learning, what I am doing could be adjusting some models, but it is different than programming, and mostly it is learning the more data that I give to it, so it is based on a large amount of information" (2023)

In terms of astronomy, AI application for data analysis is a must (Djorgovski, et al. 2022), (Impey, 2023). For instance, the AI tools can now pick out the signs of an exoplanet in periodically brightness diming at 96% accuracy. But this type of numeracy is beyond Gen ED learning objectives.

The use of AI assisted writing to organize textbook information with new discovery information in an essay submission is no stranger to students these days. In order to deliver numeracy in the topic of AI in Astronomy, we focus on the fact that AI needs training. Northwestern University Astronomy AI Center stated that "Gravity Spy uses a convolutional neural net to classify glitches based on spectrogram images; citizen scientists perform a similar task, expanding our training set, and aiding classification of uncertain glitches". Showing students on how to participate on a training of an AI Gravity Spy has been straight forward. The posted spectrogram images can be analyzed with the histogram extraction feature of ImageJ. An extracted histogram has information on the coefficient of variation CV, which is the standard deviation divided by the mean. Such a measure of complexity corresponds to the artificial-cognitive level of the training set in the Gravity Spy AI (Gravity Spy, 2024)

The concept of exquisitely tuned has been addressed in terms of the Multiverse Theory. Professor Greene of

Columbia University asserted that Multiverse Theory would be able to show that the universe that we live in belongs to a set of universes (Greene 2012). We being in a universe that supports live, it is consistent that cosmological values support the conditions for life that we know. Greene advocated the concept of exquisitely tuned values to support live, which implies that these exquisitely tuned values also support the complexity of life.

A discussion of Astrobiology and Consciousness has been posted on YouTube (Cuyamungue Institute, 2021). Edwin Turner, Professor of Astronomy, Princeton University, agreed that astrobiology and consciousness should belong to a spectrum due a shared methodology. Astronomy is based on observations without manipulation, very much similar to the conditions in investigation on consciousness.

We focus on a sub-topic, that is, the change of consciousness. Clinically it has been report that "the EEG fractal dimensions can predict high-level behavioral responses in minimally conscious patients" (Liuzzi, P., et al. 2023), (Secci, et al. 2024). ImageJ has box-counting fractal dimension analysis for complexity study. We use the coefficient of variation CV and fractal dimension FD tools in ImageJ for comparison inquiry in Astronomy data to promote Gen Ed numeracy and to educate students in terms of the change of complexity. If complexity belongs to the astrobiology-consciousness spectrum, then the CV/FD numeracy in the change of complexity will get students closer to an understanding of the change of consciousness. After all, Newton used the change of motion (acceleration) to understand motion.

Results of the Pedagogy

An assessment based on a deliverable of SDO data analysis using ImageJ profile: 10 students out of 19 students scored correctly, the same 10 students also scored correctly in all of the other ImageJ profile tasks such as feedback stability studies.

An assessment based on a deliverable of MKS assessment using cloze test and 30-sec elevator-pitch narration to explain to a fifth grader: 16 students satisfactory passing out of 39 students, introductory astronomy and conceptual physics courses.

An assessment based on a deliverable of MMA single panel data showing arrival time independent of photon energy in the peak profile in the intensity versus time curves: 16 students out of 35 students did the ImageJ analysis of the peak time correctly, introductory astronomy and conceptual physics courses.

An assessment based on Figure 5 showed that 5 students did the light-curve amplitude correctly using ImageJ, out of 19 students. For the graphic showing the binary merger in Figure 6, 3 out of 19 students did the log scale proportionality correctly.

An assessment on fine tuning and robustness questions: 15 out of 19 students got the cloze test correctly, (question

on spending of 50 dollars within 1 dollar uncertainty for a party). However, only 3 out of 19 students got the matter density exponent calculation correctly.

The learning of change of consciousness with complexity as a proxy was assessed with the coefficient of variation (CV) and fractal dimension (FD) tools in Image J. The assessment results showed that the advanced features of CV and FD calculation tools did not impose additional obstacles for students already learned the profile tool, there were 22 students satisfactory passing out of 54 students in three astronomy classes.

The AI assisted writing was found to be used by most students as a summarizing tool for writing assignments. There were 15 students (out of 19 students) using an assignment question as a prompt and copying the AI output. The remaining 4 students used the assignment question combined with a perspective of an expert on YouTube to formulate a more refined prompt for an in-depth inquiry.

Discussion and Conclusion

ImageJ can serve as a sufficient numeracy tool to analyze the robotic telescope data, NASA data, etc. with contexts in MMA (multi-messenger astronomy) to develop an inquiry mindset in terms of the Gen Ed quantitative assessments in various contexts.

Assessment showed that the learning of the robustness concept (in Gen Ed context) could be a better alternative for the learning of the Astronomy fine-tuning concept such as in the cosmological constant (matter density) requiring the manipulation of the steps containing exponent. The stability and self-regulated concepts were shown in assessment data to be easier to learn, in comparison to the fine-tuning concept.

The astrobiology and consciousness inquiries discussed by Edwin Turner at Princeton, etc. offers a natural extension to include complexity as a numeracy in astronomy data analysis using ImageJ

The online ImageJ without installation is excellent for online classes in post-COVID era.

Coupled with the online Python-SciPy, an extension for students with algebra knowledge is straight forward to make the best use of a robotic telescope. With the incorporation of Python in Excel by Microsoft (October 2024), the online delivery in post-COVID era would become easier.

Although AI-assisted writing was shown not to be used effectively by most students for learning in our assessment data, we should continue to show students on how to make better prompts for AI assisted writing in education, supported by the College Administration. The recent October 2024 Apple report on the limitations of grade-school level mathematical reasoning (basic arithmetic steps) in the current available AI Large Language Models

would not affect the use of AI assisted writing in education (Mirzadeh, et al. 2024). The importance of the Gen Ed quantitative assessments in various contexts continues and sustains the numeracy pedagogy discussed above.

Robotic telescope data collection with ImageJ analysis can facilitate of Astronomy General Education learning outcomes. The Astronomy fine-tuning in terms of feedback can be addressed with numeracy beyond description using words only. The astrobiology and consciousness relationship would be strengthened with complexity analysis using ImageJ. All of the above can be delivered online in the post-COVID era.

Recommendations

The tradition astronomy labs could use the online free ImageJ with NASA telescope data, Skynet Robotic Telescope data, etc. to facilitate the Gen Ed learning outcomes in terms of the quantitative assessments in various contexts.

The Multi-messenger Astronomy MMA pedagogy is consistent with the advances in robotic telescope technology with AI statistical learning applications, and would be useful in the upgrade of the traditional astronomy labs. The Complexity measure should be included to facilitate the relationship between astrobiology and consciousness, echoing the perspective of Professor Edwin Turner of Princeton University.

Interested high school physics teachers could adapt the numeracy pedagogy in Astronomy as extra-curricular activities since the Gen Ed quantitative assessment tools discussed above do not exceed the algebra tools used in high school physics. As the current AI failed mathematical reasoning at the level of basic arithmetic steps, reported by Apple (October 2024), the learning of numeracy in various contexts cannot be overstated in the high school activities.

Acknowledgements

We thank those authors posting their works on YouTube. Author contributions: Alexei Kisselev 20%, Arkadiy Portnoy 20%, Sunil Dehipawala 20%, Todd Holden 20% and Tak Cheung 20%.

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Reducing Speaking Anxiety among College ESL Students through Artificial Intelligence

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Abstract: Speaking anxiety continues to challenge many college ESL students, affecting confidence, fluency, and classroom participation. With the growing integration of artificial intelligence (AI) and large language models (LLMs) in higher education, new opportunities have emerged to enhance oral language learning through adaptive and low-pressure environments. This review followed the SANRA guidelines to ensure clarity, rigor, and balance. Relevant peer-reviewed studies were identified from ERIC, EBSCOhost, JSTOR, IEEE Xplore, and Scopus using the keywords artificial intelligence, large language models, ESL, EFL, speaking anxiety, and communication confidence. Research focusing on higher education contexts was analyzed for methodological quality and pedagogical insights. Findings show that AI-based tools such as chatbots, speech recognition systems, and feedback applications improve learners' fluency, pronunciation, and vocabulary while enhancing grammatical accuracy and discourse coherence. These technologies also reduce anxiety, boost motivation, and promote autonomous learning by providing immediate, personalized feedback in supportive settings. However, limitations in emotional responsiveness, contextual adaptability, and the need for teacher mediation highlight the importance of balanced integration. Overall, AI serves as a valuable complement to traditional instruction, fostering both linguistic competence and emotional well-being among college ESL learners.

Keywords: Artificial Intelligence (AI), Large Language Models (LLMs), Speaking Anxiety, English as a Second Language (ESL). Higher Education. AI-Mediated Speaking Practice

Citation: Deep, P. D., Ghosh, N., & Koptelov, A. V. (2025). Reducing speaking anxiety among college ESL students through artificial intelligence. In V. Akerson, H. Polat, & A. Tekin (Eds.), *Proceedings of IConSES 2025—International Conference on Social and Education Sciences* (pp. 139–154). ISTES.

Introduction

Background and Rationale

Oral proficiency remains a core component of communicative competence in second-language acquisition, particularly in English as a Second Language (ESL) contexts in higher education (Jin et al., 2020; Zhang et al., 2024). However, speaking anxiety continues to pose a substantial affective barrier to ESL learners' progress, often resulting in reduced participation, diminished self-confidence, and lower academic performance. Numerous studies have highlighted the psychological strain that speaking in a second language imposes on learners, particularly in formal or evaluative environments (Kang, 2022; Zhang et al., 2024). These affective constraints are compounded by structural limitations within ESL instruction, including large class sizes, limited contact hours, and insufficient individualized feedback (Kang, 2022; Zhang et al., 2024)

In recent years, the advent of Artificial Intelligence (AI) and Large Language Models (LLMs) has ushered in new possibilities for language pedagogy (Kang, 2022; Zhang et al., 2024). These technologies offer dynamic, interactive environments where learners can engage in authentic conversational practice, receive immediate feedback, and build communicative competence without the social pressures often associated with classroom speaking tasks (Grab, 2025; Lin & Mubarok, 2021). Emerging evidence suggests that integrating AI-powered tools, such as intelligent chatbots, speech recognition software, and adaptive feedback systems, can significantly mitigate learners' speaking anxiety and promote their willingness to communicate in English (Grab, 2025; Lin & Mubarok, 2021).

