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Michael P. Menchaca
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Associate Editor
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Associate Editor
Devayani Tirthali
Research Associate, India

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Publications & Communications Coordinator: Mark Kenneth Camiling
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From the Editors

Since late 2022, generative AI has become increasingly mainstream, with systems such as ChatGPT, Claude, and Copilot becoming commonplace in educational contexts, deeply influencing how students learn, how teachers prepare, and how institutions assess. This has prompted educators to rethink fundamental aspects of their work such as authorship, critical thinking, and assessment integrity. At the same time, as AI driven personalization becomes a norm in EdTech platforms, educators have to grapple with outsourcing evaluation and decision making to opaque algorithms.

With this background, there is a growing discourse emerging from scholars and educators to examine and critically engage with educational technology. This critical turn urges educators, researchers, and policymakers to look beyond questions of efficacy, scalability, and user experience and reflect on whose values are embedded in the technology, whose voices are amplified or silenced, and what forms of knowledge are legitimized or marginalized. Scholars are increasingly engaging with the socio-political context of education, highlighting issues of surveillance, algorithmic bias, digital colonialism, and corporatization of learning. As we present this issue, we invite readers to move beyond surface-level enthusiasm about new tools and toward a deeper reflection on the values, assumptions, and power structures embedded in technology. We invite readers to, in a word, think.

The current issue brings together a diverse set of contributions reflecting the growing centrality of artificial intelligence (AI) and gamified educational apps, as well as the impact of technology on various fields such as library science, graphic design, and alternative education. The offerings in this issue present AI as both tools, examples including AI mediated intercultural communication and AI assisted robotics for children with autism, as well as articles highlighting need for critical consumption of AI. These articles illustrate both the promise and complexity of technology-mediated learning and information environments.

With IAFOR's commitment to bring interdisciplinary, intercultural manuscripts, we present work of authors from countries across three continents: Ghana, South Africa, Indonesia, India, Turkey, Italy, Spain, and Latvia, each bringing insights embedded in their local context but with global impact. This year, we also present diverse ways of inquiry with established methodologies such as statistical analysis of large survey samples and systematic review to newer ways of explorations such as patchwork ethnography. We trust the eight articles presented in this special issue provide a well-rounded view of how technology currently influences the field of education and beyond.

The first article reports on an impressive eTwinning initiative designed to cultivate intercultural understanding among Turkish and Italian undergraduate teacher trainees collaborating in a course mentored by Spanish Master's students. Authors analyze student reflections using Tuckman's model of group development and reflect on the findings with Allport's contact hypothesis that intergroup contact under appropriate conditions can effectively reduce prejudice among intercultural teams. The paper highlights the use of AI translation tools by

participants as Lingua Franca and what it takes for an international telecollaboration project to serve as a catalyst to foster inclusive and digitally competent educators.

Asking the question what it means to be "AI literate," the second article proposes instructional design for a course focused on knowledge, application, evaluation and creation of AI tools as well as their ethical consumption. With detailed description of the four aspects of the course including specific outcomes, course activities and assignments, the paper will provide a useful starting point for course design. Documenting three case trajectories of course participants, the study demonstrates how reflective practice through journaling and guided tasks can turn AI into a research partner that can be interrogated rather than merely adopted.

Continuing with the AI theme, the next paper explores how AI-enabled plush robots might support children with autism spectrum disorder. The study reports on interviews of 13 experts (teachers and various healthcare professionals) who evaluated plush toy robots embedded with AI features to enhance social engagement and emotional regulation. Based on expert feedback, the paper enumerates the features and functionalities of the robots that need to be considered in varied educational and rehabilitation contexts. Although plush robotic toys were deemed promising, the paper highlights the need for expert supervision, making them a tool in structured therapeutic environments.

The fourth article interrogates the promises of gamified language learning apps through the lens of student motivation and cognitive engagement. Rather than focusing on design or pedagogy, the authors focus on the psychological response and subjective learning experience of the gamified elements and how it affects the intention to use the app. The statistical modeling confirms what many designers intuitively know: Playful, evaluative experiences drive sustained use. However, the more interesting contribution is how the elements of need, search, and evaluation embedded in the apps for L2 learning mediate this relationship.

Article five presents novel integration of mindfulness, a psychological construct, with research on digital competence and AI acceptance. Drawing on survey data from pre-service teachers in India, the authors argue that digital competence shapes attitudes toward AI most powerfully when mediated by mindful attention. Instead of the binaries of utopian adoption and dystopian resistance, the article presents a third space of fostering mindful digital practices for critical awareness and openness in adopting technological innovations.

In exploring how teachers in Alternative Learning System (ALS) develop and enact technological pedagogical content knowledge (TPACK), the sixth article reclaims the context specific complexity of classroom practice. Similarly, the methodological move to patchwork ethnography underscores context specific departure from traditional ethnography, to collect rigorous data in flexible and non-linear ways to stitch together a holistic picture of teacher practice. Teachers negotiate curriculum mandates, infrastructural constraints, and personal pedagogy in ways that reveal TPACK as a lived, adaptive process. The paper describes the contexts of ALS teachers that support or hinder the development of TPACK and suggests solutions at the systemic, institutional, and individual levels.

The next article systematically reviews research at the intersection of library and information science (LIS) and the growing global challenge of disinformation. Surveying a decade of scholarship, the authors make visible the changing role of librarians, archives, and information professionals as they integrate technology in combating misinformation. The librarians are increasingly positioned as front-line actors in promoting information literacy, verifying sources, and cultivating critical digital citizenship. The paper presents a conceptual map simplifying the complex landscape of information ecosystem involving librarians, information technology, misinformation, and information literacy. The article provides a useful resource for multiple stakeholders including teachers, journalists, activists, and policymakers.

The last article reports how Ghanaian graphic design students from two universities approach the ideation phase. Through classroom observations, interviews, and analysis of student work, the authors map practices and tools students use for idea generation and development. Providing examples of student sketchbooks as well as digital tools, the article describes intermingling of tradition and technology. The authors highlight how the classroom is a microcosm of global shifts in creative practice and underscore the need for pedagogies that embrace digital practices without sacrificing traditional processes.

Happy reading and thinking!

Devayani Tirthali, Associate Editor
Michael P. Menchaca, Editor, and
Daniel L. Hoffman, Associate Editor

IAFOR Journal of Education: Technology in Education
tech.editor.joe@iafor.org

Notes on Contributors

Article 1

An Investigation of Group Behavior, Leadership and Intercultural Communication: An eTwinning ITE Project

Dr Ahmet Göçen

Ahmet Göçen is an Associate Professor at Afyon Kocatepe University in Türkiye, specializing in educational management, AI, and ethics. He has led multiple projects on STEM, AI literacy, and innovative teaching methods, contributing to both academic research and practical school applications. He actively supports international collaboration on teacher development under eTwinning ITE projects. His current research explores educational leadership, AI ethics, and teacher training systems across global contexts.

Email: agocen@aku.edu.tr

Dr Francesca Mancini

Francesca Mancini is a lecturer at the University of Florence and an English teacher at Liceo Statale "E. Montale" in Pontedera, Italy. As an eTwinning ITE Ambassador, she guides teachers and students in creating innovative, inclusive, and cross-cultural projects. She has contributed to regional and national seminars, supporting teacher training and advancing digital pedagogy. Her work focuses on fostering intercultural dialogue, enhancing digital competence, and encouraging collaborative learning through EU project initiatives.

Email: francesca.mancini@unifi.it

Izaskun Jorajuria Elizondo

Izaskun Jorajuria Elizondo is an Associate Professor at the Public University of Navarre (UPNA) and Education Inspector in Pamplona, Spain. With over twenty-five years of experience as a tenured secondary school teacher of Physics and Chemistry, she combines classroom practice with innovation, teacher training, and institutional responsibilities. She has been an eTwinning Ambassador in recent years and continues to serve as a Scientix Ambassador, promoting collaboration and innovation in science education.

Email: izaskun.jorajuria@unavarra.es

Dr Muhammet Emin Türkoğlu

Muhammet Emin Türkoğlu is an Assistant Professor at Afyon Kocatepe University, Department of Educational Studies. Formerly an English teacher, his academic work centers on educational leadership, with a focus on instructional leadership, teacher agency, and inclusive practices. He publishes in international journals and engages in research projects that examine how school leadership fosters effective teaching and learning.

Email: mturkoglu@aku.edu.tr

Atahan Doğmuş
Atahan Doğmuş completed his secondary education at Milliyet Anadolu Öğretmen Lisesi in Erzincan / Türkiye. After gaining admission to Boğaziçi University, he earned his bachelor's degree in Foreign Language Education in June 2023. Building upon this pedagogical foundation, he commenced postgraduate studies in Educational Administration at Afyon Kocatepe University in February 2024. His academic objective is to research and implement evidence-based leadership practices that enhance educator efficacy and improve student outcomes.
Email: atahan.dogmus@usr.aku.edu.tr

Article 2
Building Artificial Intelligence Literacy for Research: Technical Understanding as the Foundation for Critical Evaluation

Prof Diler Öner
Diler Oner is a professor in the Department of Computer Education and Educational Technology at Bogazici University in Istanbul. She has held leadership positions as the director of both the Center for Teaching and Learning and the Center for Educational Technology Research at the university. Dr Oner earned her MSc and PhD degrees from the University of Wisconsin-Madison, USA, in the Department of Curriculum and Instruction, specializing in educational technology with a minor in learning sciences. Her research focuses on the design, development, implementation, and evaluation of computer-based tools and processes to support learning.
Email: diler.oner@gmail.com

Article 3
AI-Powered Plush Robots for Children with ASD in Education, Rehabilitation: Expert Evaluation

Dina Bethere
RTU Liepāja Academy, Centre for Pedagogy and Social Work, Latvia
Email: Dina.Bethere@rtu.lv

Inese Tīģere
RTU Liepāja Academy, Centre for Pedagogy and Social Work, Latvia

Anete Hofmane
RTU Institute of Digital Humanities, Latvia

Airisa Šteinberga
RTU Institute of Digital Humanities, Latvia

Undīne Gavriļenko
RTU Liepāja Academy, Centre for Pedagogy and Social Work, Latvia

Santa Meļķe
RTU Liepāja Academy, Centre for Pedagogy and Social Work, Latvia

Aleksandrs Okss
RTU Institute of Architecture and Design, Latvia

Aleksejs Kataševs
RTU Institute of Mechanical and Biomedical Engineering, Latvia

Aleksandrs Vališevskis
RTU Institute of Architecture and Design, Latvia

Article 4

Language Learners' Intentions to Use Gamified Learning Apps: The Role of Gameful Experience and Cognitive Engagement

Dr Irum Alvi
Dr Irum Alvi, Assistant Professor of English (Humanities) in the Department of Applied Sciences and Assistant Dean of Applied Sciences at Rajasthan Technical University, Kota, brings over 18 years of distinguished academic experience. A prolific researcher, she has contributed extensively to blind peer-reviewed journals, and her work has been featured at esteemed national and international conferences as a Resource Person, guest speaker, and keynote speaker. Her research interests span Post-Colonial Writings, Diaspora Studies, Professional and Technical Communication, Language Teaching and Learning, Technology Adoption in pedagogy, and comparative American and Indian literature.
Email: irumalvi@gmail.com

Article 5

Digital Competence and Attitudes Toward AI: Mindful Attention Awareness as a Mediator

Tasaduk Musood
Tasaduk Musood is a PhD scholar at the Department of Education, Akal University, Talwandi Sabo, Punjab. Her research interests include higher education, internal migration, educational psychology, teacher education, cognitive flexibility, mindful attention awareness, and resilience. She has published widely in national and international journals such as the MIER Journal of Educational Studies Trends and Practices, Journal of Information Systems Engineering & Management, The International Journal of Indian Psychology and Interdisciplinary International Journal of Advances in Social Sciences, Arts and Humanities.
Email: wanitassu6@gmail.com

Dr Birender Kaur
Birender Kaur is an Assistant Professor in the Department of Education at Akal University, Talwandi Sabo, Punjab. Her research areas span higher education, teacher education, ICT,

social networking sites, mental health, and self-disclosure. She has published widely in national and international journals such as the *MIER Journal of Educational Studies Trends and Practices*, *Journal of Information Systems Engineering & Management*, *The International Journal of Indian Psychology, Journal of Psychiatry Research and Treatment*, *Indian Journal of Psychology and Education*, *International Journal of Multidisciplinary Education Research*, and S*hodhSarita*. In addition, she has contributed book chapters and guided research projects in educational psychology and teacher education.
Email: kr.birender@gmail.com

Article 6
Unpacking Technological Pedagogical Content Knowledge (TPACK): Context of Non-Formal Teachers in the Philippines

Luigie Lursh G. Almojano
Luigie Lursh Almojano is an Assistant Professor of Anthropology at the Department of Social Sciences of the University of the Philippines Los Baños, Philippines. His research expertise is in anthropology of education, design anthropology, digital anthropology, and heritage and museum studies. He teaches courses on socio-cultural anthropology and Science, Technology, and Society. He holds a Bachelor of Arts in Anthropology (Magna Cum Laude) from the University of the Philippines Diliman and an Erasmus Mundus Master of Arts in Euroculture (Summa Cum Laude) from the University of Strasbourg, France. He is also a Learning Experience Designer (LXD) at Habi Education Lab, a research and design studio focused on creating well-designed learning experiences for preschoolers to professionals.
Email: lgalmojano1@up.edu.ph

Article 7
A Systematic Literature Review on the Role of Library Science in Combating Disinformation

Ismiatun
Ismiatun, SAP., M.AP. completed her undergraduate and master's degrees in Public Administration. She worked as an editor at Brawijaya University Press from 2012 to 2023 and obtained an editor certificate from BNSP. In 2024, she continued her career in scholarship at Brawijaya University Library. Ismiatun actively publishes scientific works related to public policy, innovation, digital transformation of libraries, and the legal and ethical aspects of the use of artificial intelligence. Her research demonstrates her dedication to the development of public administration science and the important role of libraries in the digital era.
Email: ismi.editor@ub.ac.id

Dr Farida Nurani
Farida Nurani, S.Sos., M.Si., is a lecturer at Brawijaya University specializing in social policy and community development. She actively researches social issues such as early marriage, social capital, and female labor migration. Dr Farida has published a Scopus-indexed paper on the analysis of social capital in reducing maternal and infant mortality. Her most recent research

focuses on the phenomenon of early marriage in rural social systems through the BIMA-Kemenristekdikti 2024 program. She has published two books: *Female Migrant Workers: Affirmative Policies for Marginalized Communities* (2017) and *Social Policy in Indonesia: Perspectives and Implementation* (2022). Farida Nurani is also an active speaker at international conferences.

Agung Suprapto

Agung Suprapto, S.Sos., MA was born in Surabaya on October 3, 1965. He currently serves as an Associate Librarian at the Brawijaya University Library with the rank of Supervisor, Class IV/a.As an experienced librarian, he has conducted various studies that have contributed to the development of library services, including research on “The Influence of Music on Learning Activities in the Library” and “Preparation of Standard Operating Procedures in State University Libraries.” With a strong dedication to librarianship, Agung Suprapto continues to contribute to improving the quality of academic library services in Indonesia.

Article 8

Unearthing the Ideation Process Used by Graphic Design Students in Ghanaian Universities

Dr Sylvanus Ametordzi

Sylvanus Ametordzi holds a PhD in Visual and Performing Arts from the Durban University of Technology in South Africa. He began his academic journey at Saint Paul’s Secondary School, completing a Visual Arts program, and then earned a Certificate in Education from the Teachers' Training College in Jasikan, Ghana. After three years of teaching, he pursued a bachelor’s degree in Integrated Rural Art and Industry at Kwame Nkrumah University of Science and Technology (KNUST). In 2008, he returned to KNUST for a master’s degree in Art Education. Currently, Dr Ametordzi is a Computer-Aided Design lecturer at Cape Coast Technical University, and his areas of interest in research include Graphic Design Pedagogy and Computer-Aided Design.

Email: sylvanus.ametordzi@cctu.edu.gh

Dr Folasayo Enoch Olalere

Folasayo Olalere is an interdisciplinary researcher, designer and educator, and he holds a PhD in Product Design from the University of Malaysia Kelantan in Malaysia. He is an academic at the Open University in the UK and serves as an honorary research fellow at the Durban University of Technology, South Africa. Before joining the OU, he had worked as a senior lecturer at the Durban University of Technology and as a postdoctoral research fellow at the Vaal University of Technology and University of Zululand in South Africa. His research interests include design for culture and social change, and design education, with a particular interest in the intersection between internationalization and decolonization of design curricula.

Email: folasayo.olalere@open.ac.uk

An Investigation of Group Behavior, Leadership and Intercultural Communication: An eTwinning ITE Project

Ahmet Göçen
Afyon Kocatepe University, Türkiye

Francesca Mancini
Florence University, Italy

Izaskun Jorajuria Elizondo
Universidad Pública de Navarra, Spain

Muhammet Emin Türkoğlu
Afyon Kocatepe University, Türkiye

Atahan Doğmuş
Afyon Kocatepe University, Türkiye

Abstract

This qualitative case study examines how undergraduate students from the education faculties of Türkiye and Italy navigated the processes of group development, leadership, and communication throughout a six-month online eTwinning Initial Teacher Education (ITE) project conducted in the 2024-2025 academic year. Written reflections by 75 participants were collected at both the project's onset and completion. Drawing on Tuckman's model of group development and Allport's contact hypothesis, the analysis identifies initial challenges such as language barriers and weak cohesion that were alleviated by AI translation tools acting as a makeshift lingua franca. By the end of the exchange, despite some underperforming groups, most teams achieved high levels of collaboration and reported substantial personal and professional growth, including stronger digital competencies and greater intercultural sensitivity. Ultimately, these findings illustrate that well-structured international telecollaboration projects, underpinned by proactive peer leadership, purposeful technology use, and expert scaffolding, can serve as powerful catalysts for fostering inclusive and digitally competent teacher education.

Keywords: group behavior, leadership, intercultural communication, eTwinning, initial teacher education

In an era of global connectedness, higher education institutions are increasingly integrating telecollaboration projects to foster international cooperation and intercultural communication skills among educators and undergraduate students. Telecollaboration or virtual exchange projects connect learners through online collaboration with partners from diverse cultural and geographical contexts as an integral component of their educational programs (O'Dowd, 2018). These virtual exchange opportunities have become a cornerstone of 21st-century pedagogy, essential for preparing undergraduate students for success in their future professions (Heymans et al., 2024). Across disciplines from health sciences and engineering to teacher training, universities are developing shared virtual exchange modules to equip students with the global competencies needed in today's interconnected world (Bassani & Buchem, 2019; Commander et al., 2022).

One of the largest virtual exchange platforms that has been in action is eTwinning, which targets teachers across the EU and program countries. Launched in January 2005, eTwinning's vision was to connect teachers across Europe through meaningful collaboration. Over these 20 years, eTwinning has connected 1.2 million teachers from 295,000 schools in 46 countries, who have run more than 160,000 projects reaching over 3 million pupils (European School Education Platform, 2025). Building on this success, eTwinning has expanded its scope to include university-level teacher education programs, introducing Initial Teacher Education (ITE) specifically for teacher trainees (La Marca & Gulbay, 2021). This strategic expansion aims to cultivate international teaching perspectives from the earliest stages of professional development, preparing future educators for increasingly globalized education.

eTwinning ITE epitomizes internationalization at home, allowing participants to gain cross-cultural experience without travel (European Education and Culture Executive Agency, 2023). Research indicates that such virtual exchange projects can enrich pre-service teachers' professional growth, broadening their pedagogical horizons and intercultural awareness (Napal-Fraile et al., 2024). Indeed, engaging with overseas peers through eTwinning has been reported to sharpen trainees' digital competences and learn about other education systems (European Education and Culture Executive Agency, 2023). These trends align with broader educational goals of global citizenship education, which emphasizes equipping learners to collaborate across linguistic and cultural divides in an ever-more interconnected world (Heymans et al., 2024). Thus, international collaborative projects are becoming increasingly essential in cultivating globally competent educators and trainees.

A critical component of these international initiatives is the intentional cultivation of intercultural understanding across nationalities and regions united by the shared purpose of effective education. The emergence of technologies facilitating cross-cultural connection and information exchange creates an educational mandate where schools must embrace global cultural and linguistic diversity (Silva, 2014). This modern technological imperative also resonates with Gordon Allport's the intergroup contact hypothesis (1954). Allport proposed that interaction between diverse groups, when occurring under specific favorable conditions, can significantly reduce prejudice, foster mutual respect and mitigate intergroup tensions. These complementary perspectives, technological opportunity and psychological insight,

provide a strong foundation for today's virtual exchange programs, suggesting that structured cross-cultural collaboration in educational settings can transform both teaching practices and intercultural attitudes.

Within these expectations, the eTwinning ITE provides a clear, unifying purpose that effectively channels the multicultural team's collective efforts toward a tangible educational outcome. While creating mutual respect and cooperation, these collaborative online projects also present distinct challenges. Chief among these is the linguistic barrier inherent in any intercultural team using a lingua franca, along with ensuring equal participation of all countries' participants (Archer, 2023). Even when all members agree to work in English, varying levels of proficiency can make basic interaction arduous. Executives and project managers around the world agree that poor communication contributes to project failure (Project Management Institute, 2013). While new AI translation tools promise much for cross-cultural communication (Koech et al., 2025), recent research has shown that although such technologies can facilitate real-time translation and reduce surface-level misunderstandings, they still struggle with capturing cultural nuances, idiomatic expressions, and context-specific meanings that are essential for authentic intercultural dialogue (Khasawneh, 2023).

Beyond language itself, the dynamics of teamwork in an intercultural setting warrant careful exploration. Effective collaboration requires more than a shared language; it also depends on group cohesion, negotiation, and leadership (Hill & Bartol, 2016; Tretter, 2025; van der Voet & Steijn, 2020). Teams operate on these units and may exhibit similar developmental patterns. Despite its limitations, such as oversimplifying complex group dynamics and assuming a linear progression (Bonebright, 2010), Tuckman's (1965) model remains a useful heuristic for understanding how teams mature over time. Tuckman identified several progressive socio-emotional phases: Forming (orientation and initial meeting), Storming (task-related conflict), Norming (establishing shared norms), and Performing (a cohesive, goal-oriented unit). In intercultural teams, these stages often become more pronounced due to divergent communication norms and work styles inherent in culturally diverse groups. Early miscommunications or divergent work approaches can intensify task conflict during the Storming phase, representing a key source of process losses in diverse teams. Effectively navigating this conflict through structured negotiation and empowering leadership behaviors fosters stronger cohesion and mutual respect during the Norming stage. Once a robust set of norms is established, teams typically transition to a high-performing state characterized by autonomy, streamlined collaboration, and enhanced productivity. Finally, as project goals are achieved, groups enter the Adjourning phase, during which task-related activities wind down and members begin to disengage, consistent with Tuckman and Jensen's (1977) revised group development model.

Purpose of the Study

Grounded in these scholarly perspectives, our paper sets out to investigate the complex interplay of factors in a cross-cultural eTwinning ITE project that included Turkish and Italian undergraduate students who were guided by Spanish master's degree students and experienced

educators/experts from the partner regions. We situate our analysis at the nexus of intercultural competence development, group development theory, and contact hypothesis. By collecting data at the start and end of the eTwinning ITE project in the 2024-2025 academic year, we capture the participants' journey as they form international teams, confront communicative hurdles, employ digital tools, and strive to co-create innovative lesson plans. We also examine how group processes unfolded under those conditions and consider whether participants' accounts reflect known patterns of group formation and how leadership roles developed over time. The main research question is as follows:

> RQ1: How do undergraduate students from different countries navigate group development, leadership, and communication in an international telecollaboration project?

Methodology

This study employed a qualitative case study design (Baxter & Jack, 2008). This section outlines the study's methodological design, participant details, and data collection process, followed by an explanation of the project context and thematic analysis approach. Through a two-phase data collection and inductive coding strategy, the study explores how teacher candidates experienced intercultural collaboration and AI-integrated instructional design tasks during the eTwinning ITE project.

Participants

The project involved 113 teacher trainees (99 females, 14 males) hailing from universities in Türkiye and Italy. The project activities were assigned to 20 groups who were formed from 62 Italian participants and 51 Turkish participants. However, only 75 of them fully took part in both pre-project and post-project data collections. Thus, the opinions of these 75 participants were included in the qualitative analysis. Participants ranged in age from 19 to 24 years, with a smaller subgroup of teacher candidates who were attending their second university, aged between 30 and 36 years. The ethical permission was taken from the ethics committee in Afyon Kocatepe University (Decision no: 2024/364), and informed consent was taken online. They were informed that they could withdraw from the study at any time. Participants were pursuing various education-related degrees (e.g., primary education, math, science education). They were coded P1-P75 with ethical considerations in mind.

One important point to note regarding the project participants is that eTwinning projects in undergraduate education generally include educators and students with a sufficient level of English proficiency so that cooperation can be rendered effectively without language problems. However, in this project, all students who wanted to be part of this project were welcomed, irrespective of their language knowledge, thinking they could use automated chat or translation tools to perform their task. Thus, the study is unique as it investigates how some students with less or no English proficiency can achieve the project objectives using the available AI translation tools.

With the first data collection and initial group formations, participants were organized into mixed-nationality teams, typically comprising 4–8 members to work on intended tasks in the project. This structure intentionally created intercultural groups where participants worked as peers on shared deliverables.

Data Collection

Data collection through structured open-ended questions was conducted at two key points (October/November 2024–March 2025) in the project. Participants were given the option to write in their native language to express themselves more effectively. These responses were then translated into English using an AI tool by the researchers.

Initial Data Collection (Start of the Project)

Written, structured questions were sent to Italian and Turkish participants by mail. There was an introduction of tasks online in the first meeting, and group formations followed by an initial data collection survey for each participant. The first data collection was deliberately scheduled three weeks after the project's start to allow participants time to meet their groups and understand the project objectives; otherwise, initial responses might have been based only on generic excitement. This approach of data collection is based on the project leaders' experiences of other projects. The first data collection questions included feelings about joining the project, opinions about formed groups, impressions of the overall project, first challenges, group leader selection, and motivation.

Final Data Collection (End of the Project)

More extensive coverage in the form of structured questions was sent to the participants after project completion to assess overall experiences, perceived learning, communication effectiveness, challenges encountered and resolved, and reflections on group dynamics and leadership. In the final data collection, all the groups completed their tasks that required contributions from both Turkish and Italian undergraduate students. The questions included performance at its best and its lowest, emotional and cognitive gains within the groups, overall experience working in the groups, group leader and expert help, overall challenges, resolved and unresolved problems.

This two-phase approach allows for a prolonged perspective, tracking the evolution of individual perceptions and group processes throughout the project lifecycle. Analysis focused on identifying recurring themes across participant narratives, which were then interpreted through the theoretical lenses.

Project Scope

The eTwinning ITE project, formed to integrate AI into instructional design of teacher trainees in the faculties of education, connected different cohorts of undergraduate education students,

one from Türkiye and another from Italy, through telecollaboration. These two groups of student teachers were guided in the completion of activities by master's degree students in Spain. However, only the opinions of Italian and Turkish students were considered in this study, as the role of Spanish participants was to provide expert guidance on final lesson plans created by the undergraduate students, mainly in the final weeks of the project.

The project's main goal was to introduce AI-enhanced teaching to teacher trainees. It had dual objectives: training teacher candidates about effective lesson planning within an intercultural setting while developing their ability to integrate AI tools into instructional design. The primary deliveries were group meetings, seminars, instructional design trainings, and a published collection of lesson plans for primary and middle school students, each structured according to the 5E instructional model (Engage, Explore, Explain, Elaborate, Evaluate). The activities were based on incorporating age-appropriate AI-based activities implementable in tablet or computer lab settings for primary and middle school students. All activities were conducted under the guidance of project leaders. The project participants from both nationalities were assigned to the groups for each task to foster intercultural collaboration.

While English served as the official medium of communication between the Turkish and Italian participants, language proficiency varied significantly among team members. Some participants had a very limited command of English. There was no deliberate selection of English-speaking students at the outset, as the project was intended to be inclusive and project leaders aimed to include the classes they taught to promote international collaboration and explore new ways of initiating communication through AI and translation tools. To overcome language barriers, participants increasingly relied on AI translation tools, which became essential intermediaries. These technologies effectively acted as an informal lingua franca, enabling the exchange of ideas, feedback, and collaborative problem-solving throughout the project. However, their use also disrupted the organic flow of communication and led to delays in responses.

To help undergraduate students effectively manage all project activities, all 20 groups in the project were advised to appoint a task leader within the first month of the project, following the presentation of all activities during the initial week. In addition to this guidance, project leaders got help from experienced public-school teachers and master's degree students from project partner regions to support group leaders in addressing academic challenges or unmet needs. For example, one main task required groups to design a lesson plan for primary education using the 5E instructional model, with a specific focus on integrating AI tools into classroom activities, in line with the project's objectives. Upon encountering difficulties, group leaders and participants requested training on the 5E model from experienced expert teachers and sought feedback on their final lesson plans whenever needed. Expert teachers' emails and details were provided to each group, and they were introduced to each other during online meetings. Also, a group of master's degree students from education departments in Spain were invited to the project as young experts who served in the project in the final weeks.

Based on this project scope, Italian and Turkish teacher candidates engaged in precisely the kind of meaningful cross-cultural interaction that develops essential professional competencies, communicating across cultural boundaries, navigating meaning in non-native languages, and collaboratively developing educational resources. These immersive experiences foster enhanced communication skills and deeper intercultural sensitivity, directly supporting international teacher education standards. By bringing together diverse nationalities during undergraduate activities, virtual exchange initiatives help dismantle preconceptions among future educators while establishing pathways for international professional collaboration.

Data Analysis

Data analysis was conducted through a thematic approach following Braun and Clarke's (2006) six-phase framework. All written reflections (75 from initial stage and 75 from the final stage) were treated as qualitative data and coded inductively; meaning that codes emerged directly from participants' own words without pre-established categories. Two researchers conducted the analysis collaboratively, using investigator triangulation and reflexive journaling to enhance the study's trustworthiness. Thematic development followed six iterative stages as outlined below.

Familiarization

The researchers reread every reflection multiple times and took analytic notes.

Generating initial codes

We systematically coded the data in an open, data-driven manner. Each meaningful segment of text was labeled with one or more concise codes. For instance, in the first data collection a student wrote, "I felt excited, but also scared because I don't have much confidence in my English." We coded this as "initial excitement" and "language anxiety" based on the feelings expressed. These codes were taken verbatim from the text where possible (e.g. "excited", "scared") and captured the essence of each comment without imposing external categories. For example, these codes mentioned above formed the base for Initial Feelings & Expectations (First Data Collection) theme. A codebook was built from these codes, covering both the first and final reflection data separately, which are merged in Figure 1.

Constructing Candidate Themes

We grouped related codes into eight preliminary draft themes (Table 1), mirroring the temporal structure of our two data collections:

Table 1
Draft Themes in the Study

Theme	Sample Codes
1. First Feelings	initial excitement; initial anxiety; uncertainty about tasks; forming optimism; affective-filter stress
2. Challenges	language anxiety; use of AI translation; motivational imbalance; faux-friend translations; storming friction
3. Group formation	shared understanding; rapport; leadership selection; harmony; conflict
4. Achieving the Expectations	expectations met; active participation; task clarity; equal-status contact; performing autonomy
5. Changing Collaboration	deadline peak performance; synchronous session breakdowns; time-zone stress; brief returns to storming
6. Personal Growth	digital competence gain; intercultural sensitivity; stress-management skills; patience development
7.Solving the initial problems	problems; language barrier; positive sentiments; dis/continuation of challenges
8. Expert Help	expert help vital; mentor encouragement; scaffolded learning; feedback loops

Reviewing & Refining Themes

Each candidate theme was checked against its underlying extracts for coherence (all extracts "fit" the theme) and distinctiveness (no two themes conveyed the same core idea). Where necessary we split overly broad themes (e.g. separating task-peak vs. synchronous-breakdown codes) and merged overlapping ones (e.g. "expert encouragement" with "feedback loops" under reflection on expert support).

Defining & Naming Themes

We drafted clear definitions for each theme, anchored in participants' language. We selected exemplary quotes to illustrate each theme's scope.

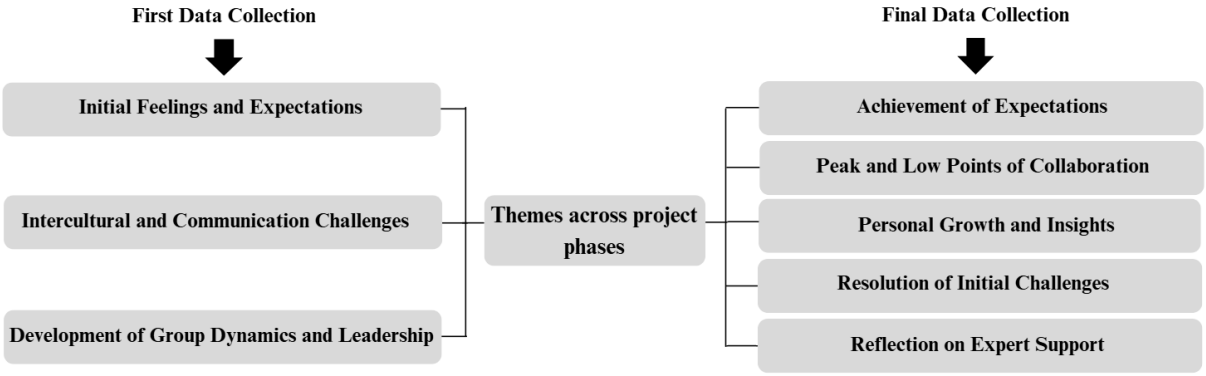
Writing Up & Theoretical Interpretation

In the final report, we first presented each theme with its exemplar quotations and analytic commentary. Only after the themes were fully described did we interpret them through Tuckman's and Allport's lenses—showing, for example, how "Initial Feelings & Expectations" echoes the Forming stage, and "Intercultural & Communication Challenges" corresponds to Storming unless scaffolded by expert support or peer leadership (Norming).

Findings

The analysis revealed several key themes tracing the participants' journey through the project. As we collected data in two stages, we grouped our findings under first data collection and final data collection headings so that the reader can easily compare the changes in groups. All main themes in the project are visualized in Figure 1.

Figure 1
Themes Identified from Pre- and Post-Project Reflections



All the themes are explained along with Figure 1 as follows:

Initial Feelings and Expectations (First Data Collection)

Initial participant reactions to the project presented a dichotomy. Enthusiasm for the international collaborative opportunity was clearly documented; one participant described being "*excited and curious*" (P40). Concurrently, apprehension was also present, frequently related to anticipated communication challenges and unfamiliarity with intensive intercultural teamwork. This is evidenced by statements such as, "At first, I was a bit scared... I wasn't sure how well we could work together" (P27). Instances of initial confusion about the project's specific parameters and how different people in different groups would work well were also reported (P27, P16). This observed combination of positive anticipation and underlying uncertainty corresponds directly with the characteristics of the 'Forming' stage in Tuckman's model of group development (Tuckman, 1965). The reported anxieties about communication, in particular, prefigured later linguistic difficulties and correspond with Krashen's (1985)

"Affective Filter" hypothesis, which posits that emotional stress can inhibit language input from being effectively processed and acquired.

Intercultural and Communication Challenges (First Data Collection)

First interactions rapidly surfaced communication problems, signaling the project's entry into Tuckman's "Storming" phase (Tuckman, 1965). Unequal English proficiency levels constituted the principal barrier in the first weeks of the project. One participant (P34) lamented that initial expectations were not met, highlighting the severity of the language barrier. These language issues sometimes dampened the early enthusiasm as P34 stated that:

> I was hoping to collaborate with colleagues from different countries and work together in English and with new technologies. Our communication has been limited to the project itself, with various misunderstandings and difficulties (due to English competence).

However, some participant narratives showed that groups strove to overcome the storm. P46 recalled that:

> One of the challenges I encountered was the language difference: communicating in English required some effort from everyone, and this sometimes led to misunderstandings among group members. Despite this, we tried to clear up any confusion and find a better way to collaborate.

In addition to language, differences in motivation and participation emerged as challenges. For instance, one participant (P27) observed:

> Up until now, we've only had long conversations to determine our topic and group leader. I may feel this way because we haven't started exchanging ideas together yet, but in general, I don't see my group mates as very motivated and enthusiastic.

These frustrations illustrate the conflict typical of Tuckman's Storming stage, where early optimism gives way to communication breakdowns. They reflect the absence of established group norms and mirror Allport's contact hypothesis: without supportive conditions like equal status and shared goals, early intergroup interactions may reinforce tension rather than reduce bias (Allport, 1954).

Development of Group Dynamics and Leadership (First Data Collection)

As teams navigated early challenges, some began transitioning toward Tuckman's Norming stage (Tuckman, 1965), marked by emerging trust, clearer goals, and improved collaboration. For instance, P16 noted that teamwork improved "when we chose the topic," highlighting how shared focus fostered cohesion. P15 simply remarked, "we felt we could trust one another," while P13 elaborated on the group's growing rapport:

> From the moment we first started chatting as a group, we've been having really nice conversations… I think what strengthened the collaboration in our group was our conversations, because we created a warm environment… Every member is aware of their responsibilities and fulfills their part.

These reflections indicate that some teams were successfully negotiating group norms and developing mutual trust, hallmarks of the Norming stage, when members resolve differences and establish how to work together (Stein, n.d.). Not all groups passed this stage smoothly. In one case, student P43 observed that:

> At first, I didn't find the instructions and objectives of the project very clear, but fortunately, our Turkish partners helped us and provided clarification. However, communication and cohesion within our group are still not fully established.

Despite clarified tasks, some groups continued to struggle with cohesion. To address this, project leaders encouraged each team to appoint a group leader from students capable of managing intercultural coordination. Leadership played a pivotal role across the 20 groups, often based on their English proficiency. As P15 noted, "The leader was chosen based on his knowledge of the English language." Similarly, P38 explained, "We chose a girl with excellent language skills, good at listening and communication," underscoring the importance of both linguistic and interpersonal competence in effective leadership.

When leadership was proactive and inclusive, groups tended to progress more smoothly into a Norming pattern of cooperation. However, substantial variability in leadership effectiveness was documented. Certain assigned or self-identified leaders reported feeling ineffective due to their normal life issues as P34 shared:

> I decided to relinquish my position as leader to another member due to my work commitments, which prevented me from actively managing the course as a leader.

In certain teams, different leadership processes emerged to fill gaps, as described by P37:

> Within the Italian group, we agreed together on the choice of leader, while in the Turkish group, the leader is self-appointed since he is the one person who is most active and collaborative.

These examples show that simply naming a leader did not guarantee effective facilitation in a multilingual context. Nonetheless, when strong, communicative leadership took hold, it clearly helped the team establish norms and cohesion. In sum, by the end of the first phase, many groups had experienced some initial enthusiasm and fear of being not able to carry out project activities. They had also storming conflicts and developing shared understandings of how to communicate and work together, thanks in large part to finding common ground and the guidance of effective student leaders.

Achievement of Expectations (Final Data Collection)

While initial reflections varied in tone, most participants ultimately reported that their expectations were met or exceeded by the project's end, indicating that many teams had reached Tuckman's Performing stage (Tuckman, 1965). Retrospective accounts emphasized active collaboration, clear task division, and shared decision-making. As P45 noted:

> The group fully met my expectations. To ensure effective collaboration, we all actively participated and decided each step of the work together." P15 highlighted a turning point when the group "managed to choose, among the many ideas that were proposed, those that we considered most appropriate… After that, in my opinion, everything got better.

Nonetheless, positive outcomes in the final data collection were not universal across all groups and participants. Several participants and groups described only partial fulfilment of initial expectations, attributing their dissatisfaction to enduring communication barriers. As P63 observed, "One of the main goals was to communicate and collaborate actively, but this was not possible due to two members' difficulties with English." Another participant (P52) reported that inequitable task distribution undermined motivation:

> Unfortunately, we couldn't achieve effective collaboration. As the group leader, I had to handle the entire project with the help of only a few group members… my friends' attitude unfortunately dampened my motivation and enthusiasm.

Despite some teams continuing to face language and participation challenges, most overcame early hurdles. The majority's positive evaluations suggest they reached the Performing stage (Tuckman, 1965), collaborating efficiently, ending possible prejudices, fostering respect for each other and achieving their objectives (Allport, 1954)

Peak and Low Points of Collaboration (Final Data Collection)

As participants reflected on the project's high and low points, they repeatedly highlighted the final phase as the moment when teamwork truly peaked. Approaching the deadline, many groups reported operating at their smoothest and most satisfying level: "The highest point was when, in the final part, we all collaborated for the success of the project" (P37). Another group chose to present their work "at the end… we were satisfied with it and received wonderful feedback from the professors for a complete and rich project" (P6). Such comments indicate that, by this point, each team had reached Tuckman's Performing stage, members had gelled, communication flowed, and collective effort translated seamlessly into results (Tuckman, 1965).

By contrast, the most difficult moments often arose during live, synchronous sessions. Real-time video conferences posed a double challenge: juggling time-zone differences while processing language on the spot, without the safety net of editing or translation. One participant

noted, “Our group’s performance was at its lowest at the beginning … as we initially struggled with the language barrier…” but added that extra coordination eventually resolved the issue (P16). Even in the final stages, there were brief returns to the Storming stage, where frictions resurfaced and required intentional, collaborative problem-solving. Participants emphasized that by “coordinating together” and patiently untangling misunderstandings, they could move past such setbacks, demonstrating a resilience rooted in the trust and problem-solving habits forged during the Norming phase (Tuckman, 1965).

Personal Growth and Insights (Final Data Collection)

Beyond accomplishing the project tasks, participants found the experience to be a significant source of personal and professional development. Students reported learning in multiple domains. Intellectually, many became adept with new digital tools and pedagogical techniques; for instance, one student learned even more about artificial intelligence and the various applications used (P39) because of the project. Equally important were emotional and interpersonal gains. Participants spoke of becoming better at handling pressure and collaborating with others. They noted “the ability to adapt to unexpected situations” (P53), “patience and constructive communication” (P7), and “problem-solving” skills (P45). Furthermore, working closely with peers from another country led to tangible growth in intercultural competence. Several participants mentioned “intercultural communication” (P48) and reflected on the confidence gained from “talking to friends who speak different languages” (P8). These comments illustrate an increase in confidence about cross-cultural teamwork and a reduction in the psychological barriers that can accompany language differences.

Such diverse growth outcomes highlight the deeply experiential learning that took place as groups navigated challenges together. This resonates strongly with Allport’s prediction that well-structured intergroup contact can yield positive attitude change and personal development (Allport, 1954). At the same time, participants recognized the limits of their progress in certain areas. In terms of language learning, for example, heavy reliance on translation technology may have improved their strategic communication skills (knowing how to overcome a language gap) more than their underlying English fluency. However, it is crucial to temper this observation with insights from analyses focusing specifically on language acquisition. Heavy reliance on translation technology among participants with lower initial English proficiency likely channeled their learning towards enhancing strategic competence (Piątkowska, 2015), rather than advancing overall linguistic communicative competence. While linguistic gains were likely limited, potential development in intercultural competence might still have occurred, as this aspect can be somewhat independent of language proficiency.

Resolution of Initial Challenges (Final Data Collection)

Data from multiple participants indicate that primary language issues and fear of group work in an intercultural setting were managed for most groups or resolved to some extent by the end of the phase. AI translation tools are frequently cited as key facilitators in this process, evidenced by statements such as, “We discovered new ways (AI tools) to communicate... and

learned to leverage technology effectively" (P16). Predominantly relying on email and chat communication improved clarity, as messages were automatically translated. Interpersonal strategies, notably "mutual respect and a sense of responsibility" (P34), were also identified as playing a critical role in overcoming miscommunications. However, participants also recognized that not every challenge disappeared completely. In some cases, the solutions were only partial. For example, one student reflected that using text chats and translation software was helpful but did not solve everything, as P17 stated:

> This was resolved, at least partially, by using written chats and translation tools. However, the language barrier continued to impact the depth of communication and our ability to fully explore cultural differences and traditions

In conversations, less proficient English speakers sometimes still contributed only minimally (e.g. through "emojis or short answers," noted P3) despite the tools, showing the limits of technology in fostering deep interaction. Additionally, a few non-linguistic problems lingered; for instance, problems related to "task division" were never completely ironed out in one group (P9). This finding suggests that while technology bridged basic comprehension gaps, it inadequately addressed factors like the affective filter or provided the quality of interactive input considered necessary for significant language acquisition (Krashen, 1985). These acknowledgments underscore that while the groups made great strides in overcoming their initial Storming-phase problems and establishing Norming-stage cohesion, there were practical limits to what they could achieve within the project's timeframe and context. Participants' reflections in the Adjourning phase demonstrate an overall trajectory from early challenges to eventual success, with lessons learned even from the hurdles that persisted.