Defining Core Constructs: AI, LLMs, and ESL

Artificial Intelligence (AI)

Artificial Intelligence in the context of language education refers to machine-based systems capable of simulating human cognitive functions, such as understanding, reasoning, and generating natural language (Elov et al., 2025). Historically, AI in language learning has evolved from early rule-based grammar and ICT-based tools to more sophisticated applications capable of speech processing and conversational interaction The emergence of AI-integrated tools such as chatbots and speech-processing applications has enabled learners to receive real-time, individualized feedback on pronunciation, fluency, and intonation, feedback that traditionally required the direct intervention of a language instructor (Grab, 2025; Lin & Mubarok, 2021). These affordances have established AI as a pivotal component of next-generation language pedagogy.

Large Language Models (LLMs)

Large Language Models (LLMs), as described by Du and Daniel (2024), represent advanced neural network architectures that underpin modern artificial intelligence (AI) chatbots. They are trained on vast textual corpora and leverage natural language processing (NLP) and machine learning to generate coherent, contextually

appropriate, and human-like responses that facilitate interactive communication in educational settings (Du & Daniel, 2024). Models such as GPT-3, GPT-4, and the multimodal GPT-4o exemplify the evolution of generative AI systems capable of composing text closely resembling human language and reasoning across modalities such as video, audio, vision, and text in real time, offering versatile and efficient support for pedagogical interaction (Celik et al., 2025). Their ability to sustain open-ended, personalized conversations in real time represents a significant advancement over earlier, scripted language learning tools. In doing so, Large Language Models (LLMs) enable learners to participate in authentic communicative tasks within psychologically safe, feedback-rich environments that foster confidence and linguistic growth (Celik et al., 2025; Yildiz, 2024).

English as a Second Language (ESL)

English as a Second Language (ESL) refers to the acquisition and use of English by individuals whose first language is not English, particularly within immersion or academic settings (Kang, 2022; Muniandy & Selvanathan, 2025).In higher education, ESL learners are expected to develop both academic and social communicative competencies. However, speaking remains the most anxiety-inducing skill due to its real-time nature, high cognitive load, and fear of negative evaluation (Kang, 2022; Zhang et al., 2024).Despite curricular reforms emphasizing communicative competence, speaking instruction often remains underdeveloped, thereby necessitating innovative interventions that can address both linguistic and affective domains (Celik et al., 2025; Kang, 2022; Zhou et al., 2025).

Challenges in Conventional ESL Speaking Instruction

Learners frequently report apprehension about speaking in front of peers, fear of making mistakes, and lack of confidence, all of which contribute to what Krashen (1982) termed a high affective filter. In conventional ESL classrooms, these affective barriers are often intensified by teacher-centered instruction, public error correction, and limited opportunities for authentic communication (Krashen, 1981). According to Krashen (1982), emotional variables such as anxiety, low self-esteem, and fear of negative evaluation restrict learners' ability to process and internalize comprehensible input. These emotional and contextual barriers significantly hinder oral language development and diminish learners' willingness to take communicative risks, thereby reducing opportunities for meaningful interaction and spontaneous speech. Consequently, traditional speaking instruction often emphasizes grammatical accuracy and performance evaluation over communicative confidence, resulting in inhibited participation and reduced fluency development (Krashen, 1981). The limited availability of real-time corrective feedback constrains learners' ability to internalize and improve their spoken performance, underscoring the importance of adaptive AI systems that can provide immediate, individualized responses (Torkhani, 2025; Zhou et al., 2025). While some educators have adopted flipped learning, mobile-assisted language learning (MALL), or blended learning approaches to address these issues, the integration of intelligent systems remains uneven and under-theorized (Zhou et al., 2025).Thus, there is an urgent need to explore how emerging technologies can be systemically incorporated into ESL pedagogy to overcome the persistent challenge of speaking anxiety.

Research Gap and Objectives

Recent scholarship has highlighted the growing significance of artificial intelligence (AI) and large language models (LLMs) in transforming second-language learning; however, the literature remains fragmented across several key dimensions (Yildiz, 2024).Current empirical research offers limited insight into how AI-driven platforms influence oral proficiency among university-level ESL learners, particularly in the interrelated domains of fluency, pronunciation, and lexical development(Du & Daniel, 2024). Studies have shown that AI-powered chatbots and virtual tutors can enhance pronunciation accuracy and fluency while reducing speaking anxiety (Celik et al., 2025; Du & Daniel, 2024; Yildiz, 2024).Yet, much of this research remains exploratory, often focusing on short-term interventions or general technological affordances rather than systematically examining the mechanisms that drive long-term improvement in spoken interaction (Du & Daniel, 2024; Yildiz, 2024).

The emotional and motivational aspects of AI-enhanced speaking practice are also underexplored (Kang, 2022; Muniandy & Selvanathan, 2025; Zhang et al., 2024).Research suggests that AI-integrated learning environments such as ChatGPT can increase learners' confidence and speaking self-efficacy by providing immediate, personalized feedback in psychologically safe contexts (Yildiz, 2024).However, little is known about how these affective changes unfold over sustained use or how they interact with learners' cognitive processes, emotional regulation, and communicative competence (Yildiz, 2024).This lack of longitudinal, theoretically grounded studies limits our understanding of how AI-mediated feedback contributes to self-efficacy and motivation in real-world ESL classrooms (Yildiz, 2024).

The pedagogical integration of intelligent systems remains uneven and under-theorized (Hùng Cường, 2024; Torkhani, 2025).While AI chatbots have shown promise in fostering learner engagement and alleviating speaking anxiety, empirical evidence on their pedagogical limitations and contextual adaptability is still emerging (Szyszka et al., 2024).Questions persist regarding how students perceive these systems, the extent to which they complement or challenge existing instructional practices, and the conditions under which they facilitate authentic communicative competence in higher education (Lin & Mubarok, 2021; Szyszka et al., 2024).

Accordingly, this study addresses these gaps through the following research objectives:

1. To examine the impact of AI and large language models on the speaking fluency, pronunciation, and lexical proficiency of university ESL learners.
2. To investigate how AI-mediated feedback influences the accuracy, syntactic complexity, and coherence of learners' spoken output in academic English contexts.
3. To analyze the pedagogical benefits and challenges of integrating AI technologies for speaking practice in higher education ESL programs.

By pursuing these objectives, the study seeks to contribute to a more comprehensive understanding of AI-mediated language learning, offering conceptual and pedagogical insights into how intelligent systems can support ESL learners' communicative competence, motivation, and affective engagement.

Method

This study adopted a narrative review approach to synthesize diverse perspectives and provide a comprehensive understanding of how artificial intelligence supports ESL speaking development in higher education. Narrative reviews are particularly useful for exploring complex and evolving topics that require interpretation, critique, and integration of findings from varied methodologies (Sukhera, 2022).This approach enabled the examination of both empirical and conceptual studies, facilitating a nuanced understanding of pedagogical and technological trends. Relevant peer-reviewed studies were identified through the databases ERIC, EBSCOhost, JSTOR, IEEE Xplore, and Scopus. The review followed the SANRA (Scale for the Assessment of Narrative Review Articles) guidelines to ensure academic rigor, transparency, and structural coherence (Baethge et al., 2019).SANRA provides a validated framework for maintaining scholarly quality by assessing six essential dimensions: the significance and purpose of the review, clarity of the literature search process, accuracy of referencing, logical reasoning, and presentation of relevant evidence. Employing SANRA ensured methodological consistency, critical depth, and clarity in presenting evidence across diverse studies, thereby strengthening the review's overall academic integrity and reliability (Baethge et al., 2019). The Boolean operators applied to refine and structure the database search are summarized in Table 1.

Table 1. Search Strategy Using Boolean Operators

Keywords	Boolean Operators
Artificial intelligence and ESL learning	"Artificial intelligence" AND "ESL" OR "EFL" AND "language learning"
AI and speaking anxiety	"AI" AND "speaking anxiety" OR "language anxiety"
Large language models in education	"Large language models" OR "ChatGPT" AND "education" OR "language learning"
ESL speaking fluency	"ESL" AND "speaking fluency" OR "oral proficiency"
Pronunciation improvement	"AI-assisted pronunciation" OR "speech recognition" AND "ESL learners"
Communication confidence	"Communication confidence" AND "language learning"
Student motivation	"Student motivation" AND "AI tools" OR "ESL speaking practice"
Feedback systems	"Adaptive feedback" OR "AI feedback" AND "speaking performance"
Higher education context	"Higher education" AND "ESL students" OR "university learners"
Technological challenges	"Digital literacy" OR "technology access" AND "AI language learning"

The inclusion and exclusion criteria used to select relevant studies are summarized in Table 2.

Table 2. Inclusion and Exclusion Criteria

Criteria	Inclusion	Exclusion
Accessibility	Open-access or institutionally accessible journal articles retrievable through databases such as ERIC, Scopus, JSTOR, IEEE Xplore, and EBSCOhost.	Restricted or non-accessible sources and grey literature without peer review.
Language	Publications written in English and available in full text for analysis.	Articles not in English or unavailable in full-text format.
Publication date	Studies published between 2020 and 2025 were conducted to ensure contemporary relevance and inclusion of post-pandemic AI advancements in education.	Studies published before 2020 may not reflect current developments in AI or recent shifts in ESL pedagogy.
Research design	Empirical, experimental, mixed-method, or review studies providing measurable or conceptual insights on AI-mediated language learning.	Opinion papers, blog posts, or non-peer-reviewed sources lacking methodological rigor or empirical grounding.
Study context	Research focused on higher education and university-level ESL or EFL learners.	Studies based on primary, secondary, or vocational education contexts.
Topic focus	Articles examining AI, large language models (LLMs), or digital tools in enhancing ESL speaking, pronunciation, fluency, or anxiety reduction.	Studies unrelated to AI integration or focusing only on reading, writing, or general ICT without reference to speaking practice.

Table 3 provides a concise overview of fourteen empirical studies examining the role of AI tools in enhancing ESL/EFL learners' speaking performance, confidence, and motivation across diverse higher education contexts.

Table 3. Summary of Reviewed Studies

No.	Author(s)	Country	Purpose	Method / Participants	AI Tool / Focus	Key Results
1	(Celik et al., 2025)	Iraq	Examine ChatGPT as a virtual speaking tutor to enhance EFL learners' self-efficacy.	Mixed-method; university students.	ChatGPT	Findings indicate that ChatGPT is a promising tool for increasing students' speaking self-efficacy scores. They could relieve speaking anxiety and speak more self-assuredly
2	(Cường,	Vietnam	To investigate the	Mixed-method;	SmallTalk2.me,	Students preferred using AI

No.	Author(s)	Country	Purpose	Method / Participants	AI Tool / Focus	Key Results
	2024)		attitudes of university students towards the effectiveness of AI-based websites and applications to promote the improvement of speaking skills	university students.	VoiceTube	tools for speaking practice, though current AI apps have some limitation
3	(Du & Daniel, 2024)	Global	To review existing research on AI-powered chatbots used for developing English-speaking skills.	Systematic review of 24 SSCI papers (2017–2023).	AI chatbots (general)	Chatbots were found to enhance speaking proficiency, confidence, motivation, and pronunciation while reducing speaking anxiety.
4	(Elov et al., 2025)	Uzbekistan	To examine how Intelligent Computer-Assisted Language Assessment (ICALA) influences EFL learners' shyness, speaking anxiety, autonomy, and enjoyment.	MANOVA; university students.	Intelligent Computer-Assisted Language Assessment (ICALA)	Reduced anxiety and shyness; enhanced enjoyment and learner autonomy.
5	(Grab, 2025)	Türkiye	To evaluate the impact of sustained AI chatbot use on ESL students' speaking fluency, pronunciation, grammar, vocabulary, and confidence.	Mixed-method; university students.	AI conversational chatbot	Improved fluency, pronunciation, and confidence; self-recording supported self-reflection.
6	(Jin et al., 2020)	China	To test whether contracting students' speaking behavior can reduce foreign language classroom anxiety and improve engagement.	Mixed-method; university students.	Contract-based intervention	Contracting significantly reduced speaking anxiety, enhanced self-efficacy and reflection, and increased engagement and positive emotions in EFL classrooms.
7	(Kang, 2022; Lin & Mubarok, 2021)	USA	To compare the effects of AI avatars and native speakers on ESL learners' speaking ability and affective factors across proficiency levels.	Mixed-method; university students.	AI vs. native speakers	Both improved oral skills; the AI group showed lower anxiety and greater comfort.

No.	Author(s)	Country	Purpose	Method / Participants	AI Tool / Focus	Key Results
8	(Lin & Mubarok, 2021)	Taiwan	To examine the effectiveness of a mind map–guided AI chatbot approach (MM-AI) in improving EFL students' speaking performance in a flipped classroom.	Quantitative; university students.	AI chatbot with mind-map scaffolding	Enhanced speaking scores and engagement; weaker students needed more technological support.
9	(Muniandy & Selvanathan, 2025)	Malaysia	Analyze ChatGPT's effect on ESL learners' oral performance and perception.	Mixed-method; university students.	ChatGPT	Improved fluency, lexical range, and willingness to communicate; students valued non-judgmental feedback.
10	(Szyszka et al., 2024)	Poland & Finland	To examine the relationship between language anxiety and speech fluency among advanced foreign language learners during monologue tasks.	Quantitative; university students.	No AI tool – focus on language anxiety and fluency measures (speech rate, articulation rate, pauses).	Higher processing and output anxiety correlated with more filled pauses and lower speech/articulation rates; anxiety negatively affected fluency.
11	(Torkhani, 2025)	Kuwait	Evaluate Talkpal.AI's effects on EFL students' oral proficiency.	Quantitative; university students.	Talkpal.AI chatbot	Significant posttest improvements in fluency, pronunciation, vocabulary, and grammar ($p < .05$), confirming the tool's potential to enhance EFL speaking skills.
12	(Yildiz, 2024)	Türkiye	To examine the effect of ChatGPT use on EFL learners' speaking self-efficacy and confidence in communicative tasks.	Mixed-method; university students.	ChatGPT	Learners using ChatGPT showed significant improvements in speaking self-efficacy, confidence, and enjoyment; interviews revealed reduced stress and enhanced motivation.
13	(Zhang et al., 2024)	China	Examine AI-speaking assistant Lora on enjoyment, anxiety, and WTC.	Quantitative; university students.	AI assistant 'Lora'	Reduced anxiety, enhanced enjoyment and willingness to communicate.

No.	Author(s)	Country	Purpose	Method / Participants	AI Tool / Focus	Key Results
14	(Zhou et al., 2025)	Malaysia	To assess the effect of an AI chatbot-integrated mobile-assisted blended learning (MABL) framework on EFL students' spoken English abilities and learning perceptions.	Quantitative; university students.	AI chatbot embedded in the MABL framework for real-time speaking feedback and dialogue	The experimental group showed significant gains in fluency and appropriateness in spoken English, with high levels of engagement, satisfaction, and technology acceptance.

Discussion

The Impact of AI and Large Language Models on University ESL Learners' Speaking Fluency, Pronunciation, and Vocabulary

In a controlled study by Torkhani (2025), the implementation of Talkpal AI, an AI conversational chatbot, over an eight-week period led to statistically significant improvements in university EFL students' speaking fluency ($p < .001$). Participants exhibited increased utterance length, more coherent discourse, and reduced hesitation markers in post-test recordings. The system's feedback loops and unlimited rehearsal opportunities fostered the automatization of language production, reinforcing fluency through low-pressure repetition (Torkhani, 2025). Zhou et al. (2025) corroborated these findings in a tertiary context, reporting enhanced fluency among ESL learners following extended use of AI chatbots. Participants in the experimental group demonstrated smoother transitions between speech segments and greater temporal fluency, attributed to the chatbot's dialogic prompts and learners' reduced affective inhibition. Moreover, students expressed greater willingness to engage in oral production tasks in the low-stakes environment of human–computer interaction (Zhou et al., 2025).

A recent study examined the use of AI-based speaking applications Smalltalk2.me and VoiceTube among university students in Vietnam and found that these tools effectively enhanced learners' English-speaking performance (Cường, 2024). The platforms' AI-driven feedback and progress-tracking systems improved students' pronunciation, fluency, and confidence by allowing them to identify phonological weaknesses, receive instant corrective feedback, and practice shadowing techniques to align their speech with authentic English models. Learners reported greater engagement and relaxation during speaking activities, attributing their improvement to the applications' user-friendly interfaces, real-time feedback, and personalized learning tasks (Cường, 2024)

Muniandy and Selvanathan (2025) investigated the use of ChatGPT as a partnering tool to enhance ESL learners' speaking skills within a flipped classroom at a Malaysian public university. The study found that learners benefited from ChatGPT's ability to provide relevant examples, contextual prompts, and vocabulary-rich feedback, which facilitated lexical and grammatical development. Participants reported that interacting with the chatbot introduced

them to a wider range of expressions and academic vocabulary, increased their confidence, and improved their overall speaking fluency through authentic, context-based engagement (Muniandy & Selvanathan, 2025).

The reviewed studies confirm that AI-mediated interaction fosters more fluent, accurate, and lexically rich oral performance, validating its pedagogical value in supporting core dimensions of ESL speaking competence (Celik et al., 2025; Hùng Cường, 2024; Kang, 2022).

AI Influence on Accuracy, Complexity, and Coherence in University ESL Speaking

The use of AI-based tools in ESL instruction has been shown to facilitate measurable improvements in learners' grammatical accuracy, syntactic complexity, and discourse-level coherence in spoken English (Kang, 2022). Torkhani (2025) reported that undergraduate EFL participants using Talkpal.AI demonstrated statistically significant reductions in syntactic errors over an eight-week period, with learners identifying the system's real-time corrective feedback as essential for recognizing and addressing recurring grammatical issues (Torkhani, 2025) . Similarly, Zhou et al. (2025) found that integrating an AI chatbot within a Mobile-Assisted Blended Learning (MABL) framework enabled learners to recognize and correct recurring grammatical errors during task-based dialogues. The chatbot's real-time feedback, combined with the iterative practice afforded by the MABL environment, led to significant gains in grammatical precision in post-test oral assessments (Zhou et al., 2025). *Muniandy and Selvanathan* (2025) observed that learners perceived ChatGPT's responses as grammatically accurate and lexically rich, enabling them to model more complex sentence structures and improve their overall speaking fluency.

Du and Daniel (2024) reported that AI chatbots provide precise feedback on pronunciation, syntax, and semantic logic, enabling learners to produce grammatically accurate and contextually appropriate utterances. Their review also indicated that adaptive feedback expanded learners' lexical resources and syntactic range, reflecting greater linguistic complexity (Du & Daniel, 2024). Yıldız (2024) found that regular interaction with ChatGPT significantly improved grammatical accuracy and discourse organization among tertiary-level EFL students. Learners in the experimental group demonstrated higher post-test scores in linguistic accuracy and fluency and described ChatGPT's real-time corrections as instrumental in maintaining logical sequencing and semantic coherence (Yildiz, 2024).

Cường et al. (2024) further demonstrated that sustained interaction with AI-driven speech recognition systems led to measurable linguistic gains in accuracy, syntactic complexity, and discourse coherence. By engaging in structured retelling and guided speaking tasks, learners progressively aligned their oral production with standard discourse frameworks and displayed greater control over sentence structure and idea organization. The adaptive nature of the AI feedback loop enabled individualized progress, fostering self-regulated learning and enhanced communicative competence in university-level ESL contexts (Cường, 2024)

In addition to the findings of Cường et al. (2024), several studies corroborate the positive influence of AI-assisted

tools on linguistic accuracy, complexity, and coherence in university ESL speaking. Lin and Mubarok (2021) demonstrated that a mind map-guided AI chatbot in a flipped EFL classroom enhanced students' organization, discourse coherence, and syntactic complexity by scaffolding idea development and promoting structured interaction. Similarly, Grab (2025) found that sustained use of AI chatbots such as TalkPal AI, Gliglish AI, Langotalk, and ChatGPT (Voice Mode) significantly improved learners' grammatical accuracy, lexical range, and coherent oral production through adaptive feedback and self-regulated practice. Complementing these results, Szyszka et al. (2024) highlighted that reduced language anxiety was associated with more fluent and organized speech, suggesting that AI-mediated, low-anxiety environments can foster higher cognitive efficiency and coherence in ESL speaking performance.

The Benefits and Challenges of Using AI Tools for Speaking Practice in Higher Education

Multiple studies across higher education contexts have documented the pedagogical advantages of AI-assisted speaking practice (Cường, 2024; Grab, 2025). Among the most cited benefits is AI tools' ability to provide personalized, immediate feedback without the social pressure often associated with peer or teacher evaluation (Grab, 2025). *Muniandy and Selvanathan* (2025) reported that learners viewed ChatGPT as a convenient and supportive tool that enabled smooth English communication and easier interaction. Its accessible design and immediate feedback increased learners' confidence and improved their speaking performance (Muniandy & Selvanathan, 2025)

Another notable benefit is the scalability and accessibility of AI tools, which extend speaking practice beyond the physical classroom (Grab, 2025).Zhang et al. (2024) reported that consistent interaction with the AI-speaking assistant Lora significantly enhanced learners' enjoyment and willingness to communicate while reducing anxiety. Students perceived the AI as supportive and non-judgmental, which fostered sustained engagement and confidence in English-speaking tasks (Zhang et al., 2024).In line with these findings, Celik et al. (2025) found that ChatGPT provided learners with flexible, autonomous opportunities to practice speaking beyond classroom boundaries. Its accessible, feedback-oriented environment helped reduce anxiety, increase self-confidence, and sustain engagement in oral communication. The study indicated that such AI-mediated interaction supports ongoing skill development and encourages students to take greater ownership of their learning (Celik et al., 2025).