Reflection on Expert Support (Final Data Collection)

A frequently mentioned factor contributing to positive experiences was the presence of effective support, particularly helpful leaders and readily available expert advice. The groups received assistance from experienced teachers in partner-region schools. They were also aided, when needed, by master's students (young experts) from education departments in Spain. Thus, before completing their tasks, participants could seek help from university academics, master's students, and experienced teachers. Comments such as "expert help was invaluable in guiding our progress" (P23) and "receiving expert help provided valuable insights" (P26), together with praise for the leaders' guidance, indicate that this readily available assistance made navigating the project's complexities more manageable. It seems this supportive scaffolding (Billings & Walqui, 2017) and reflecting the importance of institutional backing (Allport, 1954) was key in allowing students to process the difficulties and ultimately appreciate the substantial learning derived from the collaboration. While expert mentors played a key role in supporting group progress, their impact varied across teams. Groups that actively sought guidance from mentors often demonstrated clearer task outcomes. In contrast, teams with minimal engagement reported more ambiguity. These differences highlight the importance of timely, structured, and accessible expert support in facilitating successful collaborative learning in virtual intercultural contexts.

Finally, while technology offered essential support, the final interaction quality and the extent of problem resolution were heavily contingent upon human factors: participant interpersonal skills, mentor and leadership actions, and pre-existing language capabilities. With the rapid development of AI translation tools, future collaborations might mitigate these communication problems more effectively, potentially lessening the reliance on a common lingua franca.

Discussion

The comparative analysis of initial and final reflections reveals a dynamic trajectory in this eTwinning ITE project, highlighting how participants' experiences evolved across the eight main themes. At the outset, *Initial Feelings and Expectations* combined excitement about international collaboration with anxiety over language and cultural barriers. Early interactions then surfaced *Intercultural and Communication Challenges*, followed by *Development of Group Dynamics and Leadership*, laying the groundwork for the group's eventual *Achievement of Expectations*, though not all teams fully met their goals. As the project unfolded, groups experienced both *Peak and Low Points of Collaboration*, alternating between seamless teamwork and moments of disengagement. Throughout, *Personal Growth and Insights* became increasingly pronounced: participants reported gains in intercultural sensitivity, digital competencies, and socio-emotional resilience. *Resolution of Initial Challenges* was achieved to some extent; however, certain initial problems such as language barriers were not fully resolved for whole groups as originally envisioned in the project design. Finally, *Reflection on Expert Support* underscores how targeted scaffolding, through peer leadership, mentoring from master's students, and academic guidance, was crucial for overcoming hurdles in groups, clarifying task structures, and helping many groups progress from formality to high-performing cohesion.

In this study, intercultural teams followed developmental trajectories that mirrored Tuckman's (1965) stages to some extent. Participants began the collaboration with mixed emotions, alongside apprehension about navigating language and cultural barriers. By the project's end, these initial ambivalences had typically solidified into a strong sense of fulfilment, particularly among teams that confronted early obstacles directly. Simultaneously, participants reported significant personal growth, marked by enhanced intercultural sensitivity, greater facility with AI-mediated tools (Pan, 2024), and improved socio-emotional skills such as patience and stress management that exemplify transformative experiential learning (Faruki, 1993; Peters, 1989). However, some groups fell short of their objectives and could not maintain group cohesion and produce intended outputs of high quality. The intensity of collaboration likewise fluctuated. While Tuckman's model provided a useful heuristic, it did not fully capture the recursive and asynchronous nature of collaboration in these digitally mediated intercultural teams. The data suggests that the phases were non-linear and recursive to some extent. Several groups appeared to cycle repeatedly between "storming" and "norming" till the end of the project, especially when linguistic misunderstandings could not be settled. These patterns indicate that virtual, multicultural teams may not always follow Tuckman's sequence. Intercultural tensions and asynchronous collaboration can cause groups to oscillate between stages such as Norming and Storming even while realizing the project activities. This fluctuation may reflect a loss of

participant motivation during the early phase, despite project leaders' efforts to bolster engagement.

Effective management of the project's core communicative challenges hinged on some intersecting factors: the strategic deployment of AI-based translation tools, the quality of group leadership, and the expert support participants received. AI applications offered clear operational advantages, enabling baseline mutual intelligibility and sustained task progress across linguistic divides. Yet, from a second language acquisition perspective, their limitations become more apparent. The technology functioned chiefly as a compensatory "patch" (Cai, 2023; Ferlazzo, 2024), supplying surface-level comprehension without cultivating substantive linguistic growth or guaranteeing equitable participation for less-proficient speakers. In Krashen's (1985) terms, these tools did not lower the affective filter in a way that encouraged authentic language development or risk-taking. Moreover, passive reliance on AI may have inadvertently reduced opportunities for meaningful negotiation of meaning, a core component of language learning in intercultural contexts**.**

In the study, AI translation tools proved to be effective with side effects. While AI tools may bridge immediate communication gaps (Pan, 2024; Özyurt, 2024), they must be embedded within human-centered instructional frameworks to unlock the full potential of multilingual, intercultural teams. AI and normal translation tools cannot replace the cultivation of authentic communicative competence and therefore demands intentional and context-sensitive pedagogical integration (Ferlazzo, 2024). Participants relied on translation outputs to manage task demands, but opportunities for authentic language acquisition were limited, highlighting the need for pedagogical scaffolding if linguistic growth is to accompany digital collaboration (Krashen, 1985).

Notwithstanding the considerable challenges, most notably those related to language in the initial stage, the project achieved somewhat success in cultivating favorable intergroup dynamics. The deliberate emphasis, through project activities, on cooperation, shared objectives, and parity among participants substantiates key propositions of Allport's contact hypothesis (Allport, 1954), contributing to reduced intergroup anxiety and, by implication, more positive intercultural orientations. The project's overarching aim, participants' self-development through the joint creation of lesson plans, served as a superordinate goal that maintained cooperation, consistent with Sherif's findings (Insko et al., 1992). Although the design broadly satisfied Allport's optimal contact conditions, disparities in language proficiency and uneven participation prevented the full realization of the expectations. Such partial fulfilment could be a typical feature of digitally mediated, multinational collaborations, where the absence of face-to-face interaction may amplify coordination challenges.

Human leadership emerged as an indispensable complement. Teams led by proactive student leaders who structured interaction, fostered inclusivity, and clearly distributed tasks navigated communicative obstacles more effectively than those guided by passive or disorganized student leaders. External support in the project through expert teachers, academics, and other master's degree students proved decisive; reflective accounts highlighted the motivational and

procedural value of expert scaffolding and resolute team leadership, affirming theoretical perspectives on instructional scaffolding (Billings & Walqui, 2017) and institutional facilitation (Allport, 1954). These findings underscore the necessity of instituting a clear peer-leadership framework, sustained mentorship, and explicitly defined individual roles from the outset of any collaboration. Expert guidance proved most effective when groups engaged in consistent, structured interactions with their mentors; under these conditions, skillful leadership and educational scaffolding (Billings & Walqui, 2017) became critical drivers of success. Conversely, groups that relied on ad-hoc or last-minute consultations derived limited benefit, suggesting that mentor support must be proactive, readily accessible, and embedded within a well-defined system of engagement. Peer leaders are equally vital: by sustaining group cohesion, coordinating task progress, and soliciting assistance from project mentors as needed, they act as the linchpin of effective teamwork. Accordingly, virtual international projects should integrate mentorship systematically, supported by clear protocols, timely access, and reciprocal accountability between students and experts. Ultimately, effective intercultural education rests on a balanced approach that couples technological tools with language development, intercultural awareness, teamwork skills, and robust support mechanisms, thereby transforming challenges into opportunities for learning.

Practical Recommendations for Future Telecollaboration Projects

Building on the present findings and discussion, we recommend that future intercultural eTwinning or telecollaboration projects begin with a comprehensive briefing for all prospective teacher-trainee participants. This introductory session should (a) outline the full sequence of planned activities, (b) inform students to anticipate likely linguistic and cultural challenges, (c) explain how multinational teams will be formed, and (d) specify the kinds of contributions expected from each participant. After this briefing and feedback from the trainees, applications should be finalized, ensuring that the project design incorporates student input from the start.

Designating student leaders at the very outset of the project—ideally chosen by their own groups—proved highly effective. These peer leadership roles and their responsibilities should be clearly defined and explicitly woven into the project's structure.

Because participants' proficiency in the project's lingua franca will vary, leaders should anticipate this linguistic diversity from the outset and cultivate inclusive practices that allow every participant to contribute meaningfully. Task distribution should be carefully designed to mitigate communication barriers. It is also advisable that each national group includes at least one linguistically competent student to support peer communication. Furthermore, providing participants with brief training on AI-based translation tools is essential to enhance their strategic competence in overcoming language gaps.

Finally, implementing a standardized mentoring framework across all groups will ensure equitable, sustained support for both intercultural collaboration and academic development. By working together, mentors and student leaders can anticipate and address early challenges, guiding teams smoothly through the project's initial stages.

Conclusion

Taken together, this paper contributes to a nuanced understanding of how intercultural collaboration unfolds in a digital education context and offers empirical support for classical theories while also extending them. The progression of the eTwinning ITE groups, from an uncertain forming stage through storming challenges to a norming/performing synergy and ultimately adjourning with learned lessons, largely aligns with Tuckman's stage model of group development, but with the caveat that in virtual, cross-cultural settings the stages may recur or blend (e.g. brief returns to conflict even late in the project). The study also affirms the value of Allport's intergroup contact conditions: groups that effectively upheld equal-status, cooperative interactions toward a common goal (and were supported by institutional support from experts) reaped the greatest benefits in terms of trust and mutual understanding. Where those conditions were lacking (as in instances of unequal participation or poor communication), collaboration suffered, highlighting areas where additional pedagogical design or facilitation is needed. Moreover, the results emphasize the importance of managing the affective filter in intercultural student teams. By gradually lowering anxiety through peer support, clear norms, and expert guidance, participants were able to increase the flow of comprehensible input, not only improving their language confidence but also enabling deeper intercultural exchange.

In sum, this study extends theoretical models by illustrating their interplay in practice: it shows how structured digital collaborations can move groups into the performing stage given proper mentorship, scaffolding and peer leadership, how equal-status contact and mentorship mitigate the pitfalls of online intercultural work, and how a lowered affective filter opens the door for richer learning. These insights contribute to the literature on intercultural collaboration and digital pedagogy by providing a detailed, evidence-based account of what helps diverse learner groups succeed. By bridging classic social-behavioral theories with modern online educational practice, the study offers a framework for educators to foster meaningful, prejudice-reducing, and academically productive collaborations among future teachers in an increasingly connected world.

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Corresponding author: Ahmet Göçen
Email: agocen@aku.edu.tr

Building Artificial Intelligence Literacy for Research: Technical Understanding as the Foundation for Critical Evaluation[1]

Diler Öner
Boğaziçi University, Türkiye

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Abstract

This case study investigated the development of AI literacy among novice educational researchers through an AI literacy course. AI literacy requires a high level of competence involving the ability to understand AI, use it effectively for specific tasks, evaluate and create AI, and exhibit ethical behavior in its use. The AI literacy course was designed for graduate students in the field of educational sciences and was based on four main dimensions: knowing and understanding AI, using and applying AI, evaluating and creating AI, and considering and following AI ethics. Data were collected quantitatively, using an AI literacy scale, and qualitatively, through semi-structured interviews and AI literacy journals kept by the course participants throughout the semester. Students were investigated as cases, selected using the maximal variation sampling method, focusing on the changes in their AI literacy scores throughout the semester. The analysis of the AI literacy scale showed that the biggest improvement for each case participant was in technical understanding, followed by critical appraisal and practical application. However, the qualitative data analysis also indicated that all case participants significantly improved their critical perspectives on using AI in research and began considering various ethical issues related to AI. Key course elements contributing to this outcome included allocating sufficient time to cover what AI is and how it works, and implementing an AI-based course assignment that required critical reflection on AI's performance.

Keywords: AI literacy; higher education; graduate education

As artificial intelligence (AI) technologies continue transforming industries and daily life, researchers emphasize the importance of promoting AI literacy (e.g., Chee et al., 2024; Ng et al., 2021), particularly in higher education (Chiu, 2024; Laupichler et al., 2022; Sperling et al., 2024). Although AI literacy is an emerging concept, it can guide our efforts to prepare students for a future driven by AI (Oner, 2024). While the term AI literacy is sometimes considered self-explanatory, it lacks a single definition in the literature (Chee et al., 2024; Memarian & Doleck, 2024; Sperling et al., 2024). Earlier definitions primarily focused on the knowledge of computer science concepts underpinning AI (e.g., Kandlhofer et al., 2016). More recently, AI literacy is increasingly viewed as a non-technical subject and a level of competence attainable by everyone (Laupichler et al., 2022). Acknowledging the significance of developing AI literacy in the age of AI, researchers highlighted the need to integrate AI literacy into higher education curricula (Chiu, 2024; Hazari, 2024; Southworth et al., 2023). In fact, some scholars have turned their attention to investigating how particular higher education courses can enhance students' AI literacy (Kong et al., 2021; Tzirides et al., 2024). The limited number of studies on this topic demonstrates the ongoing need to design effective AI literacy courses that closely align with the specific AI literacy conceptualizations adopted.

This study aimed to design and evaluate an AI literacy course for graduate students in the educational sciences field, considering the increasing importance of using AI ethically and effectively in research (Cotton et al., 2023). Based on the literature, AI literacy is defined as a high level of competence involving the ability to understand AI, use it effectively for given tasks, evaluate and create AI, and exhibit ethical behavior in its use. Thus, it is characterized by four dimensions: (a) knowing and understanding AI, (b) using and applying AI, (c) evaluating and creating AI, and (d) considering and following AI ethics (e.g., Ng et al., 2021; Southworth et al., 2023). The specific outcomes of the AI literacy course were determined based on the four dimensions. The course content, learning activities, and assessment strategies were designed to meet these outcomes. The evaluation of AI literacy development is also based on the dimensions of the framework.

The Rise of AI

The term *artificial intelligence* was first coined in 1956 by John McCarthy at a research conference at Dartmouth University. In the most general sense, AI refers to the capability of machines or computers to perform tasks that typically require human-like intelligence. These tasks can include understanding languages, making decisions, or solving problems. Additionally, AI describes the broader scientific discipline that studies these intelligent computer systems, encompassing research areas such as neural networks, machine learning, data mining, and computer vision (Getchell et al., 2022). Moreover, while the term was highly criticized when it first appeared in the 1950s (Taulli, 2019), some argued that, over time, it has become a marketing term. That is, it was used to make certain types of automation appear more advanced than they were, thereby facilitating research funding in the field (Bender, 2023). All of these aspects contribute to our understanding of AI today.

Research on AI has been conducted since the 1950s (Thon et al., 2021). However, significant progress has been made more recently due to advancements in the machine learning paradigm, particularly through neural networks and deep learning approaches. AI technologies have become more visible in public, especially since the release of ChatGPT by OpenAI in November 2022. ChatGPT is based on GPT-4, a continuously updated large language model (LLM), initially designed for natural language processing and understanding, which has been trained on extensive datasets. LLMs have rapidly evolved to become multimodal, capable of processing text and various other types of media. After developing the base model, models such as GPT-4 can be fine-tuned for specific tasks using smaller training datasets and integrated into various domains using application programming interfaces (APIs). These significant technological advancements have facilitated the widespread adoption of AI-based systems and applications in all aspects of life today.

The rise of AI has significant implications for society, and teaching and conducting research in higher education are no exception. Responsible and effective use of AI in teaching and research is becoming increasingly important in higher education. The concept of AI literacy is an emerging term that can inform both theoretical and practical efforts to prepare future educators and researchers for an AI culture.

AI Literacy: An Emerging Concept

UNESCO (2018) defines literacy as "the ability to identify, understand, interpret, create, communicate and compute, using printed and written materials associated with varying contexts" (p. 2). With various forms of literacy present, AI literacy is becoming increasingly important to capture the essential skills and mindset needed in the age of AI.

The term is sometimes considered self-explanatory and, at best, lacks a fixed meaning in the literature (Chee et al., 2024; Memarian & Doleck, 2024; Sperling et al., 2024). Researchers have proposed various definitions of AI literacy. In an early publication on the topic, Kandlhofer et al. (2016) defined it as understanding the computer science concepts underlying AI tools rather than merely using these technologies. They particularly emphasized its significance for careers in science and engineering. On the other hand, Long and Magerko (2020) described it as "a set of competencies that enables individuals to critically evaluate AI technologies; communicate and collaborate effectively with AI; and use AI as a tool online, at home, and in the workplace" (p. 2). This definition presents AI literacy as a non-technical subject, positioning it as an outcome accessible and relevant to a broader audience. Furthermore, this perspective appears to be gaining wider acceptance as Long and Magerko's definition has been more frequently referenced and utilized in the higher education literature (Laupichler et al., 2022).

Promoting AI Literacy in Higher Education Curricula

Recognizing the importance of this concept, researchers investigated how specific courses, whether already available or particularly designed for research, can foster AI literacy among

students in higher and adult education. In their scoping review of studies published between 2016 and 2022, Laupichler et al. (2022) found that these courses employed mixed pedagogical formats, including flipped classrooms, programming environments, and a combination of knowledge transfer and hands-on activities. Most courses introduced fundamental AI concepts, machine learning, and deep learning, with some addressing ethical issues such as bias and transparency. While the studies concluded that participants improved their AI literacy after completing the courses, it was not always clear what types of measurements led to these conclusions, as they were sometimes based on self-created, non-validated scales. In addition to Laupichler et al.'s observations, there was a lack of alignment among the AI conceptualization, the course content, and the measured outcomes in these courses.

Kong et al. (2021) designed a specific AI literacy course for undergraduate students from diverse disciplines and evaluated the development of their AI literacy. The authors conceptualized AI literacy as comprising three components: AI concepts, using AI concepts for evaluation, and applying AI concepts to understand the real world through problem-solving. The seven-hour-long course, taught using the flipped classroom method, focused solely on major AI concepts (such as machine learning, supervised learning, and unsupervised learning), the first component of their AI literacy conceptualization. To assess participants' AI literacy, they developed and conducted an AI Concepts Test, an AI Literacy Survey, and an AI Empowerment Survey. The course was found to be effective, as participants demonstrated an increased understanding of AI concepts and significant gains in their self-perceived levels of AI literacy. However, they found no statistically significant differences in test performance between participants with and without prior programming knowledge, leading them to argue that programming is not a prerequisite for understanding AI concepts. The course further contributed to participants feeling more empowered.

Tzirides et al. (2024) examined the development of AI literacy among graduate-level students enrolled in three existing courses focusing on various aspects of AI in education. Referencing earlier research, they indicated that "AI literacy is a multifaceted concept that encompasses not only the understanding of AI technologies but also their responsible and effective use, along with the application of critical thinking to their design and implementation" (pp. 1–2). Course A compared machine and human learning, emphasizing the role of AI in education. Course B connected learning theories with educational technology, exploring psychological paradigm shifts in digital learning. Course C investigated teaching methods and knowledge acquisition, highlighting literacy and critical engagement with materials. Tzirides et al. (2024) employed an AI review tool that provided automated feedback on students' class projects. In the project workflow, students submitted a draft, generated an AI review using the tool based on the rubric, and then revised their work according to the AI feedback. They collected both self-report survey data and qualitative data from participants' responses to open-ended questions in the post-course survey and written reflections on their AI literacy progress. Their findings suggest that integrating AI tools and relevant pedagogical strategies into higher education curricula can enhance students' AI literacy.

While fostering AI literacy in higher education is recognized as an important goal, there remains a need for high-quality AI literacy research (Laupichler et al., 2022). AI literacy can be promoted in higher education at the program level (Southworth et al., 2023) and through well-designed courses (Oner, 2024). However, only a limited number of studies have explored the role of specific courses in developing participants' AI literacy within higher education. The available studies have investigated courses that did not always fully align with the conceptualizations of AI literacy adopted, the course content, and the intended outcomes. Some were not explicitly designed for research purposes, but examined existing AI courses.

To address this gap, this study aimed to design an AI literacy course specifically for graduate students, as the effective, ethical, and responsible use of AI in research has become one of the most significant issues in higher education (Cotton et al., 2023). This course is developed based on a specific AI literacy framework.

The AI Literacy Framework

This study adopts an AI literacy framework suggested by Ng et al. (2021) based on their review of the related literature. This framework is grounded in Bloom's taxonomy and thus provides flexibility across different contexts and subjects. Furthermore, it has been used in program-level adaptation of AI literacy in some universities in the USA (e.g., Southworth et al., 2023).

AI literacy is an advanced level of competence encompassing the abilities to understand AI, use it effectively for given tasks, evaluate and create AI, and exhibit ethical behavior in the use of AI. AI literacy is characterized in terms of four dimensions: (a) knowing and understanding AI, (b) using and applying AI, (c) evaluating and creating AI, and (d) considering and following AI ethics. (Ng et al., 2021; Southworth et al., 2023). It has been assumed that AI literacy is both possible and essential for everyone in the age of AI. Table 1 provides brief explanations of these dimensions.

Table 1

AI Literacy Dimensions (Oner, 2024)

Knowing and Understanding AI · Knowledge of fundamental concepts related to AI and existing AI systems. Understanding the foundations of AI and how it operates. Knowledge about the data used to train AI systems and the limitations of this data.
Using and Applying AI · Effectively and ethically using AI tools and platforms to solve problems or complete tasks.
Evaluating and Creating AI · Evaluating existing AI systems from technical and ethical perspectives; designing and building ethical and fair AI systems, or creating original AI usage strategies.
Considering and Following AI Ethics · Understanding the social, ethical, and environmental consequences of using AI, making informed decisions about AI use in different contexts, and demonstrating ethical behavior.

The study aimed to evaluate the effectiveness of the course through a case study approach by examining the development of AI literacy in three students, drawing on multiple data sources aligned with the adopted AI literacy framework.

Method

Code of Ethics

This study has been reviewed and approved by Bogazici University Institutional Review Board, with the date and meeting number 20.11. 2023, SBB-IAEK 2023-51. Before data collection, necessary permissions from the participants were obtained.

The Research Design

This study was designed as a qualitative multiple-case study (Creswell, 2012; Merriam, 2009). As a research design, case studies are useful when the main research questions are "how" or "why" questions (Yin, 2018). A qualitative case study is typically defined as "an in-depth description and analysis of a bounded system" (Merriam, 2009, p. 40). Therefore, the key features of case study research include providing a detailed description of a phenomenon of interest by using multiple data sources and investigating this phenomenon by identifying a "bounded system," known as the case (ibid.). A multiple-case study consists of more than one case within the same research (Yin, 2018) and facilitates the examination of several related cases (Stake, 2006). Including more cases with diverse characteristics may strengthen the conclusions, as patterns can be validated across various situations rather than just one (Merriam, 2009).

The multiple cases investigated in the study consisted of three graduate-level students pursuing degrees in educational sciences. These students were enrolled in the *AI Literacy for Educational Research* course offered by the researcher in the Spring semester of 2024. The three cases were defined by their participation in a specific course for a set duration, focusing on the development of their AI literacy throughout the course based on multiple sources of data. These cases were identified based on the maximal variation sampling strategy. The first case participant (C1) showed the smallest gain, whereas the second (C2) and third case (C3) participants demonstrated the largest gains based on their pre- and post-test scores on the AI literacy scale (described below). This purposeful variation in case selection was intended to enhance the strength and credibility of the study's findings and conclusions.

The Research Context: The AI Literacy Course

The AI Literacy course was designed and offered by the researcher for graduate students majoring in education. The learning outcomes of the course were based on the dimensions of the AI literacy framework: (a) know and understand AI, (b) use and apply AI, (c) evaluate and create AI, and (d) consider and follow AI ethics (Table 1). The descriptions of the four categories served as a guide for designing general and specific course outcomes based on

Gronlund's (2004) approach (see Table 2). The course materials (e.g., readings), instructional activities, and assessment strategies were tailored to the specific learning outcomes listed.

Table 2

General and Specific Outcomes for the AI Literacy for Educational Research Course

Dimensions of AI Literacy	General AI Literacy Outcomes	Specific AI Literacy Outcomes for the Course
Knowing and Understanding AI	Knows the fundamental concepts related to AI and existing AI systems Understands the foundations of AI and how it operates Knows about the limitations and biases of AI systems	Defines AI Explains how AI works Explains AI-related basic concepts Describes the limitations and biases of AI systems
Using and Applying AI	Uses AI tools ethically and effectively to solve problems or complete tasks	Identifies research purposes and stages where AI tools are beneficial Develops criteria to select and use AI systems for research purposes Identifies specific AI tools to complete research tasks Conducts AI-based literature reviews
Evaluating and Creating AI	Evaluates existing AI systems from technical and ethical perspectives Designs and builds ethical and fair AI systems Develops original AI usage strategies	Develops strategies to assess content generated by AI tools for accuracy, reliability, and ethical aspects Develops novel strategies to effectively utilize AI tools for research tasks
Considering and Following AI Ethics	Understands the social, ethical, and environmental consequences of using AI Makes informed decisions regarding AI use in different contexts Demonstrates ethical behavior in using AI	Explains the social, ethical and environmental considerations surrounding the use of AI in research

Course Activities and Assignments

The course was divided into four major sections, each focusing on an AI literacy dimension: knowing and understanding AI, using and applying AI, evaluating and creating AI, and considering and following AI ethics. Students were given readings related to one of these AI literacy dimensions each week. They were expected to post summaries and questions for each reading before the class. This allowed them to reflect on the material and identify the unclear sections before the class. It also allowed the researcher to use class time effectively by concentrating on these less-understood aspects of the weekly topics. Each student was expected to moderate at least one class session, which provided the opportunity for students to be responsible for others' learning, not just their own. Throughout the semester, students were expected to keep an AI literacy journal (simply the AI journal). The journal involved questions based on the dimensions of the AI literacy framework. After each class session, participants were expected to answer as many questions as they would like and revise their answers from previous weeks. This enabled them to keep track of their AI literacy development throughout the course. These strategies were mainly geared towards course outcomes related to "knowing and understanding AI" and "considering and following AI ethics" dimensions.

Regarding using and applying AI and evaluating and creating AI dimensions, the class investigated a set of AI tools in class and created a collective comparison table regarding these tools' affordances and limitations in research processes. The students were further asked to conduct an AI-based literature review on a research topic they know well and present a critical evaluation of AI's performance. As a final paper, they were asked to analyze their final AI journal and reflect on their AI literacy development over the semester. These class activities and assignments provided opportunities for the students to enhance their repertoire of AI tools that can be used for research. They further afforded the students to develop skills to create new strategies and evaluate AI-generated content, corresponding to the "use and apply" and "evaluate and create" dimensions of the AI literacy framework.

Data Collection

All class participants were given the AI literacy scale before and after the course. This scale, developed by Laupichler et al. (2023), is named "the scale for the assessment of non-experts' AI literacy" or SNAIL for short. Laupichler et al. (2023) indicate that the scale can evaluate the effectiveness of AI literacy courses for individuals without a formal AI or computer science background. It uses a seven-point Likert format and consists of three factors: (1) Technical Understanding (TU), (2) Critical Appraisal (CA), and (3) Practical Application (PA). The first factor contains 14 items, the second has 10 items, and the third includes seven items, resulting in 31 items. The factors broadly align with the following dimensions of the AI literacy framework: Knowing and understanding AI (TU), using and applying AI (PA), evaluating and creating AI, and considering and following AI ethics (CA).

Other forms of data were the one-on-one semi-structured interviews conducted with the participants and the AI journals they kept throughout the semester. The questions used during

the interview and in the journal prompts were determined based on the dimensions of the AI literacy framework adopted for the study. After each class session, participants were asked to respond and revise their answers in their AI journals. End-of-the-semester interviews were conducted with each participant in two rounds, and each interview lasted around one hour.

Data Analysis

The first round of analysis involved comparing class participants' pre- and post-scores using data gathered from the AI literacy scale. Total scores and sub-scores corresponding to the three factors (TU, CA, PA) for each participant were calculated accordingly. The analysis of the quantitative data illustrated AI literacy development across the three factors of the scale. Furthermore, it allowed for the identification of the cases to be investigated in detail through the qualitative data. Three participants were selected based on their scores, using a maximal variation sampling strategy. The first case participant (C1) showed the smallest increase on the AI literacy scale, while the other two case participants (C2 and C3) demonstrated the most significant improvements in their pre- and post-test scores throughout the semester.

This study analyzed two types of qualitative data, transcripts from one-on-one semi-structured interviews and entries in participants' AI journals. MAXQDA was used to manage and organize the qualitative data. The primary purpose of the qualitative analysis was to explain the data regarding the dimensions of AI literacy and compare and contrast the findings regarding each case. The first step in the qualitative data analysis was to review the whole data set to obtain a general sense (Creswell, 2012). Next, data parsing took place, identifying the "potentially meaningful segments" in the data (Merriam, 2009, p.179) and considering the dimensions of AI literacy adopted in the study (Table 1). The data was coded deductively, corresponding to the specific AI literacy outcomes of the course (Table 2). A descriptive account of the comparisons of each case regarding the specific course outcomes was provided, focusing on the commonalities and differences across cases.

Findings

Description of the Three Cases

Before the course, the case participants stated they had experience with AI tools. C1, a second-year master's level student, used AI tools for various tasks, including research, professional tasks (creating CVs, writing formal emails, and creating presentations), and daily activities, such as meal planning. She used AI tools to find and examine research papers. Similarly, C2, a first-year master-level student, utilized AI tools for professional tasks, such as preparing teaching materials, and leisure activities, such as getting assistance in video games. He also created an AI-powered tutor for use in a school setting. C2 sometimes used AI to identify potential research gaps, but was skeptical of using AI tools for academic writing. C3, a doctoral student, explained mainly using AI tools for academic writing and research efficiency. She used AI tools to quickly evaluate the relevance of research sources, summarize key points, and perform translations. Additionally, C1 expressed concerns about the accuracy of AI-generated

citations in the free version of ChatGPT and preferred to use Bing AI. C2 was also skeptical about AI's role in academic writing and mainly used it for other purposes, such as creating teaching materials and gaming. C3 did not express apparent skepticism and relied on AI for more focused academic tasks, such as summarization and translation.

All three case participants were above-average users of AI tools prior to the course, using them for research and productivity purposes. Table 3 is a summary of the cases.

Table 3

Case Study Participants' Level of Study, Pre-Course AI Usage, and Change in AI Literacy Scores

Case	Level of Study	Pre-Course AI usage	Level of Change on AI literacy scores
Case 1 (C1)	Master's level	Used AI for research, professional, and personal tasks	The smallest increase in pre- and post-course AI literacy score
Case 2 (C2)	Master's level	Used AI for professional tasks, leisure activities. Created an AI-powered tutor for classroom use	The second highest increase in pre- and post-course AI literacy score
Case 3 (C3)	Doctoral level	Mainly used AI for academic writing and research efficiency	The highest increase in pre- and post-course AI literacy score

In the analysis below, similarities and differences between the three cases will be presented first by focusing on the AI literacy scale results, then along the dimensions of the AI literacy framework and specific course outcomes based on the qualitative data.

Comparison of the Three Cases Based on the AI Literacy Scale

Based on the results of the AI Literacy scale, all case participants increased their total scores and subscores in all three factors of the scale at the end of the semester: technical understanding (TU) (Factor 1), critical appraisal (CA) (Factor 2), and practical application (PA) (Factor 3) (Table 4 and Figure 2).

Table 4

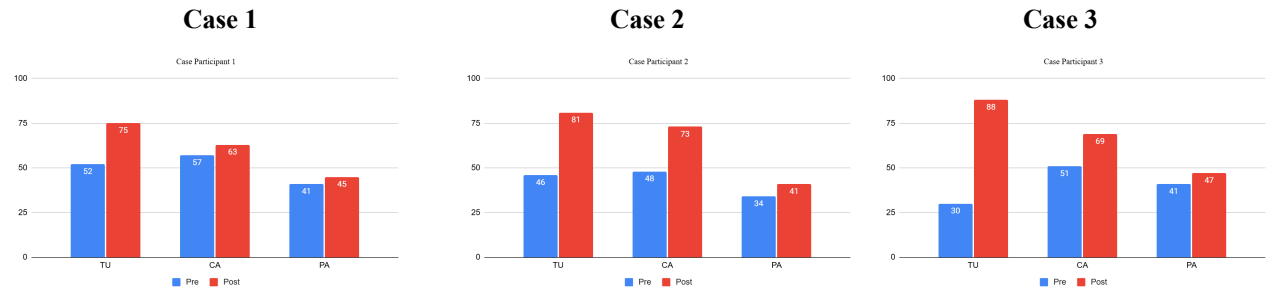
Pre- and Post-Course Scores on the AI Literacy Scale by Case

	Pre-Course	Post-Course	Difference
Case 1	150	183	33
Case 2	128	199	71
Case 3	122	204	82

Note. The highest possible score is 217.

Figure 2

Pre- and Post-Course Subscores by Subscale and Case



Note. TU = Technical Understanding CU = Critical Appraisal (CU), and PA = Practical Application (PA)

Given that the number of questions under each factor differed, the average scores for each factor before and after the semester were compared (14 questions for TU, 10 questions for CU, and 7 questions for PA). When comparing the average scores in each factor, it is evident that all case participants showed the highest differences in technical understanding, with C3 showing the biggest improvement (4.14). However, regarding critical appraisal and practical application scores, C2 demonstrated the largest improvement in average scores (2.50 and 1.57, respectively), followed by C3 and then C1 (Table 5).

Table 5

Pre- and Post-Course Subscores by Subscale and Case

	Pre-Course			**Post-Course**			**Difference**		
	TU	CA	PA	TU	CA	PA	TU (Post-Pre)	CA (Post-Pre)	PA (Post-Pre)
C1	3.71	5.70	5.86	5.36	6.30	6.43	1.64	0.60	0.57
C2	3.29	4.80	4.86	5.79	7.30	6.43	2.50	2.50	1.57
C3	2.14	5.10	5.86	6.29	6.90	6.71	4.14	1.80	0.86

Note. TU = Technical Understanding CU = Critical Appraisal (CU), and PA = Practical Application (PA)

Comparison of the Three Cases Based on the AI Literacy Framework

Knowing and Understanding AI

When asked about a general evaluation of their AI literacy improvement, all case participants expressed a common theme: an increased understanding of what AI is and how it works.

For example, C1, who had the lowest gains based on the AI literacy scale, said:

> [In the literature], there were four main categories identified about how to foster AI literacy. And there, the first part was "know AI"; and honestly, that part was missing in me. It was directly missing. And realizing and feeling this — I mean, in my mind, I tell myself, ah, okay, then my AI literacy is slowly improving. I mean, I only had the "apply" part of the four categories; the first three parts were mostly missing. (C1-Interview 1)

When asked about the development of her AI literacy over the semester, C3, who achieved the highest gains on the AI literacy scale, stated:

> In this course, I definitely learned to look at it much more broadly. I didn't know the technical parts. I didn't even know how it [AI] worked. Honestly, I wasn't very interested either. I mean, yes, I knew that it wasn't really like a human, but I didn't really know the underlying statistical mechanisms very well. Or, I didn't know about the different algorithms. I had no knowledge about neural networks. (C3-Interview 1)

Below, the differences and similarities among each case regarding the specific course outcomes under the "knowing and understanding" dimension will be explained.

Defines artificial intelligence

C1 defined AI as a system that imitates human thought processes and behaviors, highlighting the aspects of Natural Language Processing and generative AI, by its capacity to make decisions and generate new content. C2 similarly defined AI as a helpful tool that can assist humans in various domains using human language in a human-like manner. C3 initially contrasted rule-based AI with machine learning, but later defined AI as data-driven systems that perform statistical calculations to achieve specific goals based on researcher-defined objectives. All case participants have agreed that AI differs from traditional computing in its adaptability and ability to make decisions by learning from data.

Explains how artificial intelligence works

C1 described AI as relying on both machine learning and deep learning, which utilize different approaches based on specific objectives. C2 focused on probabilistic calculations as the foundation of AI, explaining how AI predicts outcomes based on input data, utilizing mechanisms such as n-grams and attention layers. C3 explained AI systems through neural networks, providing examples used to classify cognitive strategies in educational contexts. While C2 offered a more mathematical explanation, all three case participants recognized AI as driven by data and statistical calculations.

Explains AI-related basic concepts

C1 mainly discussed machine learning, deep learning, neural networks (recurrent and convolutional), and various learning types (such as supervised and unsupervised), along with the ethical considerations of AI. C2 similarly explained several AI concepts, including supervised and unsupervised learning, recurrent and convolutional neural networks. He explained the differences between machine learning and deep learning in terms of

explainability, highlighting the challenges in understanding and explaining the decision-making processes of deep learning models, compared to machine learning models. C3 also explained various AI concepts, such as the differences between machine learning and deep learning, supervised, unsupervised, semi-supervised, and reinforcement learning paradigms. All of them discussed machine learning, deep learning, and different AI training paradigms (e.g., supervised, unsupervised, semi-supervised, and reinforcement). C1 and C2 mentioned more specific AI concepts, such as recurrent and convolutional neural networks, while C3 focused more on the relevance of AI to her thesis.

Describes limitations and biases of AI systems

Throughout the course, C1 became aware that a vast amount of online information is used as training data to develop AI systems. She expressed concerns about data quality and unauthorized access to personal data. However, she initially acknowledged her lack of understanding regarding what bias meant in the context of AI systems (which she later learned in class). She was primarily concerned with using inaccurate or incomplete information generated by AI systems in research, which she held to a higher standard for accuracy. C2 was aware of the role of data in AI systems at the beginning of the semester, citing the Tay-AI incident (Wakefield, 2016). This incident involved an infamous AI chatbot that turned hateful with hateful data. He talked about the role of researchers in identifying and mitigating biases in educational contexts. Meanwhile, regarding data ethics, he took a rather practical approach and seemed content with accessing otherwise paid academic content through AI systems. C3 was aware of AI hallucinations before the course. However, she later became concerned with AI's "black box" nature, expressing concerns about data quality, sample size, ethical data collection, and the potential dangers of AI reaching human-level capabilities. After the course, all case participants developed their initial understanding of the role of data in AI systems. They have come to recognize the role of data in AI systems and expressed concerns about unauthorized data collection and processing, though to varying degrees.

In conclusion, while all case participants started the course with certain experiences with AI, the qualitative data indicated that they all improved their knowledge and understanding of AI throughout the course. This significantly affected the development of other AI literacy dimensions, such as critical evaluation of AI-generated content.

Using and Applying AI in Research

Identifies research purposes and stages where AI tools are beneficial

C1, who had the highest technical understanding based on the AI literacy scale prior to the course (Table 4), had a clear idea of the purposes and stages of research where AI can be helpful. She initially thought that AI can help generate a research outline and engage in dialogue with articles during the literature review phase. It can interpret data and provide insights, but should not be used to write the results section without proper data and interpretation tools. Additionally, AI may identify overlooked research ideas. Later in the course, however, C1 stated that AI-powered tools could be used only sparingly for research. They can assist in finding research papers, help her express ideas in English, and with data

visualization. However, they should not be used to generate core content for literature reviews or conduct data analysis. Similarly, C2 initially identified some research phases where AI tools could be used, such as finding literature, summarizing research, or assisting with data analysis. However, after the course, C2 also expressed a shift in his views. This shift was towards a more cautious and critical stance towards the use of AI tools for research purposes. It highlighted the irreplaceable role of human judgment and critical thinking in research. C3 also emphasized AI's value in finding research papers, clarifying unclear points, improving grammar for non-native speakers, and structuring literature reviews. She emphasized the importance of using AI responsibly and ethically in research while maintaining a balanced approach, avoiding excessive reliance on it.

Develops criteria to select and use AI systems for research purposes

C1 was already familiar with various AI tools and selecting the most suitable ones for specific tasks before the course. She said she developed additional criteria during the course to select AI tools for research, emphasizing the importance of careful and thorough readings of AI output. Consequently, although she did not adopt new tools for research purposes after the course, she developed a more critical stance toward AI-generated content. C2 stated that after examining and comparing several tools in class, he began to consider multiple criteria when evaluating AI tools for research. He suggested assessing accessibility, affordability, scope of resources, underlying AI model, and ethical concerns, although he believed ethical aspects were more the responsibility of the tool provider than the individual user. C3 developed the perspective that researchers must deeply understand the topics they are investigating and possess AI literacy before employing AI tools in their research. Researchers should have AI literacy and apply human judgment to ensure the integrity of the research process.

Identifies Specific AI Tools to Complete Research Tasks

C1 preferred using Notion for task management and Gemini for literature reviews. She did not particularly adopt the tools introduced in class, as she already had experience with some AI tools and had established a method for using them. C2 favored tools such as Semantic Scholar, Elicit, and Grammarly for literature review and formatting tasks. He was cautious about over-relying on AI for qualitative analysis, emphasizing the importance of human judgment in critical aspects of research. C3 relied on Semantic Scholar, Elicit, and PopAI, although she acknowledged their limitations in tasks such as writing literature reviews. She appreciated learning about new tools, but remained critical to ensure reliability and accuracy.

In summary, all case participants had utilized AI tools for research and other purposes prior to the course, albeit to varying degrees. However, during the course, they became more cautious about relying solely on AI tools for research. They all emphasized the importance of human oversight and critical thinking in the research process. They generally preferred using AI to find relevant research papers, create outlines, and enhance their writing. C1 appeared more hesitant about using AI tools introduced in class, as she had already developed methods for employing specific AI tools before taking the course. C2 and C3 were more open to using AI for various research tasks but remained mindful of its limitations.

It is important to highlight that no participant approached AI tools from a narrow perspective that considered their functionalities in isolation. Instead, they reflected on AI use in research more holistically, exploring their various affordances and implications.

Evaluating and Creating AI for Research

Develops strategies to assess content generated by AI tools for accuracy, reliability, and ethical aspects

Early in the course, C1 relied on AI-generated content checks, such as plagiarism and AI-generated content detectors. She even used AI tools to assess other AI outputs. However, by the end of the course, she adopted a more human-centered evaluation approach. She recognized the limitations of relying on AI to detect AI-generated content and switched to human expertise to assess content accuracy and authenticity. C1 emphasized a blend of AI-based and human-based strategies, with a growing reliance on human evaluation over time, reflecting an evolving skepticism about AI's reliability for detecting content authenticity. She said she shifted her perspective after the "critical evaluation of AI-based literature review" assignment.

She wrote in their journal:

> Honestly, before this course, or rather before the "critical evaluation of AI-based literature review" assignment, I had ideas about how we could distinguish between content created by AI and by humans. However, after seeing the results in Turnitin's AI-Detection, my ideas disappeared. Since the AI detector could not detect content written by another AI, I do not think any software can easily make this distinction. However, as we interact with AI for research purposes (for example, making it write a literature review) and gain experience about its writing style, I think we can somewhat distinguish it ourselves. If […] it is a paper with underdeveloped arguments and general statements about articles, I could say it is AI-based. Of course, I would also check the given references and articles to understand if such information really exists. (C1, AI journal)

C2 also shifted his perspective toward a more critical approach regarding AI-generated content. Towards the end of the semester, he started thinking about more external strategies, such as institutional evaluation mechanisms (e.g., UNESCO-led initiatives) to assess AI-generated content. He also emphasized the importance of human control.

C3 strongly emphasized the importance of subject-matter expertise in assessing the accuracy and relevance of AI-generated content. Her strategy was based on having a deep knowledge of the research area, which she considered critical for ensuring the reliability of AI outputs. Towards the end of the semester, C3 wrote in her journal that AI outputs should be validated through thorough expert review, considering both the sources used by AI and the concepts presented. She believed that only those with extensive knowledge of the subject could accurately assess AI's contributions.

> I think that to evaluate content produced by AI in terms of accuracy and authenticity, one must be highly competent in that research subject. This is critical both in the process of assessing how fundamental and reliable the sources used are for the topic and in verifying the correctness of the concepts used. (C3, AI journal)

She also stated that she developed most of these strategies to evaluate AI outputs throughout the course, especially after the "critical evaluation of AI-based literature review" assignment.

> Researcher: Were you also using these strategies you mentioned at the beginning of the course?
> C3: These were mainly developed during and at the end of the course. I did not have such awareness at the beginning. At the beginning, I only knew that it [AI tools] generated articles that did not exist, and for me, that was the entire danger it posed. But later on, especially after that literature review assignment, I could see more clearly. It [AI] actually does not write or produce many things correctly at all. (C3, Interview 2)

Develops novel strategies to effectively utilize AI tools for research tasks
C1 considered herself quite capable of using the AI tools prior to the course. However, over time, she became more selective in using them. By the end of the semester, she adopted three main tools, Notion, Connected Papers, and ChatGPT, for academic tasks, such as taking notes and creating paper summaries and literature matrices. C2's strategy involved combining several AI tools to streamline research processes. He preferred using tools such as Semantic Scholar or Elicit to identify research trends and commonly discussed topics, while Grammarly was used for format checks, and ChatGPT was used for creating outlines. His strategy highlighted integrating AI in the early research stages but limited its involvement in later research processes. C3's strategy involved a combination of traditional research methods with AI. She primarily relied on Semantic Scholar to find the most relevant articles, then further filtered them based on her familiarity with the authors and content. Next, she used PopAI and ChatGPT to assess the relevance and quality of the articles. She has stated that she does not use these AI tools for writing literature reviews but receives assistance with translation and language during the research process.

The three case participants mainly discussed using AI tools for the early stages of research, such as finding related literature and creating literature matrices, as this has been the main focus of the course. They have developed strategies that blend the use of AI with traditional research methods. None of them wanted to rely solely on AI tools for their writing, with a common emphasis on human oversight and critical evaluation.