Despite these advantages, several challenges were consistently noted. One significant issue is the limited adaptability of AI feedback to context. Celik et al. (2025) identified a notable challenge in using ChatGPT as a speaking tutor. It has limited capacity to express emotional nuance and contextual sensitivity. Although students valued its accessibility and constructive feedback, about 40% found the chatbot lacked emotional intelligence compared with human instructors, making it harder to maintain focus or feel genuinely understood during practice. The authors further noted that ChatGPT still struggles to emulate human empathy and affective responsiveness, both of which are essential for sustaining learners' motivation and engagement in communicative settings (Celik et al., 2025)

Grab (2025) acknowledged that while AI chatbots can generate grammatically correct and contextually appropriate responses, they often struggle to integrate pragmatic conventions, cultural nuances, and implicit meanings, limiting learners' exposure to authentic discourse features. The study cautioned that such tools may overlook sociolinguistic norms and politeness strategies, which are essential for developing pragmatic competence in real-world communication (Grab, 2025). Similarly, *Muniandy and Selvanathan* (2025) reported that ChatGPT sometimes produced unclear or confusing responses, requiring learners to rephrase prompts multiple times to obtain appropriate answers. Participants also noted instances of grammatical inaccuracies and overly complex phrasing, indicating that while AI supports general dialogue, it remains limited in addressing subtle pragmatic and discourse-level aspects of language use (Muniandy & Selvanathan, 2025).

Zhang et al. (2024) cautioned that AI-speaking assistants should be used under pedagogical guidance rather than independently. They emphasized that students need training to interact effectively with AI tools and that teachers should integrate them alongside human instruction to foster supportive, low-anxiety, and communicative learning environments (Zhang et al., 2024). Likewise, Lin and Mubarok (2021) noted that although AI-assisted flipped classrooms can improve speaking skills, their success depends on adequate scaffolding and adequate technological readiness. They found that students with lower proficiency often struggled to benefit fully, highlighting the need for teacher guidance and equitable instructional design (Lin & Mubarok, 2021).

These findings suggest that while AI tools can effectively enhance learners' confidence, engagement, and speaking performance, their impact is maximized only when integrated with sound pedagogy and active teacher support.

Limitations of the Current Review

This review presents a synthesis of recent empirical studies on AI-mediated speaking instruction in higher education ESL contexts; however, several methodological and contextual constraints must be acknowledged. A primary limitation concerns the duration of the interventions examined. The majority of studies reviewed were conducted over relatively short periods, typically ranging from four to eight weeks, which restricts the capacity to assess the sustainability and longitudinal efficacy of the observed speaking improvements. Furthermore, much of the evidence presented across the studies was based on self-reported data rather than objective performance measures. This reliance on subjective learner perceptions may introduce reporting bias and reduce the reliability of conclusions regarding learner development.

A further delimitation lies in the considerable heterogeneity of the AI tools under investigation. Studies differed markedly in their use of language models, feedback mechanisms, and instructional integration, yet provided limited technical detail regarding the nature and functioning of these systems. This lack of transparency inhibits comparative analysis and makes it difficult to determine which specific affordances of AI tools contribute most effectively to learning outcomes. In addition, while improvements in fluency and accuracy were frequently reported, there was a notable absence of studies focusing on the durability of these gains, their transferability to

spontaneous communicative situations, or their relevance to broader discourse-level competencies. The scope of this review was restricted to English-language, peer-reviewed academic sources. This linguistic and publication bias may have excluded pertinent research conducted in other languages or published in regional educational journals, thereby limiting the generalizability of the findings to a truly global ESL learner population.

Directions for Future Research

To address the limited temporal scope of existing studies, future research should implement extended-duration designs that track the impact of specific AI-mediated speaking tools, such as ChatGPT, iFLYTEK, or Liulishuo, on learner development across academic semesters or full instructional cycles. Expanding participant demographics to include a broader spectrum of linguistic backgrounds, proficiency levels, and educational environments would enhance the external validity of emerging findings. In place of reliance on self-reported learner feedback, future studies are encouraged to incorporate performance-based evaluation instruments grounded in validated constructs such as linguistic complexity, grammatical precision, and discourse cohesion. A comparative analysis examining distinct categories of artificial intelligence technologies, including generative language models, speech analytics platforms, and dialogic agents, would elucidate which functional features most effectively support various dimensions of spoken language acquisition.

Empirical attention should be directed toward the instructional architecture of AI-mediated interactions, particularly regarding adaptive feedback strategies, communicative authenticity, and learner autonomy. Exploring the extent to which AI-assisted speaking practice transfers to spontaneous, unscripted communicative contexts, such as academic discourse, professional engagements, or peer collaboration, remains an underdeveloped yet critical line of inquiry. Future research would benefit from interrogating the broader pedagogical and ethical implications of AI integration, including learners' perceptions of system reliability, instructional transparency, and their evolving role as co-constructors of meaning in human–machine interaction.

Conclusion

As AI technologies become increasingly embedded in higher education, their role in supporting second-language learning has grown notably significant. This review found that artificial intelligence and large language models enhance ESL learners' speaking fluency, pronunciation, and vocabulary by providing real-time, individualized feedback in low-anxiety settings. AI-mediated feedback also strengthens grammatical accuracy, syntactic complexity, and discourse coherence, fostering greater communicative confidence and learner autonomy. While notable pedagogical benefits include improved motivation, engagement, and accessibility, challenges remain regarding emotional responsiveness, contextual adaptability, and the continued need for teacher mediation. Overall, AI tools serve as valuable supplements to traditional instruction when applied within ethically informed, learner-centered pedagogical frameworks.

Statements and Additional Information

Funding

This research received no external funding.

Institutional Review Board Statement

Not applicable.

Informed Consent Statement

Not applicable.

Data Availability Statement

All data are contained within the manuscript.

Conflicts of Interest

The authors declare no conflicts of interest.

Acknowledgements

The author extends sincere gratitude to Suvenker Ghosh and Lipu Ghosh for their unwavering guidance, encouragement, and invaluable support throughout the completion of this study.

Author Contributions

Conceptualization, P.D.D. and A.V.K.; methodology, P.D.D.; software, P.D.D.; validation, P.D.D., N.G., and A.V.K.; formal analysis, P.D.D.; investigation, P.D.D.; resources, P.D.D. and N.G.; data curation, P.D.D. and N.G.; writing, original draft preparation, P.D.D.; writing, review and editing, N.G. and A.V.K.; visualization, P.D.D.; supervision, A.V.K.; project administration, P.D.D.; funding acquisition, N.G. All authors have read and agreed to the published version of the manuscript.

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e-Safety in Primary School Communities: The Role of School Leadership

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Abstract: This study examines the concept of e-safety in primary education, with an emphasis on the role of school leadership and the exploitation of European frameworks such as DigCompEdu and DigCompOrg. The study examines the strategic importance of educational leadership in shaping e-safety policies and culture in the school environment, as well as the contribution of tools such as SELFIE to self-assessment and improvement of schools' digital readiness. The study follows a qualitative research approach using a semi-structured interview as a research tool. The interview guide consisted of two main parts. Part A included 11 demographic questions that captured basic information about the participants. Part B included 14 questions, organized into thematic sections corresponding to the main research areas: Digital competence and familiarity with e -safety, Leadership and strategic policies, Qualified knowledge and professional development, Collaboration with institutions and parents, Familiarity with the European frameworks DigCompEdu, DigCompOrg and the SELFIE tool, Legal compliance and data protection (GDPR). Ten primary education leaders participated in the study. The results indicate that all participants recognize that they have a strong responsibility to promote e-safety, most of them report that they implement specific practices, such as limited access to websites, awareness-raising activities, and collaboration with IT teachers, all consider cooperation with parents to be crucial, but only two participants reported sufficient familiarity with and active utilisation of the DigCompEdu and DigCompOrg frameworks as well as the SELFIE tool. The most significant obstacles they report are lack of institutional support, inadequate technical infrastructure, lack of targeted training, and overload with administrative tasks.

Keywords: e-Safety, primary education, educational leadership, DigCompEdu, DigCompOrg, SELFIE, digital competence

Citation: Karatrantou A, Vokolodou, C. (2025). e-Safety in Primary School Communities: The Role of School Leadership. In V. Akerson, H. Polat, & A. Tekin (Eds.), *Proceedings of IConSES 2025—International Conference on Social and Education Sciences* (pp. 155–174). ISTES.

Introduction

In the rapidly evolving digital age, the integration of information and communication technologies (ICT) has fundamentally transformed education systems worldwide. Schools, as key pillars of education, have increasingly adopted digital tools to improve both teaching and administrative processes. While these tools offer numerous

benefits, such as increased efficiency and personalized learning, they also pose significant challenges, particularly in e-safety. Educational institutions are now required to manage and protect large amounts of sensitive data, making digital security a critical priority (Redecker, 2017).

To address such challenges, frameworks such as the European Framework for the Digital Competence of Educators (DigCompEdu) and the European Framework for the Digital Competence of Educational Organizations (DigCompOrg) have been developed. These frameworks provide structured guidance on the competences that teachers and institutions need to thrive in a digital environment while maintaining high standards of safety (Kampylis, Punie, & Devine, 2015). However, the degree to which these frameworks are implemented varies significantly across regions, particularly in countries such as Greece, where inequalities in resources and infrastructure create additional barriers (Fazekas, 2021).

e-safety in schools encompasses a wide range of practices aimed at protecting both data and individuals from cyber threats. In the context of education, e-safety includes securing sensitive information, such as student records, teacher evaluations, and administrative data, from unauthorized access or breaches. The increasing prevalence of remote and hybrid learning environments, driven primarily by the COVID-19 pandemic, has further highlighted the importance of robust cybersecurity measures. Beyond data protection, e-safety involves creating an environment where students and staff can safely navigate the internet. This includes protecting students from cyberbullying, exposure to inappropriate content, and other risks associated with digital platforms (Van Wart et al., 2019). Failure to address these issues not only undermines the integrity of the educational process but also poses ethical and legal risks for schools and their leadership. Ensuring e-safety in schools is a complex process that is influenced by various factors, such as technological infrastructure, staff training, and institutional culture. In many cases, teaching staff have outdated systems at their disposal that are unable to support modern safety protocols. In addition, a lack of awareness and training among staff members often leads to poor compliance with safety policies, leaving institutions vulnerable to cyberattacks.