Considering and Following AI Ethics

Explains the ethical and environmental considerations surrounding the use of AI in research
All three case participants expressed concerns about the privacy and security of data used by AI systems and ethical research practices when using AI. C1 emphasized the importance of

ensuring that AI content does not discriminate against or infringe on people's rights. She was also concerned about using research data in AI systems to protect individual privacy. In addition, she was especially influenced by the class discussion on the environmental impacts of AI systems. She said:

> First of all, […] I think it [AI] should be used as briefly and concisely as possible. I was really affected by the amount of water and electricity it [AI] consumes. I was truly very affected by this. Because when I saw that it uses fresh water, it caused me quite a bit of concern. This part is quite important for me.

C2 focused on transparency, arguing that researchers should clearly state where AI is used. AI could assist and facilitate certain aspects of research, such as accessing literature and formatting, but it should not replace critical analysis and thinking, which are the foundations of scientific research. While data bias and limitations are important, his primary ethical concern was preserving the core research processes that required human critical thinking. This was a perspective he developed within the course.

C3 raised concerns about the privacy and security of participant data and highlighted the need for researchers to be transparent about handling research data. Regarding reliability, her only initial concern was AI hallucinations before the course. However, her views regarding AI use in research shifted throughout the course. She recognized that AI-generated content could perpetuate misinformation and bias, creating a self-reinforcing cycle of incorrect data that affects future AI systems. This could ultimately undermine the scientific enterprise.

All case participants recognized the importance of ethical AI use in research. Meanwhile, their concerns varied in focus. C1 emphasized the environmental impact and data privacy. C2 focused on the risk of AI undermining critical thinking and research integrity. C3 highlighted the dangers of misinformation and bias, emphasizing protecting participant data and the broader implications of AI systems for research. These varying perspectives show the complexity of the ethical challenges researchers may face when integrating AI into their work.

Discussion

This study provided an in-depth examination of the AI literacy development of three graduate students within an AI literacy course, employing a case study design. The curriculum for the course was structured around four key dimensions of AI literacy: knowing and understanding AI, using and applying AI, evaluating and creating AI, and considering and following AI ethics. Data was collected quantitatively, using an AI literacy scale, and qualitatively, through semi-structured interviews and AI journals kept by the case participants over the semester. The cases were determined using maximal variation sampling based on course participants' improvement scores in the AI literacy scale.

All case participants were familiar with various AI tools and used AI for research and productivity purposes before the course. The analysis of the results from the AI literacy scale

showed that the biggest improvement for each case was in technical understanding, followed by critical appraisal and practical application. However, the qualitative data analysis also indicated that all three cases significantly improved their critical perspectives regarding the use of AI in research. This finding may be explained by the self-report nature of the AI literacy scale, which relies on participants' self-evaluation. Participants may not accurately assess their actual level of AI literacy, even though they are adult learners. This issue can be addressed by collecting multiple sources of data when evaluating AI literacy. In addition to using scales, researchers can utilize other evaluation methods, such as the AI literacy journal used in this study. Keeping an AI journal allows learners to track their improved understanding throughout the semester. Each week, learners are invited to revisit the same questions based on the class readings and discussions and incorporate their newly acquired knowledge. At the end of the semester, they are also asked to analyze their journal and explain how their understanding has changed.

Evaluation of all data collection instruments used in the study showed that all case participants improved their AI literacy across the four dimensions of the AI literacy framework. It is reasonable to suggest that this outcome results from the specific design elements of the course.

An important aspect of the course involved dedicating sufficient time to covering the fundamental concepts of AI and its operational mechanisms. This implementation was the natural consequence of applying the AI literacy framework. Instead of rushing into exploring AI tools, the current AI literacy course first emphasized the development of a comprehensive understanding of the technical aspects of AI. This included delving into diverse AI concepts such as data, algorithms, criteria for assessing intelligence in machines, probability-based decision-making processes, AI training paradigms, and various AI architectures. Before the course, although the participants had experience with AI tools, they mostly perceived AI as a "black box" that seemed to think and know everything. However, the first part of the course allocated considerable time to explaining the human-made nature of AI, particularly its reliance on probability-based decision-making algorithms and the data on which it is trained. Recent research in marketing indicates that individuals with lower AI literacy are generally more receptive to AI. Specifically, those with a limited understanding of AI often view it as 'magical' (Tully et al., 2025). Therefore, this aspect of the course, emphasizing an understanding of what AI is and how it works, must have helped participants develop a more critical stance by demystifying AI. That is, covering the fundamental concepts of AI before moving into introducing AI tools may have led the participants to recognize that AI can be error-prone and is subject to human biases.

There is a divide in how AI literacy is defined in the literature, especially regarding an emphasis on the knowledge of computer science concepts related to AI. The more widely accepted definitions of AI literacy in higher education, such as that of Long and Magerko (2020), underline the use and critical evaluation of AI tools rather than the technical knowledge of these tools. However, the findings of the present study showed that knowing and understanding AI were crucial for developing other dimensions of AI literacy, especially a critical perspective toward AI. The case participants were already moderately advanced users of AI tools before

the course. Nevertheless, the most significant improvement was observed in their technical understanding scores at the end of the course (based on quantitative and qualitative data), along with a notably improved critical perspective toward AI (primarily based on qualitative data).

This situation also highlights an obvious limitation in many professional development programs that primarily focus on introducing AI tools and capabilities. While selecting and using AI tools effectively for given tasks is important, it often contributes little to developing AI literacy. Simply put, as one participant stated, focusing solely on the skills of using AI tools for given tasks only addresses one aspect of AI literacy (using and applying AI). Hence, educators aiming to enhance a critical perspective on AI—an important dimension of AI literacy—should prioritize cultivating a sufficient technical understanding of AI. However, determining the appropriate learning content for AI concepts across various participants and levels requires further research. Jia et al. (2025) outlined learning content for AI literacy for children. This content includes a description of the range of topics to be covered and the level of detail for each topic. There is a similar need to define content for AI concepts to help higher education students develop an understanding of AI and recognize its human-made nature.

Along with sufficient coverage of each AI literacy dimension in the course, the pedagogical strategies employed also contributed to enhancing AI literacy. These involved asking the participants to complete a set of readings and identify poorly understood sections before class. Therefore, the class used a flipped classroom format to allocate sufficient time to explain the less-understood aspects of the weekly topics. Kong et al. (2021) utilized the flipped classroom strategy to teach AI literacy at the university level, and they received positive feedback on its effectiveness from their course participants. The present study suggests that the flipped classroom strategy is especially useful for the "knowing and understanding AI" category of the framework. The strategy gave the participants sufficient time to grasp complex AI concepts and promote active learning. Understanding AI concepts helped the participants recognize that AI is human-led, aligning with one of the curricular goals outlined in UNESCO's AI competency framework for students, particularly the human-centered mindset (Miao et al., 2024). As a result, the participants were better equipped to evaluate AI-generated content critically.

Another important element of the course that encouraged a critical approach to AI involved an assignment focused on analyzing AI-generated content. During a panel discussion, Margaret Bearman proposed that fostering evaluative judgment could enhance AI literacy in higher education (de Barba et al., 2024). This suggestion aligned well with the objectives of this course assignment. The class was tasked with composing an AI-based literature review and critically assessing the AI's performance for this task. During the interviews, the case participants often expressed concerns about over-relying on AI tools for research. As they evaluated AI's performance on writing a literature review on a research topic they knew well, they could recognize the limitations of AI tools firsthand, identifying where AI was hallucinating or missing the main points. Thus, they became more cautious about AI use, especially in professional settings. While this assignment made the case participants more critical towards AI-generated content, other researchers found that integrating AI into course assignments had

the opposite effect. Tzirides et al. (2024) employed a specialized AI-based review tool that provided automated feedback on students' class projects. Students received feedback from both peers and the AI. Furthermore, they were asked to compare human and AI-based reviews and reflect on the process. As a result of using this tool in class, the course participants started integrating AI tools, such as ChatGPT, more extensively into their personal and professional work. This discrepancy can be explained by the participants' varying AI proficiency levels in the two studies. In the present study, the case participants had already used AI for professional and personal tasks prior to the course. Thus, they were ready to develop higher levels of proficiency in AI.

The findings of the study also suggest that different AI literacy dimensions do not develop independently; rather, they influence and support each other's growth. The case participants were not able to discuss the AI tool usage strategies without addressing critical and ethical aspects of AI. Similarly, conversations about AI ethics did not occur without discussions on AI usage. This was particularly noteworthy given that the interview questions and the prompts provided for the AI journal specifically targeted a singular aspect of AI literacy. For instance, particularly related to the usage and application dimensions of AI, case participants were asked questions such as: *Provide examples of research phases where AI applications can be used and explain their potential contributions in each phase. And, how would you choose an appropriate AI tool for a specific research task, considering factors such as data needs and project goals?* Despite this focus, the participants demonstrated a multifaceted understanding when answering these questions, considering broader contexts and interconnections beyond just the specified dimensions and aspects of AI. These connections among the different AI literacy dimensions may suggest that they are interconnected; thus, they reinforce each other and promote the development of the other dimensions. However, further research can quantitatively investigate the relationships among AI literacy dimensions (e.g., SEM).

The AI literacy framework adopted in this study, based on Bloom's taxonomy, proved effective for designing an AI literacy course for graduate students. This framework is flexible enough to be applied across various subjects and contexts. Furthermore, this study has also demonstrated that the AI literacy framework is helpful in evaluating the development of AI literacy. Once the specific course outcomes were determined, researchers could use them as targets for AI literacy. Researchers highlight that assessing AI literacy poses challenges. Most studies in higher education relied only on self-reported measures (Chiu, 2024); in some cases, these were self-developed, unvalidated questionnaires (Laupichler et al., 2023). While these concerns are valid, it is equally important to collect multiple sources of data from participants when assessing AI literacy that correspond to the particular AI literacy framework adopted. This study collected qualitative data through semi-structured interviews and AI literacy journals kept by the course participants over the semester, while quantitative data were gathered using an AI literacy scale. The variety of definitions for AI literacy can be less problematic than the issue of not aligning what we aim for with the concepts we measure.

This study had some limitations. While the case participants developed some strategies for using AI tools in research, they mainly talked about using AI tools for the early stages of the

research, such as finding the related literature and creating literature matrices, as this has been the primary focus of the course. They have developed strategies based on blending AI with traditional research methods as a result of adopting a more critical stance towards AI. None of them wanted to rely on AI tools for their writing, with a common emphasis on human oversight and critical evaluation. Further research could also focus on introducing AI tools in qualitative and quantitative data analysis and investigating how this influences participants' AI literacy development.

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Declaration of Generative AI and AI-assisted technologies in the writing process
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Corresponding author: Diler Oner
Email: diler.oner@bogazici.edu.tr

AI-Powered Plush Robots for Children with ASD in Education, Rehabilitation: Expert Evaluation

Dina Bethere
RTU Liepāja Academy, Centre for Pedagogy and Social Work, Latvia

Inese Tīģere
RTU Liepāja Academy, Centre for Pedagogy and Social Work, Latvia

Anete Hofmane
RTU Institute of Digital Humanities, Latvia

Airisa Šteinberga
RTU Institute of Digital Humanities, Latvia

Undīne Gavriļenko
RTU Liepāja Academy, Centre for Pedagogy and Social Work, Latvia

Santa Meļķe
RTU Liepāja Academy, Centre for Pedagogy and Social Work, Latvia

Aleksandrs Okss
RTU Institute of Architecture and Design, Latvia

Aleksejs Kataševs
RTU Institute of Mechanical and Biomedical Engineering, Latvia

Aleksandrs Vališevskis
RTU Institute of Architecture and Design, Latvia

Abstract

The study investigates the potential of AI-powered plush robots to serve as assistive technologies for children with Autistic Spectrum Disorder (ASD) within educational and rehabilitation settings. It employed a qualitative research approach, utilizing semi-structured interviews with 13 experts from related fields to gather insights into the features and functions of the robots. Data analysis employed thematic analysis coupled with expert triangulation to ensure scientific rigor. Results from the experts' evaluations highlight critical aspects of AI-powered plush robots deemed suitable for the various needs of children with ASD, including appropriate visual elements, functions, and psychosocial benefits. Experts also identified some limitations due to individual differences and needs, which underscore the potential of customizable features such as eye illumination and controllable volume. The findings also emphasize the importance of specialist-guided interventions with assistive technologies.

Keywords: artificial intelligence, AI-powered plush robots, autistic spectrum disorder, semi-structured interviews, education and rehabilitation

The study investigates the potential of AI-powered plush robots as an innovative assistive technology to address specific challenges encountered by children with autistic spectrum disorder (ASD) in educational and rehabilitation contexts. Recent data indicate a significant rise in ASD prevalence, from 1 in 36 children in 2020 (CDC, 2023; Maenner et al., 2020) to 1 in 31 in 2022 (Shaw et al., 2025). Prevalence estimates have shifted dramatically over time - from 1 in 110 in 2006 to 1 in 68 in 2014, and 1 in 36 in 2023 (CDC, 2023). In Europe, ASD affects approximately 1 in 100 children (Zeidan et al., 2022), a marked contrast to US rates, likely due to methodological and diagnostic differences across regions. A notable gender disparity persists with boys diagnosed three times more frequently than girls (Shaw et al., 2025), despite only a 5% higher male birth rate (UN, 2024). This discrepancy may stem from biological factors or diagnostic biases, as girls often exhibit subtler symptoms or engage in "camouflaging" (Hull et al., 2018; Seers & Hogg, 2023). Late diagnoses remain a global issue, with children identified only at school age (Russell et al., 2025).

Per the DSM-5 (APA, 2013), ASD is characterized by social-communication deficits and restricted behaviours. Addressing these challenges requires tailored support strategies to improve outcomes. Individuals with ASD often exhibit atypical sensory processing (Hilton & Ratcliff, 2022). With growing emphasis on personalized therapeutic approaches (Laurie et al., 2022; Veronesi et al., 2023), the development of novel strategies is imperative. Effective interventions must address core challenges, such as difficulties in recognizing others' emotions and limited social awareness (Nagy et al., 2021). Timely prevention and early intervention for children with ASD are crucial (Fuller & Kaiser, 2020; Hadders-Algra, 2021; Lovaas, 1993; Towle et al., 2020), enhancing cognitive development and fostering social interaction (Daniolou et al., 2022; Vivanti et al., 2022)

We have developed AI-powered plush robots as tools for children with ASD. Given the absence of an established, universally accepted definition for "AI-powered plush robots," this concept has been developed within the framework of this paper by synthesizing and integrating relevant definitions derived from various scientific studies and research literature in the field. For this study, AI-powered plush robots are interactive, adaptive, and emotion-recognizing devices with mechanical parts covered in fur or wool to resemble animals, equipped with AI technologies to respond to children's emotional states, monitor behaviour, and provide personalized emotional support and insights for educators (Alabdulkareem et al., 2022; Berrezueta-Guzman et al., 2023; Yee et al., 2024). The aim of these tools is to enhance social engagement and emotional regulation. Such innovations provide personalized support, effectively addressing diverse needs of children with ASD in educational and rehabilitation settings. AI-powered plush robots present a novel alternative. Their consistent, predictable nature and capacity for repetition make them particularly suitable for children with ASD, while their interactive capabilities can enhance motivation and participation in therapeutic activities.

The study employs a qualitative research strategy involving semi-structured in-depth interviews with a focus group of thirteen experts. These experts were selected for their experience in social rehabilitation and education of children with ASD, their use of technology in practice, and their backgrounds across diverse fields. The approach is particularly well-

suited to exploring the potential of AI-powered plush robots as a novel intervention for children with ASD, as it leverages the collective knowledge and diverse perspectives of specialists to identify key features, benefits, and challenges associated with this technology. Thematic analysis, informed by previous investigations (Alabdulkareem et al., 2022; Ghiglino et al., 2021; Kim et al., 2013; Pop et al., 2013), alongside expert triangulation, is utilised to guarantee the rigour and validity of findings.

The aim of the research is to gather and analyse expert evaluations about the features and functions of AI-powered plush robots to identify their suitability for educational and rehabilitation contexts for children with ASD. In addition, the study will help to determine key aspects for further development and improvement of the robots based on expert insights. To achieve these aims, two research questions are established: 1) Which features and functions of AI-powered plush robots are suitable for use in educational and rehabilitation contexts for children with ASD? 2) What aspects should be considered for further development and improvement of AI-powered plush robots?

The publication first establishes a theoretical framework for ASD and general description of assistive technology. Then it details the study's qualitative methodology and subsequently presents the expert-driven findings. Expert evaluations highlight critical aspects of AI-powered plush robots deemed suitable for children with ASD. Experts also indicate some limitations, due to individual differences of each child, which underscore the potential necessity of customizable features, especially eye illumination and controllable volume to accommodate individual sensory needs. The findings also indicate the importance of specialist-guided intervention with AI-powered plush robots. Finally, the article concludes with actionable recommendations for further scientific study of AI-powered plush robots for children with ASD.

Literature Review

A rigorous search and selection methodology was applied to ensure the accuracy and reliability of the reviewed literature. The literature was systematically searched using the following databases: Scopus, Web of Science, PubMed, and Google Scholar. The search strategy was based on the keywords related to ASD to identify articles: "autism," "autistic," "ASD," combined with "sensory," "manipulative," "toys," "tools," "assistive devices," or "materials." The initial search yielded 117 relevant articles. After reviewing the titles and abstracts, 38 articles were selected for full-text evaluation. From these sources, seven articles (N=7) were selected for inclusion in the literature review based on their relevance to the research questions, methodological rigor, and clear formulation of conclusions regarding the use of AI-powered robots for children with ASD (Alabbdulkareem et al., 2022; Ghiglino et al., 2021; Kim et al., 2013; Laurie et al., 2022; Pop et al., 2013; Syriopoulou-Delli & Zygopoulou, 2021; Veronesi et al., 2023).

ASD comprises a diverse range of neurodevelopmental conditions characterized by core impairments in social communication and interaction. The primary difficulties are

accompanied by restricted interests, repetitive behaviours, and sensory processing differences, forming a complex symptom profile as defined in the DSM-5 (APA, 2013). Sensory processing variability is a notable characteristic of ASD, influencing how individuals perceive and react to environmental stimuli (Hilton & Ratcliff, 2022). Given the differences in ASD manifestations, there is a need for individualized therapeutic strategies that address both sensory regulation and social engagement. Among these interventions, sensory toys have emerged as valuable therapeutic tools, offering targeted support for developing emotional regulation, while providing structured ways to practice new skills (Laurie et al., 2022; Veronesi et al., 2023).

Children with ASD exhibit delays or absence of responses to social stimuli, despite intact hearing abilities (Banire et al., 2020). This manifests in reduced or delayed responses to their own name (Perochon et al., 2021; Zhu et al., 2023), diminished reactions to others' facial expressions and emotions (Masaļska, 2020; Wedyan et al., 2021). Such impairments manifest in negative responses to caregivers' requests or displays of affection. The inherent complexity and unpredictability of social stimuli pose particular challenges for children with ASD in perception, processing, and imitation. Consequently, their attention fails to pick up cues, resulting in deficient early social experiences that may further compound developmental delays.

Children with ASD often exhibit reduced awareness of personal space or intolerance when others enter it (Krishnappa Babu & Lahiri, 2024; Muraškaitė & Žardeckaitė-Matulaitienė, 2024), which leads to solitary play, which may hinder social skill development (Schiltz et al., 2024). Additional barriers to social interaction include deficits in nonverbal communication (Xavier et al., 2023). Children with ASD often fail to percept pointing gestures or use them to address something with others (Alcañiz et al., 2022; Stuart et al., 2023). While similar social communication issues may occur in other developmental disorders, these impairments typically persist longer in ASD and often fail to develop adequately over time (Frazier et al., 2021; Whiteley et al., 2019).

Children with ASD each develop verbal language in a different manner, ranging from delay to regression or complete absence (Félix et al., 2024; Schaeffer et al., 2023; Vogindroukas et al., 2022). Characteristic speech patterns include atypical prosody and frequent echolalia (Vogindroukas et al., 2022). Pronoun difficulties further reflect impaired self-other differentiation, affecting identity formation and social skills (Zane et al., 2021). Children with ASD demonstrate preferences for individual play or repetitive actions over social engagement, showing particularly limited interest in imaginative, cooperative, or verbal activities (Chaxiong et al., 2022). Limited social play interactions worsen existing difficulties with social interaction, hindering overall development.

Another area influenced by engaging in daily activities for children with ASD is the presence of repetitive motor behaviours, often self-reported as calming by individuals with ASD (McCarty & Brumback, 2021). While these stereotyped movements may serve a regulatory function, they can impair social interaction and daily functioning (Hijab et al., 2024). Left

unaddressed, such behaviours may escalate, further limiting skill acquisition and social integration (O'Keeffe & McNally, 2025). Repetitive behaviour also manifests during play, including rigid object arrangement (González-Sala et al., 2021; Westby, 2022). Atypical sensory processing represents a core feature of ASD, influencing environmental perception and interaction. Visual processing alterations manifest as either hypersensitivity to bright lights/colour contrasts (Banire et al., 2020) or preferential attention toward predictable stimuli like spinning objects (Alcañiz et al., 2022). Similarly, tactile sensitivities frequently lead to texture avoidance or sensory-seeking behaviours for self-regulation (Hilton & Ratcliff, 2022). These patterns reflect underlying neural processing differences, where sensory input is atypically modulated, either being amplified or under-registered.

Children with ASD benefit from various evidence-based interventions, including behavioural, communication, and creative arts therapies, as well as occupational and sensory integration approaches. While resource availability varies globally, these interventions target core ASD challenges in social communication and behaviour (APA, 2013). Effective rehabilitation must incorporate both social domains and sensory needs (Hilton & Ratcliff, 2022), recognizing play's therapeutic value - as Landreth (2012) notes, "Toys are children's words, and play is their language." Optimal outcomes require individualized support in structured environments to foster social-emotional development (O'Keeffe & McNally, 2025).

AI-Powered Therapeutic Plush Robots: Advancing ASD Intervention Through Research, Design, and Theory

AI-powered plush robots are gaining recognition as valuable therapeutic tools for children with ASD. Alabdulkareem et al.'s (2022) systematic review of 38 robot-assisted therapy studies identified this as a promising field but highlighted critical research gaps: the need for supervised applications to build trust, improved sensory development integration, and more focus on eye contact and self-initiated interactions. Their findings particularly emphasize the necessity of interdisciplinary collaboration to design intelligent robots with appropriate safety and ethical considerations.

Our expert-driven study addresses this gap through a comprehensive evaluation of adjustable sensory features and social mediation capabilities in plush robot design. Examples include Probo (Pop et al., 2013), Cozmo (Ghiglino et al., 2021), and Pleo, which have been shown to enhance verbal interaction with adults (Kim et al., 2013). Animal-inspired AI-powered plush robots serve as social mediators. These animal-inspired tools represent an evolution beyond traditional approaches, offering individualized support in structured environments (O'Keeffe & McNally, 2025) while maintaining the therapeutic benefits of play-based intervention.

Our research results, grounded in social constructivism (Vygotsky, 1978), demonstrate that adult supervision critically mediates interactions between children with ASD and AI-powered plush robots. Furthermore, our data analysis, informed by attachment theory (Bowlby & Solomon, 1989), reveals that the robots' consistent behavioural patterns show significant potential to enhance emotional security and self-regulation in participants.

Methodology

Design

A qualitative research design was used, employing thematic analysis (Braun & Clarke, 2021) and expert triangulation to systematically evaluate professionals' perspectives on AI-powered plush robots for children with ASD. Purposive sampling was used (Campbell et al., 2020; Nyimbili & Nyimbili, 2024), selecting 13 professionals applying strict inclusion criteria. Semi-structured interviews were selected to explore both technical specifications and therapeutic applications (Ghiglino et al., 2021), with a particular focus on the sensory-social integration gap identified in autism spectrum disorder interventions (Hilton & Ratcliff, 2022; Zhai et al., 2023). Thematic analysis followed Braun and Clarke's (2021) six-phase approach with three-researcher triangulation (Nowell et al., 2017), using DSM-5 criteria (APA, 2013) as the analytical framework. This design promotes robotic therapy research with a focus on customizable features: a critical need highlighted in recent systematic reviews (Alabdulkareem et al., 2022).

AI-Powered Plush Robots

AI-powered plush robots were the focus of this research. There were four robots in total, two cats and two dogs. They were made from smart e-textiles, with sensors registering the touch, strokes, and other tactile interactions. Importantly, the robots provided feedback reactions to touch, whether the touch and the ways of interaction were pleasant or unpleasant. If the plush toy was pulled by the tail, it gave off sounds of a real cat or a dog that indicated dislike, and if the plush toy was petted, the cat purred and the dog panted. In addition, the eyes lit up as a sign of like (green eyes) or dislike (red eyes). These properties provided auditory and visual feedback to the person interacting with the plush toy. The profiles of the AI-powered plush robots can be seen in Figure 1.

Figure 1

AI-Powered Plush Robots' Profiles

Note– Visual representation of AI-powered plush robots from the authors' original research data. Image copyright by Bethere, D., Tīģere, I., Hofmane, A., Šteinberga, A., Gavriļenko, U., Meļķe, S., Okss, A., Kataševs, A., & Vališevskis, A.

Participants

Data were gathered from 13 experts (n=13) who fit the inclusion criteria. The inclusion criteria consisted of 1) having at least two years of experience in social rehabilitation and education in work with children with ASD, 2) having higher education, 3) having used technologies in their work, and 4) being willing to be interviewed and interested in participating.

Table 1

Participant Eligibility According to Inclusion Criteria

Respondent code	Education	Area of expertise	Years of practice	Used technologies, agrees to interviews
R1	Master's Degree in Pedagogy	Preschool teacher, speech therapist	24	Yes
R2	Master's Degree in Pedagogy	Preschool teacher, speech therapist	23	Yes
R3	Master's Degree in Pedagogy	Special education teacher, behaviour analyst	23	Yes
R4	Master's Degree in Pedagogy, Doctor's Degree	Special education teacher, physician assistant	15	Yes
R5	Bachelor's Degree in Health Care	Masseur	3	Yes
R6	Bachelor's Degree in Health Care	Physiotherapist	2	Yes
R7	Bachelor's Degree in Health Care	Audiologist-speech therapist	7	Yes
R8	Doctor's Degree	Paediatrician, palliative care doctor, floor specialist	25	Yes
R9	Master's Degree in Physiotherapy	Physiotherapist, occupational therapist	20	Yes
R10	Master's Degree in Physiotherapy	Physiotherapist	16	Yes
R11	Master's Degree in Psychology	ABA therapist, psychologist	6	Yes
R12	Master's Degree in Psychology	Psychologist, psychotherapy specialist	10	Yes
R13	Master's Degree in Social Work	Social worker	3	Yes

Ten respondents had a master's degree or corresponding level of education, three had a bachelor's degree, and on average, all of them have 13.6 years of expertise (M=13.6, SD=8.84). Four participants had education in Pedagogy, three in Health Care, one is a doctor, two in Physiotherapy, two in Psychology, and one in Social Work. The sample includes specialists from various education and social rehabilitation areas with various backgrounds. This accounted for diversity and thus contributed to the scientific rigor of the study's qualitative approach.

Data Gathering Methods

The study employed semi-structured interviews to systematically evaluate AI-powered plush robots for children with ASD. The interviews were organized into five thematic sections: (1) potential applications of AI-powered plush robots in ASD rehabilitation/education, (2) robots' role in mediating social interactions, (3) robots' visual design properties, (4) robots' functional features, and (5) participants' professional expertise. This approach systematically evaluated both the therapeutic potential for children with ASD and the technical specifications of the robotic tools. The interviews were recorded.

Procedure

At first, an application was submitted to Rīga Technical University's Ethics Committee, which allowed the study to move forward with data gathering and processing. Then the research group agreed and established a semi-structured interview as a data gathering method, and invited social rehabilitation centres and places of education that specialize in ASD. The invitations were sent via email or phone call. A video instruction was made about the usage of AI-powered plush robots. The centres received the semi-structured interview question categories beforehand, the video-instruction, and an explanation that the interview would be recorded, as well as a briefing on how the data would be collected and processed. The interviewer and interviewee agreed on the date and time, visited the interviewee in person, explained informed consent, and gathered their signature. Then, the interviewer asked permission for the voice recording, switched on the recorder, and started the interview. The interviewer brought the AI-powered plush robots with them, so the interviewee could interact with them to have a better comprehension of their features and capabilities. After the interview, the recording was stopped. The interviewers exported the interviews on an external hard drive, along with the signed informed consent documents, and placed them in a safe. After all the interviews were conducted, they were transcribed in a text format. Later, three researchers separately analysed the transcripts by categorizing all the data and then making subcategories, backing up with citations from the interviews. Then the experts came together and presented data analysis, agreed on the common categories and subcategories, and citations. Findings were presented to the research group, who gave additional comments.

Data Processing Methods

Thematic analysis was used in data processing. Five steps were taken: familiarization with the data, generating initial codes, searching for themes, reviewing themes, defining and naming themes, and producing the report (Braun & Clarke, 2021). Initially, three experts separately reviewed the transcriptions and extracted categories and subcategories from the semi-structured interview results. Three experts were chosen to ensure triangulation, which in turn corresponds to the principles of scientific rigor, bolstering the reliability and validity of the data (Nowell et al., 2017). The categories and subcategories ensured the highest reliability and validity. There were some categories that other experts indicated as subcategories, and two major categories were recognized by one expert. All the data were analysed in accordance with the research questions.

Findings

The reception of AI-powered plush robots was positive, with the specialists showing verbal and non-verbal excitement about the intervention and expressing more benefits than challenges in rehabilitation and education contexts.

To answer the first research question: “Which features and functions of AI-powered plush robots are suitable for use in educational and rehabilitation contexts for children with ASD?”, four themes were extracted with subthemes. All researchers consistently identified ‘visual properties’ as the primary theme emerging from triangulation, comprising four key subthemes of their design for children with ASD: 1) colour, 2) size, 3) fabric texture and material composition, and 4) safety features.

Table 2

Subcategories and Descriptions of the "Visual Properties" Theme

Subcategory	n	Description with citations
Colour	4	Neutral and calming colours are suitable for children with ASD, helping to avoid sensory overload. Bright or intense colours can provoke negative reactions, natural tones are safer: "*I like that the colours are neutral*", "(…) *colours are calm, which is an important aspect for children with ASD.*"
Size	6	The toy's size is described as appropriate for children with ASD, easy to hold, carry and play with ("*Size is good, not too big, not too small.*"). 5 respondents note it as "*the perfect size*" and "*well-suited*," indicating that the size supports both functional use and emotional comfort.
Texture of fabric and material	5	Material texture is highlighted as a key factor influencing toy preference, noting the importance of varied tactile experiences ("*Children want to feel the texture*"). Preferences vary, some favour soft or compact textures, while others respond better to rougher surfaces, diverse materials to accommodate individual sensory sensitivities ("*they may or may not like*").
Safe and suited for children with ASD	7	The toys are perceived as safe, with no small parts that could be removed or swallowed, and all mechanisms safely concealed ("*Everything about the toys is very safe... everything is concealed*."). The toys are also a safe way to teach social interaction, especially with animals: "*A child can learn what acceptable touches are. You shouldn't start with a live animal right away, as harm could be caused.*" 2 experts indicate that the sounds might be loud and could jump-scare the child: "*Children with ASD can react strongly to sounds. Toys should not be too loud, as they may frighten the child*."

The analysis highlighted that the toys' visual and tactile characteristics played a crucial role in their suitability for children with ASD. Neutral colours, appropriate sizing, and varied textures contributed to both sensory comfort and engagement. The toys were perceived not only as physically safe, but also as safe tools for teaching interactions with real animals. Varied but thoughtfully chosen textures contributed to sensory comfort and engagement, reflecting the need for toys to accommodate individual sensory sensitivities (Hilton & Ratcliff, 2022). Sound intensity must be regulated to avoid overstimulation, underscoring the need for sensory-adapted design in educational and therapeutic contexts.

The second category, all three experts agree on, was "functions", which included four subcategories: 1) sounds, 2) eye illumination, 3) area touch, and 4) reaction consistency.

Table 3

Subcategories and Descriptions of the 'Functions' Theme

Subcategory	n	Description with citations
Sounds	6	Experts agree that toys with sound features can be both engaging and challenging for children with ASD, depending on individual sensitivity. While some children enjoy specific sound-based feedback like purring or hissing ("*The sounds toys make can help the child learn what toys they like and dislike*"), many may react negatively to loud or unexpected noises ("*Children with ASD often react strongly to loud sounds*"; "*If a toy suddenly starts making noises, it can cause distress.*").
Eye illumination	5	Eye light reactions in toys are viewed as meaningful and beneficial for children with ASD, helping them interpret emotional responses ("*It's important for the child to see whether the reaction is good or bad.*"). The lights' intensity and colour should be considered, as overly bright or red lights might frighten some children ("*Red eyes look scarier in the video.*"; "*It could scare the child, as they tend to avoid eye contact.*"). Opinions vary as some experts note that the eyes are the focal point: "*This is the first thing kids react to*", "*those eyes, they instantly catch the attention, the colours… the kids are mesmerized.*"
Area touch	7	Touch-sensitive responses in different body zones of the toy are valuable for children with ASD, as they help teach emotional cues and social boundaries. Purring when stroking the head or hissing when pulling the tail can signal what is pleasant or unpleasant ("*When you stroke the head, it purrs; when you pull the tail, it gives an unpleasant reaction.*"), supporting the development of empathy and appropriate touch ("*This teaches boundaries and mutual understanding.*"). Experts indicate some areas to be further equipped with sensors – under the paws, under the tail, tongue, because those are the areas that are the most interesting to the child.
Reaction consistency	7	Consistency in toy reactions is generally preferred for children with ASD, as many find comfort in predictability and may struggle with change ("*Children with ASD prefer things to stay the same; change is hard to accept.*"). Most respondents suggest using one specific sound per action ("*If he is angry, then one sound, better than several.*"), some note that varied reactions could be beneficial for higher-functioning ASD or to stimulate curiosity ("*Changing reactions could suit children with higher functioning.*"; "*Different sounds might increase interest.*").

The findings suggest that interactive features play a critical role in toy design for children with ASD. While elements like purring or illuminated eyes can enhance engagement and support social-emotional learning, their effectiveness depends on calibration to individual sensory needs. Experts emphasized the importance of predictable and contextually appropriate

responses, particularly in sound and touch, as a means to foster emotional insight and reinforce social boundaries. Variation in preferences highlighted the need for customizable features.

The third category that all three experts agreed on was "psychosocial aspects", which included eight subcategories: 1) initial reaction and adjusting, 2) similarity with pets, 3) social interaction, 4) empathy, 5) training under adult supervision, 6) imitation, 7) language and speech development, and 8) advantage for children with ASD.

Table 4

Subcategories and Descriptions of the 'Psychosocial Aspects' Theme

Subcategory	n	Description with citations
Initial reaction and adjusting	7	Children with ASD often display varied initial reactions to new toys: "*The first reaction - some might throw it away, others might become curious and explore it*", so it takes some time for the child to adjust to these toys: "*Initially they might not want to, but after a while, they begin adjusting to the sensation.*"
Similarity with pets	9	The toy's realistic resemblance to actual animals is praised by experts, with several noting that its appearance, weight and texture closely mirror real pets ("*The cat is fantastic, completely analogous to a real cat.*"; "*The fur texture resembles a British Shorthair.*"). This realism not only supports sensory engagement but also serves as a safe way to teach social behaviour and responsibility, preparing children with ASD for potential interactions with real pets ("*You shouldn't do to the toy what you wouldn't do to a real animal.*"; "*This toy can be used as training before getting a real pet.*").
Social interaction	8	The toy is seen as a supportive medium for developing communication, cooperation and behavioural boundaries in children with ASD. Experts note that it could help children distinguish between acceptable and unacceptable touch ("*They can learn what is good or bad, what is allowed or not.*") and serve as a trusted companion in both therapeutic settings and social play ("*It could be a reliable friend for communication and play.*") and enhance interaction with specialists ("*The toy can also serve as a support in therapy to help the child better cooperate with the specialist*.").
Empathy	6	The toy is recognized as a valuable tool for teaching empathy and helping children with ASD comprehend emotional and physical boundaries. Experts note that children can learn that others can feel differently ("*The most important social skill to learn is empathy. Toys can teach that others may feel differently.*"), some behaviours are inappropriate with real animals and the toy itself ("*You shouldn't do to the toy what you wouldn't do to a real animal.*").

Training under adult supervision	6	Effective use of the toy for children with ASD requires structured adult involvement. Experts emphasize the importance of a guided, supportive environment where adults help children interpret the toy's reactions and avoid distress ("*You don't just hand over the toy and expect the child to know what to do.*"; "*It should be a controlled environment where the adult explains what happens and why.*").
Imitation	2	The toy's ability to imitate real animal behaviour is seen as a valuable educational tool, particularly for imitation skills. Children could learn through modelled actions, such as feeding or petting, in a way that closely resembles interactions with real animals ("*It resembles a real animal - all those reactions, body zones, sounds… it's like an imitation.*"; "*The toy could be effective for teaching imitation, like when the child copies feeding.*").
Language and speech development	4	The toy is considered beneficial for supporting language and speech development in children with ASD, especially through sound repetition and interactive feedback. Experts note that such toys can help improve articulation ("*Toys that repeat words work very well, the child starts to pronounce sounds more clearly.*") and build vocabulary essential for communication ("*Vocabulary is very important for social skills… they might start saying 'the cat meows, purrs.*"), potentially reducing broader socialization difficulties linked to language delays.
Advantage for children with ASD	12	The toy is seen as beneficial for children with ASD, offering a multisensory learning experience that supports emotion recognition, communication and self-regulation ("*These toys include everything we need to learn - something to touch, something to hear, and something to see.*"). Their realistic, pet-like design makes it emotionally relatable and safe, while features like responsive sounds or glowing eyes help teach social norms and improve cooperation in therapeutic settings ("*It can be used as a calming object or even as a reward in ABA therapy.*"; "*Sounds or glowing eyes help children learn social interaction.*").

The findings suggest that interactive, animal-like toys offer significant developmental benefits for children with ASD across multiple domains. Those domains can be divided into two subsections: (a) interaction dynamics and (b) interaction subject. Interaction dynamics answers the question: "How could children with ASD interact with the toys?". This process comprises three sequential phases: (a) initial reaction, (b) behavioral adjustment, and (c) adult-guided imitation learning. While initial reactions may include hesitation or sensory sensitivity, structured adult guidance facilitates adjustment and engagement. The second subsection answers the question: "What do children learn from the interaction?" The answer to this question is social interaction, empathy, language, and speech. The five animal-like toys in our study, as shown in Figure 1, share a realistic design that enhances sensory integration and serves as a safe medium for teaching imitation, empathy, behavioural boundaries, and appropriate social behaviour. Their interactive features, particularly sound repetition, collectively support speech and language development. As a multisensory toolkit, these toys

prove effective in therapeutic and educational contexts when introduced with adult support and tailored to individual sensory profiles.

To answer the second research question, "What aspects should be considered for further development and improvement of the AI-powered plush robots?", experts gathered the results in one theme: specialist recommendations. This theme had two subcategories: 1) adjustable features and 2) function enhancements.

Table 5

Subcategories and Descriptions of the 'Specialist Recommendations' Theme

Subcategory	n	Description with citations
Adjustable features	6	The data highlight the importance of flexibility and individualization in the design of therapeutic toys for children with ASD. Experts emphasize that children with ASD vary widely in their sensory preferences and regulatory needs, and no single toy configuration is universally suitable: *"Each child has different needs – there should be multiple modes"* and *"Children with ASD are very diverse – there can't be one universal toy"*. Adjustable features are considered essential to accommodate this variability: *"It's good if you can adjust the volume and reactions."* Even visual elements, like colour brightness, may affect engagement: *"When the child likes it – the green and red looks very nice… green not as much"*. These findings support the need for customizable toys that can be tailored to individual sensory profiles and preferences.
Function enhancements	5	Findings emphasize the need for adaptable and customizable features, highlighting that some children may experience discomfort from fixed or intense stimuli, making it important to offer control over features such as automatic reminders and sound levels: "*It should be possible to turn off automatic reminders*", "*Loud sounds can cause discomfort, so it's better if they can be adjusted*". Suggestions are made to enhance sensory engagement by adding features like warmth or increasing the variety of reactions "*It would be good to add more sensory stimuli*", "*There could be more variations of negative reactions.*" The ability to choose between different materials is also considered important, as children with ASD can be highly selective: "*Children with ASD can be very selective about materials, so it's good there is a choice*". These insights support the value of modularity and sensory diversity in toy design.

The findings underscore the necessity of flexibility, individualization, and sensory adaptability in the design of AI-powered plush robots. Given the variability in sensory needs and preferences among children with ASD, no single toy design is universally suitable. Experts emphasized the importance of customizable features such as adjustable volume, multiple operating modes, and options for turning off automatic responses to minimize overstimulation. Enhancements like thermal feedback, increased reaction variability, and material options

further support engagement and comfort. Overall, the data point to the importance of modular, customizable toy systems that can be tailored to individual sensory profiles, thereby increasing the toy's therapeutic potential and usability in diverse contexts. It is important to note that, whilst these insights are valuable, they can vary from one specialist to another. While these specialist-derived insights are valuable, specific recommendations about functional modifications may vary between experts. At this stage, the proposed design enhancements represent a working hypothesis rather than definitive conclusions about required feature adjustments.

Discussion

The investigation into AI-powered plush robots yields valuable insights into their suitability and areas for further enhancement. A convergence of expert opinions underscores the potential of such robots to address core challenges faced by children with ASD, particularly in the realms of social interaction, communication, behavioural challenges, and sensory processing. Research confirms children with ASD struggle with eye contact (Xavier et al., 2023), gesture interpretation (Alcañiz et al., 2022), and joint attention (Banire et al., 2020). The results of this study suggest the animal design of AI-powered plush robots proves particularly engaging: *"The cat is fantastic - completely analogous to a real cat"* (R9) and *"The fur texture resembles a British Shorthair"* (R4), aligning with findings about animal-mediated therapy (O'Haire, 2013). Regarding tactile interaction, specialists report: *"When you stroke the head, it purrs; when you pull the tail, it gives an unpleasant reaction"* (R4), demonstrating clear cause-effect learning. The eye illumination system, while controversial (*"Red eyes look scarier in the video"* - R2), is praised by others: *"It's important for the child to see whether the reaction is good or bad"* (R4). Turn-taking emerges organically: *"The child pets, waits for the purr, then responds"* (R2), creating natural social routines. One specialist perfectly captured the mediation value, sharing *"The toy can also serve as a support in therapy to help the child better cooperate with the specialist"* (R3). For nonverbal children, experts observed potential breakthroughs: *"At first, the child starts to pronounce sounds more clearly"* (R4) and *"They might start saying: the cat meows, purrs"* (R3), validating language facilitation approaches (Kim et al., 2013).

In addition to difficulties with social interaction, children with ASD often also experience significant speech and communication difficulties, including delayed or absent language development, atypical prosody, and frequent use of echolalia as a compensatory communication mechanism (Schaeffer et al., 2023; Vogindroukas et al., 2022). The AI-powered plush robots evaluated in this study demonstrate significant potential for addressing these communication barriers through their responsive, multisensory feedback system. The AI-powered plush robots provide clear cause-and-effect responses that help establish a basic communication framework - purring when gently stroked or showing distress sounds when handled roughly: *"When you stroke the head, it purrs; when you pull the tail, it gives an unpleasant reaction. This teaches boundaries and mutual understanding"* (R7). The auditory feedback system proves particularly valuable for language development: *"Toys that repeat words work very well - at first, the child starts to pronounce sounds more clearly"* (R4), with another specialist noting: *"Vocabulary is very important for social skills... they might start*

saying 'the cat meows, purrs'". As emphasized by one specialist: *"These toys include everything we need to learn – something to touch, something to hear and something to see"* (R11), making them a transformative tool for addressing the complex communication profile of ASD when integrated with professional therapeutic guidance.

The expert evaluation reveals how AI-powered plush robots can address repetitive behaviours in ASD. The sensory design proves particularly effective, as noted: *"The weighted design provides deep pressure that satisfies proprioceptive needs"* and *"Children specifically want to feel the texture."* These features help redirect self-stimulatory behaviours, supporting findings by Syriopoulou-Delli and Zygopoulou (2021). Experts emphasize the importance of predictable responses: *"Children with ASD prefer things to stay the same; change is hard to accept"* (R1, Table 3: Reaction consistency), confirming the need for stability in ASD interventions (O'Keeffe & McNally, 2025). The adjustable features are particularly valued: *"It's good if you can adjust the volume and reactions"* (R4, Table 5: Adjustable features). For language development, specialists have observed: *"Toys that repeat words work very well - at first, the child starts to pronounce sounds more clearly"* (R4, Table 4: Language and speech development), demonstrating the AI-powered plush robots' potential to support communication skills. The most significant benefits emerge in therapeutic settings: *"You don't just hand over the toy and expect the child to know what to do"* (R4, Table 4: Training under adult supervision) and *"It should be a controlled environment where the adult explains what happens and why"* (R4, Table 4: Training under adult supervision), highlighting the importance of professional guidance (González-Sala et al., 2021).