Education leaders play a crucial role in shaping the e-safety landscape in schools. As decision-makers, they are responsible for establishing policies and procedures that ensure the safe use of digital technologies. This includes establishing protocols for data protection, setting guidelines for ethical use of technology, and promoting a culture of accountability among staff and students (Fazekas, 2021; Panetas et al., 2025).

e-safety and Education

e-safety in education is an issue of critical importance, as schools manage large amounts of sensitive data and rely on digital platforms for the teaching process. This safety concerns both the protection of the data of students, teachers, and their families, as well as ensuring the safe and responsible use of digital media by all members of the school community (Redecker, 2017).One of the main objectives of e-safety in education is to protect personal data stored and managed by schools. This data includes grades, assessments, personal details, and other sensitive

information. Compliance with regulations such as the General Data Protection Regulation (GDPR) is essential to ensure the legality of the management of this data (European Commission, 2020). Schools must adopt appropriate technological solutions, such as encryption and network protection systems, to reduce the risks of hacking.

At the same time, e-safety in education includes protecting students from online threats such as cyberbullying, phishing, and exposure to inappropriate content. Teachers have a role to play in raising students' awareness of the dangers of the internet and educating them on how to navigate and use digital media safely (Wu, Yu, & Hu, 2019). Creating a safe digital environment requires collaboration between teachers, administrators, and parents. Schools need to develop safety policies that promote responsible use of technology, while also investing in staff training to address contemporary digital challenges (Van Wart et al., 2019). The adoption of self-assessment tools, such as SELFIE, can help improve safety policies, enhance student protection and the overall safety of the school environment. The digital space comes with a variety of threats and risks that directly impact education, making e-safety a critical issue for school communities. With increasing dependence on technology, schools are becoming vulnerable to data breaches, cyberattacks, and malicious actions, underscoring the need for comprehensive protection measures (Redecker, 2017). Finally, such threats underscore the need for a comprehensive e-safety strategy that includes technical measures, educational interventions, and cooperation among all stakeholders. Fostering a culture of safety is the keystone to creating a safe digital environment in education. The implementation of best practices is key to ensuring e-safety in education, providing a protected environment for students, teachers, and administrators. These practices include both technical measures and educational interventions to address contemporary digital challenges (Redecker, 2017).

User education and awareness is also a critical practice. Teachers and students need to be able to recognize online threats such as phishing and fake websites. Training and awareness programs help foster a culture of safety, where all users take an active role in protecting their data (Wu, Yu, & Hu, 2019). In addition, creating safety policies and establishing clear guidelines help protect the school community. These policies should include standards for data management, safe use of the internet, and prevention of misinformation and cyberbullying (Van Wart et al., 2019). Lastly, the use of self-assessment tools, such as SELFIE, enables schools to identify their weaknesses and develop targeted actions to improve e-safety (Kampylis, Punie, & Devine, 2015; Panetas et al., 2025).

The Role of Education Leaders in e-safety in the School Community

Teachers are at the heart of DigCompEdu's implementation, as they are the key actors who translate the theoretical framework into practical action. DigCompEdu was designed to strengthen their role by providing teachers with the tools and skills they need to meet the modern demands of education. Through the guidance of the framework, teachers are empowered to integrate digital technologies into their teaching in an effective and meaningful way (Redecker, 2017). The role of teachers in DigCompEdu is multifaceted. First, they are called upon to use digital tools to improve the teaching process. This includes the use of interactive applications, educational platforms, and assessment tools that facilitate personalized teaching and enhance student engagement in learning. In addition,

teachers contribute to the creation of a safe and responsible digital environment by promoting the proper use of technology by their students (Kampylis, Punie, & Devine, 2015). At the same time, teachers act as mediators in the development of students' digital competence. They guide students in cultivating skills such as critical evaluation of information, creative use of digital tools, and online safety management. In addition, they are actively involved in promoting a culture of collaboration and knowledge sharing, creating a supportive learning environment (Wu, Yu, & Hu, 2019). Teachers are not just users of technology, but also leaders of the digital transition in schools. Their role in the context of DigCompEdu includes not only developing personal skills but also empowering students and the wider school community to respond to the challenges of the digital age.

Policy development and effective crisis management are two key areas where principals and vice principalsat schools can make a real difference to e-safety in schools. E-safety policies set the framework within which schools operate, ensuring data protection, the proper use of technological tools, and the prevention of online threats (Redecker, 2017).

Principals need to develop clear and realistic policies that meet the needs of the school community. These policies should cover critical issues such as personal data management, safe internet access, and the use of educational platforms. In addition, it is important to include guidelines for protecting students from online threats such as cyberbullying and misinformation. Compliance with regulations such as the General Data Protection Regulation (GDPR) is central to these policies (European Commission, 2020). Alongside policy development, managers must be able to manage crises relating to e- safety. This includes responding immediately to data violation incidents, taking measures to restore safety, and informing the parties involved.

Crisis management skills are vital, as they determine how effectively a school can limit the consequences of such incidents (Wu, Yu, & Hu, 2019). Furthermore, safety policies must be accompanied by appropriate training and awareness-raising among users. Teachers, students, and parents must be informed about the measures taken and actively participate in their implementation. The involvement of all members of the school community enhances the effectiveness of policies and creates a supportive environment (Van Wart et al., 2019; Panetas et al., 2025).

Policy development and crisis management are not only administrative practices but also measures that enhance trust and safety in a school community. With the right guidance, principals and vice principals can ensure that schools operate as safe digital environments, responsive to the challenges of the modern age. Collaboration with the wider educational community and parents is a critical aspect of ensuring e-safety in schools. Principals and vice principals play a key role in creating a collaborative environment that promotes awareness, prevention, and response to threats in digital space (Redecker, 2017; Panetas et al., 2025).

One of the key priorities in this collaboration is raising awareness among the school community about the importance of digital safety. Teachers, students, and parents need to understand the threats that exist online, such as misinformation, phishing, and cyberbullying. Principals can organize seminars and workshops that focus on safe browsing practices, boosting the knowledge and confidence of everyone involved (Wu, Yu, & Hu, 2019).

In addition, parents are important partners in this effort. Their involvement in e-safety issues can strengthen the

consistency of measures taken in both school and family environments. Principals and vice principals can provide parents with informational materials and guidance on the safe use of the internet by their children. Regular meetings between schools and parents can also facilitate the exchange of views and the development of common strategies (European Commission, 2020).

Collaborating with external partners, such as technology companies, non-profit organizations, and e-safety experts, can also yield significant benefits. These partners can provide specialized support, training, and access to modern safety tools, strengthening schools' ability to respond to threats (Van Wart et al., 2019). Collaboration with the educational community and parents creates a strong support network that contributes to the creation of a safe and responsible digital environment. Strengthening these relationships is a key step in adapting education to the demands of the digital age. Effective administrative support is fundamental to ensuring e-safety in schools. Principals and vice principals are called upon to adopt best practices that not only enhance protection against threats but also foster a climate of trust and cooperation within the school community (Redecker, 2017).

One of the key prospects is the development of self-assessment systems, such as the SELFIE tool, which enables schools to identify weaknesses and plan improvement strategies. Self-assessment enhances transparency and enables managers to make informed decisions about resource allocation and the implementation of safety policies (Kampylis, Punie, & Devine, 2015). At the same time, best practices include the creation of e-safety support teams, involving teachers, technical experts, and administrators. These teams can act as advisory bodies, providing guidance on crisis management, threat prevention, and training for the school community. This collaboration enhances the effectiveness of measures and ensures that all parties are actively involved in the process (Wu, Yu, & Hu, 2019).

Investment in infrastructure is also a critical dimension. Principals must advocate for funding to upgrade technological tools and ensure access to modern protection systems. Technological support may include installing safety software, upgrading the network, and providing specialized technical assistance (European Commission, 2020). Administrative practices should focus on creating an educational environment that encourages collaboration, innovation, and continuous learning. Principals can develop policies that support the development of e-safety skills for both educators and students, promoting the creation of a safety culture that is in line with the demands of the modern digital age (Van Wart et al., 2019). Through the systematic implementation of best practices and appropriate support, principals and vice principals can play a decisive role in creating a safe and functional digital environment in schools.

Literature shows that e-leadership in schools is an emerging and fragmented field, where issues such as personal data protection and cybersecurity are increasingly falling under the responsibilities of administrators (Wollscheid et al., 2024). Given that the integration of e-safety practices into education is a relatively new challenge, exploratory methods are needed to capture the subtle differences in leaders' experiences and strategies (Savvidou, 2022).

Aim and Research Questions

The aim of this study was to investigate and discuss the role of education leaders, specifically principals and vice principals of primary schools, in managing e-safety in the school community, as they themselves perceive it.

The research questions are formulated as follows:

- *How do primary school principals and vice principals perceive their role in promoting e- safety at school?*
- *What practices do they employ to manage digital safety issues in everyday school life?*
- *How do they perceive cooperation with parents and the wider school community on e-safety issues?*
- *What is the relationship between schools and the European frameworks DigCompEdu, DigCompOrg, and the SELFIE tool?*
- *What are the obstacles and challenges that principals face in their efforts to promote e-safety?*

Method

This study adopts a qualitative research methodology, using semi-structured interviews as the primary research tool, to explore the perceptions, practices, and challenges faced by primary school principals and vice principals regarding e-safety in the Greek educational context. Qualitative methods are appropriate when the goal is to gain an in-depth understanding of social phenomena, emphasizing interpretation rather than quantitative generalization (Creswell, 2016; Savvidou, 2022). Given that e-safety is linked to organizational culture, leadership decisions, and local conditions, the qualitative approach allows for the exploration of complex and multifactorial situations that are not easily captured with standardized tools (Beauchamp et al., 2022). The main research tool for data collection was the semi-structured interview, which combines guided questioning with flexibility, allowing participants to freely develop their experiences and opinions (Patton, 2015). The interviews focused on two thematic areas: (a) digital competence and leadership in e-safety issues, and (b) strategies and institutional approaches to ensuring a safe digital environment at school. The method allowed for the exploration of both individual perceptions and organizational practices.

To enhance the clarity and appropriateness of the interview guide, a pilot interview was conducted with a school principal. The purpose of the pilot interview was to evaluate the clarity, flow, and appropriateness of the questions. Minor adjustments were made to the wording and order of some questions, particularly those related to European digital skills frameworks such as DigCompEdu and DigCompOrg. This process helped to improve the flow of the interviews and better align them with the research objectives (Patton, 2015).

The study applies thematic analysis as the data analysis approach. Thematic analysis is a flexible and widely used method for identifying, analyzing, and presenting themes from qualitative data (Braun & Clarke, 2006; Savvidou, 2022). It is particularly suitable for studies that seek to understand participants' perceptions of complex social processes, such as the implementation of digital safety practices in schools. This approach allowed for the

development of themes based on participants' narratives, while maintaining a focus on the conceptual dimensions of leadership in e-safety.

Ethical issues were considered at every stage of the research process. All participants were informed about the purpose and scope of the research and signed a consent form. The anonymity and confidentiality of their responses were ensured, and the data were stored securely. Participation was entirely voluntary, and participants had the right to withdraw from the study at any time without consequences (Creswell, 2016).

The Research Tool

The main research tool used in this study was a semi-structured interview guide, designed to elicit in-depth information from school principals and vice principals about their role in e-safety. The guide was structured in line with the research questions and theoretical framework of the study, which includes the European Digital Competence Framework for Educators (DigCompEdu), the Digital Competence Framework for Educational Organizations (DigCompOrg), and the guidelines of the General Data Protection Regulation (GDPR) as applied to the school environment (Redecker, 2017; Kampylis, Punie, & Devine, 2015). The interview consisted of two main parts.

Part A included 11 demographic questions that captured basic information about the participants, such as gender, age, role (principal or vice principal), teaching and administrative experience, school location (urban, suburban, rural), and type of school (e.g., number of classes, staffing). This data was crucial for understanding the context and identifying possible patterns related to geographical or organizational factors (Creswell, 2016; Beauchamp et al., 2022).

Part B consisted of 14 questions, organized into thematic sections corresponding to the main axes of the study:

- Digital literacy and familiarity with e-safety (Questions 1–2)
- Leadership and strategic policies (Questions 3–5)
- Specialized knowledge and professional development (Questions 6–7)
- Collaboration with institutions and parents (Question 8)
- Familiarity with the European DigCompEdu and DigCompOrg frameworks and the SELFIE tool (Questions 9–11)
- Legal compliance and data protection (GDPR, cybersecurity) (Questions 12–14).

The questions were formulated based on the DigCompEdu and DigCompOrg framework indicators directly related to digital safety, such as safe use of technology, awareness of digital risks, and the existence of protection strategies at school (European Commission, 2022; Kampylis et al., 2015). At the same time, the structure of the tool was based on previous studies that emphasize the critical role of education executives in implementing digital leadership policies and cultivating a digital culture (Beauchamp et al., 2022). The interview guide was reviewed by an expert in educational research and then tested through a pilot interview with a school principal. The pilot

interview aimed to assess the clarity, logical sequence, and comprehensibility of the questions. After the pilot phase, minor modifications were made, mainly in terms of the wording of technical terms and the flow of the thematic sections (Patton, 2015). Particular care was taken to clarify concepts such as "e-safety," "GDPR compliance," and "implementation of digital frameworks" to ensure a common understanding among all participants.

The Participants

The participants were ten (10) school leaders, six of whom were principals and four vice principals, all serving in public primary schools in three regional units of Greece. Participants were selected using purposive sampling, a common technique in qualitative research that allows for the focused selection of individuals with specialized knowledge and experience relevant to the subject of the study (Etikan, Musa, & Alkassim, 2016; Creswell, 2016). All participants held administrative positions in their schools and had significant teaching and administrative experience.

In terms of demographic characteristics, the sample included five men and five women. Their ages ranged from 50 to 63 years old, representing the age range most found in administrative positions in Greek primary schools. All had more than 16 years of teaching experience, while their administrative experience ranged from 5 to more than 20 years. This diversity in experience enriched the data, offering perspectives from both younger and more experienced leaders.

The participants served at a variety of schools in terms of the size and structure of the schools, including single-class, multi-class, and twelve-class schools. In terms of geographical distribution, participants came equally from the three target areas included educational leaders from urban, semi-urban, and rural schools, which allowed the study to examine whether local infrastructure, access to technology, and policy implementation differ by region. This regional dispersion strengthened the interpretation of the findings, particularly in relation to the challenges faced by schools in areas with limited technological support.

Data Analysis

The study used thematic analysis as the main method for processing data collected from semi-structured interviews with principals and vice principals of primary schools. Thematic analysis was chosen for its flexibility, accessibility, and suitability for identifying, analyzing, and presenting recurring patterns (themes) in qualitative data (Creswell, 2016; Braun & Clarke, 2006). Given that this research focuses on how school leaders perceive and implement e- safety strategies, thematic analysis allowed for the interpretation of their narratives and the drawing of meaningful conclusions about their leadership practices, challenges, and organizational strategies (Beauchamp et al., 2022; Krein, 2024).

The analysis followed the six-phase model proposed by Braun and Clarke (2006), which is widely used in

qualitative research in education due to its clarity and adaptability. The six stages are: (1) familiarization with the data, (2) creation of initial codes, (3) search for themes, (4) review of themes, (5) definition and naming of themes, and (6) writing of the final report.

To enhance reliability, strategies related to the validity, stability, and objectivity of the results were implemented. The researchers kept a detailed diary throughout the process, recording decisions related to coding and theme development. In addition, peer debriefing was conducted, in which a colleague reviewed selected excerpts and themes, enhancing methodological validity (Creswell, 2016; Lincoln & Guba, 1985). Data analysis was also performed on a question-by-question basis, as participants' responses to each question were examined separately before being incorporated into broader thematic categories. This question-by-question analysis allowed for the identification of common perceptions, differences, and characteristic narratives. The following chapter presents representative excerpts under each question to reflect the relevance to the emerging themes (Patton, 2015; Braun & Clarke, 2006). The data analysis process was carried out systematically and transparently, in accordance with the established principles of qualitative research methodology. Thematic analysis allowed for an in-depth interpretation of the narratives, while remaining faithful to the lived experiences of the educational leaders. Through careful coding, theme development, and validity checks, the study's findings offer reliable information about the reality of leadership in e-safety in Greek primary education.

Transparency was ensured by maintaining an audit trail. All versions of the transcribed texts and topic maps were stored and recorded chronologically, along with the reasons for decisions made during the analysis (Creswell, 2016; Wollscheid et al., 2024). This enhanced the reproducibility and overall reliability of the research.

Validity and Reliability of the Research

In qualitative research, the concepts of validity and reliability are approached through the framework of research trustworthiness, which includes four basic criteria: credibility, transferability, dependability, and confirmability (Lincoln & Guba, 1985). These criteria are particularly important in studies based on interviews and thematic analysis, where the researcher actively participates in the collection and interpretation of data. This study incorporated multiple strategies to enhance the reliability of its findings, while ensuring methodological rigor and ethical consistency.

Credibility refers to the extent to which the data and interpretations derived from them reflect the "truth" or lived experience of the participants. In the present study, credibility was enhanced through the researcher's extensive engagement with the data and methodological transparency. Each interview was transcribed word-for-word, allowing the researcher to remain close to the original narratives and minimize the risk of interpretive distortion (Creswell, 2016). The analysis followed Braun and Clarke's (2006) six-stage model, which ensures the systematicity and traceability of the interpretive process. *Transferability* refers to the extent to which findings can be applied or are meaningful in other contexts. Although qualitative research does not seek to generalize, this study provides rich descriptions of the participants and the school settings in which they work to facilitate

knowledge transfer. *Dependability* is related to the stability and consistency of the research process. To ensure this, the researcher kept a detailed audit trail, recording all critical decisions: coding strategies, thematic determinations, and changes during the analysis. This file allows for the verification of research consistency and enhances transparency (Creswell, 2016; Braun & Clarke, 2006). *Confirmability* refers to whether the findings are derived from the participants' data rather than from the researcher's biases or assumptions. To this end, analytical memos were kept, recording observations, interpretive patterns, and logical choices during the analysis process. Through this practice, the researcher made interpretive paths visible and enhanced reflexivity (Patton, 2015). Manual coding with comments and annotations enhanced transparency, while avoiding the introduction of pre-existing theoretical impositions. The themes emerged inductively, from the participants' own narratives. Finally, the *anonymity* and *confidentiality* of participants was ensured. Providing a safe environment enhanced the honesty of responses and reduced the risk of falsification due to socially desirable responses (Okunlola, 2024). A key element in enhancing credibility was the *researcher's reflexivity,* i.e., his constant awareness of his role and its potential influence on the research process. The researcher recognized his dual role—as analyst and interpreter—and tried not to influence or distort the participants' views. After each interview, personal observations and impressions were recorded to enhance the understanding of verbal and nonverbal communication.

Results and Discussion

The thematic analysis of the data revealed findings as below:

Perceptions and Familiarity with e-safety

Analyzing participants' responses to the question about the knowledge and skills necessary for school administrators in e-safety, nine out of ten pointed out that administrative roles require a comprehensive understanding of the basic principles of digital protection. Specifically, seven participants stated that they consider knowledge of personal data protection in accordance with the GDPR to be essential, as well as the ability to manage digital tools such as email, cloud storage, and digital learning platforms. Six principals mentioned that it is important for them and their vice principals to have skills in assessing digital risks and implementing appropriate safety policies. As one principal noted: "*Knowledge of technical issues is not enough; you have to be able to make decisions that protect the school as a whole*." In addition, four participants emphasized the importance of being able to monitor activity on teachers' or students' accounts and respond appropriately in cases of violation. Regarding communication skills, five participants emphasized that the role of the principal requires the ability to inform and guide the educational community on safety issues. This communication concerns teachers as well as parents and students. As one participant noted: "*You have to be able to explain why something is dangerous and convince people of the need for measures*." Three participants mentioned that basic technical skills, such as using strong passwords, creating backups, and updating software, are essential. In contrast, two said they prefer to rely on the school's IT manager and do not feel comfortable with technology but emphasized the need to at least be aware of the risks and protocols. Eight out of ten participants agreed that this knowledge cannot be taken for

granted and that formal training is required. At the same time, six mentioned that training should include practical scenarios and not just theoretical knowledge, while three stated that such skills should be a prerequisite for selection for a management position. It is worth noting that two participants admitted that they do not yet possess all these skills but are trying to enhance their knowledge through collaboration with other educators and self-training. The responses highlight a common demand for strengthening the professional development of executives with the aim of understanding and applying e-safety principles, which participants consider essential for the smooth and safe operation of the school.