The expert interviews provide critical insights into how specific sensory features affect engagement for children with ASD, with particular attention to sensory sensitivities. These findings align with current research on sensory processing in ASD (Hilton & Ratcliff, 2022) and assistive technology design (Alabdulkareem et al., 2022). Regarding visual sensitivity, multiple specialists emphasize the importance of neutral colours: *"The colours are calm, which is an important aspect for children with ASD" (R4).* This observation supports research suggesting that neutral and calming colours aid in sensory regulation. Bright or intense colours are noted to potentially provoke negative reactions, making natural tones essential *("I like neutral colours" - R1),* consistent with findings on visual hypersensitivity in ASD (Banire et al., 2020; Cañete et al., 2024). For tactile sensitivity, texture emerges as a decisive factor: *"Children specifically want to feel the texture" (R3).*

Experts expressed that some children might prefer soft or compact textures, while others might prefer rougher surfaces *("They may or may not like [certain textures]" - R6),* reflecting differences documented in ASD (Hilton & Ratcliff, 2022). The safe, enclosed design is praised: *"Everything about the toys is very safe... everything is concealed" (R10),* aligning with safety recommendations for sensory toys (O'Keeffe & McNally, 2025). While sound feedback is seen as beneficial *("The sounds toys make can help the child learn what they like and dislike" - R3),* experts caution that unexpected or loud noises could be distressing: *"Children with ASD can react strongly to sounds" (R1),* supporting research on auditory hypersensitivity in ASD. This might be an indication to implement volume change features in the current design. It is

indicated that visual feedback through eye illumination also might need adjustment for sensory comfort. Although illuminated eyes help clarify reactions *("It's important for the child to see whether the reaction is good or bad" - R4),* some specialists note intense colours could be overwhelming *("Red eyes look scarier... it could scare the child" - R2),* consistent with the sensitivity to the light. Others find the lights engaging *("Those eyes... instantly catch the attention" - R7),* demonstrating expert comprehension of individual differences in sensory processing. The predictability of responses is crucial for sensory regulation. Children with ASD thrive on consistency: *"Children with ASD prefer things to stay the same" (R1),* supporting established findings about the need for predictable environments. Some suggest minor variations for higher-functioning children *("Changing reactions could suit children with higher functioning" - R11).* Finally, touch-sensitive zones provide structured sensory input while teaching social boundaries: *"When you stroke the head, it purrs; when you pull the tail, it gives an unpleasant reaction" (R4).*

The experts stressed how each child is different when it comes to sensory needs: "*Each child has different needs – there should be multiple modes"* (R4) and *"Children with ASD are very diverse – there can't be one universal toy"* (R6). This aligns with research underscoring the importance of accommodating unique sensory profiles and emphasizing the need for individualized approaches aligned with current ASD research (Hilton & Ratcliff, 2022; O'Keeffe & McNally, 2025). Experts particularly acknowledged auditory customization: *"Loud sounds can cause discomfort, so it's better if they can be adjusted"* (R1), recommendations that directly address sound hypersensitivity. Enhanced tactile variability was proposed, suggesting: "*It would be good to add more sensory stimuli"* (R9) and: *"Children with ASD can be very selective about materials, so it's good there is a choice"* (R3). Experts recommend expanding tactile feedback *("under the paws, under the tail" - R3)*, aligning with multisensory intervention approaches (Laurie et al., 2022).

Experts suggested diversifying the reactions: *"There could be more variations of negative reactions"* (R5), but to maintain core predictability. It is important to note that children with ASD should interact with these robots under adults' supervision, which is in agreement with the literature (O'Keeffe & McNally, 2025), with one specialist summarizing: *"You don't just hand over the toy – it should be a controlled environment where the adult explains what happens and why"* (R4). This expert guidance collectively demonstrated how these robots can achieve therapeutic efficacy through: (1) modular sensory customization, (2) graduated exposure capabilities, and (3) professional-guided interaction – fulfilling the call for individualized, sensory-adapted interventions in ASD care (Hilton & Ratcliff, 2022).

Our study reveals that experts emphasized a multisensory approach in the design of adjustable robots. This approach could offer more comprehensive support for children with ASD than focusing on individual sensory modalities. Adult supervision proves crucial. This indicates the need to integrate these robots into structured therapeutic environments.

The study has several limitations, which should be addressed in future work. First, our sample consisted solely of experts. Subsequent phases of research will include direct observations of

children interacting with the robots. This will likely lead to a more in-depth understanding of their experiences with the toys. Second, our study was conducted in only one country; future work should examine whether the findings are similar across regions and cultures. Finally, future research should assess the long-term impact of these robots on children's behaviour, to evaluate their long-term effectiveness, which is a limitation of the current study.

Conclusion and Recommendations

The current research highlights the promising role that AI-powered plush robots can play in supporting children with ASD. It can be concluded that AI-powered plush robots may be useful in educational and rehabilitation settings for children with ASD. Data analysis reveals that the visual properties and functions are valuable for social interaction, empathy, and communication, which are areas in which children with ASD struggle. The animal-inspired design, realistic textures, and responsive features are especially appreciated by professionals, as they help children engage more naturally by encouraging early speech and social behaviours. These findings show that such technology can offer valuable support in both rehabilitation and educational settings.

It is important to note that no single design works for every child. Children with ASD have very different sensory preferences and needs. The effectiveness of these tools depends not only on their design but also on how they are introduced and used — ideally with adult involvement. These findings serve as permission to move forward with introducing AI-powered plush robots to children with ASD. In conclusion, the main recommendation is to gather data from children with ASD using these tools under specialist supervision.

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Institutional Review Board Statement

The study is conducted in accordance with the Declaration of Helsinki and approved by the Ethics Committee of the Research Committee of Riga Technical University (protocol code 04000-10.2.3-e/11 on 25 March, 2025).

Conflicts of Interest

The authors declare no conflicts of interest.

Declaration of Generative AI and AI-assisted Technologies

No AI tools have been consulted or utilized in the creation of this manuscript.

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Corresponding author: Dina Bethere
Email: Dina.Bethere@rtu.lv

Language Learners' Intentions to Use Gamified Learning Apps: The Role of Gameful Experience and Cognitive Engagement

Irum Alvi
Rajasthan Technical University, Kota, India

Abstract

Gamified learning apps have proliferated for language learning in contemporary Higher Educational contexts, owing to their capacity to enhance learner engagement and motivation. However, limited empirical attention has been given to the psychological and cognitive mechanisms through which learners' interactions with gamified elements translate into behavioral intentions (BI) to adopt gamified learning apps. This study explores the impact of Gameful Experience (GE) on BI, operationalized through the GAMEX Experience Scale. It further probes how the components of the Involvement Load Hypothesis (ILH), namely, need, search, and evaluation, both influence BI and mediates the GE and BI relationship. Data were collected from 250 respondents based on a structured online questionnaire disseminated on social media platforms through convenience sampling. The dataset was analyzed using Partial Least Squares Structural Equation Modeling (PLS-SEM). The findings demonstrated that GE significantly influenced need, search, and evaluation. Among the ILH components, need and evaluation exerted significant and substantial effects on BI. Furthermore, the influence of GE on BI was fully mediated through the ILH components *need* and *evaluation*, whereas search did not exhibit a mediating effect. The study offers both theoretical and practical insights for designing more interactive, challenging, and engaging educational technologies that incorporate gamified elements for language learning.

Keywords: behavioural intention, GAMEX scale, involvement load hypothesis, gamified learning, structural equation modeling (SEM), gameful experience

Gamification refers to the incorporation of game design elements – such as points, badges, leaderboards, and feedback – in non-game contexts (Deterding et al., 2011) to enhance learner engagement and effectiveness (Christopoulos & Mystakidis, 2023). It has gained popularity in digital education as an innovative strategy to support language acquisition. Studies suggest gamification can foster various competencies and skills, including communication, teamwork, competitiveness, creativity, and problem-solving, and ultimately enhance self-perceived performance (Saraswat et al., 2025). However, its effectiveness lies not merely in the superficial inclusion of game-like elements but in their thoughtful integration and alignment with the instructional strategies that support active learning. Moreover, gamification has been shown to reduce common negative experiences such as anxiety and frustration, resulting from a lack of a personalized, flexible learner-centered approach (Solati et al., 2024).

A closely related, but distinct concept is *gameful learning*, which refers to pedagogical approaches that intentionally incorporate game principles, such as narrative, challenge, and progression, to create meaningful, engaging learning environments. These designs aim to foster learner autonomy and promote deeper cognitive engagement. In contrast, *gameful experience* (GE) represents the psychological response of learners to the gamified elements. Encompassing aspects such as enjoyment, challenge, feedback, immersion, and control, GE reflects how learners internalize and respond emotionally to the gameful elements (Eppmann et al., 2018) embedded in the language learning apps. In other words, while gamification is about design, and gameful learning about pedagogy, GE is about the subjective learner experience.

While extensive research has been conducted on gamification and gameful learning, the underlying psychological and cognitive mechanisms that drive behavioral intention (BI) remain under-explored. Particularly, there is a lack of clarity on how learners emotionally and cognitively respond to gamified elements, and how their responses translate into intention to adopt gamified apps. Moreover, there has been little empirical work linking GE with established cognitive frameworks such as the Involvement Load Hypothesis (ILH) (Laufer & Hulstijn, 2001), which highlights how the components of need, search, and evaluation drive language acquisition. This study bridges these gaps by examining the influence of GE on learners' BI, both directly and indirectly through ILH components. Specifically, it explores how emotional and cognitive responses to gamified elements shape learners' intention to use language learning apps.

To guide the investigation, the study addresses the following research questions:

1. How does GE influence learners' BI to use gamified language learning apps?
2. How does GE influence Involvement Load Hypothesis (ILH) components - need, search, and evaluation - in the context of gamified learning apps?
3. What is the influence of need, search, and evaluation on learners' BI?
4. Do the components of the ILH mediate the relationship between GE and BI?

The next section presents a review of relevant literature on GE and ILH, followed by a description of methodology. The subsequent sections analyze and discuss the findings, and the

paper concludes by outlining theoretical and practical implications, limitations, and scope for future research.

Literature Review and Research Model Development

Gameful Experience in Gamified Language Learning

"Gameful Experience" (GE) refers to the motivational and immersive psychological state that arises when a learner interacts with an application incorporating game elements. Grounded in frameworks like Self-Determination Theory (Ryan & Deci, 2000), Flow Theory (Csikszentmihalyi, 1990), and social constructivism (Vygotsky, 1978), GE centers on learners' subjective psychological responses to gamified elements, particularly when tasks are perceived as tailored, personalized, and adaptive (Klock et al., 2020). It is closely associated with the satisfaction of learners' psychological needs, namely relatedness and autonomy, with competence playing a lesser role (Li et al., 2024). It is characterized by feelings of autonomy, competence, relatedness, immersion, and playful challenge. Moreover, experience of flow, a state of deep absorption and enjoyment in the learning activity (Hamari & Koivisto, 2014), enriches the emotional quality of GE and contributes to both increased motivations and improved learning outcomes in language acquisition.

Building on this theoretical base, the GAMEX model (Eppmann et al., 2018; 2022) provides a structured understanding of GE through six dimensions: enjoyment, absorption, creative thinking, activation, absence of negative emotions, and dominance. When this concept is applied to the domain of language learning apps, each of the dimensions acquires significance. Enjoyment stems from interactive elements, including animations, rewards, milestones, and game-based tests, which appeal to the learners and result in a pleasant experience. These enhance the intrinsic motivation and sustain the learners' interest in the tasks (Högberg et al., 2019). Absorption occurs when learners become fully engrossed in the tasks and lose track of time. The narrative, stories, and tasks ensure the learners become mentally immersed, decreasing distractions to a minimum. Creative thinking is encouraged through open-ended challenges, problem-solving tasks, quizzes, and puzzles, which enhance language learning and communication. The activation aspect, which refers to the mental state of being alert, attentive, and activated (Högberg et al., 2019), manifests itself in time-bound quizzes, competitions, and dynamic interfaces that keep the users attentive and observant. Negative emotions have been found to work both positively and negatively; they either demotivate or enhance learning and resilience (Mekler et al., 2017). In gamified apps, the absence of negative affect is ensured by reducing negative feedback, boredom, and frustration. This supports emotional regulation and enhances active participation. Finally, dominance refers to learners' sense of control, supported through choice, customization, and flexible learning paths. Dominance enhances their feelings of self-efficacy and control (Eppmann et al., 2018). While the main function of the gamified language learning apps is not to provide mere enjoyment for learners, the presence of elements related to these dimensions optimizes learner experience as the app makes learning more enjoyable and appealing. Overall, GE enhances the relationship between the learner and the app by providing a pleasant experience that lasts even after the game is over.

Additionally, a growing body of evidence suggests that GE blurs the boundaries between intrinsic and extrinsic motivation. Landers et al. (2019) maintain that GE involves distinct psychological variables that influence the learners' behavior, including playfulness, autonomy, and personal agency. Both the rewards and competition-based elements serve as external motivators in gamified apps, while the emotions of autonomy and competence derived from game-based elements augment intrinsic motivation (Schmidt et al., 2023), which leads to improved academic performance (Alvi, 2024). Habachi et al. (2023) maintain that GE enhances engagement and loyalty, which may ensure sustained interest and continued usage among users. GE comprises distinct psychological elements, including goal perceptions, rule validation, and motivation (Landers et al., 2019).

However, it is important to acknowledge that GE may not be uniformly experienced across all learners. Research increasingly acknowledges the presence of mixed learner experiences, particularly due to individual differences in preferences and perceptions. Learners may react differently to gamified elements resulting in negative experiences (Wang et al., 2024; Santos et al., 2021). In response, recent studies have examined how different gamification designs affect user experience and explored avenues for personalized gamification (Bennani et al., 2022; Ayastuy et al., 2021). However, the empirical evidence remains inconclusive, with findings reporting positive, negative, or null effects depending on the context and user group (Almeida et al., 2023; Xiao & Hew, 2024a; Xiao & Hew, 2024b). Consequently, researchers stress the need for enhanced personalization (e.g., Habachi et al., 2023) to ensure learner engagement and motivation. The narrative and aesthetic elements should align with cultural and contextual learner preferences for a meaningful and engaging experience (Schmidt et al., 2023), which is possible only if learners perceive relevance between their perceptions and the game-based environment.

Finally, to foster engagement and GE, the gamified apps need to transform learners from passive learners to empowered, active, and thrilled participants by enhancing their cognitive involvement using elements for sustaining their attention, improving their strategic thinking, and enhancing their engagement (Landers et al., 2019). In alignment with this approach, Llorente-Cejudo (2024) outlines six key dimensions that contribute to a richer GE: challenge fosters a feeling of achievement and growth; feedback delivers prompt insights which reinforce motivation; enjoyment renders positive affect; immersion fosters sustained attention, by reducing distractions; sensation amplifies aesthetic engagement through multimodal stimuli; and dominance enhances learners' feeling of control and autonomy.

Drawing on the reviewed literature, this study hypothesizes that GE significantly influences the components of the ILH - need, search, and evaluation - which together shape learners' cognitive involvement and behavioral intention:

H1: GE positively and significantly influences learners' perception of *need* within the gamified learning environment.
H2: GE positively and significantly influences learners' perception of *search* within the gamified learning environment.

H3: GE positively and significantly influences learners' perception of *evaluation* within the gamified learning environment.
H4: GE positively and significantly influences learners' BI to use gamified language learning apps.

Cognitive Involvement and the Involvement Load Hypothesis

In the context of language learning, the Involvement Load Hypothesis (ILH) (Laufer & Hulstijn, 2001) suggests that the effectiveness of language learning tasks depends on the cognitive involvement required. A task with a higher involvement load leads to better language learning outcomes. ILH has three components: need, which is a motivational component, refers to the motivational aspect required for the completion of a task related to an unknown word (Huang & Hew, 2024); search, which refers to the cognitive energy and effort in inferring or retrieving meaning (Hazrat & Read, 2022); and evaluation, another cognitive component, refers to the comparison and contextual application of alternatives in the linguistic field. These components form the basis of 'task involvement load'. The collective load of these factors in any task influences cognitive engagement (Teng & Zhang, 2021; Alavinia & Rahimi, 2019). As Hulstijn and Laufer (2001) assert, "The greater the involvement load, the better the retention" (p. 545). In the context of gamified language learning, ILH provides a framework to comprehend how digital gamified mechanics can stimulate higher involvement with language learning tasks that go beyond rote memorization and foster deeper cognitive processing. Liu and Reynolds's study (2022) provided empirical support for ILH use across varied language learning contexts and highlighted the predictive power of need, *search*, and *evaluation* components in task design, which validates the integration of ILH within a gamified learning environment.

Each of these components has relevance in gamified learning environments; the *need* component is found to be naturally induced in the design elements, which prompt learners' curiosity and intrinsic motivation. Gamified apps, such as *Duolingo*, *Memrise*, *Babbel*, *Kahoot*!, *Quizizz*, and *Quizlet* embed tasks regularly within a narrative quest. The points, badges, streaks, or leaderboards work as incentives for learners, stimulating their interest, engagement, and enjoyment. The gamified apps, such as *Duolingo*, offer rewards for completing tasks, which include scores, prizes, and progress monitoring to enhance motivation and self-efficacy (Phanwiriyarat et al., 2025). Learners feel a thrill and engagement in the progression of levels, with the narrative adding more interest to rehearsing and repeating the tasks (Hazaymeh et al., 2024). Moreover, some offer an option for collaboration, which further provides social support and promotes a feeling of relatedness among the learners, increases motivation to perform better, and engages with others in collaborative learning. The active, lively, and low-pressure Gameful environment helps reduce stress and anxiety among learners (Raffone, 2022) and enhances learner engagement (Waluyo & Bakoko, 2022).

On the other hand, the *search* component manifests itself in the gamified tasks that require cognitive engagement. Examples include interactive tasks, such as MCQs, word quizzes, fill-in-the-blanks, puzzles, and other context-based activities. In performing these tasks, the

learners recognize and learn vocabulary, grammatical rules, and syntax with engrossment, as the gamified elements draw the learners away from distractions (Hazaymeh et al., 2024). The narrative and game mechanics sustain learner attention and engagement.

The third component *evaluation* is triggered when learners assess and select appropriate responses, given in the tasks. Gamified apps promote this through real-time assessment and feedback mechanisms, which help learners understand the correctness of their choices and learn by decoding clues and going through possible choices. Learners make decisions about word meaning, grammar usage, and real-life conversation tasks. These promote language skills, confidence, and competence, as learners reflect on their choices and receive feedback that contributes towards long-term retention and enhanced engagement (Ouyang et al., 2024).

Recent research in the context of language learning has advanced the significance of ILH by incorporating cognitive and task-related variables, which go beyond the traditional components mentioned above; these additional enrichments include test format and learning context (Yanagisawa & Webb, 2021), which highlight the importance of task design in enhancing learning outcomes. This supports the present study's objective of comprehending the mechanisms of how GE can intensify and promote task involvement and support language learning through cognitive involvement. Researchers have also emphasized the predictive abilities of ILH in comparison with other models, such as Technique Feature Analysis TFA (Gohar et al., 2018) in predicting learning outcomes. Furthermore, the latest educational technologies, including mobile-assisted language learning and android-based gamified apps provide learners with easy access to language learning tools for language practice away from the classrooms (Liu & Reynolds, 2022; Huang & Hew, 2024). Building on this foundation, the present study leverages ILH as a framework to examine how the cognitive dimensions of gamified tasks, particularly need, search, and evaluation, contribute to their behavioral intention (BI) to use gamified language learning tools:

H5: Need (ND) positively and significantly influences learners' BI to use gamified language learning apps.
H6: Search (SR) positively and significantly influences learners' BI to use gamified language learning apps.
H7: Evaluation (EV) positively and significantly influences learners' BI to use gamified language learning apps.

Mediating Role of the Involvement Load Hypothesis (ILH)

The present study investigates the mediating role of ILH components in the relation between GE and BI. GE as a motivational and psychological state is theorized to stimulate deeper cognitive engagement with learning tasks; however, mere exposure is insufficient to ensure sustained engagement and usage. Moreover, the cognitive mechanism through which GE translates into BI requires further investigation. As such, the following hypotheses were framed:

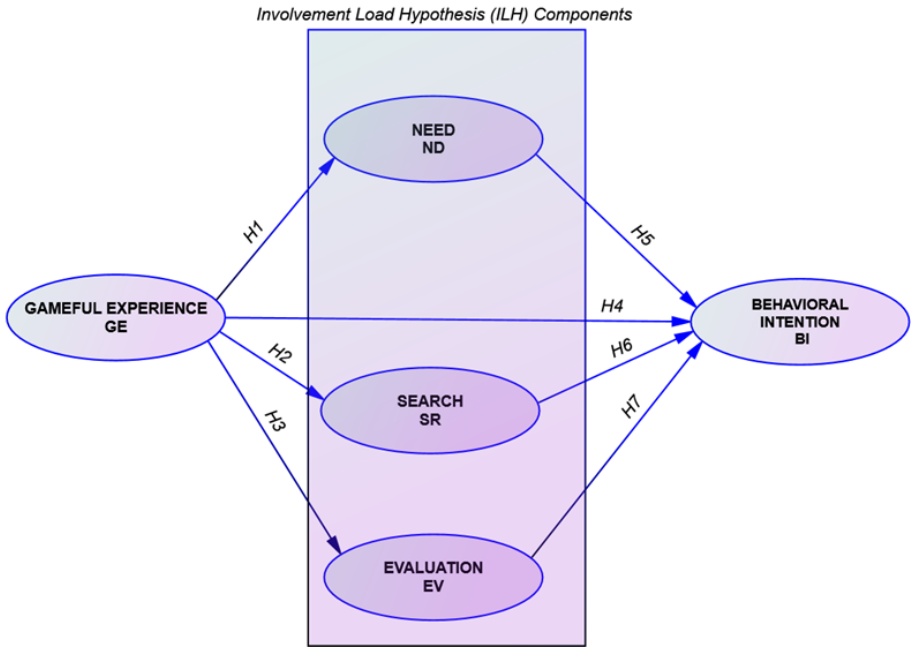
H8a: Need (ND) mediates the relationship between GE and BI.

H8b: Search (SR) mediates the relationship between GE and BI.
H8c: Evaluation (EV) mediates the relationship between GE and BI.

While gamification has demonstrated effectiveness in various aspects of language learning, including listening comprehension (Torres Rodríguez et al., 2023), vocabulary acquisition (Panmei & Waluyo, 2023), grammar improvement (Awing & Nasr, 2023), intrinsic motivation (Lavoué et al., 2019), and overall learning performance (Hamari et al., 2016), there is a growing need to move beyond general outcomes and examine the psychological mechanisms that underpin these effects. Despite the ubiquitous use of gamified learning platforms, little is known about how learners' gameful experiences (GE) with these platforms translate into sustained BI.

Particularly, there remains a conspicuous paucity of empirical studies that examine the interplay between GE and cognitive engagement, within the domain of language learning apps in developing countries such as India. While GE is often associated with increased learner motivation and satisfaction, its influence on cognitive mechanisms, such as task involvement, is markedly under-theorized. By synthesizing GE and ILH, the present study proposes an integrated framework where learners' emotional engagement (GE) drives cognitive involvement (ILH: need, search, evaluation), which in turn mediates its effect on BI to use language learning apps (See Figure 1). This model captures how affective and cognitive dimensions jointly shape learners' intention to use gamified language learning apps.

Figure 1
Conceptual Model



Methodology

This study employed a quantitative, cross-sectional survey design to investigate the relationships between GE, cognitive task involvement, and BI to use gamified language

learning applications. Data were collected through a structured online questionnaire, distributed via social media platforms (e.g., WhatsApp) and university networks. All ethical considerations were properly considered, as the empirical study involved human participants; ethical approval was obtained from the institutional review board, informed consent was secured from all respondents before data collection, and participant anonymity was maintained throughout the process.

Instrument

The structured questionnaire comprising items from a well-established framework- GAMEX for GE (Eppmann et al., 2018), Involvement Load Hypothesis (ILH) components – need, search, and evaluation (Laufer & Hulstijn, 2001), and technology acceptance constructs such as BI from Unified Theory of Acceptance and Use of Technology (UTAUT) and Technology Acceptance Model (TAM) were used for the instrument (Venkatesh & Davis, 2000; Venkatesh et al., 2003; Davis, 1989). The existing scales used helped to ensure the validity and reliability of the items. An abridged scale with six items was used to capture the learners' perception of gamification dimensions as established by the GAMEX framework. The items were: Enjoyment ("I find using this language learning app enjoyable and entertaining"); Immersion ("When I use the app, I lose track of time and become fully absorbed in the activity"); Creative Thinking ("The app encourages me to think creatively while practicing the language"); Activation ("Using the app makes me feel mentally active and energized"); Absence of Negative Effects ("I rarely feel bored, anxious, or frustrated while using this language learning app"); and Dominance ("I feel confident and in control when completing tasks in this language learning app").

The items for quantifying the three ILH components were based on the original conceptualization by Hulstijn and Laufer (2001) and subsequent adaptations. Items such as "I felt a strong need to understand the new words while using the gamified app", "I looked for the meanings of words using hints or resources within the app", and "I compared different word meanings to choose the most suitable one for the context" were used for need, search and evaluation, respectively. Four items for BI from the TAM and UTAUT frameworks, Davis (1989) and Venkatesh et al. (2003), respectively, were adapted and modified for the present context to gauge learners' BI to use gamified apps for learning. They were measured reflectively, using a 5-point Likert scale, ranging from one for "strongly disagree" to five for "strongly agree". Prior to full deployment, the survey was pilot-tested with 20 students to ensure clarity and reliability of the instrument.

Participants and Sampling

The study used a convenience sampling method. The sample of 250 comprised undergraduate students enrolled in a language course at a government university in Rajasthan, India. The learners were from diverse disciplinary backgrounds, which ensured the generalizability of the findings across various disciplines and fields. The sample consisted of 189 male respondents (75.6%) and 61 female respondents (24.4%), with ages ranging from 18 to 23 years, with a

mean age of 19.33 years and a standard deviation of 0.876, indicating a relatively homogenous age group. Among the respondents, 82.0% reported using *Duolingo* for language learning, followed by 14% who used *Memrise*, and 4% who preferred *Babbel*. The respondents were required to have used gamified language learning apps for at least two months to be eligible for inclusion. All completed responses were screened and found suitable for further analysis. The sample size of 250 was considered adequate for the analysis based on the minimum sample size requirement calculated using the Inverse Square Root Method (Kock & Hadaya, 2018). This method was considered suitable due to its conservative approach for the estimation of minimum sample size requirements (Hair et al. 2022).

Data Analysis

After conducting the preliminary descriptive statistics analysis using *IBM SPSS* v26, the data were transferred to *SmartPLS* 3.2.6 (Ringle et al., 2015) for hypotheses testing. PLS is a non-parametric method; it was the most suitable choice for the data, as the data violated the assumptions of normal data distribution, making covariance-based SEM incompatible for the study. Additionally, PLS-SEM was compatible for the study due to its power to predict the key constructs, i.e., behavioral intention to use.

Results

Measurement Model

Before testing the hypotheses framed for validation using the structural model, the measurement model was assessed (See Table 1) according to the procedures provided by Sarstedt et al. (2022a, b) and Hair et al. (2022). The constructs in the proposed conceptual framework were treated as reflective constructs, as defined by Jarvis et al. (2003): "For reflective measurement models, the direction of causality flows from the construct to the measures" (p. 203). Moreover, reflective indicators were used to account for observed variances (Jarvis et al., 2003, p. 200). The values of outer loadings were examined, and it was found that all were above the threshold of 0.7 (Hair et al., 2022). The items under the GE showed consistently high loadings (0.743 and 0.787). Strong loadings were observed for Need (0.802–0.849), indicating its critical role as a motivating construct. Equally high loadings were observed for search (0.822–0.853), confirming that cognitive processes involved in information retrieval were accurately quantified. Acceptable to strong loadings (0.730 to 0.841) were confirmed for Evaluation; all loadings were above the recommended threshold of 0.70, indicating the presence of acceptable to strong convergent validity.

To ascertain the construct reliability, coefficients of reliability ρA were assessed as per Dijkstra and Henseler's suggestions (2015). The ρA coefficients provide balanced reliability estimation, positioned between Cronbach's alpha and composite reliability (Hair et al., 2019). The observed values exceeded the recommended threshold of 0.7, affirming the internal consistency of the items in the scale. The average variance extracted (AVE) for each construct was also checked and found to be above the desired level of 0.5 (Hair et al., 1998), with values

ranging from 0.570 to 0.766, thereby providing strong evidence for adequate convergent validity. Thus, the measurement model was acceptable, and further analyses were conducted.

Table 1
Results of the Measurement Model

Indicators	Loadings	CA	ρA	CR	AVE
E1	0.730	0.867	0.869	0.867	0.620
E2	0.779				
E3	0.841				
E4	0.797				
G1	0.743	0.868	0.869	0.869	0.570
G2	0.743				
G3	0.743				
G4	0.757				
G5	0.787				
BI1	0.828	0.907	0.909	0.908	0.766
BI2	0.908				
BI3	0.888				
N1	0.809	0.890	0.890	0.890	0.669
N2	0.811				
N3	0.802				
N4	0.849				
S1	0.853	0.904	0.904	0.904	0.702
S2	0.822				
S3	0.846				
S4	0.830				

*One item G6- Absence of negative effects was deleted due to poor loadings.

Henseler et al.'s (2015) recommendations were followed for the assessment of the discriminant validity using the Heterotrait-Monotrait Ratio of Correlations, which should be *below* the threshold of 0.85. The observed values, as presented in Table 2, were below the threshold, confirming that discriminant validity was ensured (Franke & Sarstedt, 2019).

Table 2
Heterotrait-Monotrait Ratio of Correlations

	EV	GE	BI	ND	SR
EV					
GE	0.759				
BI	0.765	0.764			
ND	0.715	0.879	0.837		
SR	0.619	0.834	0.687	0.828	--

Structural Model

The structural model was evaluated using the following sequence: collinearity check; coefficient of Determination R^2; effect size f^2; predictive relevance Q^2 and model fit; and assessment of Path coefficients (significance and relevance) as per the recommendations of Sarstedt et al. (2022a, b) and Hair et al. (2022). Initially, the Variance Inflation Factor (VIF) was assessed; they were below the desired threshold value, thus confirming no collinearity issues were found.

Assessment of Coefficient of Determination (R^2)

The explanatory or in-sample predictive power of the model was measured. This was done by computing the coefficient of determination R^2 in the third step of model estimation (Sarstedt et al., 2014; Shmueli & Koppius, 2011). Based on the recommendations of (Henseler et al., 2009; Hair et al., 2011), R^2 values were construed as 0.75 = significant, 0.50 = moderate, and 0.25 = weak. In behavioral research contexts, even values around 0.20 may be considered acceptable (Vock et al., 2013). The results revealed an R^2 of 0.774 for Need (ND), 0.758 for Behavioral Intention to Use (BI), 0.695 for Search (SR), and 0.576 for Evaluation (EV). According to the figures observed, the proposed model had significant explanatory power for ND and BI, and moderate to large for SR and EV.

Assessment of Effect Size (f^2) and Model Fit

The f^2 effect sizes were computed to find the relative influence of each exogenous construct on its corresponding endogenous construct in line with past studies (Hair et al., 2022; Sarstedt et al., 2022a). For measuring the effect sizes, f^2 = 0.02 for minor, 0.15 for medium, and 0.35 for large effects (Cohen, 1988). These findings revealed that GE had the most meaningful predictive contribution to Need and Evaluation among the IHL components, while Need exerted a dominant influence on BI. Next, Normed Fit Index NFI was assessed (Hair et al., 2022) to confirm model fit. Next, the Standardized Root Mean Square Residual (SRMR) values were estimated for the model. The SRMR value of 0.040 was below the recommended threshold of 0.08 (Henseler et al., 2014) and was considered a good fit. There was only a slight

difference between the two models - the estimated and the saturated models, as confirmed by the Chi-Square estimations (323.633).

Assessment of Predictive Relevance (Q^2)

For ascertaining the structural model's ability to predict new/future observations, out-of-sample predictive performance was evaluated (Hair et al., 2022). *PLSpredict* process, which makes use of *k-fold* cross-validation, was utilized for this purpose. By randomly dividing the datasets into *k-equal* sized subsets, the method enables iterative training and testing of the model across different datasets. To assess whether there was adequate balance between computational efficacy and prediction accuracy, values of k and r each equal to 10 were employed as per past practices (Shmueli et al., 2019). The model demonstrated strong predictive relevance; Q^2_predict values exceed the minimum threshold of zero, confirming that the model possesses adequate out-of-sample predictive power (Shmueli et al., 2016; Hair et al., 2022).

Table 3
Predictive Validity of the Structural Model

	RMSE	**MAE**	**Q^2_predict**
EV	0.747	0.599	0.450
BI	0.602	0.429	0.644
ND	0.545	0.383	0.708
SR	0.627	0.434	0.616

Further, the model's Root Mean Square Error (RMSE) and Mean Absolute Error (MAE) values were used to assess predictive accuracy. The lowest RMSE was observed for Need (0.545), followed by Intention to Use (0.602), Search (0.627), and Evaluation (0.747), indicating varying levels of predictive precision across constructs. To confirm the model's level of prediction errors across constructs, the MAE values were considered; these were within the acceptable range (Table 3). The results confirmed that the structural model evaluated was capable of explaining in-sample variance as well as generalizing unseen data, ensuring it was a reliable tool for comprehending the learners' cognitive engagement and BI toward gamified language learning apps.

Assessment of Path Coefficients: Significance and Relevance

The significance and relevance of the relationships in the structural model were evaluated with *SmartPLS*. As per the recommendations of Sarstedt et al. (2016), the PLS-SEM algorithm is pertinent for assessing constructs within the reflective measurement model. Using PLS-SEM, mediation analysis was conducted within a single integrated model (Nitzl et al., 2016). Next, for verifying full mediation, another model excluding mediators was also tested. This step allowed for a clearer assessment of the direct and indirect paths and helped confirm whether the mediation was full or partial. This two-step approach is maintained Nitzl et al. (2016), who

contend that evaluating the significance of indirect/direct effects may be conducted to establish the type of mediation.

To evaluate the significance of the path coefficients, the study used a percentile bootstrap approach, with 5000 re-sampling using a two-tailed test at a 5% level of significance (Streukens & Leroi-Werelds, 2016). The following results were obtained through PLS-SEM analysis using SmartPLS v3.2.9, based on the validated measurement and structural models described above (Table 4). GE significantly predicted all ILH components: Need (H1:β=0.774), Search (H2:β=0.739), and Evaluation (H3:β=0.660), at p<0.001. However, the direct effect of GE on BI was insignificant (H4: β=0.079, p=0.385). Therefore, a second structural model without the mediating constructs, the ILH components, was evaluated for assessing the direct effects of GE on BI. The results of the alternate model revealed the direct effects were exceedingly significant (H4*: β=0.807, p<0.001), indicating GE was a strong predictor of BI in the absence of the mediators (Need, Search, and Evaluation). Additionally, the results showed that BI towards gamified learning apps was positively predicted by need and evaluation H5:β=0.449) and evaluation (H7:β=0.314) at p<0.001, while search had a positive though significant effect on BI (H6:β 0.059, p=0.430).

Table 4

Structural Model Results Highlighting Direct and Mediated Effects

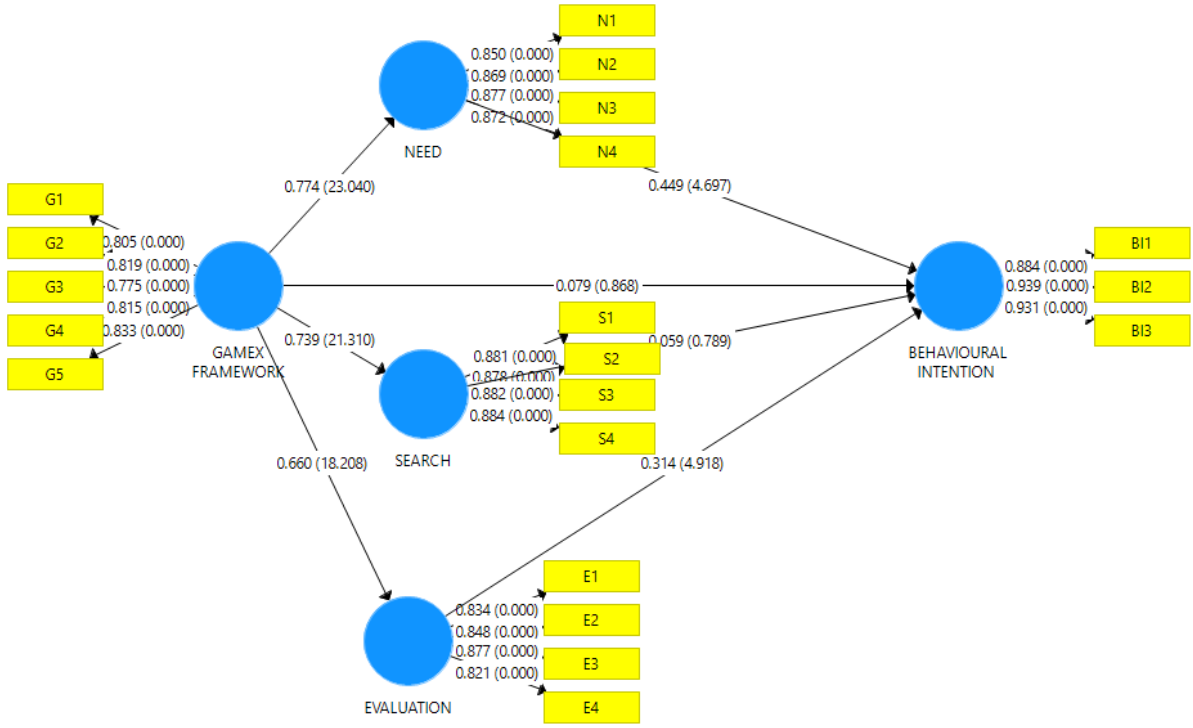
H	Relationship	β	T	P	CI [2.5%, 97.5%]	Result
H1	GE → ND	0.774	23.040	0.000	[0.704; 0.836]	Supported ***
H2	GE → SR	0.739	21.310	0.000	[0.669; 0.805]	Supported ***
H3	GE → EV	0.660	18.208	0.000	[0.587; 0.731]	Supported ***
H4	GE → BI	0.079	0.868	0.385	[-0.103; 0.257]	Not Supported
H4*	GE → BI	0.807	31.382	0.000	[0.757; 0.857]	Supported ***
H5	ND → BI	0.449	4.697	0.000	[0.261; 0.629]	Supported **
H6	SR → BI	0.059	0.789	0.430	[-0.084; 0.208]	Not Supported
H7	EV → BI	0.314	4.918	0.000	[0.195; 0.442]	Supported ***
H8A	GE → ND → BI	0.348	4.658	0.000	[0.202; 0.493]	Supported **
H8B	GE → SR → BI	0.043	0.782	0.434	[-0.063; 0.156]	Not Supported
H8C	GE → EV → BI	0.207	4.648	0.000	[0.126; 0.299]	Supported **

***p < 0.001, **p < 0.01; H4*=Alternate Model with no mediators.

The research model Figure 2 demonstrates statistically significant path relationships, with hypothesized links showing T and p values in the inner model and the loadings and p values for the outer model.

Figure 2

Research Model Displaying T and p Values



The mediation mechanisms were scrutinized through bootstrapped resampling techniques in SmartPLS (Hair et al. 2022) to access the significance of the indirect paths linking GE and BI through ILH components. This approach was deemed more suitable than the traditional Sobel test (Sobel, 1982). Bootstrapping circumvents the assumption of normal distribution in the sampling and provides more robust estimations, particularly in modestly sized datasets. The results confirmed the presence of indirect effects in the relationship between GE and BI. The hypotheses H8A (GE → ND → BI, β =0.348) and H8C (GE → EV → BI, β =0.207) were supported. Thus, need and evaluation mediated the relationship between GE and BI positively and significantly. However, H8B (GE → SR → BI, β= 0.043, p= 0.434) was rejected, as search's indirect effect was found to be insignificant. The above findings confirm that the influence of GE on BI was fully mediated by the ILH components in the structural model (Hair et al., 2022) in the presence of the mediators (need and evaluation). This suggested it was a case of an indirect-only mediation (Nitzl et al., 2016), as the relationship between GE and BI was entirely channeled through the mediators, with no direct path from GE to BI.

Discussion

This study scrutinized the impact of GE, as operationalized through the GAMEX Experience Scale, on learners' BI to utilize gamified language learning apps. It further explored how the mediating role of the ILH components (need, search, and evaluation) in the GE and BI relationship. The results revealed strong and highly significant path coefficients from GE to the ILH components, corroborating the proposition that gamified elements, such as rewards,

feedback, challenges, and goal orientation, stimulate learners' motivation (Li et al., 2024) and psychological engagement, by rendering tasks more cognitively stimulating (Landers et al., 2019). However, the direct effect of GE on BI was not significant in the main structured model (inclusive of mediators), while it became highly significant in the alternate model where mediators were excluded. This evidences a case of complete mediation, wherein the ILH components fully transmitted the influence of GE to BI. This outcome suggests primacy of cognitive processing, along with emotional and psychological learner experiences in fostering BI.

While extant literature acknowledges that gamification influences learners' adoption intentions (Hmoud et al., 2024), the current findings delineate the possibility of dual operational pathways: a psychological route (through Gameful Experience) and a cognitive route (through ILH components). The results conform with Llorente-Cejudo's (2024) empirical findings, which demonstrate that various discrete GAMEX dimensions (Challenge, feedback, enjoyment, immersion, sensation, and dominance) contribute meaningfully to an enriched gamified experience. The findings highlight that the quality and intensity of the psychological state (encompassing enjoyment, absorption, creative thinking, activation, and dominance), is not marginal but fundamental to learners' inclination to use gamified apps. This supports prior assertions that GE positively influences user engagement, which in turn predicts learners' intention (Habachi et al., 2023). The findings are supported by prior studies emphasizing that the inclusion of gamified elements elicit positive emotional states (Perez-Aranda et al., 2024), which are conducive to language acquisition. Crucially, the study affirmed that learners, who perceive gamified environment as intrinsically rewarding, tend to develop more favorable dispositions toward their use. This reinforces the motivational potency of gamification, particularly when learners' needs (autonomy, relatedness, and competence) are deliberately addressed (Sailer & Homner, 2020).

Furthermore, among the ILH dimensions, the constructs need and evaluation significantly predicted BI, while search had no meaningful effect. This unexpected outcome implies that search, traditionally inked to active information retrieval, may be less salient in the gamified learning environments. This could be attributed to the design of the apps, which offer learners stepwise instructions (hints, step-by-step tutorials, and visual cues) thereby reducing the need for autonomous exploration. While such design may optimize usability, it reduces learners' active information-seeking behavior, explaining the non-significance of the search component. Conversely, evaluation and need emerged as strong cognitive predictors of BI, as they require reflective processing, analytical engagement, and thoughtful decision-making (Laufer & Hulstijn, 2001). These components gain further importance when learners interact with cognitively demanding tasks, affirming task complexity influences learner performance (Li, 2024). Similarly, the evaluation-centric elements in learning apps require active learner involvement and participation. When learners perceive tasks as challenging, meaningful, and engaging, they are more likely to view the app as effective. These observations find resonance in the Unified Theory of Acceptance and Use of Technology (UTAUT), which emphasizes the importance of performance expectancy and effort expectancy as key predictors of both learning

outcomes and BI (Alvi, 2022). Collectively, these findings illustrate the mechanism by which GE activates ILH-driven cognitive engagement, ultimately shaping behavioral adoption.

Finally, the findings reaffirm the instrumental role of GE in shaping learners' BI, supporting prior empirical studies on the efficacy of gamified applications like Duolingo (Fadhilawati et al., 2023), Mondly (Hajizadeh et al., 2023), and Kahoot! (Alawiyah et al., 2024). These platforms exemplify how strategically embedded elements such as challenge, feedback, and immersion can foster engagement and involvement. However, it is essential to acknowledge heterogeneity of outcomes reported in the literature. As noted by Durrani et al. (2023) the effectiveness of gamified elements on learners, particularly long-term retention and effectiveness, remains contested, with some studies reporting transitory or marginal impacts. There is no one-size-fits-all solution (Xiao & Hew, 2024b) as even personalization may produce mixed effects on emotional and cognitive engagements (Xiao & Hew, 2024a). Nevertheless, more sustained positive outcomes are observed when learners' needs, preferences, and experiences are congruent with instructional goals (Oliveira et al., 2023; Santos et al., 2021). This substantiates the current study's emphasis on cognitive involvement as a critical mediating construct, suggesting that psychological state yields optimal outcomes when pedagogically aligned. Importantly, the realization of authentic gameful experience extends beyond the superficial addition of gamified elements. Just as effective gamification requires culturally appropriate, technologically supported, and pedagogically integrated environments (Sambo et al., 2025), the realization of meaningful gameful experience through gamified elements equally demands thoughtful, learner-oriented design that strategically aligns user engagement with educational objectives. Thus, the study reinforces earlier calls to consider individual learner characteristics (Qaffas et al., 2020) as it is through learner–technology interactions that gamified experiences are internalized, contextualized, and ultimately translated into BI.

Implications for Theory, Practice, and Educational Management

The study, based on two established and extensively researched frameworks in a single paradigm, proposed a new parsimonious and integrated model. It also validated the model using raw data collected from learners, thus contributing to the extant literature on gamification in educational technology. The results highlight that GE positively and significantly influences learners' BI through cognitive engagement factors like need, search, and evaluation. It also reveals the importance of designing gamified language apps that align with learners' psychological and cognitive needs to drive sustained usage. The study identified the GE effects, both direct and indirect, along with the affective and cognitive dimensions of technology acceptance, which offers immense potential for bringing about positive changes in digital educational technology, for making language learning more learner-centered. The findings confirm that task involvement fosters deeper cognitive processing within the gamified learning contexts, thereby supporting prior studies (Teng & Zhang, 2021).

These insights are valuable for teachers, policymakers, curriculum designers, and app developers for developing more effective gamified apps, which intellectually and cognitively

engage the learners through the use of tasks perceived as demanding and requiring careful evaluation. App developers and education managers should focus on adding features that make learners think and stay engaged, like challenging tasks or decision-based activities. This can help them design better learning apps that cater to the needs of language learners. Future designs could include features like point-based challenges to meet the "need" component, searchable activities for "search," and self-assessment quizzes to support "evaluation." The results may guide teachers and academicians in recognizing the needs of language learners and assist them in the proper selection and recommendation of resources, which enable learners to achieve their language learning objectives. The findings also offer managers and policymakers the opportunity to make informed decisions for technology implementation, training, and development of gamified tools to ensure they conform to the standards required for pedagogical purposes.

Limitations and Conclusion

While the present study offers valuable implications, it has limitations that need to be acknowledged, such as the generalizability and causation, which need to be further validated, particularly in different contexts, using larger sample sizes and including control variables. The study relied on self-reported cross-sectional data collected once through non-random sampling, which may introduce social desirability bias and limit the ability to infer causality between GE, cognitive involvement, and BI thoroughly. Moreover, longitudinal studies may offer deeper insights into how these relationships evolve with time. The sample drawn from undergraduate students in India is gender-biased, may constrain the generalizability of the findings across diverse learner populations. Moreover, the presence of cultural or contextual influences, such as language, technology accessibility/penetration, and digital proficiencies may interfere with the effect of GE. Depending on the socio-economic status of the users, learning apps may be used on shared devices within families, particularly in less privileged groups in India, which differs from the typical one-person-one-device usage and may also influence user experience. Future research may replicate the model in other geographical/linguistic settings to enhance its cross-cultural validity. Further studies may use mixed methods or qualitative methods to provide a more comprehensive understanding. Finally, the study focused on GE and ILH frameworks; future studies may explore hybrid models using other motivational factors (e.g., Expectancy-Value Theory, Flow, etc.) in the context of language learning for enhancing the understanding of the effects of GE.

To conclude, the study examined how GE influences learners' BI to use gamified language learning apps, with cognitive involvement dimensions as mediators. The findings revealed that although GE significantly enhances all ILH components, its influence on BI is fully mediated through need and evaluations, with search having no significant effect. The results highlight the importance of designing gamified language learning apps that engage learners not only emotionally but also cognitively, by incorporating strong gamified elements that foster meaningful learning experiences. They reveal the need to focus on learners' psychological and cognitive engagement. In short, by integrating the GE with ILH, the study offers a theoretically

grounded model that advances insights into learner cognitive engagement in gamified language learning contexts and provides practical implications to promote learner involvement.

Statement of AI Use

The author would like to acknowledge the use of artificial intelligence (AI) tools in the preparation of this manuscript. Artificial intelligence tools (Grammarly, QuillBot, etc.) were used to support language refinement, grammar correction, and paraphrasing. All AI-edited text was thoroughly reviewed and revised by the author to ensure accuracy, clarity, and adherence. AI tools were not used for other purposes, including data generation, data analysis, methodology, or interpretation of findings or conclusions. The author takes full responsibility for all aspects of the final manuscript.

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Corresponding author: Irum Alvi
Email: irumalvi@gmail.com

Digital Competence and Attitudes Toward AI: Mindful Attention Awareness as a Mediator

Tasaduk Musood
Akal University, Talwandi Sabo, Bathinda, India

Birender Kaur
Akal University, Talwandi Sabo, Bathinda, India

Abstract

The Fourth Industrial Revolution, characterized by the proliferation of Artificial Intelligence (AI), is transforming the educational landscape and calls for educators who are not only digitally proficient but also cognitively adaptive. This study investigated the relationship between digital competence and attitudes toward AI among pre-service teachers, with mindful attention awareness examined as a mediating variable. Using a descriptive survey design, data were collected from 428 pre-service teachers from government and government-aided colleges across three regions of Punjab, selected through stratified random sampling. Three standardized instruments were used, including the Digital Competence Scale, the Mindful Attention Awareness Scale, and the Attitudes toward Artificial Intelligence Scale. Correlation analysis revealed significant positive associations between digital competence, mindful attention awareness, and attitudes toward AI among pre-service teachers. Given the role of mindfulness in enhancing cognitive and emotional readiness for technology use, mindful attention awareness was explored as a potential pathway linking digital competence to attitudes toward AI. Regression analysis showed that both digital competence and mindful attention awareness significantly predicted attitudes toward AI, jointly explaining 79.6% of the variance. Path analysis confirmed a significant effect of digital competence on attitudes toward AI (β = .535), with a substantial portion mediated by mindful attention awareness. These results highlight the importance of integrating development of both technological proficiency and mindful attention awareness in teacher education to prepare reflective, AI-ready educators.

Keywords: digital competency, attitudes toward AI, mindful attention awareness, pre-service teacher, Punjab

The Fourth Industrial Revolution, fueled by technological innovations such as Artificial Intelligence (AI), is reshaping education systems across the globe. Unlike multimedia tools and online platforms that enhance teaching and learning, AI introduces a paradigm shift wherein systems can perform tasks typically requiring human intelligence such as adaptive learning, predictive analytics, and intelligent tutoring. These shifts demand that educators not only acquire digital proficiency but also develop the cognitive and emotional capacities needed to engage ethically and reflectively with emerging AI technologies.

Digital competence is defined as an individual's ability to use digital tools, applications, and platforms effectively, safely, and responsibly. According to the European Commission's DigComp 2.2 framework (2022), digital competence comprises five key dimensions: information and data literacy, communication and collaboration, digital content creation, safety, and problem-solving. In teacher education, this concept extends beyond basic digital literacy to include pedagogical applications such as designing technology-integrated lessons, analyzing student performance data, and managing virtual classrooms (Amhag et al., 2019; Falloon, 2020). Although digital literacy and digital competence are often used interchangeably, the present study adopts a broader understanding of digital competence to reflect the complex pedagogical and ethical demands of AI integration in classrooms.

While developing technological proficiency is essential, it is insufficient for ensuring the effective and ethical adoption of AI in education. AI tools raise critical concerns around autonomy, algorithmic bias, and data privacy (Aghaziarati et al., 2023), which require not just technical skills but also psychological readiness. In this context, mindful attention awareness emerges as a crucial variable. Defined as an individual's capacity to attend to present experiences with openness and without judgment (Brown & Ryan, 2003), mindful attention awareness has been linked to improved emotional regulation, cognitive flexibility, and reduced techno-stress. In educational contexts, these capacities are instrumental for pre-service teachers navigating rapidly changing technological environments. Research indicates that mindfulness contributes to better classroom management, ethical technology use, and improved educator well-being (Yang et al., 2015; Gordon et al., 2022; Rechtschaffen, 2014).

Global educational initiatives have recognized the value of mindfulness as a 21st-century competency. For instance, UNESCO's Mahatma Gandhi Institute of Education for Peace and Sustainable Development (MGIEP) promotes mindfulness, empathy, and cognitive flexibility through programs like LIBRE (Halder, 2024). These developments have influenced teacher training programs worldwide, with increasing emphasis on preparing educators to be both technologically competent and emotionally intelligent.

A third critical dimension in AI integration is attitudes toward AI encompassing beliefs, perceptions, and emotional reactions to AI technologies in education (Choi et al., 2023; Wang et al., 2023). Teachers' attitudes significantly influence their willingness to adopt AI tools. Positive attitudes are associated with openness to innovation, personalized instruction, and data-informed decision-making. Conversely, negative attitudes often rooted in anxiety, fear of job displacement, or ethical concerns can hinder adoption (Smith, 2024; Qin & Yan, 2020).

These attitudes are shaped by both cognitive factors, such as perceived usefulness, and emotional dispositions, including trust and anxiety.

Despite the growing scholarly interest in digital competence and mindfulness, limited empirical research exists on how these constructs jointly predict pre-service teachers' attitudes toward AI in education. This intersection is particularly significant in the Indian context, where the National Education Policy (NEP, 2020) underscores the need to integrate digital education with holistic learner development, including socio-emotional competencies.

Within this national framework, Punjab offers a distinctive context for exploration. The state's teacher education system is spread across diverse regions Majha, Malwa, and Doaba comprising both urban centers and under-resourced rural areas. While Punjab has made considerable progress in implementing digital initiatives such as smart classrooms, e-learning platforms, and online teacher training through programs like *ICT@Schools* and *DIKSHA*, disparities persist, particularly in rural and government-aided institutions. Studies highlight that rural colleges in districts such as Mansa, Fazilka, and Barnala face infrastructural challenges, including inadequate internet bandwidth, limited access to digital hardware, and insufficient faculty training for effective ICT integration (Nag et al., 2024; Government of Punjab, 2023). Unlike IT hubs in states such as Karnataka (Bangalore) or Maharashtra (Pune), Punjab lacks a concentrated digital investment zone, resulting in uneven policy execution. The state's education technology roadmap also shows variation in implementation across districts due to differing administrative capacities and local governance priorities (Punjab Education Department Report, 2022). These disparities contribute to a persistent digital divide between urban and rural educational institutions in the state.

Given these contextual challenges and opportunities, this study investigates how digital competence and mindful attention awareness relate to pre-service teachers' attitudes toward AI in education. In doing so, it addresses a critical research gap by examining the mediating role of psychological readiness in technology adoption within a regionally grounded, policy-relevant framework. The findings are expected to offer actionable insights for teacher education programs seeking to align with NEP directives and foster future-ready, reflective educators equipped to thrive in AI-enhanced educational ecosystems.

Research Questions

To understand the interplay between technological proficiency and psychological readiness in teacher education, the present study is guided by the following research questions:

1. Is there a significant relationship between digital competence, mindful attention awareness, and attitudes toward AI among pre-service teachers?
2. Do digital competence and mindful attention awareness significantly predict pre-service teachers' attitudes toward AI?
3. Does mindful attention awareness mediate the relationship between digital competence and attitudes toward AI?

By exploring these questions, the study aims to uncover the complex interplay between technological skills and psychological dispositions in shaping pre-service teachers' readiness for AI integration. The findings are intended to inform more balanced and future-oriented teacher education programs that emphasize not only digital fluency but also reflective and ethical technology use.

Literature Review and Theoretical Framework

The growing adoption of AI in education has transformed expectations for teacher preparedness. AI tools ranging from intelligent tutoring systems to predictive analytics demand that educators possess not only technical proficiency but also the cognitive and emotional agility to use such tools ethically and effectively.

Digital competence has emerged as a critical 21st-century skill for educators. According to the DigCompEdu framework (Christine, 2017) and India's NEP 2020, digital competence encompasses information literacy, communication, collaboration, digital content creation, and problem-solving. In the context of teacher education, it refers to the ability to select, use, and evaluate digital tools for pedagogical purposes (Amhag et al., 2019). Teachers with high digital competence are more likely to personalize learning, interpret learner analytics, and adapt content to meet diverse needs (Idowu, 2024).

While previous research (e.g., Falloon, 2020; Spante et al., 2018) has linked digital skills to positive technology adoption, few studies have directly examined how digital competence shapes attitudes toward AI, a subset of technology that demands more complex cognitive engagement. This gap is especially relevant as AI requires teachers not only to use tools but to understand algorithms, data ethics, and automation processes.

Alongside technical skills, mindfulness defined as present-focused, nonjudgmental awareness (Brown & Ryan, 2003) has gained attention in the field of education. Mindful attention awareness enhances emotional regulation, stress reduction, and cognitive flexibility (Motevalli et al., 2023; Rechtschaffen, 2014). It helps educators remain grounded in fast-paced, tech-mediated environments and may influence how they assess and integrate AI into their teaching. Programs like UNESCO MGIEP's LIBRE promote mindfulness as a foundational life skill, especially when navigating the ethical and emotional demands of digital education (Halder, 2024). Research has shown that mindfulness can reduce technostress and increase openness to innovation (Yang, 2023), suggesting it may play a moderating or mediating role in technology acceptance.

Educators' attitudes toward AI defined as beliefs and affective responses to AI tools strongly predict actual usage (Qin & Yan, 2020). Positive attitudes enhance willingness to experiment with adaptive systems, while negative ones are often linked to fear, ethical concerns, and low confidence (Wang et al., 2023; Smith, 2024). These attitudes are not fixed; they are influenced by cognitive variables (e.g., digital skills) and emotional dispositions (e.g., mindfulness).

This study integrates three theoretical models to explain how digital competence and mindfulness may jointly influence attitudes toward AI:

1. Technology Acceptance Model (TAM) posits that perceived usefulness (PU) and perceived ease of use (PEU) predict an individual's attitude toward technology and intention to use it (Davis, 1989). In this study:

- Digital competence supports PEU and PU assuming those confident with digital tools may find AI easier to use and more beneficial.
- Mindfulness may indirectly influence PU/PEU by promoting calm engagement and reducing anxiety, thus encouraging favorable perceptions of AI.

2. Theory of Planned Behavior (TPB) asserts that attitudes, subjective norms, and perceived behavioral control predict behavioral intentions (Ajzen, 1991). This model is relevant because:

- Digital competence enhances perceived behavioral control teachers who are digitally skilled feel more capable of integrating AI.
- Mindfulness could also strengthen perceived control and reduce perceived risks, influencing intention through emotional readiness.

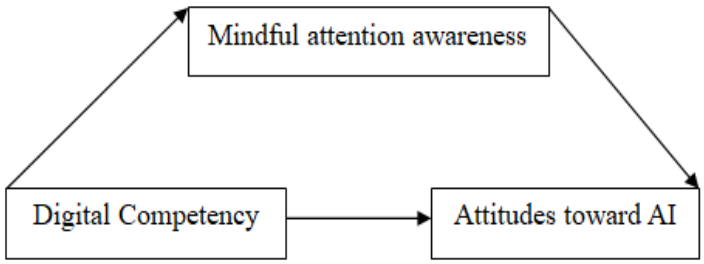
3. Cognitive Flexibility Theory (CFT) emphasizes adaptive thinking and the ability to restructure knowledge in response to novel situations key traits for AI adoption (Spiro et al., 2017).

- Mindful individuals exhibit greater cognitive flexibility, enabling them to respond thoughtfully to AI-based challenges and integrate such tools ethically.
- This theory supports the mediating role of mindfulness, suggesting that it helps translate digital competence into a balanced, open attitude toward AI.

Integrating these three models we propose a theoretical framework as follows:

- Digital competence and mindfulness both influence attitudes toward AI.
- Mindful attention awareness acts as a mediator, strengthening the effect of digital competence on AI attitudes.
- This approach reflects an emerging paradigm in teacher education that values both technical and psychological readiness for AI integration.

Figure 1
Theoretical Model



This integrated model holds particular relevance in the Indian educational landscape, with the NEP emphasizing the development of educators who are both digitally proficient and reflective in their pedagogical practice (NEP, 2020). By transcending reductionist approaches that address either technological skills or psychological dispositions in isolation, the present model offers a more holistic and balanced conceptualization of AI readiness in teacher education. It underscores the imperative for cultivating both cognitive and affective competencies among pre-service teachers, thereby aligning with contemporary demands for ethically informed and contextually responsive integration of artificial intelligence in educational settings.

Hypotheses of the Study

The study proposes the following hypotheses based on the theoretical framework and literature reviewed:

H1: There is a significant positive correlation between digital competency, mindful attention awareness, and attitudes toward artificial intelligence among pre-service teachers.
H2: Digital competency and mindful attention awareness significantly predict attitudes toward artificial intelligence among pre-service teachers.
H3: Mindful attention awareness mediates the relationship between digital competency and attitudes toward artificial intelligence among pre-service teachers.

Methodology

This study used a descriptive quantitative research design to examine the mediating role of mindful attention awareness in the relationship between digital competence and attitudes toward AI among pre-service teachers in Punjab, India. A path analysis approach was utilized to test the hypothesized relationships among the study variables.

The participants of the study consisted of prospective teachers enrolled in Bachelor of Education (BEd) programs across government and government-aided colleges from the three major regions of Punjab: Majha, Malwa, and Doaba. To ensure representativeness and adequate regional coverage, a stratified random sampling technique was adopted. Initially, 500 prospective teachers were approached. After screening the data for completeness and

consistency, 428 valid responses were retained for the final analysis. The final sample size was deemed sufficient for statistical procedures including correlation, regression, and path analysis. It is important to note that responses were based on participants subjective perceptions, which may be influenced by personal experience and contextual factors. Collaboration with college principals played a crucial role in participant recruitment. Principals were contacted through formal letters, emails, and follow-up phone calls to obtain institutional permission. The data collection was conducted over four weeks during the academic semester. A structured questionnaire was distributed through Google Forms, enabling broad and efficient access to participants. Repeated follow-ups were conducted with faculty coordinators to ensure maximum participation and timely submission of responses.

To examine the relationships among the study variables and test the proposed model, a comprehensive statistical analysis was conducted. Descriptive statistics, including means, standard deviations, minimum, and maximum values, were calculated to summarize the dataset. Pearson's correlation coefficients were computed to determine the strength and direction of relationships among digital competence, mindful attention awareness, and attitudes toward artificial intelligence (AI). To assess the predictive power of digital competence and mindful attention awareness on attitudes toward AI, multiple regression analysis was employed. Additionally, mediation analysis was carried out to evaluate the indirect effect of mindful attention awareness in the relationship between digital competence and attitudes toward AI.

All statistical analyses were conducted using SPSS (Statistical Package for the Social Sciences) version 26.0 and AMOS (Analysis of Moment Structures) version 21.0, ensuring methodological accuracy and robustness.

Ethical Considerations

Although formal institutional ethical approval was not obtained, the study adhered strictly to ethical standards for research involving human participants. All participants were clearly informed about the purpose and objectives of the study. An informed consent form was integrated at the beginning of the online survey, and only those who provided explicit consent were allowed to proceed.

Participants were assured of the anonymity, confidentiality, and voluntary nature of their participation, including the right to withdraw from the study at any time without any consequences. No personally identifying information was collected, and the data were used solely for academic purposes. The study conformed to widely accepted ethical guidelines in educational and social science research, including the protection of participant autonomy, dignity, and data privacy.

Measures

The research tools used for this study were divided into two sections: demographic information and psychological variables. The first section collected information on participant's locale, age and gender. The second section assessed three variables: mindful attention awareness, digital competence, and attitude towards artificial intelligence.

1. Digital competence developed by Ramakrishna and Phoghat, (2017), was used to assess Digital Literacy among preservice teachers. The scale consists of 50 items and follows a 5-point Likert scale ranging from (1 = Strongly Disagree to 5 = Strongly Agree). The digital competence demonstrated strong test-retest reliability with a correlation coefficient of 0.89. Sample items include:
   "I can communicate online with other students for homework assignments."
   "I know how to connect various hardware components of computers."

2. Additionally, mindful attention awareness was assessed using the Mindful Attention Awareness Scale (MAAS) by Brown and Ryan (2003). This 15-item tool is rated on a 6-point Likert scale (1 = Almost Always to 6 = Almost Never) and measures dispositional mindfulness, where higher score indicates greater mindfulness. The MAAS demonstrated strong internal consistency, with Cronbach's alpha value ranging from 0.77 to 0.91. The scale included items such as:
   "I could be experiencing some emotion and not be conscious of it until sometime later."
   "I break or spill things because of carelessness, not paying attention, or thinking of something else."

3. Lastly, attitude towards artificial intelligence was measured using the Artificial Intelligence Scale developed by Mukherjee and Dasgupta (2024). This 30-item scale, based on a 5-point Likert scale ranging from 1 (Strongly Disagree) to 5 (Strongly Agree), evaluates four key dimensions: General Understanding, Perceived Benefits, Concerns, and Applications. The scale demonstrated strong reliability (Cronbach's alpha = 0.832) and construct validity (0.679). Sample items include:
   "AI is an advanced technology that is only beneficial for the wealthy."
   "Spread of AI-based machines and software in every sector will reduce socialization, so it is not suitable for Indian culture."

Table 1
Demographic Profile of the Sample (428)

Variables	Category	*f*	*%*
Gender	Male	216	51%
	Female	212	49%
Age	18-22 years	330	77%
	20-25 years	98	23%
Locale	Rural	186	43%
	Urban	242	57%

Note: *f*- Frequency, *%*- Percentage

Table 1 presents the demographic characteristics of the participants. The sample consisted of 428 pre-service teachers, of whom 216 identified as male (51%) and 212 as female (49%), indicating a nearly equal gender distribution. In terms of age, the majority of participants (n = 330, 77%) were between 18 and 22 years old, while a smaller proportion (n = 98, 23%) were within the 23 to 25 years age range. Regarding locale, 186 participants (43%) reported residing in rural areas, whereas a slightly higher proportion, 242 participants (57%), were from urban regions. These demographics provide a balanced representation across gender and residential backgrounds, with a predominant concentration of younger pre-service teachers.

Results

It is important to note that the analysis is based on cross-sectional, self-reported data, and the findings are associational in nature.

Table 2
Descriptive Analysis of Data (N = 428)

Variable	Mean	S.D.	Minimum	Maximum
Digital Competence	71.17	23.68	31	140
Mindful Attention Awareness	65.50	12.75	25	82
Attitudes toward AI	67.56	16.83	28	132

Note: S.D.-Standard Deviation

The descriptive statistics indicate that the pre-service teachers in the sample demonstrated a moderate level of digital competence (M = 71.17, SD = 23.68), mindful attention awareness (M = 65.50, SD = 12.75), and attitudes toward AI (M = 67.56, SD = 16.83). The wide range in digital competence (Min = 31, Max = 140) suggests considerable variability in participants' technical skills, while the narrower range for mindful awareness indicates relatively more consistent self-reported mindfulness. Attitudes toward AI also varied notably across the

sample, reflecting diverse perspectives on the integration of artificial intelligence in educational settings.

Table 3 displays the Pearson correlation coefficients among digital competence, mindful attention awareness, and attitudes toward artificial intelligence (AI) among pre-service teachers.

Table 3

Correlation Matrix: Digital Competence, Mindful Attention Awareness, and Attitudes toward AI among Pre-Service Teachers (N = 428)

Variables	Digital Competence	Mindful Attention Awareness	Attitudes toward AI
Digital Competence	1		
Mindful Attention Awareness	.685**	1	
Attitudes toward AI	.748**	.867**	1

***Note**: **p**< .01*

Digital competence was found to be positively and significantly correlated with mindful attention awareness (r = .685, p < .01), indicating that higher levels of digital proficiency are associated with greater mindfulness. Similarly, digital competence demonstrated a strong, positive correlation with attitudes toward AI (r = .748, p < .01), suggesting that digitally competent individuals are more likely to hold favorable views toward the integration of AI in education. Furthermore, mindful attention awareness was highly correlated with attitudes toward AI (r = .867, p < .01), highlighting the potential role of mindfulness in shaping pre-service teachers' openness to AI technologies. Therefore, the H1, which states that "*There is a significant positive correlation between digital competency, mindful attention awareness, and attitudes toward artificial intelligence among pre-service teachers*", is approved.

Multiple regression analysis was conducted to examine the extent to which digital competence and mindful attention awareness predict attitudes toward artificial intelligence (AI) among pre-service teachers *(See Table 4).*

Table 4

Multiple Regression Predicting Attitudes Toward AI (N= 428)

Predictor	***B***	***S.E.***	***β***	***t***	***p***
(Constant)	-4.893	1.947	—	-2.513	.012
Digital Competence	.207	.021	.291	9.692	.000**
Mindful Attention Awareness	.881	.040	.667	22.211	.000**

$R = .892$, $R^2 = .796$, Adjusted $R^2 = .795$, $F(2, 425) = 830.245$, $p < .001$

The overall model was statistically significant, $F(2, 425) = 830.25$, $p < .001$, explaining approximately 79.6% of the variance in attitudes toward AI ($R^2 = .796$, Adjusted $R^2 = .795$). Both predictors made significant contributions to the model. Digital competence was a significant positive predictor ($\beta = .291$, $t = 9.69$, $p < .001$), indicating that higher levels of digital skills are associated with more favorable attitudes toward AI. Mindful attention awareness also significantly predicted attitudes toward AI ($\beta = .667$, $t = 22.21$, $p < .001$), and was a stronger predictor than digital competence. These results suggest that both technological proficiency and present-moment awareness play a crucial role in shaping pre-service teacher's openness and readiness to engage with AI in educational settings. Therefore, the H2, which states that "*Digital competency and mindful attention awareness significantly predict attitude toward artificial intelligence among pre-service teachers", is also approved.*

Figure 2

Path diagram showing direct and indirect effects

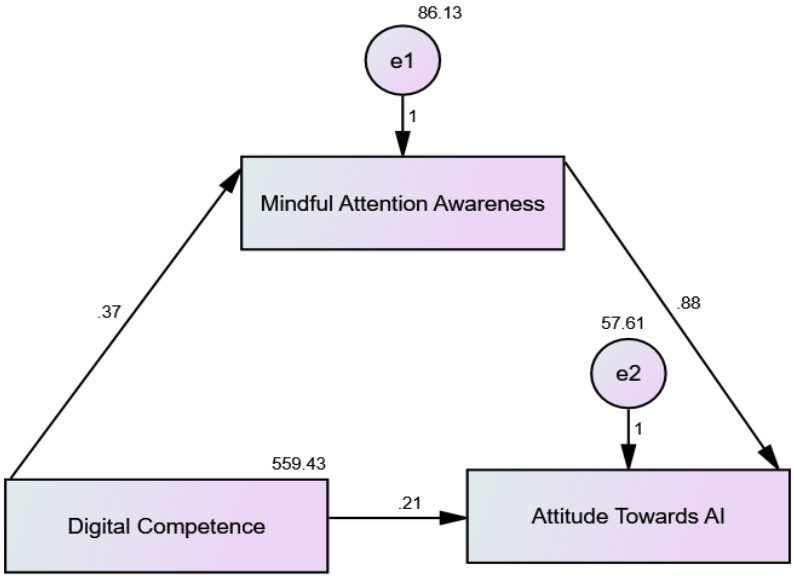


Figure 2 presents the path diagram illustrating both the direct and indirect effects of digital competence on attitudes toward artificial intelligence (AI) through the mediating role of mindful attention awareness. The direct effect of digital competence on attitudes toward AI was statistically significant ($\beta = .21$), suggesting a modest yet meaningful influence. Additionally, digital competence significantly predicted mindful attention awareness ($\beta = .37$), which in turn strongly predicted attitudes toward AI ($\beta = .88$), indicating a substantial indirect effect. The total effect of digital competence on attitudes toward AI, incorporating both the direct and indirect pathways, reflects a more robust influence, highlighting the mediating role of mindfulness in this relationship. This model demonstrates that while digital competence contributes directly to shaping pre-service teacher's attitudes toward AI, its influence is significantly enhanced when it also fosters mindful awareness, thereby promoting more thoughtful and adaptive engagement with emerging educational technologies. Therefore, the H3, which states that "*Mindful attention awareness mediates the relationship between digital*

competency and attitudes toward artificial intelligence among pre-service teachers", is supported.

Table 5 presents the regression weights for the hypothesized structural model examining the relationships among digital competence, mindful attention awareness, and attitudes toward artificial intelligence (AI).

Table 5
Regression Weights: (Default Model)

Variables	Estimate	*S.E.*	*C.R.*	*p*
Mindful Attention Awareness ←Digital Competence	.369	.019	19.412	***
Attitude Towards AI← Mindful Attention Awareness	.881	.040	22.264	***
Attitude Towards AI ← Digital Competence	.207	.021	9.715	***

Note: S.E- Standard Error, C.R- Critical Ratio, ***-<0.001

The results indicate that digital competence significantly predicts mindful attention awareness ($\beta = .369$, SE = .019, CR = 19.412, $p < .001$), suggesting that higher levels of digital competence are associated with greater mindful awareness among pre-service teachers. Furthermore, mindful attention awareness significantly predicts attitudes toward AI ($\beta = .881$, SE = .040, CR = 22.264, $p < .001$), highlighting its strong influence on how pre-service teachers perceive and engage with AI technologies. Digital competence also exhibits a significant direct effect on attitudes toward AI ($\beta = .207$, SE = .021, CR = 9.715, $p < .001$), reinforcing the notion that technological proficiency plays a critical role in shaping educators' dispositions toward AI.

Discussion

This study examined the relationships among digital competence, mindful attention awareness, and attitudes toward AI in pre-service teachers, with a particular focus on the mediating role of mindfulness. The findings addressed all three research hypotheses and provide valuable insights into how psychological and technological traits interact in the context of 21st-century teacher education.

Supporting Hypothesis 1, the results revealed significant positive correlations among digital competence, mindful attention awareness, and attitudes toward AI. This finding is consistent with prior studies by Spante et al. (2018) and Hatlevik et al. (2015), who observed that greater digital competence enhances confidence and fosters positive perceptions of educational technologies. Similarly, Sütçü and Dönmez (2023) found that digitally skilled pre-service

teachers are more inclined to engage with innovative instructional tools, including AI-driven platforms.

In line with Hypothesis 2, multiple regression analysis demonstrated that both digital competence and mindful attention awareness significantly predicted attitudes toward AI, jointly explaining 79.6% of the variance in the outcome variable. Importantly, mindful attention awareness emerged as the stronger predictor, suggesting that psychological readiness may have a more profound influence on technology acceptance than technical skills alone. This finding resonates with research by Brown and Ryan (2003) and Meiklejohn et al. (2012), who emphasize that mindfulness fosters cognitive flexibility, emotional regulation, and openness to new experiences, traits essential for embracing emerging technologies in education. Further supporting this, Zhou and Chen (2021) found that individuals with higher levels of mindfulness were less resistant to AI-enabled tools due to their adaptive and accepting mindset.

Addressing Hypothesis 3, the mediation analysis revealed that mindful attention awareness partially mediates the relationship between digital competence and attitudes toward AI. This suggests that while digital competence directly influences attitudes, its impact is enhanced through mindfulness, which facilitates reflective engagement and reduces resistance to technological innovation. This finding aligns with the theoretical framework of Fredricks et al. (2004), who proposed that dispositional traits play a key role in shaping cognitive and behavioral engagement. Similarly, Kostova and Dimitrova (2022) demonstrated that mindfulness training improved pre-service teachers' openness to digital learning tools, supporting the mediating role of mindfulness in technology acceptance.

The study's findings are further underpinned by Self-Regulation Theory (Zimmerman, 2000) and Cognitive Load Theory (Sweller, 1988), both of which underscore the importance of attentional control and emotional regulation in learning and decision-making. Mindfulness, by enabling individuals to remain present-focused and self-aware, contributes to managing cognitive load and reducing techno-stress, thereby facilitating more thoughtful and confident engagement with AI in the classroom.

From a pedagogical perspective, these results align with the work of Laursen and Nielsen (2016) and Nissila et al. (2022), who advocate for emotionally grounded, competence-based approaches to teacher education. These approaches are especially relevant to the goals of India's National Education Policy (NEP, 2020), which emphasizes the need for reflective, adaptive, and technologically proficient educators who can navigate the ethical and practical challenges posed by AI and digital transformation.

Finally, this study contributes to the growing literature highlighting the dual importance of digital fluency and psychological flexibility in preparing teachers for AI-integrated learning environments (e.g., Choi, 2024; Bothe, 2023). The findings suggest that teacher training programs should move beyond technical training alone to incorporate mindfulness-based interventions, equipping future educators with the emotional resilience and cognitive adaptability required to thrive in complex, technology-enhanced educational settings.

Practical Implications

Given these findings, several pedagogical and policy-oriented implications emerge. First, teacher education programs must prioritize the systematic inclusion of digital competence modules that provide hands-on experience with AI tools and data-informed instructional strategies. Second, the incorporation of structured mindfulness training into teacher preparation curricula is strongly recommended. Such interventions may include practices that develop attentional focus, emotional resilience, and metacognitive awareness competencies that are vital for managing the cognitive demands and ethical dilemmas posed by AI integration.

Third, curriculum developers are encouraged to adopt interdisciplinary approaches that fuse technological proficiency with psychological well-being, thereby cultivating educators who are both technically adept and emotionally balanced. Such hybrid curricula will ensure that the next generation of teachers can engage meaningfully with AI while maintaining a strong humanistic orientation in their pedagogical practices. Finally, policymakers and regulatory bodies should consider establishing national guidelines and assessment frameworks that recognize the dual importance of digital and dispositional competencies in teacher education. Such standards will promote consistency and accountability in preparing educators for an AI-enriched educational future.

Therefore, this study underscores the critical importance of adopting a holistic, future-facing perspective in teacher education, one that acknowledges not only the instrumental role of digital skills but also the foundational influence of mindful awareness in shaping adaptive and ethical engagement with artificial intelligence in education.

Conclusion

This study provides empirical evidence of the significant interrelationships between digital competence, mindful attention awareness, and attitudes toward AI among pre-service teachers. The results supported all three research hypotheses: digital competence and mindfulness were positively correlated with favorable attitudes toward AI, and mindfulness significantly mediated the relationship between digital competence and attitudes toward AI. These findings highlight that while technological proficiency is important, psychological dispositions such as mindfulness play an equally crucial role in influencing how future educators perceive and integrate AI tools in educational settings.

The multiple regression and path analyses revealed that mindful attention awareness was a stronger predictor of AI-related attitudes than digital competence. This underscores the importance of preparing educators not only with technical knowledge but also with cognitive and emotional tools to navigate complex, AI-integrated learning environments. These results align with theoretical frameworks such as Self-Regulation Theory and are supported by prior research emphasizing the influence of affective and dispositional traits in educational technology adoption.

However, several limitations must be acknowledged. First, the study relied on cross-sectional, self-reported data, which may be influenced by social desirability bias and participants' subjective interpretations, potentially affecting the precision of the findings. Second, the non-experimental research design prevents causal inferences. While path analysis was used to explore directional relationships, the possibility of endogeneity where digital competence and attitudes toward AI may influence each other reciprocally cannot be fully ruled out. Moreover, the sample was restricted to pre-service teachers from three regions of Punjab (Majha, Malwa, and Doaba), which may limit the generalizability of the findings to broader populations with different cultural or educational contexts. Despite efforts to ensure regional representation through stratified sampling, the results may not fully reflect the perspectives of pre-service teachers across India or globally. Furthermore, the study did not incorporate qualitative methods, such as interviews or open-ended responses, which could have provided deeper, contextual understanding and served to validate the quantitative findings.

To build upon the current findings, future research should consider using longitudinal or experimental designs to examine causal relationships and temporal changes in digital competence, mindfulness, and technology-related attitudes. Expanding the sample to include diverse regions, institutional types (e.g., private colleges), and in-service teachers would enhance the external validity of the study. Additionally, investigating other potential mediating or moderating variables such as digital self-efficacy, AI-related anxiety, or institutional support could offer a more comprehensive understanding of the psychological and contextual factors influencing AI adoption in teacher education.

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The authors would like to acknowledge the use of artificial intelligence (AI) tools in the preparation of this manuscript. The AI tool *ChatGPT* was used exclusively for grammar checking and language refinement. All AI-assisted text was carefully reviewed and edited by the authors to ensure accuracy, clarity, and academic integrity. AI tools were not used for any other purposes, including data generation, data analysis, development of methodology, or interpretation of findings and conclusions. The authors take full responsibility for the content and quality of the final manuscript.

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Corresponding author: Tasaduk Musood
Email: wanitassu6@gmail.com

Unpacking Technological Pedagogical Content Knowledge (TPACK): Context of Non-Formal Teachers in the Philippines

Luigie Lursh G. Almojano
University of the Philippines Los Baños, Philippines

Abstract

The persistent digital divide in the Philippine education sector poses significant challenges for both teachers and learners, particularly in the non-formal pathway of education called the Alternative Learning System (ALS). Using the Technological Pedagogical Content Knowledge (TPACK) framework, this study explored how the contexts of ALS teachers shape integration of digital technology into teaching and learning activities. Twenty two ALS teachers from Luzon, Visayas, and Mindanao were selected through purposive sampling to represent the program's geographical reach. Drawing on patchwork ethnography, the research employed semi-structured interviews, focus group discussions, and design thinking tools to uncover complex and nuanced layers of micro (individual), meso (institutional), and macro-level (systemic) narratives of contexts (scope-specific) and the teacher and student-related contexts (actor-specific) that surround the TPACK development of ALS teachers. The research uncovered that the context of ALS teachers was influenced by the push and pull of systemic and localized contexts, which can impact the development of ALS teachers' TPACK. These contexts need to be considered in resource programming, capacity-building efforts, school-based management, and boosting the morale and drive of ALS teachers. This study contributes to the broader discourse on TPACK by sharing narratives from the perspective of ALS teachers to inform policy and programming reforms in educational technology locally and globally.

Keywords: Alternative Learning System, contexts, patchwork ethnography, teachers, TPACK

One of the biggest challenges of the Philippine education sector is the need to address the digital divide affecting learners, teachers, and schools nationwide. Introduction of new technologies in education has prompted exploration of innovative ways for the efficient and effective use of technology in teaching and learning (Philippine Normal University, 2023). Access is at the forefront of these concerns, as some areas in the country face challenges such as unavailability of computers and unstable internet connections. On the other hand, in areas where access is not an issue and stable internet connection is available, the most pressing concern is the gap in capacity and knowledge to properly use and apply technology in learning contexts. Unfortunately, there are also areas where both access and knowledge gaps act as barriers to the effective use of technology in learning, making technology integration a challenging reality for some teachers and learners.

This research focuses on the current realities and experiences of teachers in the Philippines, specifically within the Alternative Learning System (ALS) of the Department of Education (DepEd), as they integrate digital technology into their teaching and learning activities. The ALS program is a parallel system of education that caters to Out-of-School Youth and Adults (OSYAs), who have mostly dropped out of the formal education system due to various reasons, including poverty, employment, and a lack of interest (Osawa, 2021). Given that most research in educational technology is centered on formal learning systems, this study focuses on the impact of digital technology in education from the context of non-formal learning systems. Moreover, a majority of educational technology research primarily focuses on pre-service teachers or in-service teachers in formal education (Brianza et al., 2022). This study aims to make space for a nuanced understanding of the unique situation and characteristics of ALS in-service teachers that support or impede their technology use in teaching and learning.

This research conducts a focused analysis of the use of technology by ALS teachers in teaching and learning, utilizing the Technological Pedagogical Content Knowledge (TPACK) framework developed by Mishra and Koehler (2006). The TPACK framework serves as a theoretical lens that explains the necessary knowledge of content, pedagogy, technology, and context that teachers need to effectively use technology in their teaching and learning (Koehler & Mishra, 2016). By employing the TPACK lens, this paper aims to analyze stories that provide insight into the contexts surrounding the development of ALS teachers' TPACK.

The section that follows presents a review of the literature, providing an overview of the ALS program as well as the related opportunities and challenges of technology integration in formal and non-formal learning. This is followed by a brief discussion of the TPACK framework, the current global trajectories of TPACK research, and the current context defined in relation to the TPACK framework. The methodology section covers the data gathering methods, sampling, qualitative analysis, and ethical considerations of the research. The third part will cover the results and discussions, presenting the context of the TPACK of ALS teachers using the scope and domain of contexts as the analytical frame. We conclude with recommendations for further research and policy reforms for the development of TPACK of non-formal teachers nationally and internationally.

Review of Related Literature

ALS and the Challenge to Maximize Digital Technologies

As of 2022, there are approximately 3.6 million Filipino OSYs, according to the Annual Poverty Indicator Survey (APIS), primarily due to the need to find employment, familial responsibilities, and low interest in finishing basic education (Albert et al., 2024). With the significant number of OSYAs, the ALS program of DepEd is faced with the big task of providing non-formal education to these learners who are mostly labeled as the deprived, depressed, and underserved or DDUs (Arzadon & Nato, 2015).

According to the Republic Act No. 10533 or the Enhanced Basic Education Act of 2013, the ALS program serves as the parallel program of the formal education system that is aimed at giving OSYA Filipinos a chance to have access to basic education in a learning mode that fits their contexts. The program has undergone several changes, starting from the early efforts of the Philippine government to meet the Education For All (EFA) agenda in the early 2000s, the creation of the Bureau of Alternative Learning System (BALS) in 2004, and the institutionalization of the Bureau of Alternative Education (BAE) in 2020 as the official implementor of the program. The primary feature of the ALS program is its flexible learning setup, which offers numerous learning modalities that cater to the diverse contexts and situations of its target learners. It provides modular learning, face-to-face instruction in the ALS community or school-based learning centers, and blended learning approaches using digital and analog technologies. Given the program's flexible nature, it has a big potential to benefit from strong and sustainable technology integration for teaching and learning activities.

Being a parallel system to formal basic education, the ALS program has faced numerous difficulties and challenges. One is the othering and inferiority associated with ALS learners and teachers, being branded as the 'other side' of education (Arzadon & Nato, 2015). This inferiority has created a stereotypical impression and stigma that ALS provides low-quality education, which also affects its capacity and program resources. Despite catering to around 2.7% of learners as of 2024, Albert et al., (2024) noted that ALS only got 0.09% budget share from DepEd, a very low proportion of budget allocation in relation to the number of learners served.

Albert et al., (2024) added that ALS is also faced with issues of understaffing, with its learner-teacher ratio standing at 1:75. In terms of resources, ALS is also affected by the prevailing digital divide, with only 1/3 of the Community Learning Centers (CLCs) across the country having a reliable internet connection. Moreover, many ALS teachers and learners lack access to basic digital infrastructure, as revealed during the pandemic (Santos, 2020). These constraints related to resources and digital infrastructure have a serious impact on the capacity and capability of ALS teachers and learners to benefit from the blended learning approaches.

Given the numerous challenges and limitations to technology integration in ALS, one of the key questions in the ALS Road Map is how the curriculum and ALS implementers can

maximize the various ICTs to match learners' needs (Department of Education, 2021). The present realities and resources of ALS have created a double layer of othering – its identity as the other side of formal education and its meager resources for staffing, materials, and digital infrastructures. Looking at the literature on ALS and non-formal learning systems in the Philippines, the majority of the studies are focused on highlighting the secondary role or the other side role of ALS in the Philippine education system (Guiamalon et al., 2022; Javillonar & Elma, 2021; Moralista & Delariarte, 2014; Pimentel & Banares, 2020). This research aims to uncover insights and learnings from the experiences of ALS that can inform programs and policy reforms on alternative learning system in the Philippines, especially on program resources and teacher support for capacity building and professional development.

Teaching With Technology Using the TPACK Framework

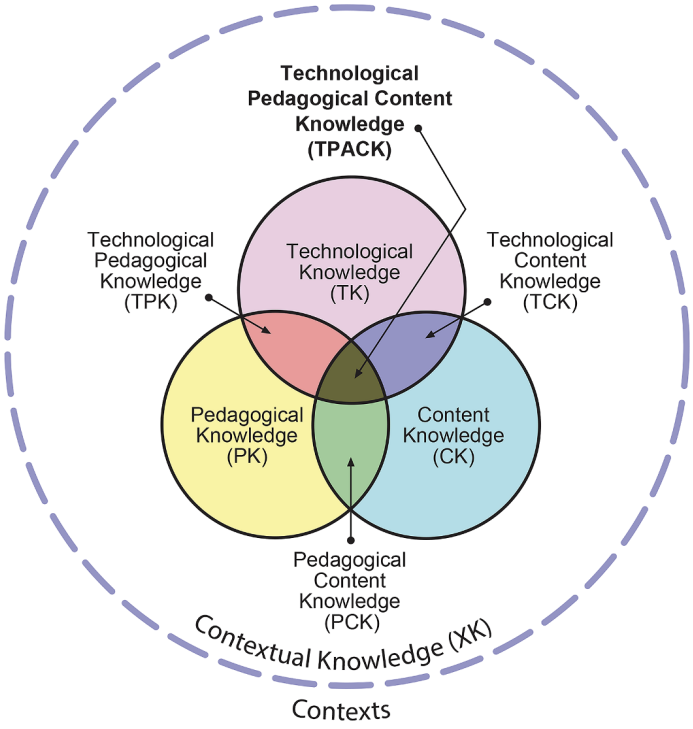
Numerous studies have emphasized the many benefits of integrating technology for teaching and learning (Brianza et al., 2022) – these may be related to student engagement (Nkomo et al., 2021), using more learner-centered pedagogies (Fu, 2013), and helping to lessen teachers' load and tasks (Selwood & Pilkington, 2005). As the need to better understand the relationship between teaching, learning, and technology emerged in recent years, coupled with the unprecedented pressure to shift to online learning due to the COVID-19 pandemic, various theories and frameworks have been proposed to help understand how technology can be beneficial for the education sector.