A key theme that emerged from all interviews was the varying degrees of understanding and familiarity among participants with the principles of e-safety. Although all participants recognized the ever-increasing importance of digital security in the daily operation of their schools, their understanding of what exactly constitutes "e-safety" and how it should be implemented varied significantly. Of the ten participants in the study, seven reported feeling familiar with the basic principles of e-safety. Of these, four have attended specialized seminars or training programs on data protection, GDPR, and cybersecurity, organized by the Ministry of Education or university institutions. Three stated that their familiarity stems mainly from personal involvement and the experience they have gained in the context of their administrative work at school. Three participants stated that they did not feel adequately trained in this area. As one deputy headteacher noted: "*I have a general idea, but I feel I need further training to be sure I am following e-safety rules correctly*." The same participants emphasized the need for practical training on topics such as the secure management of students' personal data, the use of passwords, email security, and software protection against attacks.

When asked about the areas in which they felt they needed more knowledge or skills, six participants mentioned the need for training on issues related to the protection of students' and teachers' personal data, the use of secure online tools, and the prevention of phishing attacks. One school principal said: "*I know the theory, but I find it difficult to apply the principles when I encounter technical problems with the school's networks*.". Two participants noted that they felt very confused about how to properly implement GDPR guidelines in day-to-day school administration, while one stated that they were unaware of the existence of formal security protocols. The majority agreed that the Ministry of Education should offer systematic and regular training for education executives in this area. Although most participants claim to be familiar with the basic principles of e-safety, there are serious shortcomings in both theory and practice. The need for institutional and continuous training remains acute, especially in critical areas such as personal data protection and digital risk management at the school level.

The Role of School Leaders in Policymaking

The ability to manage crises related to digital security emerged as one of the key challenges for school administrators. Six out of ten participants reported that they had encountered some type of digital incident at their school, such as account breaches, inappropriate use of the internet, or cyberbullying. Of these, four reported that they were able to manage the incident in collaboration with teaching staff, while two noted that they had to seek help from external agencies, such as the School Violence Observatory or the police. As one principal

characteristically stated: "*It's not easy to know how to react when a student posts something aggressive. Clear protocols are needed, which unfortunately do not always exist.*" Eight of the participants emphasized the need for clear policies and procedures to deal with such crises. However, only three of the schools had developed policy documents or protocols describing the steps to be taken in the event of a digital incident. The rest reported that they operate mainly based on experience and personal judgment, which carries the risk of inconsistency and delayed response.

Most participants, specifically eight out of ten, emphasized the need for clear strategic planning at the school level to address e-safety issues. Of these, six said that this planning should include clear policies on the use of technological tools by students and teachers, while five spoke of the need to create internal regulations that incorporate data protection principles. Four principals pointed out that strategic planning should be linked to the overall planning of the school and not be a separate activity. As one of them aptly noted: "*e-safety is not something you do on top of everything else. It is part of the overall functioning of the school."* Seven of the participants stated that strategic planning should include explicit provisions for possible violations, as well as mechanisms for immediate response to such incidents. Of these, three mentioned the need for standardised procedures in cases of personal data violations, while two said they had already developed basic protocols in collaboration with teachers. Five participants emphasized that the creation of an e-safety strategy must be the result of collaboration with teachers and parents, rather than being imposed unilaterally by the administration. As one participant stated: "*If the design does not include the users of the system, then it is meaningless*." An important finding was that three participants admitted that they had not yet developed such a plan in their school, citing either a lack of knowledge or an inability to find the time. In addition, two reported that they had not received guidance from the Education Directorate on how to develop such a policy. It is worth noting that six of the ten participants stated that they would need support, mainly through training programs and guidance from experts, in order to be able to organize and implement an effective strategic plan. Most participants recognise the importance of a strategic approach to strengthening e-safety in schools, but at the same time highlight the need for institutional support, training and a collaborative planning process.

The need for training of principals in e-safety issues emerged as critical, as eight out of ten participants reported that they do not consider themselves adequately trained in this area. Of these, five stated that their knowledge came mainly from personal research and empirical engagement with digital media, while only three had attended organised training programmes related to internet safety. Seven participants reported that the training they had received in the past focused more on the use of digital tools and less on their safe use. As one principal noted, "*We learned how to use platforms, but no one talked to us about the risks or how to protect students.*" It is important to note that four participants expressed the view that training should be continuous and institutionalized, rather than fragmented. Five also suggested the creation of specialized seminars for education executives covering both theoretical knowledge and practical scenarios for managing digital threat incidents. Only two of the respondents said they felt sufficiently informed to deal with digital incidents within their school. The rest either expressed uncertainty or admitted that they would try to find solutions on a case-by-case basis without a clear strategy. In addition, six participants suggested introducing specific modules on digital security as part of the training provided

by the Institute of Educational Policy or other official bodies. As one deputy headteacher stated: "*We need practical examples and case studies, not just theory.*" It should also be noted that three participants suggested the creation of practice groups between schools to exchange experiences and good practices related to e-safety. Networking and horizontal training are considered important tools for developing a digital culture. Training for school leaders is considered a prerequisite for strengthening e-safety in schools. Despite existing efforts, the research indicates the need for more targeted, practical, and systematic training that empowers school community leaders in the digital environment.

Regarding prevention, five principals stated that they organize annual information events or collaborate with specialized agencies to educate students and staff on the safe use of technology. However, two of the participants admitted that they have not yet systematically incorporated preventive measures into their school program. In addition, six participants stated that they consider it necessary to train principals and vice principals in crisis management, with a particular focus on digital threats and psychological support for students and parents. According to four of them, the lack of relevant seminars or training opportunities is a serious obstacle. This issue demonstrates that crisis management in the digital space cannot be left to chance or the instincts of executives, but requires coordinated preparation, resources, and continuous professional development. The interview data clearly highlights the gap between needs and available tools, underscoring the urgent need for institutional support for schools in this area.

Cultivating a Culture of e-safety

Fostering a culture of e-safety in the school environment emerged as a fundamental priority for the school administrators in this study. Seven out of ten participants emphasized that creating this culture starts with school leadership, with five reporting that they implement practices that promote awareness and responsible use of digital tools. Six principals reported that they hold regular informational meetings with teaching staff on digital behavior issues, while four emphasized the importance of incorporating relevant topics into technology and computer science classes. As one principal said: "*Safety is not just a matter of regulation; it is also an attitude, a culture that we must instill in everyday school life.*" Regarding the student community, eight participants stated that they encourage teachers to develop activities that promote conscious and responsible use of the internet. These activities include presentations, posters, experiential workshops, and participation in initiatives such as "*Safer Internet Day*." However, only three of the participants reported the existence of a clear e-safety policy within their school. The rest either operate with informal practices or state that they follow general guidelines without adapting them to the needs of their school. This demonstrates a lack of an overall strategic framework for cultivating this culture. Five participants reported that they seek to establish dialogue and cooperation with parents, considering that the family is a key ally in establishing positive attitudes towards internet use. As one participant said: "*It is important that parents are not left out. They need to share our knowledge, our risks and our strategy."* It is noteworthy that two of the participants referred to examples of cyberbullying incidents, in which the school's lack of preparation highlighted the need for clear procedural protocols and staff training. Overall, safety culture is not just a technical issue, but an ongoing educational and administrative challenge that requires collaboration,

leadership, and strategy. The experience of the research directors shows that the effective integration of e-safety into school life requires the shaping of attitudes and everyday practices.

Working with Parents and the School Community

Working with parents and the wider school community was seen by participants as a key factor in boosting e-safety. Eight out of ten principals/vice principals reported that their school seeks active communication with parents on issues related to the safe use of technology by students. Specifically, five reported that they have organized informational events or workshops with the participation of experts (e.g., e-safety officers, representatives of the Hellenic Police), while three have limited themselves to information notes or posts on the school website. Only two principals admitted that they have not yet developed systematic actions to inform parents, citing lack of time or response from parents. When asked how often parents are involved in digital offending, seven participants stated that they immediately inform guardians when an incident occurs (e.g., cyberbullying, inappropriate use of devices), and four of them reported that they proceed with joint counseling intervention with the school teacher or psychologist. Regarding cooperation with the rest of the school community (teachers, associations, municipal authorities), six executives stated that they maintain frequent communication and cooperation for the implementation of digital safety actions, while four emphasized that this cooperation remains fragmented and depends on the initiative of certain staff members. As one participant noted: "*When the teaching staff is not particularly interested, it is difficult to move forward with such issues on your own*." In addition, five schools had developed a digital behavior code or similar policy, which had been communicated to parents, while two participants stated that they were preparing such a document. The remaining three reported that they did not have a written policy but operated on a case-by-case basis. This demonstrates the need for institutionalized procedures that involve parents and teachers in a common framework of prevention and response. The overall picture from the responses shows that, although most principals recognize the importance of cooperation with parents and the school community, the systematization of this cooperation remains a challenge. Differences in approach, the lack of involvement of some parents, and the absence of defined protocols underscore the need to strengthen dialogue, build relationships of trust, and implement joint actions that promote digital responsibility.

SELFIE: Experience and Implementation

The SELFIE tool (Self-reflection on Effective Learning by Fostering the use of Innovative Educational technologies) seems to be known to most participants in this study, but its use is neither universal nor systematic. Of the ten principals and vice principals who participated, six said they had used the SELFIE tool in their school, while four said they were aware of it but had not used it in practice. Among the six who have implemented it, four reported that they used it in the context of European programs or educational activities aimed at strengthening digital skills. The other two stated that the tool was used for internal evaluation purposes, mainly to record the views of teachers, students, and parents regarding the school's digital profile. According to participants, the main findings from the implementation of the tool included equipment shortages, a need for professional development,

and a lack of digital safety policy. As one headteacher said: "SELFIE helped us understand where we are lagging behind and how to target our next actions." The four participants who had not used the tool cited mainly a lack of knowledge about how to access and implement it, as well as a lack of guidance from the relevant management or education advisors. One of them admitted that he had only heard about SELFIE without having clear instructions on how to use it. This points to the need for better information and systematic training for staff. It is noteworthy that, of the six who implemented it, three took specific actions based on the results of the tool. These included reorganizing the use of technological tools in the classroom, creating working groups to strengthen digital literacy, and submitting proposals for upgrading equipment. The other three, although they evaluated SELFIE positively, were unable to make substantial changes, mainly due to a lack of resources or organizational support. Overall, it appears that SELFIE can be a useful self-assessment tool for schools, provided it is used in a targeted and systematic manner. Making the most of its results requires a strategy, the involvement of all stakeholders, and support from the state and local education authorities. Its integration into everyday administrative practice, as shown by the examples of some participants, can significantly enhance the cultivation of a culture of digital safety and innovation.