The TPACK framework is one of the key theories recognized for explaining the complexities of integrating technology, content, and pedagogy. It emphasizes the need to see an emergent form of knowledge, acknowledging the relationship among content, pedagogy, and technology to maximize the use of technology in teaching and learning (Koehler et al., 2013). Focusing on this relationship, the following domains of knowledge were formed (Koehler & Mishra, 2009):

- Content Knowledge (CK): knowledge of the relevant subject matter
- Pedagogical Knowledge (PK): knowledge of the different teaching methods, theories, and approaches
- Technological Knowledge (TK): knowledge of various technologies and how to use them in teaching and learning
- Pedagogical Content Knowledge (PCK): knowledge of how to teach subject matter effectively, considering learner contexts
- Technological Pedagogical Knowledge (TPK): knowledge of how to use technology to enhance teaching and learning practices
- Technological Content Knowledge (TCK): knowledge of how to use technology to deliver content effectively
- Technological Pedagogical Content Knowledge (TPACK): knowledge of how to effectively integrate technology in teaching and learning to enhance understanding of content

Figure 1

TPACK Framework Model (Petko et al., 2025)



These different domains of knowledge emphasize that TPACK is dependent on interweaving technology, pedagogy, and content (Mishra & Koehler, 2006). Moreover, these domains of knowledge have crucial roles to play individually and as a whole body of knowledge (Mishra & Koehler, 2006), and thus there is a need to move beyond the perspective and approaches that simplistically treat technology as an add-on for teaching and learning (Koehler & Mishra, 2009).

Global research on TPACK has garnered significant attention over the last 15 years, as evidenced by the extensive literature on its conceptualization and application (Koehler & Mishra, 2016). The majority of current studies focus on either defining the parameters and measures of TPACK or examining its application in the context of formal schools (Brianza et al., 2022). It is apparent from the literature that only a few studies used the TPACK framework in the context of non-formal settings and marginalized areas (Bell, 2024; Li et al., 2025; Nepembe & Simuja, 2023). Shambare and Simuja (2024) focused on understanding the development of TPACK among teachers in rural and marginalized schools in the Eastern Cape Province, South Africa. The study revealed a distinct gap in TPACK domains related to the technology used by teachers in marginalized settings. Another study, although applied to a formal educational context in China, considered urban and rural factors in analyzing the TPACK of teachers (Li, 2025). The study revealed that the TPACK capacity of urban teachers is significantly higher than that of their rural counterparts, largely due to limited access to and support in rural areas. Nepembe and Simuja (2023) as well as Bell (2024) have revealed the usefulness of the TPACK framework as a lens for understanding the complexities of using technology in non-formal and distance education contexts within marginalized learning spaces.

This research contributes to the existing body of literature by offering a unique perspective on ALS teachers in the Philippines, who primarily serve vulnerable and marginalized students in non-formal settings.

This research will use the TPACK framework as a guidepost to properly unpack the affordances and limitations of using technology in education for ALS teachers. The blended learning approach of ALS presents a rich opportunity to understand how technology in education can be better understood within the context of an alternative learning pathway. Given that most TPACK research focuses on either pre-service or in-service teachers in the formal system, this study aims to distill rich insights and recommendations that can inform a more contextualized approach to supporting the development of TPACK in ALS teachers.

Aside from the difficulties regarding digital infrastructure, several studies also highlighted the skill and knowledge gap among ALS teachers in their capacity to integrate technology into their teaching and learning activities. This skill gap in ICT use in education is seen in both formal and non-formal teachers because of the prevailing design of most of the professional development programs focused on understanding the hardware rather than the application of technology in teaching and learning (Global Education Monitoring Report Team UNESCO & South-East Asian Ministers of Education Organization, 2023), which contradicts the primary theoretical perspectives of the TPACK framework. The current state of technology integration in ALS is what Mishra and Koehler (2006) describe as focusing on what technology is and not how technology can be used. Through the TPACK framework, this research aims to uncover new opportunities for teacher training and support in technology integration for ALS teachers, enhancing the teaching and learning process. We hope to help transform the ALS program from being stigmatized and othered, to becoming a model for efficient and effective use of technology in education.

Enhancing TPACK through Contextual Knowledge and Contexts

With the increasing popularization of TPACK as a theoretical foundation in educational technology, several studies have focused on either further defining or measuring the different domains of knowledge for pre-service and in-service teachers. Beyond TPACK's seven domains of knowledge, the framework has been expanded to describe the domains of Contexts and Contextual Knowledge (XK), highlighting that these other domains are central to the situated basis of TPACK (Petko et al., 2025).

Although there is an acknowledgment of the centrality of context, most current TPACK research has little to say about Context and Contextual Knowledge (Brianza et al., 2022). This study aims to contribute to the existing literature by exploring the context surrounding the TPACK of teachers from the Philippines, particularly within the ALS program by focusing on the lived realities of ALS teachers. The research also aims to investigate the interplay between cultural, social, political, and economic factors that shape the non-formal education system in the Philippines.

From the standpoint of digital anthropology, the context and consequences of using different technologies are particularly important, as these are subject to further cultural, social, political, and economic factors. Thus, the digital should always be analyzed within its context (Miller, 2018). Moreover, context emphasizes the nature of technology, especially when it is applied to education, as neither neutral nor unbiased, and that social contexts further enhance our understanding of the impact of technology in education (Koehler & Mishra, 2009). Contextual Knowledge is the knowledge about the overall interplay of enabling factors that affect the TPACK development of teachers. (Petko et al., 2025). Contexts, specifically social and institutional, are often identified as the primary barrier to effectively integrating technology into teaching and learning (Koehler et al., 2013). This research hopes to further extend the theoretical development of TPACK by offering empirical data from the ALS teachers' perspective to understand further the complexity and variability of TPACK's context and Contextual Knowledge (Porras-Hernández & Salinas-Amescua, 2013).

Most current research on contexts focuses on student characteristics, suitable conditions for learning environments, situated teaching and learning practices, and the teacher's beliefs (Porras-Hernández & Salinas-Amescua, 2013). One of the key studies emphasizing context in TPACK research is Porras-Hernández and Salinas-Amescua's (2013) study, which used qualitative data from teachers in Latin America to further reflect the need to extend the theoretical underpinnings within the complex context of Latin America. They provided a more organized consideration of context by establishing points of investigation based on scope and actors. These ideas are summarized in the table below (Rosenberg & Koehler, 2015):

Table 1
Scope Level Contexts and Their Definition

Scope	Definition
Macro Level	social, political, technological, and economic situations that are national and global in nature
Meso Level	social, cultural, political, organizational, and economic situations established in the local community, the schools, and learning centers
Micro Level	in-class circumstances for learning that include resources, policies, and social and cultural interactions of teachers and students

Table 2
Actor-Specific Contexts and Their definition

Actors	Coverage
Teacher	All of the characteristics of teachers, such as their motivation and beliefs
Student	All of the characteristics of students

This study will focus on utilizing these different types of contexts and actors to further explore the experiences of ALS teachers in understanding the different domains of knowledge related to TPACK. This approach also supports the theoretical move that TPACK should be understood and applied within specific educational contexts (Petko et al., 2025), thereby further improving the theoretical foundations of TPACK.

Methodology

This research employs patchwork ethnography, combined with design thinking, to understand the context of ALS teachers' experiences in defining and thinking through the different domains of knowledge within the TPACK framework. As part of ongoing ethnographic research on the potential use of ICT to improve teaching and learning in ALS, several qualitative data-gathering activities were conducted with ALS teachers from December 2021 to February 2025.

This research is situated within the parameters of patchwork ethnography, which consists of ethnographic methods that typically involve short-term field visits, resisting the impractical expectations of traditional ethnography (Günel et al., 2020). In like with this methodology that involves conducting multiple, fragmented, and short-term field visits and data-gathering activities, our data is collected over a three-year period. While the approach still values long-term engagement, language proficiency, and contextual knowledge, patchwork ethnography creates discrete patches of ethnographic knowledge from multiple sites, allowing for the collection of rigorous data in flexible and non-linear ways (Tsing, 2005). Moreover, it promotes the acknowledgment that knowledge can be built through multiple, discontinuous encounters rather than a single, uninterrupted stay like traditional ethnography.

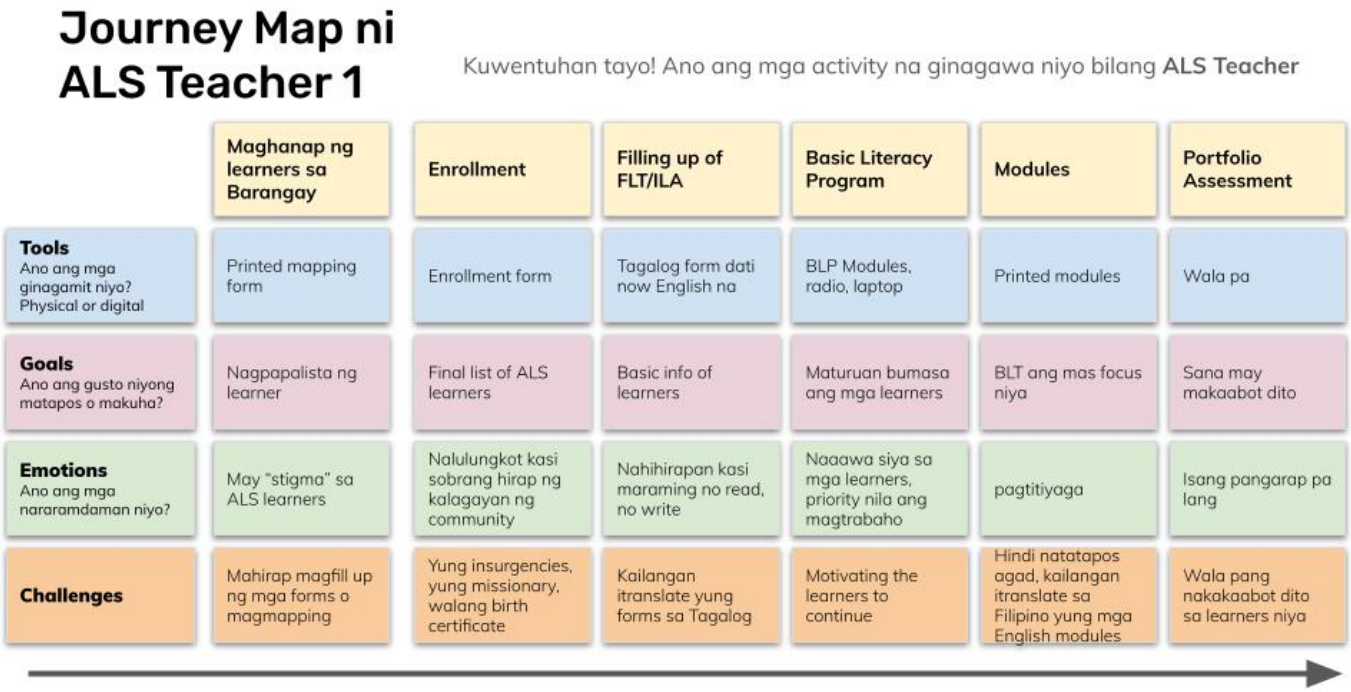
This research used the following ethnographic methods:

- Seven semi-structured interviews to understand the experiences of the ALS teachers in using ICT in their teaching and learning.
- User journey mapping to trace the teaching and learning activities of ALS teachers, including the technological touchpoints, emotions, motivators, and barriers that they encounter. The tool is guided by design thinking principles, making the methodology a human-centered approach to innovation that aims to put the needs of the research participants at the core of the analysis (Brown, 2009). The individual user journey maps

were co-created with the teachers during the semi-structured interviews and consolidated to see the commonalities and differences.

- Three Focus Group Discussions (FGDs) to triangulate the data gathered from the semi-structured interviews and to validate the consolidated user journey maps.
- Participant-observation with ALS teachers in school and community learning centers during site visits documented using field notes and photos. The field notes were used as a tool for researcher reflexivity to constantly understand the researcher's biases as a teacher in higher education, a learning experience design researcher supported by an international development agency, an outsider to the ALS community, and as a former staff in DepEd Central Office.

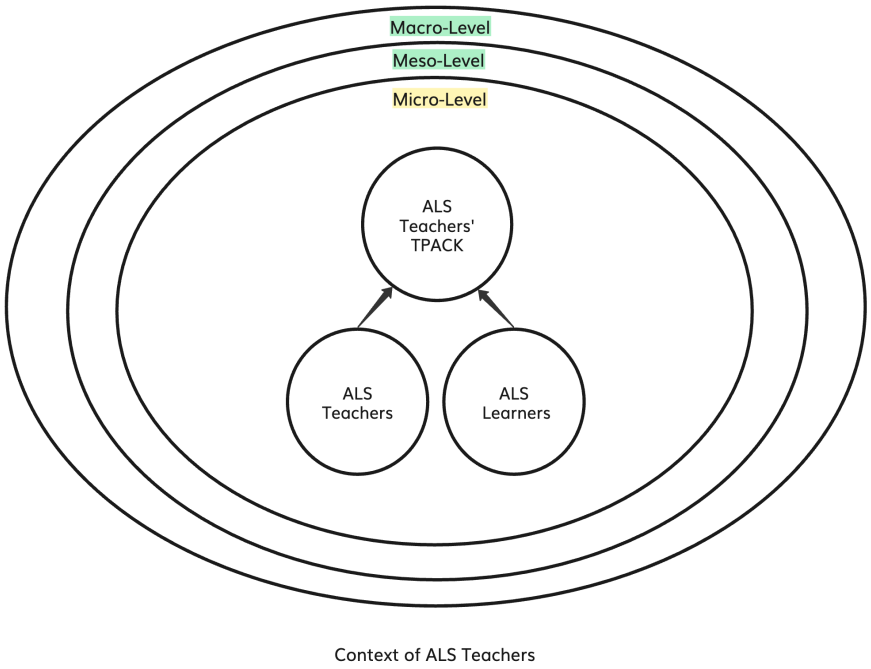
Figure 2
Sample User Journey Map



Through the use of patchwork ethnography and design thinking tools and mindset, this research aims to answer the following research questions:

1. What are the different micro, meso, and macro-level narratives of contexts (scope-specific) that surround the TPACK of the ALS teachers?
2. What are the teacher and student-related contexts (actor-specific) surrounding the TPACK of ALS teachers?

Figure 3
Conceptual Framework of the Study



Research Question 1 is built on the premise that one of the crucial foundations of developing the TPACK of teachers is the enabling factors layered in each of the micro, meso, and macro-level contexts. Using the parameters designed by Porras-Hernández and Salinas-Amescua (2013), this research aims to describe the scope-specific layers of context that affect the TPACK development of ALS teachers based on the narratives collected from the patchwork ethnography.

Research Question 2 expands the narratives of context affecting the TPACK development of ALS teachers by presenting actor-specific contexts primarily from the view of ALS teachers and their learners. This question emphasizes the impact of the dynamics of teacher and learner in learning spaces as key drivers in the TPACK development of ALS teachers. The conceptual framework in Figure 3 presents the centrality of the two sets of variables considered in this study: scope-level and actor-specific contexts. The push and pull of these contexts paint the overall picture of the development of the TPACK of ALS teachers. This research describes the outer circle in the framework, specifically the context of ALS teachers' TPACK, using the theoretical perspectives highlighted in the TPACK Framework Model (Figure 1) by Petko et al. (2025).

Participants of the Study

The participants in this study are ALS teachers from selected sites in Luzon, Visayas, and Mindanao, covering the geographical reach of ALS program implementation in the Philippines effectively. Site selection ensured diversity in socioeconomic or digital infrastructure contexts.

The inclusion criteria for the selected research participants include the age range of 18-59 years at the time of the research engagement, a minimum of one school year service in the ALS program , and the capacity to speak and understand Filipino and English, which are the primary languages of the study. The participants adhering to these inclusion criteria were recruited using a purposive sampling based on the recommendations of the DepEd Central Office's Bureau of Alternative Education as well as the Regional Offices and Schools Division Offices.

Out of the 22 ALS teachers seven teachers participated in the semi-structured interviews, and a total of 15 teachers joined the FGDs. The teaching experience of participants ranged from one year to more than 20 years, providing a suitable representation to offer a holistic perspective of the program. Given the logistical considerations for the face-to-face data gathering, 13 ALS teachers from Luzon participated in face-to-face research activities. In contrast, the remaining nine from Visayas and Mindanao participated online. The theoretical sufficiency of the data (Dey, 1999) was achieved after seven semi-structured interviews were conducted. The responses and comments gathered from the three rounds of FGDs also validated the theoretical sufficiency to build codes and themes. The FGDs and the validation of the user journey map also helped triangulate the data from the semi-structured interviews.

Data Analysis

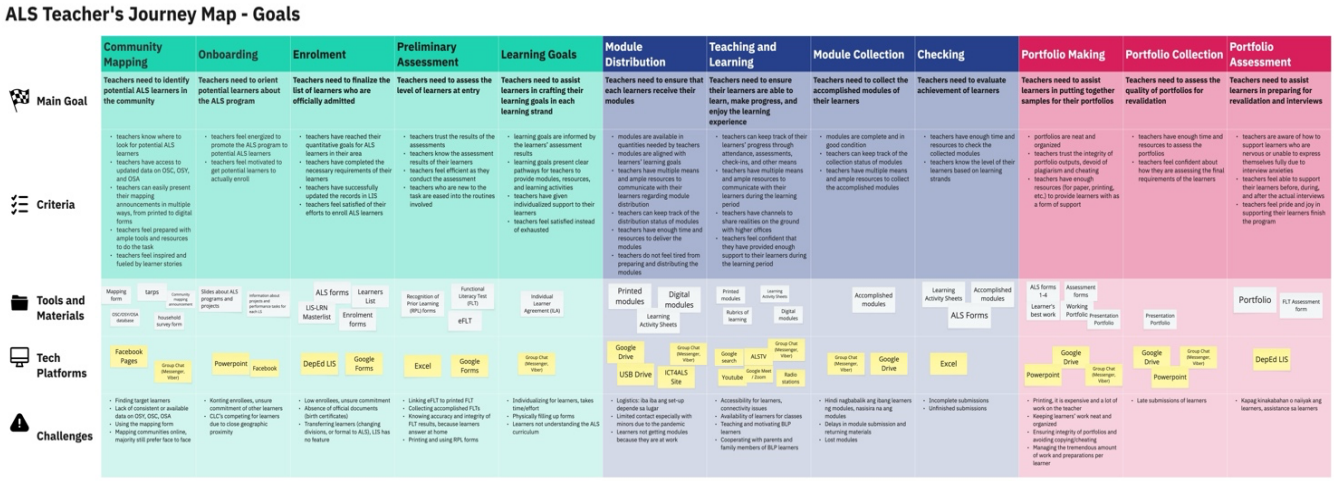
Thematic analysis (Braun & Clarke, 2006) was conducted to analyze the data and to generate key themes informed by the parameters of Porras-Hernández and Salinas-Amescua (2013). Specifically, the following steps were used to explore the data:

1. Recordings of the semi-structured interviews and FGDs were transcribed. Individual user journey maps of the ALS teachers were consolidated into a single user journey map by tracing the commonalities and differences in the experiences shared in the interviews.
2. The consolidated user journey map was validated with ALS teachers during the FGDs. The FGDs triangulated other relevant data points about the context of ALS teachers from the semi-structured interviews.
3. Familiarization with the data was achieved through close reading of the transcripts and cross-checking the initial data against the validated user journey map.
4. Initial coding was performed to identify the codes derived from the data. Two members of the research team also completed individual coding to cross-check the initial coding. The final codes were decided based on the commonalities across the three sets of coding to ensure high intercoder reliability and reflexivity, considering the researchers' biases.
5. Codes were clustered into themes using the scope and actor parameters of the context, informed by reflections from the participant-observation data. The themes generated and the final user journey map were analyzed to identify trends and patterns that can paint the context of the TPACK knowledge of the ALS teachers who participated in the study.

6. Final themes were used to write the final research article and form possible recommendations and next steps for the research.

Figure 4

Consolidated User Journey Map of ALS Teachers



Ethical Considerations

The research adhered to the research ethics process of DepEd and followed the basic principles of securing Free, Prior, Informed Consent of the research participants. They were also briefed and informed about the purpose of the research, including their expected level of involvement and the potential usage of the collected data. Consent was also obtained before recording the conversations, and these recordings were securely stored and used solely for the purposes of the research. The data and insights gathered from the other research methods were presented to the research participants, Department of Education Central Office officials, and stakeholders for verification and validation before being incorporated into this research article.

Results

The research mapped out the scope-level and actor-specific contexts based on the ethnographic data to understand the commonalities and differences in the context of ALS teachers' TPACK development. Following the thematic analysis, different themes mapped to the framework of Porras-Hernández & Salinas-Amescua (2013) describe the contexts surrounding the TPACK of the ALS teachers who participated in this study.

Macro-Level Context

Most ALS teachers acknowledge that the primary macro-level context that significantly influenced their use of technology in teaching and learning is the lack of comprehensive digital infrastructure and a reliable internet connection. They shared that these prerequisites are crucial

resources to make technology integration possible, because when ICT tools are not available, they cannot start with tinkering and exploring digital technologies. One teacher commented about the issue of ICT access in ALS, "How will it be more accessible to areas with low to no internet?" The perennial and systemic problem of lack of computer laboratories, insufficient number of computers, laptops, or tablets, and slow internet connection in schools is mostly prevalent in formal schools and ALS community learning centers situated in rural provinces and municipalities, according to the teachers in one of the FGDs.

Aside from access, ALS teachers highlighted the crucial role of national-level capacity-building efforts as a key factor in their TPACK development. They acknowledge the continuous efforts of DepEd and private institutions in providing capacity-building support, not just in education technology but also for various other topics. However, one ALS teacher mentioned during the interview that there is still a gap regarding the capacity building provided:

> "There are gaps in terms of leveling and teacher training to know how we can cater to both elementary and junior high school learners. We lack deeper training on how we can marry these competencies. There are a lot of things that come from Central that do not actualize in the field."

Several ALS teachers also echoed the sentiment that most of the capacity-building sessions they attended were typically for teachers in the formal system and, for the most part, did not consider their different situations and experiences in teaching within ALS. As shared in one of the FGDs, "Most ALS teachers receive training designed for formal education, with limited professional development opportunities tailored to ALS." Another FGD participant added that the last capacity-building program solely for ALS teachers was conducted in 2020, more than five years ago. This information is echoed by many ALS teachers, who hope that there will be capacity building focused on their contexts and realities as ALS teachers, so they will not feel left out. This general feeling of not being seen and heard and labeled as a second-class teacher and learner is echoed by one of the research participants:

> "I hope in the future, we are not just second, third, or last priority, not deprived, depressed, and underserved. The learners are the same even with formal and in ALS. Hopefully, the system will be fair with ALS learners."

Meso-level Contexts

Gaps in resources and the non-prioritization of the needs of ALS learners and teachers are also strongly felt within meso-level contexts. One key issue ALS teachers mentioned is the lack of resources they usually experience in school-based and community-based learning centers. They share that most of them felt that their resources as ALS teachers are secondary to those who are in the formal system. As one teacher shared, "The resources we have are not enough. We don't have equipment and tools for teaching and learning. The ALS funds are not enough because they only cover payment for honorarium."

Within meso-level contexts, ALS teachers must manage the school-level dynamics with the formal system. The feeling of being second-class teachers and learners is also experienced within the meso-level situations. This othering was echoed by an ALS teacher who mentioned the story about their problem of sharing a computer laboratory with the formal system:

> "One key challenge is the lack of sufficient materials and the lack of computer laboratory for ALS. We experience discrimination, especially when using shared resources like computer labs. ALS learners are often blamed when issues [like loss of equipment] arise in schools."

Despite the limitations, meso-level contexts are positively influenced by the proactive role of local community and government units. One teacher shared, "Our community learning center was donated by the municipal government. We are also very lucky because they provided us with printers and other materials." Most ALS teachers also highlighted that the support provided to ALS is heavily dependent on the leadership of the school head. They emphasized that they are very fortunate when the principal assigned to their school recognizes the needs of ALS teachers and learners, as they can then access school funds and facilities.

Micro-Level Contexts

The different meso-level contexts are crucial for teachers and learners as they negotiate and address these conditions in their micro-level contexts. Based on the narratives shared by the ALS teachers, the micro-level context is where most of their agency, personal capacities, and adjustments will be evident. In one of the FGDs, an ALS teacher shared, "[w]e have a classroom, but there are no available materials. I even have to get a personal loan so I can provide the materials for our CLC." Most of the research participants highlighted that they have to think of creative ways to find resources for their teaching and learning activities, either through solicitation or by using their personal funds.

Aside from efforts to address issues with materials and equipment, they also have to adjust to the ever-changing and expanding educational technologies, which parallel the diverse and complex needs of their OSYA learners. One teacher narrated, "In terms of technology, I need to adjust for me to be able to use it, especially with Google Meet and Zoom, that I am not really familiar." Most ALS teachers reported that they have had to learn and adjust as they utilize digital technologies, especially following the extensive development during the COVID-19 pandemic. They mentioned that they create and modify materials, such as converting PDFs into slide presentations, utilizing Open Educational Resources (OERs), referencing supplementary resources and YouTube videos, and printing worksheets to aid in teaching and make them suitable for learner needs. These different uses and applications of technology depend on ALS teachers' skill level and openness to exploring and using digital technology. One teacher candidly shared, "I would say that technology use is very limited. I only use Messenger and Google Meet on my cellphone and my laptop for creating presentations." This adjustment is difficult for most ALS teachers since they possess a basic proficiency level in using digital technology and, as they say, are not techie.

As their learners needed more guidance and support on ICTs from them, one teacher proudly shared a strategy to bridge the use of social media in teaching and learning, "I have this practice of downloading modules even before the pandemic. I usually have the PDF modules then I will forward these to the GC (group chat) on Facebook." In one of the FGDs, another ALS teacher emphasized the constant need to offer flexibility using ICTs for their learners. She shared, "The modules are a mix of online and offline modalities. Some learners do not have the time to go to schools for synchronous engagement. That's why we refer them to ALS Connect [online learning]." ALS teachers also explained that they are expected to adjust with the use of technology to ensure learning continuity. One teacher shared a strategy they used to implement hybrid learning setup, "We use Google Meet for online learning during class suspension and to help other learners to catchup if they miss the face-to-face sessions."

At this level, ALS teachers who recognize the importance of digital technology are motivated to seek donors and assistance that will help them acquire digital tools, such as smart televisions, LCD projectors, and laptops, for classroom use. One example shared by a teacher in the FGDs was the crucial role of their LGU and private sector donors in supporting their resource mobilization efforts for their CLCs. They shared that they are very lucky since their LGU granted their request for tablets and printers. ALS teachers who are active and capable of partnership linkages can slowly address some micro-level barriers to accessing digital resources and tools in their classrooms.

Table 4
Cluster of Themes per Scope Level Contexts

Scope	Themes
Macro Level	● National-level Capacity-building ● Gaps in training needs ● Limited access to digital technology ● ALS discrimination
Meso Level	● Lack of resources in schools and CLCs ● Discrimination in access to resources ● Limited digital tools
Micro Level	● Teacher agency ● Adjustments to technology ● Social media applications ● Increased engagement for learners ● Expectations for teachers ● Adjusting to a hybrid learning setup

Actor-Specific Contexts

For the level of the teachers, a key consideration evident from the data collected is their deeply rooted purpose to serve the community as ALS teachers. They see their service in ALS as a meaningful way to contribute to their community. They explained in the FGDs that ALS gives a sense of purpose and emotional connection, which motivates them to stay despite the difficult conditions in the macro, meso, and micro-level contexts. For them, teaching in ALS impacts the community because their teaching is beyond traditional classrooms. As shared by one ALS teacher, “I began my ALS journey to serve and make a difference in learners' lives.”

This sense of purpose connects their drive to continuously learn and improve their digital skills, enabling them to adapt to the demands and needs of their learners. Most of them expressed interest in learning more about new developments in technology, specifically presentation design, video editing, Artificial Intelligence, Learning Management Systems, automating grading sheets, and recognizing plagiarism and cheating. They explained that they need to learn these innovations in ICT so they can effectively integrate technology in their teaching and learning.

The teacher-related characteristics are very much attuned to the diverse situation of their ALS learners. During the FGDs, they acknowledge that many ALS learners face socio-economic inequalities and difficulties that discourage their participation in formal schooling. As narrated by one ALS teacher, “There are learners who are in the mountains who usually need to go down to the barangay to access the materials.” Other learners face difficulty with attending face-to-face sessions due to employment and family responsibilities.

Another teacher emphasized the observable disparities in access to laptops and cellphones of ALS learners: “Not all learners have cellphones or mobile data. There is only a small percentage of learners who attend our sessions whenever we use technology.” Moreover, ALS teachers reported in one of the FGDs that they mostly have difficulty with adult ALS learners who struggle to quickly adapt to the use of technology in their learning activities. One teacher shared, “Learners, especially older ones, struggle with uploading submissions and keeping up with technology.” These learner characteristics provide a deeper consideration for ALS teachers in adjusting to other micro-level contexts surrounding the TPACK of ALS teachers in the Philippines.

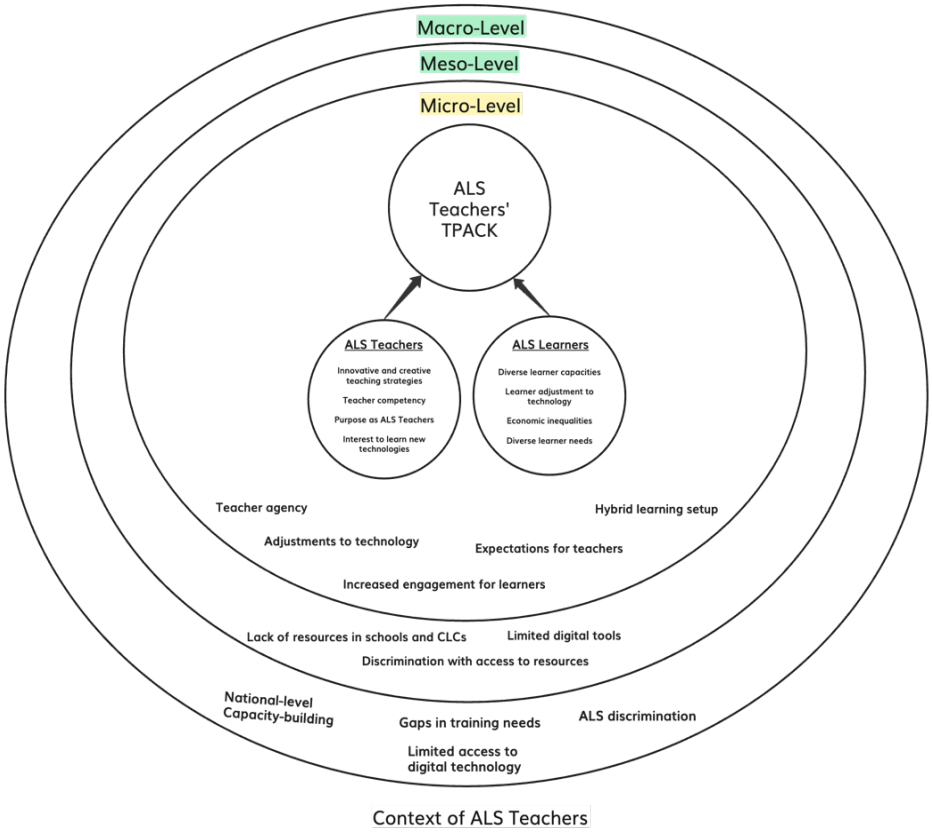
Table 5

Cluster of Themes per Actor-Specific Contexts

Actors	Themes
Teacher	● Innovative and creative teaching strategies ● Increasing teacher competency ● Deep purpose as ALS Teachers ● Interest to learn new technologies
Student	● Diverse learner capacities ● Learner adjustment to technology ● Economic inequalities ● Diverse learner needs

Figure 5

Summary of ALS teachers' TPACK context



Discussion

Within macro-level context, ALS teachers mainly highlighted the insufficient access to digital infrastructure and a reliable internet connection as a crucial factor. This problem in Philippine education spaces is a primary symptom of the digital divide, as pointed out in a study by Albert et al. (2024). The prevailing concern about the mismatch between the capacity building provided to ALS teachers is also a glaring issue on a national scale. The mismatch between the training and support provided to ALS teachers aligns with the findings by Gochuico (2021), which revealed that it is challenging to think about innovations in technology and pedagogy for ALS teachers because they are teaching learning strands for which they lack expertise. These gaps in resources and capacity are linked to the general feeling of not being seen and heard, and being labeled as a second-class teacher and learner, as noted by Arzadon and Nato (2015). ALS teachers are confronted with numerous systemic issues that overlook their unique contexts and situations.

It is apparent from the narratives of the ALS teachers that the macro-level has a crucial impact on the meso-level contexts. Most of the themes at the meso-level encompass the school dynamics that ALS teachers must manage. This aligns with the findings of Porras-Hernández and Salinas-Amescua (2013), wherein meso-level contexts are affected when school administrators do not provide sufficient resources for their teachers and learners. This limited access to funding and the unavailability of some facilities pose a barrier to the sustainable use of technology for teaching and learning activities.

Compared to the macro- and meso-level contexts, micro-level contexts are significantly influenced by the myriad combinations of ALS teachers' and learners' realities. The need to act on personal agency and adjustment, as observed among ALS teacher participants, supports the findings of Sarmiento et al. (2022) that some teachers in the Philippines incurred out-of-pocket expenses to bridge the gap in ICT tools for teaching and learning activities. This adds more pressure on ALS teachers as they are confronted with the complexities of resource mobilization. Because they face disparities in access to digital technology, they experience significant delays in further developing their TPACK, as there are gaps with access to technology to begin with. The experiences of ALS teacher participants support the findings of Paz et al. (2022), which explain that novice-like technology experiences of teachers may delay the productive integration of technology in teaching and learning. Given the variety of factors that can affect the micro-level contexts of ALS teachers, this level, as explained by David and Aruta (2022), is connected to the teachers' capacity to address and act on the gaps and barriers within their classrooms.

The teacher-related characteristics are closely aligned with the needs of ALS learners, who have diverse requirements. These learners also face numerous socio-economic inequalities and difficulties, as most of them are working professionals or young learners who leave formal schooling due to employment, financial constraints, or a loss of interest (Osawa, 2021). These varying teacher and learner characteristics provide a deeper consideration of their contribution to the complex micro-level contexts surrounding the TPACK of ALS teachers in the

Philippines. Considering the current context, it is understandable that most ALS teachers exhibit strong pedagogical expertise, given their emphasis on differentiated instruction in ALS. However, the different macro and meso-level barriers limit their content and technological knowledge to use ICT for non-formal learning settings.

Based on the different scopes and actor-specific contexts, there are connections between the various levels and characteristics in shaping the TPACK of ALS teachers. It is worth noting that the macro-level context, including resources, gaps in capacity building, and the discrimination experienced by ALS teachers, significantly impacts the complexity of the meso and micro-level contexts. The systemic issues related to access to digital technology and the gaps in capacity building significantly impacted the development of the TPACK of ALS teachers. The national and international contexts that shape the environments of ALS teachers are currently perceived by them as limitations to maximizing the use of technology in their teaching and learning activities (Zhang, 2010). These macro-level contexts serve as barriers that necessitate an institutional approach, particularly when considering the actual meso- and micro-level contexts. Very evident in the results of the research are the interrelated contexts of ALS teachers within the meso and micro-level, which are negotiated through the characteristics, motivations, actions, and reactions of ALS teachers and learners to these scope-specific contexts (Porras-Hernández & Salinas-Amescua, 2013).

Despite the different systemic challenges and barriers highlighted in the contexts of ALS teachers, it is also important to highlight some micro-level adjustments from the teachers' perspective to resist the barriers from other layers of scope. There are greater opportunities to develop teachers' TPACK if ALS teachers are capable of resource mobilization and establishing partnership linkages. The sooner they have digital devices in their classrooms, the earlier they can start experimenting with digital technology in their teaching and learning. Moreover, ALS teachers who understand the importance of digital technology in enhancing their teaching and learning strategies are the ones who are primarily motivated to seek resources for their classroom and are interested in experimenting with technology in their daily activities. This finding aligns with the study by Ertmer and Ottenbreit-Leftwich (2010), which explains that the level of interest and openness to learning digital technology is crucial in addressing some barriers to ICT in education.

Conclusion and Recommendations

This research analyzed narratives that can provide a snapshot of the contexts of ALS teachers that support or impede the development of their TPACK. The macro-level context highlights the national-level barriers to developing ALS teachers' TPACK, primarily related to systemic issues surrounding access to digital technology. Additionally, the top-down and formal education-centric approach to capacity building for teachers, which overlooks the diverse context of non-formal education, is also a limitation. ALS teachers also highlighted the feeling of being considered second-class teachers and learners, which is manifested in the limited resources and infrastructure for ALS.

The meso-level contexts are also heavily affected by the macro-level issues surrounding resources for the ALS program. ALS teachers felt that within their schools and districts, they are subjected to discrimination and othering. For micro-level contexts, narratives are more nuanced and dependent on the agency and situation of the ALS teachers, as well as their consideration of their learners. The narratives about meso- and micro-level contexts reveal the need for more localized and case-specific analysis of these contexts, as they may vary according to the management styles of local school heads, stereotypes regarding ALS teachers and learners, and opportunities to adjust to school- and classroom-level barriers and challenges.

As teachers and learners are the primary actors in the micro-level scope, the myriad combinations of ALS teachers' and learners' characteristics also affect this level. There is a strong emphasis on the teachers' drive to learn innovative and creative teaching strategies. This scenario is primarily linked to the strongly rooted purpose of ALS teachers in serving the underserved and underprivileged OSYA learners. ALS teachers also need to adapt to the socio-economic challenges faced by their learners. These actor-specific contexts add nuance to understanding ALS teachers' TPACK development as not just a competency and skill issue, but also an aspect of their professional development that is influenced by teacher-learner dynamics within and outside the learning centers.

This research offers several key points for consideration regarding resource programming, capacity-building efforts, school-based management, and enhancing the morale of ALS teachers. The DepEd Central Office can prioritize the urgent digital infrastructure needs of ALS learning centers. ALS teachers also require complementary capacity-building sessions to consistently develop their knowledge, skills, and attitudes regarding digital technology suitable for non-formal contexts. The push and pull of the different contexts warrant a more integrated approach to support ICT integration in ALS.

The perspectives on the macro, meso, and micro level contexts from the Philippines can serve as a starting point for cross-culturally comparing and contrasting TPACK development in other parts of the world. Shared lessons and best practices from the ALS teachers' TPACK development can provide a comparative lens to assess the integration and use of ICT in informal education spaces in other countries. These insights can also help inform which contexts of TPACK development among teachers are shared across different regional and international education spaces, guiding the localization and contextualization of educational technology policy.

Given the qualitative nature of this research, it is essential to acknowledge the study's limitations. The study relied on participant-observation data and narratives from ALS teachers to describe the context surrounding their TPACK development. The research participants are also limited to ALS teachers. Perspectives from ALS learners and other stakeholders were not incorporated. It is recommended that a mixed-methods approach can be employed to understand the context of ALS teachers further. Future research can utilize localized quantitative TPACK tools to measure the various domains of knowledge and their corresponding contexts. New insights and reflections may arise if TPACK development is

measured through training and workshops to enhance teachers' capacity to strike a balance between content, pedagogy, and technology in their teaching and learning practices. Further research could also focus on tracking TPACK contexts on a longitudinal basis, cross-checking and validating fluctuations and changes in the data points over time with ALS teachers, learners, and stakeholders.

As the study focuses on contexts, the findings of this research need to be revisited to ensure that adjustments in the contexts are also well-documented, given the fast pace of technological change. Given the situated nature of TPACK, this research aims to explore possibilities for a balanced approach between empirical and theoretical research that may advance the literature on the contexts influencing the TPACK of ALS teachers. Future research could also focus on understanding the challenges and opportunities presented by emerging digital technologies, such as Artificial Intelligence, big data, and micro-credential learning, as these might create new macro, meso, and micro-level TPACK implications. With the dynamic interplay of old and new digital technologies, a continued analysis of how these new waves of developments can shape the future of content, pedagogy, technology, and context in educational spaces is a crucial question to investigate.

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Statement of AI Use

The author would like to acknowledge the use of artificial intelligence (AI) tools in the preparation of this manuscript. The following tool was used for these specific purposes only: Grammarly for improving the grammar and readability of this manuscript. All AI-edited text was thoroughly reviewed and revised by the author to ensure accuracy, clarity, and adherence. AI tools were not used for other purposes, including data generation, data analysis, methodology, or interpretation of findings or conclusions. The author takes full responsibility for all aspects of the final manuscript.

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Corresponding author: Luigie Lursh G. Almojano
Email: lgalmojano1@up.edu.ph

A Systematic Literature Review on the Role of Library Science in Combating Disinformation

Ismiatun
Brawijaya University, Indonesia

Farida Nurani
Brawijaya University, Indonesia

Agung Suprapto
Brawijaya University, Indonesia

Abstract

This systematic literature review addresses the increasing difficulty society faces in distinguishing factual and misleading information in the digital age. Public trust in information institutions, including libraries, is eroding, impacting decision-making and social polarization. While previous research has examined the role of libraries, knowledge gaps remain regarding librarian practices, detection technologies, and information literacy strategies. The main objectives were to develop a taxonomy of misleading information, evaluate detection approaches, identify user resilience factors, formulate an information literacy framework, and analyze the ethical implications of the library's role. Using the PRISMA-P (Preferred Reporting Items for Systematic review and Meta-Analysis Protocols), the review included screening, review, and quality assessment MMAT (Mixed Methods Appraisal Tool) of literature available through Scopus and Web of Science. Inclusion and exclusion criteria were applied. The selection process involved data analysis, which included extraction, thematic synthesis, and gap analysis. The review highlights the evolving role of librarians, emerging methods for identifying and addressing misinformation, the use of detection technologies, and the integration of information literacy strategies. It also notes trends in human-technology collaboration, changing approaches, cross-sector partnerships, and domain-specific literacy initiatives. The review reveals libraries' adaptation to the complexity of digital information. Implications include the development of detection skills, collaboration, and information literacy programs according to user needs. Future research is suggested to explore AI technologies, the impact of information literacy, and collaboration dynamics. Findings enrich our understanding of the role of libraries in combating disinformation.

Keywords: collaboration, detection technology, information literacy, library science, misleading information

Misleading information is now a global threat affecting politics, health, and security, with its massive spread through social media fueling algorithms for sensational content. Studies show that 64% of the global public believes disinformation is undermining the political process, while 58% report being frequently exposed to bold fake news (Hameleers, 2023; Tomassi et al., 2025). Its impacts include increased political cynicism, social polarization, decreased public trust in institutions, and shifts in voter preferences favoring populist groups (Jones-Jang et al., 2020; Zimmermann & Kohring, 2020). Key factors contributing to its spread include the involvement of state and non-state actors, low digital literacy rates below 40% in many developing countries, and weak international legal frameworks (Huang, 2024; Shu et al., 2020). In response, library science plays a crucial role through strengthening information literacy, providing credible sources, and cross-sector collaboration, which has been proven to increase the ability to verify public information by up to 65% since 2020 (Herrero-Diz & López-Rufino, 2021; Nazim et al., 2024).

Misleading information significantly impacts people's lives. The spread of misleading health information during the COVID-19 pandemic resulted in poor health decisions, threatening individual and collective well-being (Nela & Parruca, 2023; Swire-Thompson et al., 2024). Finally, disinformation threatens national security by undermining public trust and creating vulnerabilities that can be exploited by foreign entities, challenging the integrity of national and international security policies (Landon-Murray et al., 2019; Tenove, 2020).

Contemporary information literacy theory addresses the challenge of digital disinformation through various complementary approaches. Association of College and Research Libraries (ACRL)'s Information Literacy Framework has evolved to emphasize critical information literacy as a tool against fake news, enabling individuals to understand the social construction of information and use it creatively and contextually (Brisola & Doyle, 2019). Through its Media and Information Literacy (MIL) model, UNESCO has developed new components that include algorithms and cognitive biases, recognizing the complexity of the digital information ecosystem (Brisola & Doyle, 2019). Longitudinal studies reveal the evolving role of librarians in the post-truth era through strategic collaboration with educators, changing traditional perceptions of their function in supporting information literacy (Whitver, 2017). Recent studies show library science curricula increasingly integrate anti-disinformation components, potentially enhancing information professionals' detection capabilities (Whitver, 2017).

While previous research has examined libraries' role in combating misinformation through information literacy and credible source provision (Adewojo et al., 2024; Goodsett, 2023; Herrero-Diz & López-Rufino, 2021; Tripodi et al., 2023), significant gaps remain regarding librarians' identification practices, automated detection technologies, and effective literacy strategies to enhance users' misinformation resilience. These studies have not fully explored the systematic approaches librarians use to verify the accuracy of data, the potential application of technologies such as AI or machine learning in the information filtering process in the library environment and how information literacy strategies can be tailored specifically to help users recognize the characteristics of misleading information and develop the critical thinking needed to evaluate information quality in the digital age.

The research is particularly relevant given generative AI's growing ability to create hard-to-detect misinformation, coordinated disinformation campaigns targeting educational institutions, and evolving regulations on platform responsibility for misinformation. Additionally, post-pandemic digital transformation has significantly altered library information access and consumption patterns. The WHO-introduced concept of "infodemic" highlights how misleading information poses significant risks to public health by promoting dangerous behaviors, increasing anxiety, and eroding trust in health authorities (Briand et al., 2021; Sell et al., 2021; van der Linden, 2022), while simultaneously driving increased demand for information literacy and fact-checking skills in the modern workforce (De Gani et al., 2024; Pérez-Escolar et al., 2021; Purnat et al., 2023).