DigCompEdu and DigCompOrg

The European frameworks DigCompEdu and DigCompOrg are recognized as important tools for strengthening digital skills in education, but awareness and implementation among the participants varied. Of the ten principals and vice principals who participated in the study, seven said they had heard of DigCompEdu, while three reported being unaware of the framework. Similarly, only four were familiar with the DigCompOrg framework, suggesting a need for greater dissemination of relevant information. Of those who were familiar with DigCompEdu, five reported that they had been informed through seminars, by training providers, while the remaining two discovered it through the internet or European projects. As one headteacher stated: "*DigCompEdu gave me a framework to enhance the professional development of staff*." However, only three stated that they put some of its guidelines into practice, mainly in terms of supporting ICT use and guiding teachers. Regarding DigCompOrg, the situation is less positive. Only two participants have used it in practice, and that was in the context of European school development projects. The other two who were aware of it said they had learned about it in theory but had not incorporated it into their administrative practices. The six who were completely unaware of the framework pointed out that they had never received any information from the official bodies. What emerges is that the use of these frameworks has not yet been systematically integrated into school management. Several principals reported that although the intentions are positive, the lack of guidance, time, and organized training makes it difficult to implement them. As one participant noted: "*DigCompOrg is very useful, but without support and training, it remains a theoretical tool*." Despite the challenges, eight participants agreed that such frameworks should be integrated into school strategies and linked to actions such as self-assessment, staff professional development, and digital safety action planning. DigCompEdu seemed more accessible, as its guidelines relate to everyday pedagogical practice and staff needs. The low adoption of DigCompOrg, on the other hand, indicates the difficulty of transferring the theoretical model to the organizational reality of schools. The research indicates that in order to make effective use of these frameworks, institutional support, guidance, training, and coordinated action by the

competent authorities are necessary. Overall, the findings show that DigCompEdu and DigCompOrg are useful tools for shaping a digitally mature and safe educational reality, but their practical application requires strengthening the information and professional development of education leaders.

GDPR Compliance

Compliance with the General Data Protection Regulation (GDPR) is a key challenge for schools, particularly in administration and information management. Of the ten participants in the study, eight reported that they had received some information about the GDPR, while two said they had no official information on the subject. Of those who were aware, five principals and vice principals said they were implementing specific compliance practices in their schools. As one of them noted, "*We have informed the staff, and we make sure that no personal data of students is published without consent*." The other three who were aware of the regulation reported that they were taking basic measures, such as obtaining consent from parents or avoiding publishing photos, but did not have a fully documented action plan. In contrast, two participants admitted that they do not implement any system of compliance with the GDPR, due to ignorance or lack of official guidelines. As one deputy headteacher said: "*We know there is something relevant, but we have not received clear instructions from the Education Directorate*." Most participants, specifically seven, emphasized the need for training and specialized guidance to strengthen school compliance with the GDPR. In addition, six participants pointed out that cooperation with specialized bodies (legal, technical) is required for the effective implementation of data protection measures. Only three of the ten principals and vice principals said they had developed a digital data management and communication protocol at their school. The remaining seven rely on general guidelines and empirical practices, without any formal management policy or monitoring mechanism. The results highlight the need for institutional support, with the development of guidelines, training seminars, and supervision by competent bodies. At the same time, there is a lack of internal policies in most school organizations, which increases their vulnerability to data breaches. In conclusion, the research shows that although there is initial awareness of data protection, the implementation of comprehensive and documented practices remains limited. It is necessary to develop clear protocols and support schools so that they can comply with the requirements of the GDPR in an organised and safe manner.

Preventive Measures for e-safety

Strengthening cybersecurity in schools is a critical issue, as technological threats increase and schools become increasingly vulnerable. Of the ten interviews, only four participants have implemented preventive measures to protect digital infrastructure and data. Of these, three mentioned the use of secure passwords for school networks and educational platforms. As one principal stated: " *All computers have unique passwords, and they are changed regularly, at least every three months*." Two participants mentioned periodically updating teaching staff on security issues, but without any standardised seminar or formal training. Only one of the ten participants mentioned the use of antivirus software and firewalls on all school computers. The rest either did not mention such practices or stated that "*support comes from the IT Center or the network manager of the Directorate*." Five

participants stated that they had not taken specific measures for cybersecurity, while two of them acknowledged that there was a lack of awareness of the risks: "*We haven't really thought about these issues; we rely on teachers and students to use computers properly*." One vice principal noted: "*We've never been attacked or had any problems, so we haven't given it much thought*." It is noteworthy that seven out of ten participants emphasized the need for an official security policy from the Ministry of Education to better guide and organize their actions. In addition, six participants pointed out the need to train staff, both principals and teachers, on practical cybersecurity issues. In conclusion, the findings highlight significant gaps in the implementation of preventive cybersecurity measures in schools. Although there is some awareness of the problem, actions are fragmented and depend mainly on the personal initiative of education officials. The need for institutional support, training, and the development of security management policies is becoming urgent for schools to be shielded from digital threats that may affect the integrity, operation, and protection of the personal data of students and staff.

The assessment of the effectiveness of e-safety practices implemented in schools revealed significant differences among participants. According to the responses of the ten education executives, only three considered that the existing practices in their school were adequate and effective. The remaining seven considered that the actions taken were either fragmented or insufficient for the actual needs of the school. The three participants who rated their practices positively cited specific actions, such as periodic staff training, the use of strong passwords, access to protected networks, and the use of tools such as antivirus software and systematic monitoring of network activity. As one principal said: "*Although we don't have a dedicated person in charge, we try to follow good practices and so far we have avoided problems*." In contrast, the seven participants who question the effectiveness of existing measures identify weaknesses in four main areas: (a) *lack of a school-level e-safety policy*, (b) *absence of continuous training*, (c) *technical issues such as outdated equipment or lack of access to protection software*, and (d) *unclear division of responsibilities in the event of a digital incident.*

Four participants pointed out that teachers have not received clear guidelines on managing digital risks. One participant emphasized: "*It is difficult to talk about effectiveness when we have never been systematically trained in these issues*." In addition, five participants stated that students have not been actively involved in digital safety-related activities, which reduces the scope of the practices. It is indicative that six executives reported that actions taken so far have been driven more by personal interest or previous experience and less by an organized strategy. One of the key conclusions is that effectiveness is directly related to the existence of an action plan, which is lacking in many units. Therefore, the analysis shows that the effectiveness of e-safety practices in schools is limited and based mainly on personal initiatives. There is an urgent need for institutional guidance, specific evaluation mechanisms, and the development of comprehensive policies that will enhance security at the school level, covering both technical and pedagogical parameters.

Conclusions

The main objective of this qualitative research was to study the role of primary school principals and vice

principals in promoting e-safety in the school environment. Based on the thematic analysis of the ten semi-structured interviews, this section attempts to systematically present the main findings, organized according to the four main research questions formulated by the study.

Most participants (7 out of 10) acknowledge that they have a direct responsibility for promoting e-safety, although they express concerns about the scope of their responsibilities and the lack of clear guidance from central administration. For them, leadership means mainly informing and monitoring staff and students, but the lack of a supportive framework weakens their actions. Only 4 out of 10 participants report implementing specific practices, such as restricted access to websites, awareness-raising activities, or collaboration with IT teachers. The rest (6 out of 10) point to either the absence of structures or the implementation of informal or ad hoc practices without a specific plan. In general, management is based on empirical criteria and personal initiatives. Eight out of ten principals consider cooperation with parents to be crucial, but only three report having implemented relevant joint actions. The rest note the difficulty of engaging parents or the absence of a relevant culture of cooperation. In addition, there is a lack of organization of thematic meetings or workshops focusing on internet safety. Only 2 out of 10 participants reported sufficient familiarity with and active use of these tools. The rest either are unaware of them (4 out of 10) or have used them superficially or for formal reasons (4 out of 10), without incorporating the findings into strategic actions. There is a lack of information, practical guidance, and connection to the Greek educational context. The most significant obstacles identified are lack of institutional support (10 out of 10), inadequate technical infrastructure (7 out of 10), lack of targeted training (8 out of 10), and overload with administrative tasks (6 out of 10). In addition, several participants note the absence of a clear digital security policy and the low level of awareness among students and parents. These findings underscore the need to strengthen institutional support, develop a culture of digital security, and implement systematic policies in schools.

The study's findings reveal a consistent interest and willingness to take action on the part of managers, but at the same time highlight serious shortcomings in terms of institutional guidance, training, and infrastructure. e-safety is mainly addressed through individual initiatives rather than a systematic or uniform policy framework. This is particularly evident in rural or semi-urban areas, where the lack of technical and administrative support exacerbates the difficulties. One of the key findings is the absence of a unified strategy in schools with regard to digital security. Although school principals recognize the risks associated with the use of digital technologies, especially by students, the actions taken are often reactive rather than preventive. There are no formal protocols or action plans, nor is there any institutionalized monitoring of the implementation of relevant measures. Special mention should be made of the relationship between the research and the European frameworks DigCompEdu, DigCompOrg, and the SELFIE tool, which, although available and theoretically adapted to the European reality, do not seem to have been meaningfully integrated into the functioning of Greek schools. The study confirms that their use remains fragmented and, often, formal. At the same time, the willingness of school leaders to be trained was highlighted, but also the simultaneous lack of access to targeted training programs. Most participants mentioned the absence of formal training on digital safety issues and highlighted the need for practical tools and guidelines for implementing policies in schools.

Another finding of particular importance concerns the relationship between school administration and parents and the wider school community. Although the need for cooperation and co-creation of digital protection policies is recognised, the research shows limited involvement of parents and students in decision-making processes, as well as a low level of awareness. However, the positive examples recorded cannot be ignored, which include awareness-raising activities, standardised policy documents, efforts to use self-assessment tools or the introduction of relevant topics in the classroom. These examples confirm that, despite the challenges, it is possible to implement good practices when commitment, knowledge, and support are combined.

A systematic approach to e-safety in education is now a necessity rather than an option. The results of this study have highlighted critical gaps and shortcomings that require the formulation of clear policies, realistic strategies, and operational support mechanisms for schools and education officials. The following guidelines are proposed as the basis for a national educational policy on digital security, with a focus on the sustainable and equitable integration of technology into everyday school life: *Establishment of a comprehensive digital policy framework for schools, Strengthening the training and professional development of staff, Establishment of support mechanisms in Education Directorates, Implementation of school e-safety plans, Systematic use of self-assessment tools, Development of a culture of cooperation with the school community, Provision of technological infrastructure and safe access, Continuous evaluation and updating of policies*.

In conclusion, e-safety in education cannot rely solely on the goodwill of officials. It requires visionary policy, institutional commitment, and operational support. The proposals formulated in this study aim to contribute to a public dialogue on building a pedagogically safe and technologically mature school.

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