This paper presents a systematic literature review that aims to comprehensively address the challenge of misleading information in library environments by developing a systematic taxonomy of types of misleading information and evaluating automated detection methods for digital library systems. The study reported in this paper seeks to understand the factors that influence library users' resilience to misinformation while creating an integrated framework for information literacy programs that emphasize source verification. By examining the ethical dimensions of libraries' roles in the modern information landscape, the research presented here provides evidence-based recommendations for library professionals. It develops a standardized assessment tool to measure the effectiveness of information literacy interventions in improving users' ability to identify and counter misleading information.

Research Methodology

Research Design

This study employed a Systematic Literature Review (SLR) methodology—a structured approach to systematically identify, evaluate, and synthesize existing research using predetermined criteria. SLR was chosen for its ability to comprehensively analyze the vast literature on misleading information in library science and provide an objective synthesis of findings across studies. The study design included a systematic database search of academic platforms, application of predetermined inclusion and exclusion criteria, quality assessment of selected studies, and thematic analysis of extracted data to ensure methodological rigor and reproducibility. This study examines misleading information in library science, analyzes its impact on user trust, and identifies technological detection innovations and effective information literacy strategies. The findings reveal the critical role of libraries in combating misleading information through the provision of trusted sources and public education, while highlighting institutional efforts to enhance user trust through information literacy programs and critical learning engagement.

Review Protocol

A protocol known as PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) was developed to ensure the review process is conducted regularly and transparently (Moher et al., 2009). PRISMA is a comprehensive guideline designed to improve the transparency and completeness of reporting systematic reviews and meta-analyses, which helps authors report rationale, methods, and findings in a standardized manner. This study implemented these guidelines to ensure consistent, reliable, and methodologically sound reporting that would be beneficial for clinicians and researchers.

Inclusion and Exclusion Criteria

The inclusion criteria for this study included several types of articles, namely articles relevant to the topic of misinformation in library science, studies that discuss the impact of misinformation on user behavior and trust, publications that review technological innovations in misinformation detection, and research that discusses information literacy strategies in the library environment. In addition, the selected articles must have been published in Scopus or Web of Science-indexed journals within the last 10 years to ensure the relevance of the information to be analyzed.

Meanwhile, exclusion criteria were applied to filter out articles that did not meet the standards of this study. These criteria included articles that did not focus on the library science context, studies that did not have full access or were only abstracts, gray literature that was not verified for quality, duplicate articles that appeared in both databases (WoS and SCOPUS), non-empirical research, and articles that were not written in English. These exclusion criteria were important to ensure that the systematic review produced appropriate, high-quality analyses.

Literature Search Strategy

The literature search in this study was conducted through two major academic databases, Scopus and Web of Science, which are leading databases for international scientific publications. The search was conducted using a carefully defined combination of keywords to obtain results relevant to the research topic. The keywords comprised two groups of terms linked by the Boolean operator “AND”. The first group included various terms related to library subjects, namely “Librarian”, “Library Professional”, “Library Scientist”, “Library Staff”, “Library Visitors”, “Library Beneficiaries”, “Library Clients”, “Library Patrons”, AND “Library Users”. Meanwhile, the second group consisted of terms related to misleading information, namely “misleading”, “Deceptive”, “False”, “Inaccurate”, AND “Misrepresentative”. This combination of keywords helped ensure that the search results covered all aspects relevant to the research topic on misleading information in the library context.

Study Selection Process

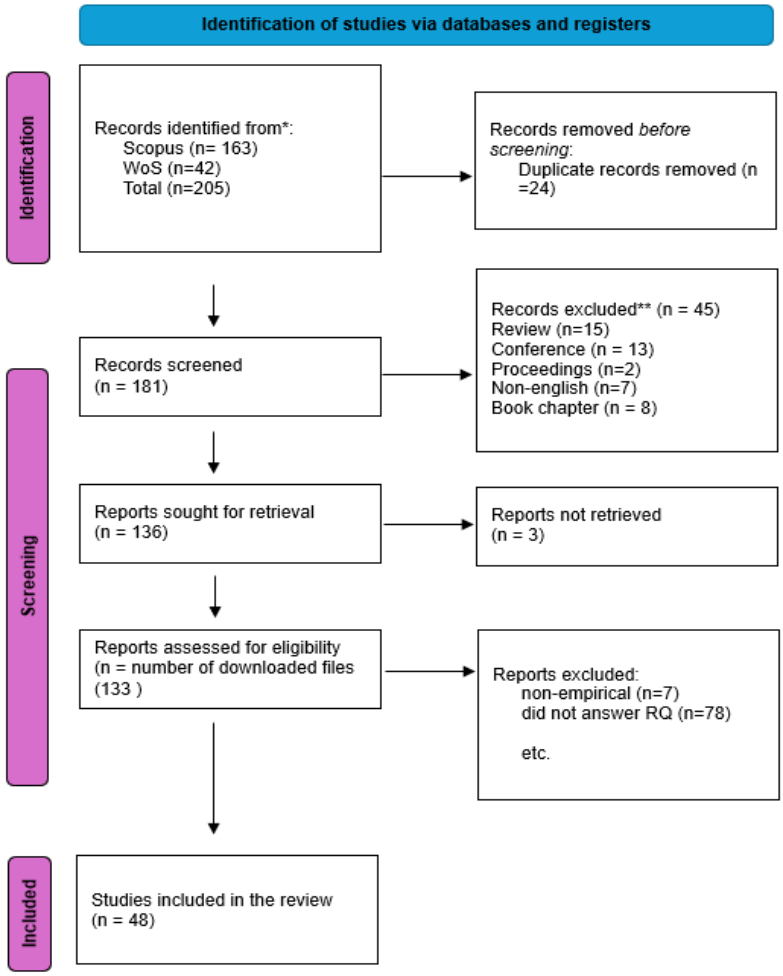
The study selection process was carried out through three systematic and comprehensive stages. The first stage was the initial screening, where selection was made based on the titles and abstracts of the articles. The purpose of this stage was to identify potentially relevant literature to the research topic. After obtaining a list of articles that passed the initial screening stage, the second stage consisted of a full review. The purpose of this stage was to evaluate the full text of the articles to ensure their compliance with the predetermined inclusion and exclusion criteria. Finally, the third stage consisted of a quality assessment that was conducted on the articles that had passed the full review stage. This assessment used the Mixed Methods Appraisal Tool (MMAT), which is a critical appraisal instrument designed to ensure that articles included in systematic reviews and meta-analyses demonstrate strong methodological quality and reliable findings, thereby contributing to high-quality evidence synthesis (Hong et al., 2018).

Data Analysis Technique

The data analysis involved three methodological stages. First, data extraction collected key information from selected articles, including research objectives, methods, findings, and practical implications. Second, thematic synthesis grouped findings based on key themes such as misinformation's impact on library users, detection technology development, and information literacy strategy effectiveness. Finally, research gap analysis identified underexplored aspects in existing literature to guide future research and address knowledge gaps in library science regarding misinformation.

Table 1

Identification of Studies via Databases and Registers



Source: PRISMA (Moher et al., 2009)

Results

The results presented in the following report are the output of a data analysis process that has been carried out systematically and comprehensively to provide an accurate picture of the conditions or phenomena being studied.

Strategies for Identifying Misleading Information

Librarians play a crucial role in identifying misinformation through systematic methods. They have developed specific strategies to recognize patterns of false information, which is increasingly important given the rapid spread of fake news through digital platforms. Librarians serve as gatekeepers who help users distinguish quality information from misleading content. The following table presents 13 methods librarians use to identify misleading information from scientific literature. These methods cover traditional approaches to modern techniques relevant to digital age information challenges.

Table 2
Misleading Information Identification Methods

No.	Identification Method	Description	Citation
1	Observe the pattern of organizing false information	Librarians identify certain patterns in how false information is organized, especially on controversial issues	Bianchini et al. (2019)
2	Using IFLA guidelines	Following the guidelines published by IFLA for recognizing fake news	Das & Ghosh (2019)
3	Careful evaluation of sources	Evaluate sources of information carefully, especially when answering reference questions	Lor (2018)
4	Verification of facts	Fact-checking using sites like Snopes, PolitiFact and FactCheck	Neely-Sardon & Tignor (2018)
5	Reverse image search	Using the reverse image search tool to verify the authenticity of an image	Anderson (2018)
6	Identify questionable journal metrics	Using criteria to identify questionable journal metrics, such as lack of information on provider location	Nazarovets & Nazarovets (2018)
7	Recognize the characteristics of predatory publishers	Identify the characteristics of predatory publishers that have poor peer review practices and questionable ethics	Pomputius (2019)
8	Error evaluation in AI response	Identifying false claims and logic errors in AI output such as ChatGPT	Way & It (2025)
9	Visual analysis of misinformation	Analyze misleading visual information by looking for parts that are true, false, or confusing	Cowles et al. (2024)
10	Identifying articles that have been retracted	Checking whether the article is still valid or has been retracted	Frederick (2023)
11	Critical examination of news sources	Apply critical analysis theory to news and information sources	Becker (2021)
12	Application of experience and basic knowledge	Use the librarian's knowledge base to identify misinformation	Yap et al. (2023)
13	Evaluation of librarian webpages	Evaluate the librarian's own website for inaccurate or outdated information	Lewis (2024)

Librarians apply various strategies to identify misleading information in the modern information ecosystem. They observe patterns in preparing false information, especially on controversial issues where evidence and expert agreement are lacking (Bianchini et al., 2019). The guidelines developed by IFLA have become an important tool for librarians to recognize

fake news and deal with the threat of misinformation (Das & Ghosh, 2018). In dealing with these issues, librarians develop skills to carefully evaluate sources, especially when answering reference questions (Lor, 2018). Fact verification has become a standard method by utilizing sites such as Snopes, PolitiFact, and FactCheck that help students independently verify claims from various sources (Neely-Sardon & Tignor, 2018). Reverse image search has also become an important tool in librarians' literacy toolkits to demonstrate the ease of verifying images to authenticate content (Anderson, 2018).

Librarians have developed specific methods to identify misleading predatory journals and publications. Jeffrey Beall, a librarian from the University of Colorado, compiled a list of criteria to identify questionable journal metrics, including a lack of information about the provider's location and the qualifications of its employees (Nazarovets & Nazarovets, 2018). Librarians also help identify the traits of predatory publishers with poor peer review practices and questionable ethics, which is a challenge because even experienced authors have difficulty identifying them (Pomputius, 2019). The emergence of AIs such as ChatGPT adds new challenges, with librarians needing to identify combinations of false claims and logical fallacies in AI output that are often difficult to detect (Way & It, 2025). Visual analysis of misinformation is becoming an important method by analyzing examples of misleading visual information to encourage critical discussion (Cowles et al., 2024). Librarians are also developing strategies to identify retracted but still cited scholarly articles, known as "zombie papers" (Frederick, 2023).

Strategies for Handling Misleading Information

Librarians implement various strategies to handle misleading information by filtering content and educating users through information literacy programs. As information professionals, they have an ethical responsibility to counter misleading information, particularly in critical areas like health, science, and public policy. The following table presents 22 coping methods from documented best practices. These strategies reflect a multidimensional approach combining direct intervention, user education, institutional collaboration, and systemic contribution to the broader information ecosystem.

Table 3

Methods of Handling Misleading Information

No.	Handling Method	Description	Citation
1	Role as mentor and companion	Librarians help users find the desired information with skillful assistance	Das & Ghosh (2018)
2	"Roaming reference librarian"	Librarians move around the library, offering assistance to users in person	Lor (2018)
3	Encourage the use of official sources	Encourage the use of authoritative information from local and national government document collections	Lor (2018)
4	Offers a variety of sources	Provides a variety of sources from the library's online full-text database	Lor (2018)
5	Information literacy teaching	Teaches users about journalistic ethics and the information cycle	Neely-Sardon & Tignor (2018)
6	Create a counter-meme	Create educational memes that encourage critical evaluation of information on social media	Boyle (2022)
7	Validate information from multiple channels	Validate information from multiple channels and disseminate only reliable and correct information	Yap et al. (2023)
8	Health information-based approach	Using an evaluation approach that is based on health information, not just on source type or political bias	Steffy & Long (2023)
9	Warned about predator journals	Warn researchers through LibGuides, videos, posters, meetings, memos and presentations	Ojala et al. (2020)
10	Evaluate the legitimacy of the publisher	Help faculty and students evaluate the legitimacy of publishers and conference invitations	Lopez & Gaspard (2020)
11	Direct users to trusted sources	Direct users to reliable sources and provide correct information	Paris et al. (2022)
12	Collection curation	Curate digital and physical collections to ensure accuracy	Paris et al. (2022)
13	Giving notes in a nonfictional book	Inserting notices in nonfictional books to explain where users can check for other information on the topic	Paris et al. (2022)
14	Organization of special classes	Organized a class on identifying and tackling health misinformation	Cowles et al. (2024)
15	Using the Retraction Watch	Encourage the use of services such as Retraction Watch to check citations	Frederick (2023)

16	Collaboration with trusted information organizations	Work with other trusted information organizations to uncover misleading sources.	Usherwood & Usherwood (2020)
17	Teaching digital health literacy (DHL)	Develop students' digital health literacy in collaboration with subject teachers	Oddone & Merga (2024)
18	Use of a simplifying approach	Simplify the process of evaluating health information sources for easy daily use	Steffy & Long (2023)
19	Free exchange of ideas as a media literacy instructor	Advocating for the free exchange of ideas with librarians as media literacy instructors	Bailey & Hsieh-Yee (2020)
20	Processing, evaluating and generalizing information	Perform processing, evaluation and generalization of information to provide reliable information for users	Kurmysheva & Pshenichnaya (2024)
21	Creating information conditions for search	Create information conditions that enable information seeking and information retrieval	Kurmysheva & Pshenichnaya (2024)
22	Contribute to the information environment	Contribute to the information environment for the development of education, science and culture	Kurmysheva & Pshenichnaya (2024)

(Das & Ghosh, 2018). The concept of "roaming reference librarians" is implemented where librarians travel around the library, offering direct assistance to users (Lor, 2018). Librarians encourage using authoritative information from local and national government document collections as trusted sources (Lor, 2018). They also offer a variety of sources from the library's online full-text database to provide diverse perspectives (Lor, 2018). Information literacy is key to teaching journalistic ethics and the information cycle to educate students about trusted news sources (Neely-Sardon & Tignor, 2018).

Librarians developed innovative approaches to address misleading information by creating educational counter-memes that encourage critical evaluation of social media information and demonstrate ethical sharing practices (Boyle, 2022). Librarians validate information from various channels and disseminate only reliable and correct information, actively countering false information (Yap et al., 2023). For health information, librarians use an evaluation approach based on the health information itself, not just on the source type or political bias (Steffy & Long, 2023). They warn researchers about predatory journals through various channels such as LibGuides, videos, posters, meetings, memos, and presentations (Ojala et al., 2020). Academic librarians help faculty and students evaluate the legitimacy of publishers and conference invitations by providing tools to identify dubious practices (Lopez & Gaspard, 2020).

Librarians use practical strategies in their daily work to deal with misinformation. They direct users to reliable sources and provide correct information (Paris et al., 2022). The curation of

digital and physical collections is done to ensure the accuracy of the information available (Paris et al., 2022). Librarians even insert notices in nonfiction books to explain where users can check other information on the topic (Paris et al., 2022). Organizing special classes on identifying and tackling health misinformation is a focused educational approach (Cowles et al., 2024). Librarians also encourage using services such as Retraction Watch to check citations and avoid using retracted articles (Frederick, 2023).

Collaboration and a systemic approach are important strategies in dealing with misinformation. Librarians work with other trusted information organizations to uncover misleading sources that threaten democracy, identify and counteract (Usherwood & Usherwood, 2020). They teach students digital health literacy (DHL) in collaboration with subject teachers (Oddone & Merga, 2024). Librarians use a simplifying approach in evaluating health information sources because complex tasks complicate the ability to reason (Steffy & Long, 2023). The role of librarians is also evolving from restricting false information to supporting the free exchange of ideas as media literacy instructors (Bailey & Hsieh-Yee, 2020). Librarians process, evaluate, and generalize information to provide reliable information for users (Kurmysheva & Pshenichnaya, 2024).

Libraries as institutions play a fundamental role in the broader information ecosystem of society. Librarians create conditions that enable information search and obtaining of quality information (Kurmysheva & Pshenichnaya, 2024). They contribute to the information environment to develop education, science, and culture (Kurmysheva & Pshenichnaya, 2024). Librarians, teachers, and journalists form the "Triad of Truth-Workers" who defend the importance of truth and the reliability of information (Herrero-Diz & López-Rufino, 2021). They feel competent in guiding users in dealing with fake news because they have concerns about disinformation and other related challenges (Herrero-Diz & López-Rufino, 2021). This comprehensive approach confirms the vital role of libraries as a reliable source of information in information exchange despite the multiplicity of information sources in the modern information space (Kurmysheva & Pshenichnaya, 2024).

Technology to Detect and Filter Misleading Information in Libraries

Libraries face significant challenges in managing information flow, particularly the circulation of misleading information that affects service quality. To maintain their role as providers of accurate information, libraries must adopt technologies that automatically detect and filter misinformation. Available solutions utilize AI, pattern analysis, source verification, mobile applications, and database integration to help librarians and users identify inaccurate information.

Table 4

Technologies Implemented by Libraries to Detect and Filter Misleading Information

Technology	Description	Mechanism of Action	Source
Linguistic Recognition Algorithm	AI technology that compares specific linguistic features in original news stories to recognize inauthentic ones	Using computational linguistics to determine how far the article deviates from the original research article and its source by analyzing language patterns and phrases.	(Pomputius, 2019)
Dispersal Pattern Analysis	A system that compares how accurate information is shared with how false information is spread	Analyze the pattern of information dissemination to identify the characteristics of fake news dissemination.	(Pomputius, 2019)
Source Credential Verification	Systems that investigate the credentials of original authors and publishers	Check the background, reputation and credibility of authors and publishers to determine the reliability of information.	(Pomputius, 2019)
News Verification Mobile App	News Verification Mobile App Apps like Listle, Owlfactor, Oigetit, Credder, Fakey News, etc.	Provides a feature to identify fake news through mobile device	(Becker, 2021)
Retraction Database Integration	A system that connects the article retraction database with the digital identification system	Using databases such as Retraction Watch linked to DOI (Digital Object Identifiers) to identify articles that have been retracted	(Frederick, 2023)

Modern libraries can utilize various advanced technologies to detect misleading information. Linguistic Recognition algorithms are a key foundation in this effort, as they utilize AI to compare linguistic features in news stories (Pomputius, 2019). This technology analyzes language patterns and phrases to determine how far an article deviates from the source. Libraries can automatically filter manipulated or inaccurate content through a computational linguistics approach. This system is particularly effective for identifying articles that have been altered from their original versions with the aim of misleading readers.

News Verification Mobile Applications offer practical solutions for real-time misinformation detection through portable technology (Becker, 2021). Applications such as Listle, Owlfactor, Oigetit, Credder, and Fakey News provide features that enable users to identify fake news directly through their mobile devices. Libraries can integrate these mobile-based verification tools into their digital services, allowing patrons to verify information authenticity on the go.

The accessibility and user-friendly interface of these applications make them particularly valuable for widespread adoption in library information literacy programs.

Retraction Database Integration represents a systematic approach to identifying previously discredited information (Frederick, 2023). This system connects article retraction databases with digital identification systems, utilizing databases such as Retraction Watch linked to DOI (Digital Object Identifiers) to identify articles that have been retracted. Libraries can implement this technology to automatically flag content that has been officially withdrawn from scientific or academic publications. This integration ensures that library collections and recommendations remain current and exclude information that has been proven unreliable or inaccurate.

News Verification Mobile Apps have become a practical solution easily accessible to library users (Paris et al., 2022). Apps such as Listle, Owlfactor, and Credder provide tools to identify fake news directly from mobile devices. These apps use specialized algorithms and up-to-date databases to verify the accuracy of the information. Libraries can promote using these apps as part of their information literacy services. Integrating the mobile app with the library system makes verifying information anytime and anywhere easy.

Retraction Database Integration is a recent technology that links information about retracted articles with a digital identification system (Frederick, 2023). This system utilizes databases like Retraction Watch, which tracks retracted scientific articles. The retraction information is linked to Digital Object Identifiers (DOIs) for easy identification. Libraries can integrate this database into their search systems to inform users of article status. This technology is essential for maintaining scientific collection integrity and preventing the dissemination of retracted information.

Combining these five technologies creates a comprehensive misinformation detection system. Libraries must adopt a multi-technology approach since each technology has limitations, but integrated use improves detection accuracy. Implementation requires investment in digital infrastructure and staff training. By adopting these technologies, libraries can maintain their role as trusted information providers amid growing misinformation.

Information Literacy Strategies to Recognize and Avoid Misleading Information

In the digital age, recognizing and avoiding misleading information has become essential. Libraries and educational institutions play an important role in developing users' information literacy. This document presents information literacy strategies that librarians and educators can implement to improve users' ability to evaluate and verify information. These strategies are grouped into eight main categories, including information evaluation frameworks, verification techniques, critical thinking development, education methods, visualization tools, field-specific literacy, campaigns, and collaboration approaches to address misinformation challenges.

The following table offers a comprehensive categorization of these strategies, along with brief descriptions and citations of relevant literature. These strategies can be adapted and implemented to suit the specific needs of different institutions and user groups.

Table 5

Technologies Implemented by Libraries to Detect and Filter Misleading Information

Strategy	Description	Citation
Information Evaluation Framework		
Use the CRAAP Framework	A source evaluation method that assesses the Currency, Relevance, Authority, Accuracy and Purpose of information	(Neely-Sardon & Tignor, 2018; Ojala et al., 2020)
Use the RADAR Framework	Infographics that provide a plan for students to check and evaluate information sources	(Neely-Sardon & Tignor, 2018)
Use the ACRL Framework	Using ACRL framework such as "Authority Is Constructed and Contextual" to teach critical evaluation of content	(Johnston, 2023; Paris et al., 2022; Yap et al., 2023)
Think. Check. Submit	A campaign supported by a coalition of publishers and scientific communication organizations to help researchers identify trusted journals	(Ojala et al., 2020)
Information Verification Techniques		
Use Lateral Reading Techniques	Techniques that encourage users to leave the document they are reading and open a new browser tab to check the author's authority, affiliations and stated facts	(Fielding, 2019a; Steffy & Long, 2023)
Use Reverse Image Search	Teaches the use of the reverse image search tool to identify the original context of images	(Cowles et al., 2024)
Use the PAPA approach (Pause, Authenticate, Prevent, Accuracy)	Strategies to teach users to pause before sharing information, check authenticity, prevent the spread of false information and ensure accuracy	(Steffy & Long, 2023)
Train News Syndication Recognition Skills	Helps students understand news syndication and impostor URLs that are often a source of confusion	(Schroeder, 2021)
Development of Critical Thinking Skills		
Develop Critical Thinking	Teaches skills to evaluate and investigate sources based on the content, appearance and context of their discovery	(Lewis, 2024; Neely-Sardon & Tignor, 2018b)
Develop Critical Media Literacy	A comprehensive program that includes partnerships between librarians and educators to teach information evaluation skills	(Lor, 2018)
Develop Skepticism towards Social Media	Encourage users to question and take additional steps to confirm information from social media	(Anderson, 2018)
Education and Outreach Methods		
Workshops and Seminars	An educational event exploring the structure of online news articles and how social media platforms can introduce bias	(Kurmysheva & Pshenichnaya, 2024; Wade & Hornick, 2018)

Use LibGuides	Creation of an online guide containing fact-checking resources and news literacy learning objects	(Neely-Sardon & Tignor, 2018b)
Learning Through Games	Use of a game-based application to train users to recognize fake news	(Becker, 2021)
Library Orientation and Outreach Program	Expanding access to library services, including book delivery services to users	(Das & Ghosh, 2019)
Using Memes as an Instructional Tool	Utilizing the popular meme format among students to teach information literacy and critical thinking	(Boyle, 2022)
Visualization Tool and Practical Guide		
Infographic "How to Spot Fake News"	A guide from IFLA that lists eight questions to ask when evaluating news credibility	(Andersdotter, 2023; Lor, 2018)
Data Literacy	Develop skills to accurately interpret data visualizations as an essential component of health literacy	(Cowles et al., 2024)
Field-specific Literacy		
Patient Library Development	Providing patients with reliable information on alternative and complementary medicine to combat health misinformation	(Bianchini et al., 2019)
AI Literacy	Development of AI literacy to evaluate AI-generated content and related policies in educational institutions	(Andersdotter, 2023; Lewis, 2024; Way & It, 2025)
Historical Context Awareness Education	Teaches the importance of understanding the historical context of old scientific publications to avoid using outdated and non-credible theories	(Frederick, 2023)
Predator Publisher Introduction	Raising awareness about predatory publishers and journals that publish research without proper peer review	(Dobson, 2016)
Campaigns and Collaborations		
"Facts Matter" Campaign	Demonstrate the importance of facts and evidence in a democracy and educate on how to find reliable information.	(Usherwood & Usherwood, 2020)
Collaboration with Educators	Ongoing partnership between librarians and educators to instill critical thinking early on	(Herrero-Diz & López-Rufino, 2021; Oddone & Merga, 2024)
Information Behavior Understanding		
Understanding of Information Sharing Behavior	Improve understanding of the types of information sharing, the purpose of the message sender and the consequences of sharing, especially when false information is involved.	(Bailey & Hsieh-Yee, 2020)

The information evaluation framework is an important foundation for recognizing misleading information. For example, the Currency, Relevance, Authority, Accuracy, Purpose (CRAAP) framework teaches users to assess information's currency, relevance, authority, accuracy, and

purpose (Neely-Sardon & Tignor, 2018; Ojala et al., 2020). Meanwhile, the RADAR framework provides a visual approach in infographics to guide the source evaluation process (Neely-Sardon & Tignor, 2018). The ACRL framework, with the principle "Authority Is Constructed and Contextual," helps users understand that authority is socially constructed and contextual (Paris et al., 2022; Yap et al., 2023). The "Think. Check. Submit" campaign provides practical guidance for identifying credible scientific journals, helping researchers avoid predatory publishers (Ojala et al., 2020). These frameworks provide a systematic structure that helps users critically and methodically evaluate information.

Information verification techniques provide a practical approach to checking the veracity of information. Lateral reading encourages users to leave the document read and open a new browser tab to check the author's authority and the veracity of the claimed facts (Fielding, 2019; Steffy & Long, 2023). The use of reverse image search tools allows verification of the original context of images that are often misused (Cowles et al., 2024). The PAPA (Pause, Authenticate, Prevent, Accuracy) approach teaches users to pause before sharing information and verify its veracity (Steffy & Long, 2023). News syndication recognition training helps users understand how news is distributed and identify fake URLs (Schroeder, 2021). These techniques provide practical tools that can be directly applied in everyday life.

The development of critical thinking skills forms the basis for practical information evaluation. Critical thinking development strategies teach users to evaluate sources based on content, appearance, and context (Neely-Sardon & Tignor, 2018). Critical media literacy involves a partnership between librarians and educators to teach comprehensive information evaluation skills (Lor, 2018). The development of skepticism towards social media encourages users not to take information for granted without further verification (Anderson, 2018). These critical thinking skills are an important foundation as they provide the mental framework necessary to deal with different types of misinformation in the future, regardless of the form or channel.

Education and outreach methods provide different ways to deliver information literacy skills. Workshops and seminars enable in-depth exploration of the structure of online news articles and the influence of social media (Kurmysheva & Pshenichnaya, 2024; Wade & Hornick, 2018). LibGuides offers extensive online resources for fact-checking and news literacy learning (Neely-Sardon & Tignor, 2018). Learning through games makes recognizing fake news more engaging and interactive (Becker, 2021). Library orientation and outreach programs expand access to trusted information sources (Das & Ghosh, 2018). The use of memes as instructional tools leverages popular formats to reach younger audiences (Boyle, 2022). This diverse approach allows the customization of teaching methods to various learning styles and demographic groups.

Practical guides help evaluate information. IFLA infographic on identifying fake news offers eight key questions for assessing news credibility (Andersdotter, 2023; Lor, 2018). Data literacy develops skills to accurately interpret data visualizations, especially in the context of health information (Cowles et al., 2024). These tools offer visual and structured guidance that

makes it easy to apply information literacy principles, especially for beginners or those who need a more direct and practical approach.

Field-specific literacy targets specify areas that are vulnerable to misinformation. The development of patient libraries provides trusted health information on alternative and complementary medicine (Bianchini et al., 2019). AI literacy helps users evaluate AI-generated content and its implications (Andersdotter, 2023; Lewis, 2024; Way & It, 2025). Historical context awareness education teaches the importance of understanding the context of old scientific publications to avoid using obsolete theories (Frederick, 2023). Recognition of predatory publishers raises awareness about journals that publish research without proper peer review (Dobson, 2016). This focus on specific areas recognizes that misleading information is often contextual and requires approaches tailored to specific domains.

Campaigns and collaborations extend the reach of information literacy efforts. The "Facts Matter" campaign demonstrates the importance of facts and evidence in a democracy and how to find reliable information (Usherwood & Usherwood, 2020). Collaboration with educators builds sustainable partnerships between librarians and teachers to instill critical thinking early (Herrero-Diz & López-Rufino, 2021; Oddone & Merga, 2024). These large-scale initiatives are important because they recognize that addressing the problem of misinformation requires a systemic approach involving multiple stakeholders and institutions.

Information behavior understanding explores the psychological and social aspects of interacting with information. Strategies for understanding information-sharing behavior increase awareness of the types of information sharing, the purpose of the message sender, and the consequences of sharing false information (Bailey & Hsieh-Yee, 2020). Research shows that analytical reasoning skills help people distinguish fake news from real news (Cowles et al., 2024). Understanding these behavioral aspects is important because the problem of misinformation is not only technical but also involves human factors. This approach recognizes that addressing information literacy challenges requires understanding how and why people interact with information in certain ways. This behavioral dimension of information complements the technical and educational strategies discussed earlier.

Discussion

This study identifies key findings on misinformation in library science. Librarians use methods to identify misleading information, including pattern observation, IFLA guidelines, source evaluation, and fact verification. Libraries implement countermeasures through user assistance, collection curation, and collaboration with trusted organizations. Modern technologies available include linguistic recognition algorithms, dissemination pattern analysis, and retraction database integration. Information literacy strategies help users recognize misleading information through evaluation frameworks (CRAAP, RADAR), verification techniques (lateral reading), critical thinking development, and specialized literacy in areas like AI and health.

Evolution of the Librarian's Role as Information Gatekeeper

This systematic literature review reveals a fundamental transformation in the role of librarians in the digital age. The studies analyzed consistently show a shift from the traditional function of providing access to information to serving as leaders in information verification (Cowles et al., 2024). This transformation has directly responded to the increasing complexity of information in the digital age, where the ease of producing and disseminating information has created new challenges in ensuring information quality and reliability.

The evolution of this role has significant technical and ethical dimensions. Technically, librarians have developed 13 misinformation identification methods identified in the review, including innovative approaches such as the observation of drafting patterns of false information (Bianchini et al., 2019) and the evaluation of errors in AI responses (Way & It, 2025). These identification methods reflect adapting professional skills to deal with new forms of misinformation. Das and Ghosh (2018) extend identification methods by exploring how librarians carry out the role of guide and companion, helping users find desired information. Lor (2018) identified the concept of the roaming reference librarian, which illustrates a proactive approach where librarians actively seek opportunities to assist users rather than simply waiting for inquiries. These approaches signal a transformation from a passive service model to active engagement in the user's information-seeking process.

The studies revealed increasingly sophisticated strategies for dealing with misinformation. User assistance was one of 22 strategies identified, with others including curating digital collections and integrating notes in nonfiction books to provide context or verification sources (Paris et al., 2022). These strategies show how librarians use various touchpoints with users to improve access to quality information. This evolution occurred in response to eroding public trust in information institutions (Bianchini et al., 2019) and the "infodemic" phenomenon identified by the WHO. In this context, librarians are emerging as important actors in rebuilding trust in an information ecosystem disrupted by misinformation.

Technology Challenges and Library Adaptation

The literature review identifies the complex dynamics between technological developments and libraries' adaptive responses. Technology functions as a double-edged sword, creating new challenges through sophisticated, misleading techniques while offering detection tools. Generative AI technologies have received particular attention in recent literature. Way and It (2025) analyzed challenges posed by AI output such as ChatGPT, identifying how librarians must develop skills to detect false claims and logical fallacies in AI-generated content. The study explores language ambiguity in AI output that makes factual errors difficult to detect.

Predatory journals and non-credible publications present another significant challenge. Nazarovets and Nazarovets (2018) investigated how academic librarians develop criteria to identify questionable journal metrics, building on Jeffrey Beall's work identifying predatory publishers through criteria like missing location information and unqualified staff. Predatory

publishers' ability to mimic legitimate journals makes detection difficult even for experienced researchers (Pomputius, 2019).

Zombie papers—retracted scientific articles that continue to be cited—require special handling. Frederick (2023) explores how ineffective retraction systems allow debunked information to continue circulating. Libraries use the Retraction Watch Database to identify retracted articles, highlighting gaps in digital infrastructure that fail to link retraction information with citation systems.

Libraries have adopted innovative technological solutions in response. Pomputius (2019) analyzed how linguistic recognition algorithms compare specific features in news stories, distinguishing authentic from inauthentic content. The technology uses linguistic computing to analyze language patterns and identify manipulation, while dissemination pattern analysis systems identify unique characteristics of fake news circulation.

Integration of retraction databases with digital identification systems provides another solution. Frederick (2023) describes systems linking databases like Retraction Watch, containing 42,000 scholarly article retractions, with Digital Object Identifiers (DOIs) to facilitate identification of retracted articles. This technology alerts users to article status, preventing further dissemination of problematic information.

Mobile apps for news verification have become part of libraries' technology toolkit. Becker (2021) analyzed apps such as Listle, Owlfactor, and Credder, which provide fake news identification tools. Librarians promote these apps as part of information literacy services, extending verification efforts beyond physical library boundaries.

Librarians have also developed internal evaluation tools. Lewis (2024) describes tools developed to evaluate library web pages, identifying and correcting inaccurate or outdated information. This reflects the recognition that libraries themselves can be sources of outdated information without proper management.

Post-pandemic digital transformation has significantly changed information access patterns. Oddone and Merga (2024) analyzed library adaptations to these shifts, highlighting new challenges in information curation and preservation. The study identifies increased pressure on librarians to verify online source quality when physical collections become less accessible, accelerating existing digital adaptation trends.

A Comprehensive Approach to Information Literacy

This literature review shows significant evolution in information literacy from simple knowledge transmission to integrated, multidimensional approaches. The strategies identified incorporate evaluation frameworks, verification techniques, and critical thinking development to empower users against misleading information.

Lateral reading techniques emerge as an innovative approach challenging traditional evaluation methods. Fielding (2019) and Steffy and Long (2023) explore how this technique encourages users to seek external information about sources, changing information evaluation paradigms. Lateral reading overcomes limitations of close reading approaches that can trap readers in convincing but misleading narratives.

The PAPA (Pause, Authenticate, Prevent, Accuracy) approach, analyzed by Steffy and Long (2023), provides a practical framework recognizing behavioral and emotional dimensions of information interaction. This strategy encourages users to pause before sharing information, integrating behavioral science understanding into information literacy.

AI literacy has emerged as a critical new focus. Way and It (2025) and Lewis (2024) explore how librarians help users evaluate AI-generated content. These studies address challenges including AI hallucinations, system biases, and attribution questions, preparing users for an era where human- and AI-generated content distinctions are increasingly blurred.

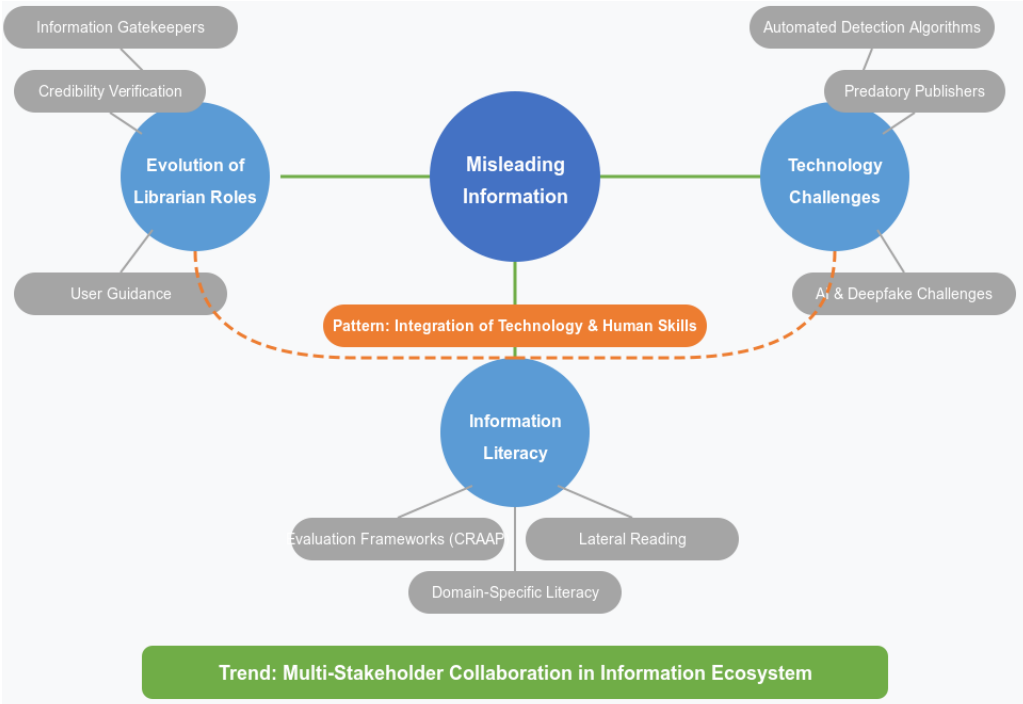
Wade and Hornick (2018) and Kurmysheva and Pshenichnaya (2024) analyzed workshops and seminars exploring online news structure and social media bias mechanisms. Neely-Sardon and Tignor (2018) examined LibGuides for fact-checking resources, while Becker (2021) explored games as tools to train users in recognizing fake news. Boyle (2022) analyzed memes as instructional tools, leveraging formats familiar to students to convey critical evaluation concepts. Usherwood and Usherwood (2020) analyzed the “Facts Matter” campaign, which emphasized facts and evidence in democracy, demonstrating how libraries engage in broader societal information literacy advocacy.

Herrero-Diz and López-Rufino (2021) and Oddone and Merga (2024) analyzed collaborations between librarians and educators, forming Triads of Truth-Workers that combine librarians, teachers, and journalists to combat misleading information. These partnerships leverage different stakeholders’ expertise, with librarians contributing perspectives on source evaluation and information management.

Bailey and Hsieh-Yee (2020) explored information-sharing behavior, analyzing sharing types, sender motivations, and the consequences of spreading false information. These target cognitive skills, information behavior, social context, and domain-specific needs, representing a significant development of traditional information literacy models adapted to increasingly complex digital information landscapes.

Figure 1

Main Findings from Systematic Literature Review on Misleading Information



Patterns, Trends, and Relationships Between Findings in A Systematic Literature Review

Identified Patterns: Integration of Technology and Human Skills

The dominant pattern that emerges is the integration of automated detection technologies and librarians' critical judgment. Studies show practical approaches combining linguistic recognition algorithms (Pomputius, 2019) with librarians' critical evaluation. Way and It (2025) showed that librarians identify errors in AI responses that are difficult for algorithms to detect. Frederick (Frederick, 2023) analyzed the integration of article retraction databases with library systems but emphasized the role of librarians in providing critical context. Cowles et al. (Cowles et al., 2024) describe using a reverse image search tool to verify image authenticity while demonstrating the technique to users.

Identified Patterns: Shift from Passive to Active Approach

The literature reveals a shift from libraries as passive filters of information to active empowerers of users. Neely-Sardon and Tignor (2018) describe the evolution from providing trusted sources to teaching users about journalistic ethics and the information cycle. Lor (2018) explores the concept of a "roaming reference librarian" who proactively guides users. Steffy and Long (2023) analyzed the PAPA (Pause, Authenticate, Prevent, Accuracy) approach that empowers users to evaluate information independently. Boyle (Boyle, 2022) demonstrated using educational memes to encourage critical evaluation of information on social media.

Emerging Trends: Multi-Stakeholder Collaboration in Information Ecosystems

A significant trend is increased collaboration between various stakeholders. Herrero-Diz and López-Rufino (2021) describe a "Triad of Truth-Workers" that combines librarians, teachers, and journalists. Usherwood and Usherwood (2020) analyzed the "Facts Matter" campaign as an example of a collaborative approach. Oddone and Merga (2024) highlighted the partnership between librarians and teachers to develop digital health literacy.

Emerging Trends: Focus on Domain-Specific Literacy

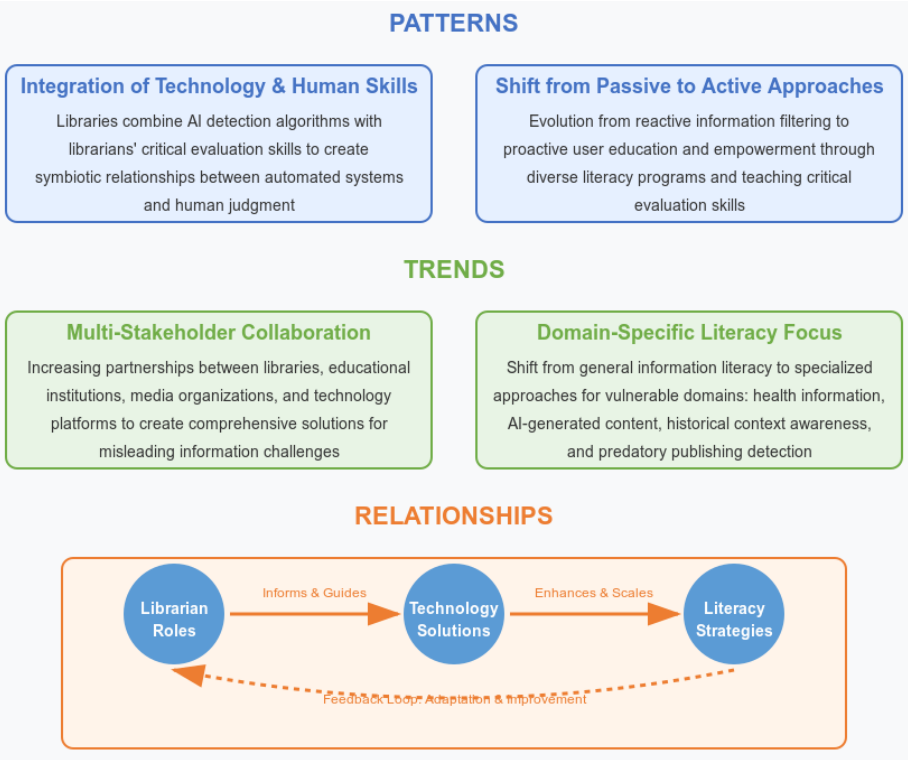
There has been a shift from generic information literacy towards approaches tailored to specific domains. Oddone and Merga (2024) and Steffy and Long (2023) analyzed the development of digital health literacy. Way and It (2025) and Lewis (2024) highlighted AI literacy to evaluate AI-generated content. Frederick (2023) identified the importance of historical context in understanding old scientific publications. Dobson (2016) and Ojala et al. (2020) emphasized academic publishing literacy to recognize predatory journals.

Relationship Between Findings: Symbiotic Relationship Between Themes

Domain-specific literacy strategies (Oddone & Merga, 2024) are evolving in response to technological challenges and contextual information. These patterns, trends, and relationships demonstrate a significant evolution in how libraries respond to misinformation with increasingly integrated, proactive, collaborative, and contextualized approaches. These models reflect adaptation to the complexity of the contemporary information landscape and the recognition that addressing misinformation requires a comprehensive ecosystem approach.

Figure 2

Patterns, Trends, and Relationships Among Findings



Conclusion

This systematic literature review reveals librarians' evolution from passive information providers to active information verification vanguards. The analysis shows effective integration between automated detection technologies and librarians' critical judgment, along with trends in multi-stakeholder collaboration and domain-specific literacy.

The review contributes to library science knowledge by revealing patterns and relationships in the handling of misleading information. Proposed frameworks, including the "Triad of Truth-Workers" and the multidimensional information literacy model, enhance theoretical understanding.

Findings indicate librarians need misinformation detection skills, stakeholder collaboration capabilities, and tailored information literacy programs. The results are relevant for policymakers developing disinformation-handling strategies.

The review's scope is limited to specific timeframes and languages, with uneven data availability across topics. Future research should explore AI technologies in misinformation detection, conduct longitudinal studies on information literacy program impacts, and investigate stakeholder collaboration dynamics to further the understanding of libraries' role in combating digital disinformation.

Declaration of Generative AI and AI-Assisted Technology in the Writing Process

At the stage of work on this article, the authors partially used Grammarly software (https://app.grammarly.com/) to improve the accuracy and clarity of English. After applying this tool, the authors made careful revisions and edits for quality and accept full responsibility for releasing this publication.

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Corresponding Author: Ismiatun
Email: ismi.editor@ub.ac.id

Unearthing the Ideation Process Used by Graphic Design Students in Ghanaian Universities

Sylvanus Ametordzi
Cape Coast Technical University, Ghana

Folasayo Enoch Olalere
The Open University, United Kingdom, &
Durban University of Technology, South Africa

Abstract

Design ideation is a critical early step in any design process to generate a large number of ideas that can be cut down into the best and most innovative ones to inspire better design solutions and products. This study seeks to unearth how graphic design students generate design ideas and the extent to which traditional analogue and digital tools are being used in the design process. Ontologically, the study assumes a subjective stance, and it is epistemologically constructive. Therefore, the research methodology adopted is qualitative, and the data collection methods are interviews and observation. The twenty-eight participants of the study were made up of twenty-four graphic design students and four lecturers from two universities in Ghana. It was discovered that during design ideation, students conducted research on design briefs; embarked on mind mapping; engaged in brainstorming; made pencil sketches and digital illustrations of selected ideas; and evaluated the ideas for final selection. Findings indicate that students predominantly depend on digital tools during idea development because these tools provide quick access to research information on design briefs, enhance design idea visualization and enable students to generate a greater volume of ideas. With the heavy reliance on digital technology in today's design idea generation process, it is recommended that design ideation models should be developed to include digital idea exploration to depict the totality of the ideation process in a modern design perspective. The use of this digital model in design pedagogy will help produce graduates who meet clients' and industry expectations.

Keywords: design ideation, design process, digital illustration, preliminary sketches

Successful innovations depend upon the inputs made during development. Similarly, effective design outputs depend on preliminary inputs from the designer, which are often unnoticed by the public. Design idea development begins as an abstract concept in the designer's cognition without physical evidence. According to Taegyun (2020), design ideation begins with a design brief and culminates in various concepts expressed through thumbnail sketches. Some consider this stage the most exciting in the design thinking process (Rikke & Teo, 2020). In graphic design, abstract ideas are communicated through sketches, with one selected for actual execution, making concepts visual and tangible for effective solution design (Dell'Era et al., 2020). Rikke and Teo (2020) note that ideation aims to generate numerous ideas that can be filtered to identify the best, or innovative options for improved design solutions. The quality of ideas generated significantly impacts the design process and its outcomes (Orthel & Day, 2016). The overall goal is to produce novel or creative solutions in response to the design brief. Ideation processes in graphic design education have changed significantly with digital technologies. Previously, students developed ideas manually using pencil sketches (McGlashan, 2017). However, integrating digital tools has transformed the ideation process, providing designers access to resources that enable experimentation with new approaches during ideation (Enninful & Boakye-Amponsah, 2022).

This study explores the ideation processes employed by graphic design students, from the initial design briefing to the final idea selection, with emphasis on their reliance on traditional and digital techniques. The study aims to uncover the characteristics of students' ideation experiences and how digital technology enhances their creativity and efficiency. It seeks to provide insights into the effectiveness of these processes and suggest improvements in graphic design education. By examining these processes, the study will help understand how design education should adapt to technological advancements and the evolving needs of the industry. Insights gained are essential for aligning educational practices with today's creative environment and design market.

This study is significant in several contexts. Firstly, it contributes to academic discourse on graphic design education. It does this by highlighting the shifts in ideation practices and the impact of digital technology on creativity. Secondly, understanding these factors can inform curriculum development, aligning educational programs with industry standards to equip students for technology-driven tasks in design. Additionally, the findings will help educators identify effective teaching strategies that encourage collaboration and creativity. Lastly, by examining the integration of traditional and digital approaches, the study can guide future research on the interaction between technology and design, thereby enhancing design studies. Originally shaped by cultural heritage and colonial influences, Ghanaian graphic design is evolving, embracing diverse styles and approaches through digital and multimedia technologies. exploring how students approach design ideation will help bridge the gap between academic training and industry requirements, ensuring that graduates are better prepared for the workforce. By identifying effective strategies and challenges in design creative processes, the study will encourage more effective practices that enhance creativity in Ghanaian design. Insights gained in the study can lead to the creation of resources, workshops, and support systems tailored to the needs of graphic design students in Ghana. This will

ultimately provide a richer, more relevant approach to design education and practice, enhancing their skills and capabilities.

Problem Statement

With the advent of technology, the ideation processes are transformed, embracing diverse styles and approaches through digital and multimedia tools. According to the Economic Commission for Latin America and the Caribbean (ECLAC, 2021), digital technologies have grown exponentially, and their use has globalized. This has led to the integration of digital technologies in the design ideation process (Camba et al., 2018; Evans & Aldoy, 2016). Each stage of design ideation is characterized by a series of design activities that lead to the generation of creative ideas (Chan, 2015; Chittka & Osorio 2007; Pettersson, 2021). There is a wealth of existing literature on the design ideation process where creative ideas are generated and evaluated (Casakin & Levy, 2020; Kim, 2020; Kelley & Kelley, 2014), with much focus on design cognition, the ideation skills of design experts and novices. However, research has not established how technology has affected design activities in the ideation process, especially in today's graphic design practices. This needs to be investigated as it may provide useful information to guide creative digital idea generation.

Aim

This study explores the current design ideation processes that graphic design students adopt and how digital technologies influence activities in the ideation stages. The study asked two research questions:

1. What are the activities that characterize the design ideation stages among students?
2. How does digital technology influence the preparation and the idea generation stages of the ideation process?

Literature Review

Ideation Models

Design idea development, which is part of the design process, started several decades ago. It is also known as the creative process. The concept of ideation is essentially the exploration and transformation of conceptual spaces to generate ideas. According to Warr and O'Neill (2005), creative process models are used to describe the various stages that occur in the process of idea generation. This section discusses some key ideation models found in the literature

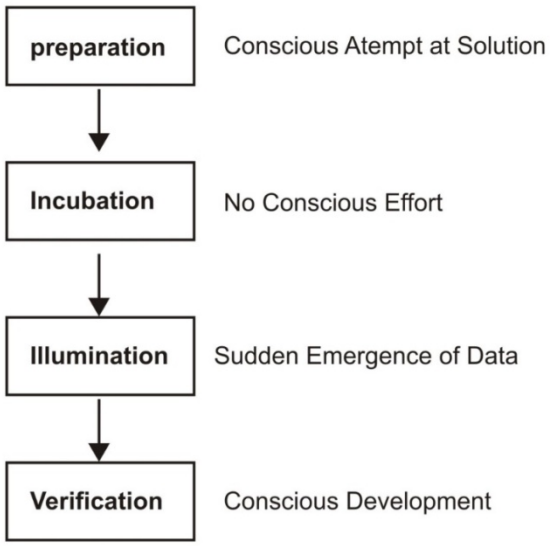
Wallas's Model of Design Ideation

One of the earliest models was created by Wallas (1926). This model consisted of a four-stage model of the creative process. As shown in Figure 1, the four stages included Preparation, Incubation, Illumination, and Verification. At the Preparation stage, the designer must acquire knowledge of the design task to produce creative solutions. Lawson (2005) notes that this stage

involves significant conscious effort in searching for a solution, with ideas emerging as the problem is reformulated. In the incubation stage, the designer reflects on the problem, seeking the best approach for idea generation. According to Lubart (2001), while taking breaks, the designer's mind continues to work on the problem unconsciously, leading to valuable idea combinations. The next stage is Illumination. Subject to mental activities in the incubation stage, ideas begin to drop into the mind of the designer, and he begins to externalize them either through writing, drawing or modeling, depending on the kind of task at hand. At the Verification stage, newly generated ideas are subjected to some form of evaluation on purpose to select the most creative one for further development.

Figure 1

Model of Design Ideation (Wallas, 1926)



Amabile's Model of Design Ideation

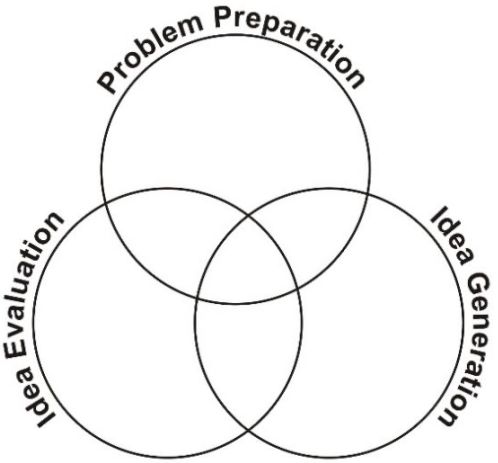
In Amabile's (1983) view, there are only two important stages in creative idea processing. Those are *Idea Generation* and *Idea Evaluation*. The author neglected the preparation and incubation stages in Wallas's (1926) model. He emphasizes the idea-finding and visual representations that help generate novel ideas. These ideas are then evaluated for appropriateness and novelty, leading to solution selection. Amabile considered the initial preparations and incubation stages, which involve cognitive processes for idea evocation, less important. He later developed a five-stage ideation model, which included P*roblem and Task Presentation, Preparation, Response Generation, Response Validation,* and O*utcome.* Amabile's model resembles Wallas's (1926) ideation model but introduces Problem and Task Presentation as the first stage, marking the designer's initial contact with the design problem through briefings. This stage helps the designer understand the task's goals and objectives. Wallas uses the terms Response Generation and Response Validation instead of Idea Generation and Idea Validation, because he perceives generated ideas as responses. Amabile's

(1983) model does not significantly alter existing frameworks, as the first stage can be placed under the second stage (Preparation), essentially mirroring Wallas's model.

Warr and O'Neill's (2005) Model of Design Ideation

Warr and O'Neill (2005), on the other hand, organized the ideation process into three stages: Problem Preparation, Idea Generation, and Idea Evaluation. As seen in Figure 2, Problem Preparation refers to preliminary preparations, such as understanding the problem, researching it, and reframing it. Idea generation is the designer's physical projection of an idea through writing, drawing, or modelling to communicate the intention to solve a problem. Idea evaluation involves selecting quality solutions based on their appropriateness and novelty.

Figure 2
Generic Creative Process Model (Warr & O'Neill, 2005)



While the models discussed, are often used as creativity support tools, they face criticism for their static, linear nature (Warr & O'Neill, 2005). As a result, new models have been developed that move beyond the basic four-stage process to include sub-processes such as problem finding, formation, and redefinition. Wallas (1926) observed noted that during creative problem solving, designers may revisit earlier phases in the process. This was supported by Warr and O'Neill (2005) as they state that the models show various stages of the intertwined and iterative nature of creativity (Warr & O'Neill 2005). In short, they were not intended to be step-wise linear models.

Reviewing these models reveals that scholars have sought to better represent the ideation process in creative design to aid designers in finding innovative solutions. While the models differ in stages and terminology, similarities exist. Amabile's (1983) model includes only Idea Generation and Idea Evaluation, neglecting the crucial preparatory phases that enhance effective ideation. This makes the model seem incomplete, potentially limiting its applicability in guiding designers through the stages of ideation necessary for developing innovative solutions.

Although Wallas (1926) incorporated important cognitive elements like Incubation and Illumination in his design ideation model, it lacks clear criteria for idea evaluation. This lack of evaluation can hinder the assessment of the quality and effectiveness of ideas. Additionally, the linear presentation of the four stages fails to capture the iterative nature of real-world design processes. This rigidity limits understanding of how designers navigate these stages.

The Generic Creative Process Model by Warr and O'Neill (2005) covered three key components: Problem Preparation, Idea Generation, and Idea Evaluation. Problem Preparation emphasizes initial research and reframing to ensure that the ideation process is grounded in a solid foundation for relevant solutions. Similar to other models, it highlights the externalization of design ideas during Idea Generation. Additionally, the model incorporates Idea Evaluation, emphasizing the need to assess design ideas based on their appropriateness and novelty. These three stages are essential components of the ideation process as they cover important aspects of the idea creation process. In view of this, this study adopted the Generic Creative Process Model proposed by Warr and O'Neill (2005) as the standard model that guided data collection and discussions related to design ideation and the impact of digital technologies.

Strengths and Limitations of the Design Ideation Models

Wallas's Model of Design Ideation

The model outlines distinct stages (Preparation, Incubation, Illumination, Verification), aiding designers in understanding creative problem-solving steps. By including the Incubation stage, Wallas highlights the value of subconscious processing and the need for time away from the problem. However, the model downplays its iterative nature, crucial in real-life design process. The model fails to capture the dynamic and non-linear aspects of creativity, which often involves fluid movement between stages. It primarily focuses on individual cognitive processes, potentially neglecting collaborative and social dimensions of design ideation.

Amabile's Model of Design Ideation

The model emphasizes the importance of evaluating ideas for novelty and appropriateness, encouraging designers to refine their concepts. However, condensing the creative process into just two stages (Idea Generation and Idea Evaluation), Amabile's model overlooks important preparatory and incubation phases essential for effective ideation. This focus on visual representation and immediate evaluation neglects the cognitive depth involved in developing creative solutions. Additionally, prioritizing novelty and appropriateness in evaluation misses a more holistic approach to creativity in design.

Warr and O'Neill's Model of Design Ideation

Warr and O'Neill's model recognizes the iterative nature of creativity, reflecting real-world design practices where designers revisit stages as new insights arise. By organizing the ideation process into three stages (Problem Preparation, Idea Generation, and Idea Evaluation), this model offers a

logical flow to guide designers. However, while these stages are helpful, the simplification overlooks the complex relationships between the stages. Additionally, the model does not explore specific sub-processes, such as emotional or contextual factors, that can influence ideation.

The Applicability of the Models to Contemporary Digital Design Practices

Similar to Wallas's model, Warr and O'Neill's model highlights the critical role of the preparation stage. The preparation stage is foundational, involving thorough research, understanding the design brief, and defining the problem, all of which are crucial for guiding the design process. This stage ensures designers align their work with user expectations and market demands. Wallas's Model of Design Ideation introduces "Incubation," a unique construct. This is very useful in contemporary idea development as it facilitates subconscious processing that can lead to innovative insights. Though Amabile's (1983) model has only two stages (*Idea Generation* and *Idea Evaluation*), which is too limited in guiding effective ideation, these stages are vital in contemporary design ideation. Like Warr and O'Neill's model, Amabile's (1983) model emphasizes idea evaluation. In a rapidly evolving digital landscape, generating a wide range of ideas and critically assessing them is essential for effective design solutions.

Overall, the stages of preparation, incubation, idea generation, and evaluation in these models are vital for promoting creativity in modern digital design practices. While none of the models perfectly captures the complexity of modern ideation, each of them offers important constructs for effective idea development in the contemporary design process.

Technological Revolution

The technological revolution has combined with changes in strategies of leading companies to enhance the role of global platforms (ECLAC, 2021). This shift is expected to impact all areas of life, including social, industrial, and educational sectors. Significant transformations are evident in education worldwide, with technology influencing design approaches among students in higher education. Sreekanth and Viswanathan (2020), as well as Camba et al., (2018), observe that new designers and graduates are more proficient in the use of Computer Aided Design (CAD) packages even in the ideation stage of product design. This corroborates an earlier study conducted by Veisz et al. (2012), which reported a significant decline in the use of pencils in the early stage of the design process among engineering students as they prefer CAD. Digitization has transformed design ideation, moving from traditional paper and pencil to digital methods using digital devices during the ideation stage. Barnes (2017) notes that computer software is replacing hand drawing as a growing trend. According to Aboalgasm and Ward (2014), laptops and tablets are the digital devices that graphic artists commonly use. Wang & Wang (2021) highlight the benefits of digital approaches, such as ease of publication, sharing, and correcting mistakes.

Philosophical Assumptions

The phenomenon of digital design ideation is complex. It consists of multiple realities shaped by students' experiences, perspectives, and social contexts. The study adopts a constructivist and

interpretivist paradigm, acknowledging that students have varying experiences, backgrounds, and environments. Individual students differ in their exposure to design tools, approaches, experiences, studio setups, and technology fluency. These realities can be understood only through effective communication and interpretation of hidden facts, allowing for the reconciliation of subjective interpretations and highlighting the complexities of the phenomenon.

Methodology and Methods

Constructivism allows a flexible process of interactions between researcher and research participants (Bhatta, 2018), which leads to openness and richness of data. As a result of this epistemological stance, the research methodology adopted is qualitative in nature. The methods of data collection adopted are interview and observation.

Population

With regards to this study, the target population is graphic design students in Ghanaian universities. Graphic design students from Kwame Nkrumah University of Science and Technology and Takoradi Technical University form the accessible population of the study.

Sample (Participants)

The sample for this study was drawn from third and fourth-year graphic design students in a Traditional University and from the second and third-year students in the Technical University. There were 28 participants. Twelve (12) students and two lecturers came from each of the two universities.

Sampling Technique

Purposive sampling was used to gather specific data on design ideation. Lecturers teaching courses like Graphic Applications, Advertising Design, and Computer Graphics were selected. These courses provided relevant information and formed the ideal participants. Twelve students and four lecturers were selected from each university, who were scheduled for one-on-one interviews with the researcher at a mutually agreed time and place, after being informed about the study and signing consent forms.

Data Collection Procedure

Observation

Since ideation flourishes in opportunistic environments as opposed to organizational ones, direct observation was carried out without interfering with the flow of concepts during the design process. This helped in capturing quality and realistic data. The observations covered two major stages of ideation: preparation (research) and the idea creative process. To capture every important detail with regard to the research questions, an observational protocol was developed. Table 4.1 provides details about this protocol.

Table 1

Observational Protocol and Tools

Area	Purpose	Observational Protocol (Activities observed)	Duration / Data Sources
Preparation	To take note of digital devices used by designers, sources of design inspiration, and the websites they visited while browsing for design inspiration.	Observations of if and how design students a. researched the design brief b. used digital portfolios c. collected inspirational materials d used theme boards (physical or digital) e. engaged in brainstorming	three hours in two separate sections Field notes and Photographs
Idea Creation	To identify digital devices used by designers, the software they used during ideation, their digital fluency and how all of these affect ideation outcomes.	Observations of if and how design students: a. used at least one electronic device when developing design ideas b. used proficiently at least one drawing software. c. accessed a personal computer d. depended on their friend's computer to work e. accessed the internet for browsing any time they want f. used only electronic devices for idea development or in combination with pencil sketches g. used multiple electronic devices when developing an idea h. utilized digital devices in search of multimodal sources of inspiration for creative ideas i. used multiple electronic devices when developing an idea j. utilized digital devices in search of multimodal sources of inspiration for creative ideas	three hours in two separate sections Field notes Photographs

Interview

Open-ended, semi-structured questions were used during the interviews (e.g. how can ideation be improved using technology?). This allowed a conversational flow that facilitated in-depth exploration. The semi-structured interviewing approach ensured the interviewer was not bound to the rigid sequence of questions outlined in the interview guide. Such flexibility enabled the investigator to ask follow-up questions, when necessary, thereby enriching the data collection process. The interviews were audio-recorded, subsequently transcribed, and subjected to thorough analysis to extract meaningful insights.

Data Analysis

In this study, a qualitative dataset was collected, transcribed, organized, and analyzed to uncover hidden trends and insights. Thematic analysis, which focuses on identifying patterns or themes within qualitative data (Maguire & Delahunt, 2017), was employed. Given the exploratory nature of the research, data collection and analysis were primarily guided by a phenomenological perspective. This approach emphasized the meaning-making surrounding contextual issues. Data from unstructured observations and interviews on the graphic design ideation process of students were systematically analyzed using thematic analysis and category coding. The research followed Braun and Clarke's (2006) six-step process for thematic analysis.

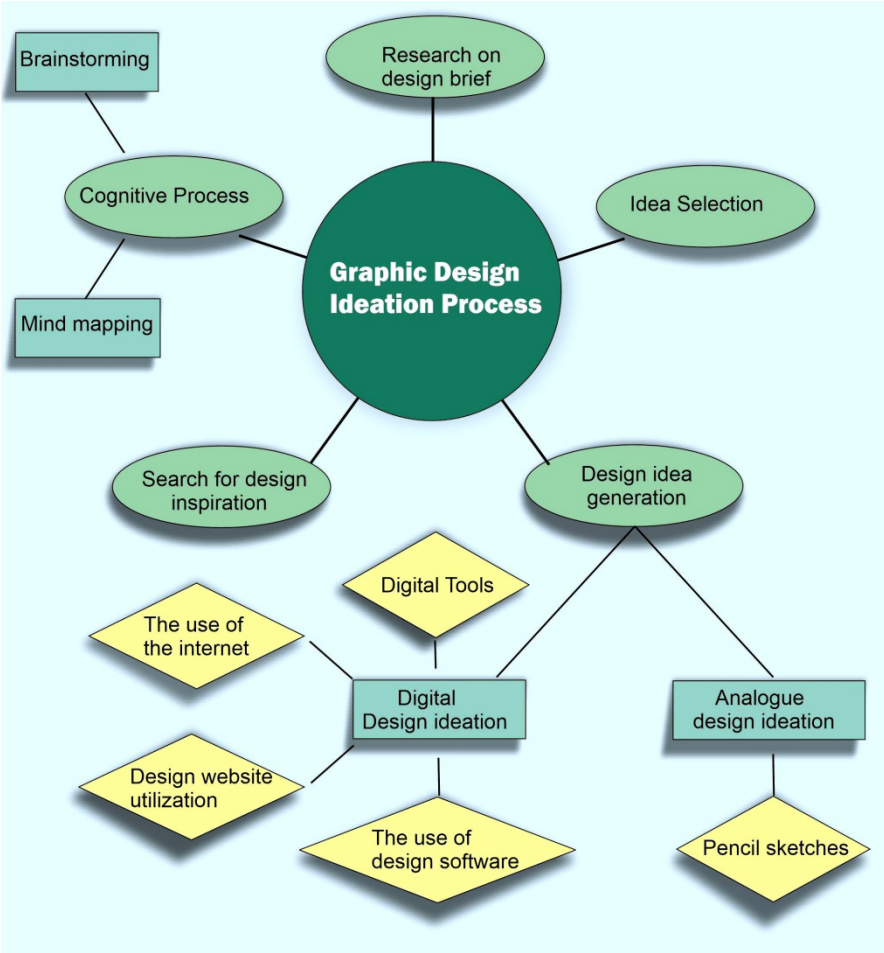
The process began with data familiarisation, where researchers immersed themselves in the dataset to understand its depth and nuances. This was followed by initial code generation to categorize data segments. Next, potential themes were identified from the coded data and refined during the theme review stage for relevance and coherence. Once established, the themes were clearly defined and named. Finally, the findings were compiled into a comprehensive report. These steps provided a structured and practical framework for conducting a thorough thematic analysis of the data.

In addition, *the students' design artifacts were evaluated using four coding parameters:* the idea counts, variety, novelty of design, and the selection made by the design students. These help to understand the variations in students' ideas and how they choose the idea to progress during the design process.

Results

An analysis of the graphic design ideation process among design students revealed five overarching themes, from which several themes and sub-themes were derived, as depicted in Figure 3.

Figure 3
Themes and Sub-Themes



The study's first research question asked, 'Which ideation processes do graphic design students adopt?' The objective of this question was to find out what characterized the design students' ideation processes from design briefing to idea selection. It was also aimed at unearthing whether students depend on the traditional approach of pencil sketches or use digital devices during ideation.

The Internet as a Necessary Tool in Graphic Design Ideation

Graphic design students in both universities depended on the internet during the design ideation process. The students connected the internet to various digital devices for their design work. When participants were asked whether they used Wi-Fi (internet) for their design ideation, they responded affirmatively. Responses revealed that every participant used the internet during design ideation. Some responses regarding the use of the internet included:

> "Yes, for research and inspirations". (Participant KN 2a)

> "It helps a lot because you kind of know what is already there, what people have and what people haven't done by researching". (Participant KN 4a)

> "Yes, if I am doing a logo for myself like OS that is to combine O and S for a design, I will go online and search how to combine O and S to form a design". (Participant 2a)

Responses from the three respondents indicated that designers primarily used the internet for research and gathering design inspiration. These stages significantly influence design output. The research stage helps designers understand the brief, while gathering inspiration supports creative ideation. Literature suggests that designers formulate the initial design problem and conduct research on similar projects for information and existing solutions (Shukla, 2011), typically using the internet. When responding to an interview question on the benefits of using the internet for ideation, one participant said,

> Benefits of using the internet during ideation is if am supposed to work on say, 'e-commerce' I will simply type e-commerce and add logos to it and you will be surprised the results that will come out with. So hardly do I take my pen to go through this ideation process. You sit back and look at ten 'e- commerce' logos designed by somebody and it exposes you to what you wouldn't have known *(*Participant 3c)

In other words, this respondent is trying to establish that ideas are readily available on the internet. Because of this, he hardly sketches with a pen. This confirms Afif's (2016) statement that the availability of modern technology leads to easier communication, access to information, and improvement in skills and work.

Research on Design Brief

It was observed that students received design briefs from their lecturers and, like all designers, sought to understand them. Depending on the brief, they engaged potential consumers for answers, visiting shops, marketplaces, or offices. They also conducted research on the briefs by browsing on the internet. In response to a question regarding research, one of the participants said, "We go out to collect information before we design. It is like you doing a newspaper. You have to go out for the information." (Participant 2a)

The internet provided design students with quick access to vast resources and visual communication designs, enabling efficient research and inspiration anytime, anywhere. The integration of online resources enhanced their skills, allowing easy exploration of existing solutions and innovative ideas.

Brainstorming

Brainstorming was one strong problem-solving approach identified among students across the two universities. The brainstorming session is always characterized by round table discussions

and free flow of ideas from every member. The researcher observed students in these discussion sessions a number of times. The researcher observed some groups from a distance and occasionally sat close to their discussion table, allowing him to listen in. The sessions were well-organized, typically led by a facilitator and a secretary for note-taking. According to Mindmanager (2019), brainstorming should avoid judgments about ideas. The discussions took place without criticism, and students sometimes used their smartphones to look up relevant information. When the team leader posed a question, they were given a break of seven to ten minutes to search online, leading to impressive ideas when the discussions resumed. Students effectively utilized their smartphones for design ideation.

Eager to hear from students regarding these brainstorming sessions, the researcher asked during face-to-face interviews why they were important. This is what the students had to say:

> We are able to get ideas from each person" (Participant KN 2b). "You have to know how to work with people. And working with groups, you can achieve greater things." (Participant 3e). "… Sometimes the assignment is not even clear but when a group member explains, we all understand it. (Participant KN 2a)

In a separate interview with one of the lecturers, he said,

> … another technique that has to do with ideation has to do with brainstorming session. Having them in groups and then encouraging them to share ideas is also a technique that the individual is supposed to have with the confidence that he will listen to other people's ideas to improve his or her idea. (KN Lecture 1)

From these responses, it is clear that brainstorming is a necessary tool in design ideation. Design ideation sessions provided team members with the opportunity to have a better understanding of the design task and generating numerous and divergent ideas that lead to creative solutions.

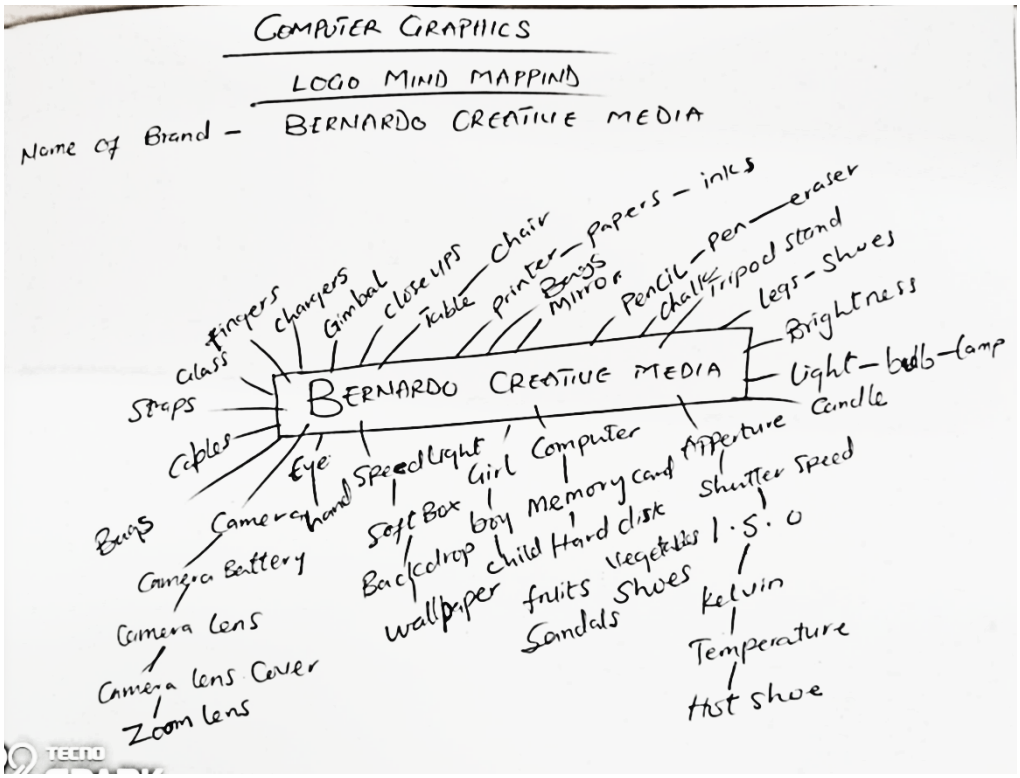
Mind Mapping

A great number of students mentioned mind mapping as an initial approach to idea development. In a response to the question, 'Which will you advice designers to use for ideation, pencil sketches or digital devices?', an interviewee said, "They should mind map, have everything on paper so that when they go behind the machine they know what they are coming to do".

The participants considered mind mapping as an integral part of design ideation. They admitted that it helped them in generating ideas. It allowed externalization of ideas as a structured network that comprises textual and visual representation of concepts emanating from a central problem and radiating outward (Elmeshai, 2021).

Figure 4

Sample Mind Map Created by a Student During a Design Brief



As can be seen in Figure 4, a central theme appeared in the rectangular shape. Connected to the rectangle were various ideas related to the theme. These elements were then analyzed and synthesized for idea creation.

The Use of Pencil Sketches and Digital Illustrations in Ideation

Design activities engaged in by the design students involved analogue and digital approaches. Some students admitted that they used electronic devices in combination with pencil sketches during ideation. When asked why they liked combining the two, they stated that they were more comfortable with that approach because it was much easier. During an interview, Participant 3d said the following:

> Me, for example, when I am designing, I have to sketch first with pencil or pen, then I transfer it to the PC. I scan it using my phone and transfer it to the PC, then I sketch it and work on it.

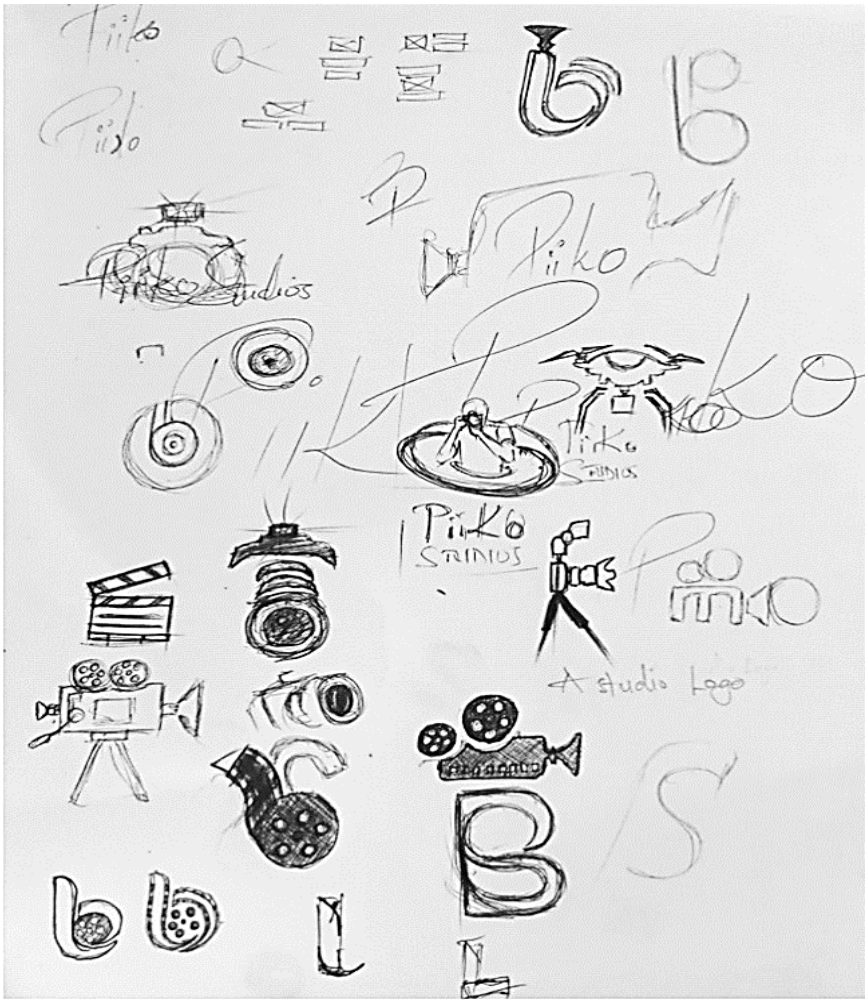
Most of the students in the two universities used sketchpads for design ideation. It was observed that the students used pencils and pens as their major drawing tools for sketching ideas. These sketches were later illustrated digitally and presented for evaluation and selection. The selection was done by the lecturer or by peer critiquing.

Idea Generation 1

Figure 5 shows the ideation outcomes of a Traditional University student who was tasked with generating ideas suitable for a video studio logo. His work page was filled with various pencil designs, some deep and others faint, each stroke meaningful to the designer. The ideas were not arranged in organized thumbnail boxes but were clearly visible. The upper part of the worksheet (Figure 5) displays scribbled ideas that were juxtaposed with faint pencil drawings, marking the start of the idea creation process. Although the pencil work is unclear for analysis, it plays a crucial role in preparing the designer cognitively for the task ahead.

Figure 5

Sample Ideas Generated by a Design Student



Looking at the pencil work from the top and moving midway through Figure 5, the ideas appeared to be becoming clear and distinct, indicating improvement in the thought pattern of the designer.

Figure 5 shows that the designer generated several ideas based on the brief, combining sketches of video-making equipment with words. While each design was distinct and impressive, one

stood out as the most novel. This idea depicted the video camera's internal structure with two exposed tape wheels, creatively incorporating the studio name, Piiko Studio, as an abbreviation.

Although the camera position and studio abbreviation were not the best, the concept was novel. To organize the design effectively, the designer created a series of drawings, alternating images and text for optimal output. Pen and paper were used to execute the work.

Idea Generation 2

In this task, the designer was required to design a logo for a corporate identity of a clpud computing company. To start with, the designer gathered different digital images from various websites and organized them into digital mood board.

Figure 6

Sample of a Digital Mood Board for Design Inspiration

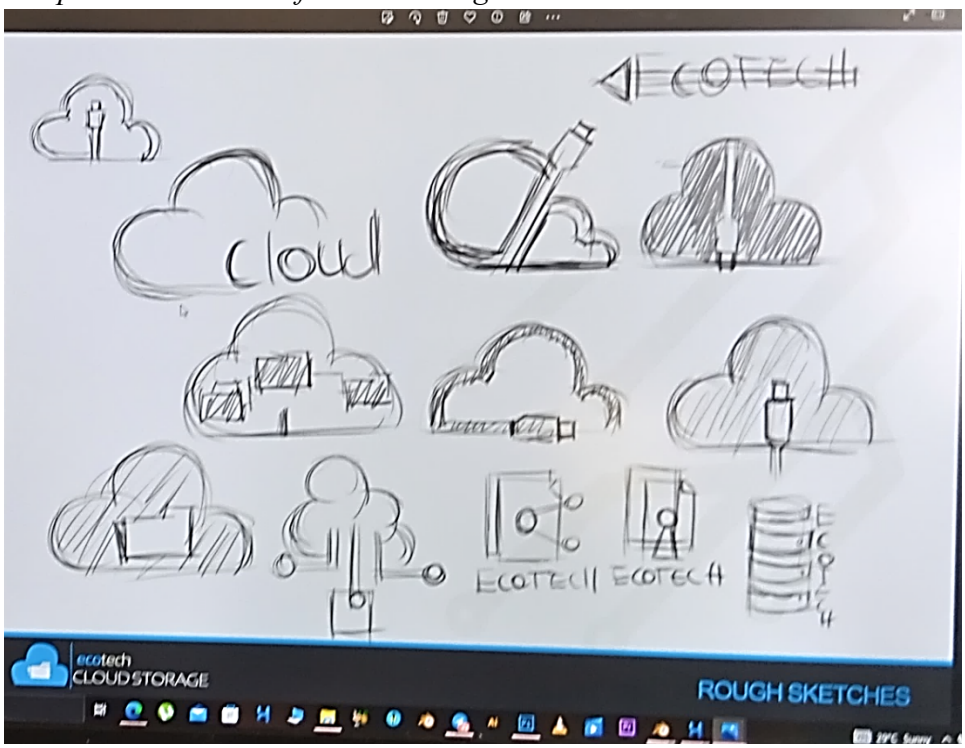
In Figure 6, the mood board included storage devices of different kinds, network cables, images of clouds, and document folders. Gathering images from diverse sources allowed the designer to generate creative ideas through analogies and metaphors. Gentes et al. (2015) described mood boards as a way to create homogeneity from heterogeneity. These collages of images, text, and object samples help designers express and explore visual concepts (Koch et al., 2020). This preparatory work significantly influences the ideas developed, as elements from the mood board often appear in the generated concepts.

Pencil Sketches of Ideas from the Digital Mood Board

Using the images in the mood board, pencil and paper sketches of ideas were generated (see Figure 7). The sketches were scanned and transferred to the laptop to be traced in a vector software for further development.

Figure 7

Sample Sketches Transferred to a Digital Form



Twelve design sketches were produced. Each idea was unique. From the twelve generated, one was chosen for refinement; this was a simplified cloud with a folder icon. It represents digital files organized in a folder, suggesting that seeing a folder in the cloud (Figure 7) relates to cloud computing.

Figure 8

Sample Selected Idea from the Various Ideas Generated

Digital Illustration

The selected idea was refined in vector software by adjusting elements to the right proportions. Each detail was considered, with new elements added or existing ones removed for balance.

Negative spaces were adjusted, and distances between shapes were examined. Disconnected elements were arranged closer to enhance connections. The colour inspiration for the design was drawn from the digital mood board. The blue and white colours, as used by the designer, made sense because they are dominant in the mood board. The size of the folder and font were also good. In all, the elements were well organized with good balance (see Figure 9).

Figure 9

Sample Colour Tests Using a Single Design

Haven achieved the main shapes and sizes of the design's elements, varied colour tests were made by the designer. The pupose of these tests was to see what outcome would look like. Out of these colour tests, one was selected to represent the final design. At this point, the pencil work was transformed into a digital image (Figure 9).

Figure 10

The Designer's Final Design

Figure 11

Application of the Final Design to Various Company Products

Selection of the Final Idea

It was observed that there were three levels of idea selection among students. In the first level, the design students selected some ideas from the multiple pencil sketches they made for presentation. At another phase of selection, peer critiquing is conducted during the lecture, which leads to the selection of the appropriate design by the lecturer for fine-tuning. Peer critique helps students gain knowledge and ideas from each other by reviewing each other's work (Goalbook, 2023). Some students reported working for clients. They transform selected pencil sketches into digital format, as clients prefer digital illustrations over traditional pencil drawings. These ideas are then presented to the client, who chooses one for further development.

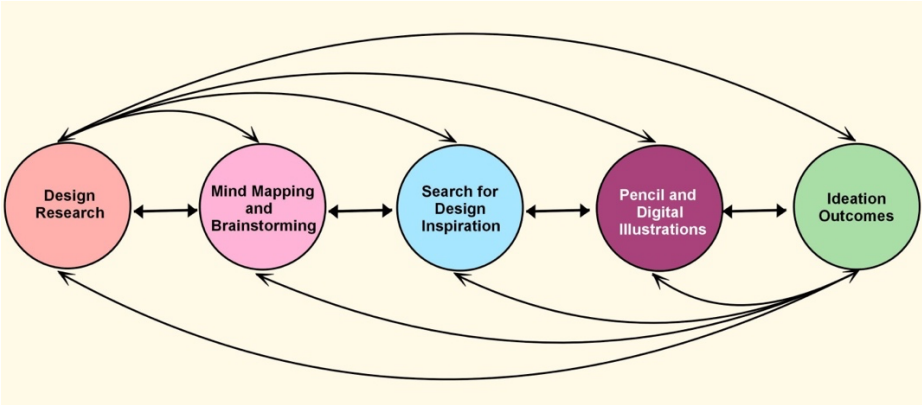
Design Ideation Process among Students

The design idea development process of students is systematic and iterative, characterized by distinct steps that guide effective design solutions. The systematic approach is a structured process for achieving creativity, while the iterative approach involves cycles of creating and refining ideas. Understanding this process is essential for educators to enhance design pedagogy and foster students' creativity.

Systematic Approach of Students' Ideation Process

Students gather information about the problem, target audience, and existing solutions. This involves understanding the design brief, analyzing competitors, and exploring user needs. Effective research equips students with the knowledge to inform their design decisions. This ensures that their ideas are relevant. Students then engage in mind mapping and brainstorming sessions. Mind mapping helps them organize thoughts and identify key themes, while brainstorming encourages group discussions where ideas flow freely. This collaboration promotes creativity and diverse perspectives. In the next phase, students sought design inspiration from art, nature, and digital platforms. They collect visual references, color palettes, and typography that resonate with their concepts. Inspiration from existing works sparks students' creativity and offers context for their design ideas. Students then move on to the illustration phase, where they begin to visualize their concepts. This involved traditional pencil sketches and digital illustrations. This dual approach encouraged students to explore various methods of visual expression. The final step is evaluating ideation outcomes. Students analyze their concepts, critiquing their work and considering feedback to determine which ideas best meet the design requirements.

Figure 12
Design Students' Ideation Process



Iterative Nature of Students' Ideation Process

While the design idea development process was systematic, it was also inherently iterative. Students could revisit any of the previous steps in a non-linear fashion, allowing for flexibility and adaptability in their creative processes. The iterative nature of these steps allowed students to refine their designs, ensuring that the final outcomes were well thought out and effectively executed.

This design process differed from models in the literature. Wallas's (1926) model includes one stage (Preparation) before idea generation, while Warr and O'Neill (2005) have two stages (Preparation and Incubation). In contrast, the current study identified three ideation stages before idea generation: 'Design Research,' 'Mind Mapping and Brainstorming,' and 'Search

for Inspiration,' each involving digital integration. These stages offer a more comprehensive framework that highlights the complexity of contemporary design ideation compared to Wallas's and Warr and O'Neill's models. Incorporating diverse design activities and digital integration enhances the preparation phase, allowing for thorough idea exploration. These stages encouraged deeper engagement and reflection, leading to creativity and innovation. While Amabile (1983) and Warr and O'Neill (2005) labelled their creative stage 'Idea Development,' this process labels it 'Pencil and Digital Illustration, capturing both the analogue and digital aspects of the contemporary design process. Effective implementation of these stages helps designers to generate multiple quality Idea Outcomes.

Variations in Students' Ideation Process

The five-stage ideation process in Figure 12 represents the general design approach of students. While many engaged with this process, a few of them skipped some stages. For example, interviews revealed that some students moved from the first stage (design research) directly to the third (search for design inspiration) or began idea generation (stage four) right after the first stage, skipping the second and/or third stages. This variation indicates differing levels of experience and confidence among students, influenced by factors like prior exposure to design concepts, learning styles, and personal preferences. Some prefer seeking inspiration before ideation, while others dive straight into generating ideas. This variation highlights the need for adaptable and inclusive design education that accommodates different learning paths. Even if students skip certain ideation steps, educators can provide guidance to encourage exploration of all stages. Instructors can emphasize a holistic approach by showcasing the impact of mind mapping and inspiration on generating diverse concepts. The tendency to skip stages reflects individual preferences and skill levels, offering educators a chance to tailor their support for diverse learners. By fostering an environment that values both systematic and iterative practices, educators can enhance students' design fluency and foster innovation in their future work.

Discussion

The Internet Use

Contemporary graphic design and the internet are inseparable. Enninful and Boakye-Amponsah (2022) note that technology is integral to 21st-century Graphic Design programs. Every study participant confirmed the internet as an essential design tool, offering quick access to information anytime and anywhere. ECLAC (2021) highlights that online information systems enable cloud-based access from any device globally. Zhang (2021) states that the internet provides designers with a wealth of visual communication resources that enhance research. Al-Qudah and Al Shari (2020) emphasize that internet tools significantly improve graphic designers' efficiency and skills. The internet is the most important information and communication technology, causing a global shift in information quality (Yebowaah, 2018). Enninful and Boakye-Amponsah (2022) note that technology positively impacts the design industry, helping designers enhance their skills and work.

Research on Design Brief

Existing literature emphasizes the importance of research in the early stages of ideation to gather relevant information for design tasks. Shukla (2011) notes that designers research about similar projects and existing solutions to understand the strengths and weaknesses of current designs, with the aim of developing better solutions. Research helps students learn about the target audience and their requirements, enhancing their project understanding and supporting effective problem-solving. Findings show that the internet significantly improves students' design ideation processes, making it an essential tool in graphic design education.

Brainstorming

The brainstorming session provided the grounds for a lateral thinking approach to problem solving where team members were encouraged to think beyond existing patterns to generate creative ideas (Liubashenko & Kavytska, 2020). Brainstorming is a team-based problem-solving approach that, according to Mindmanager (2019), encourages free thinking without fear of judgment and fosters ongoing collaboration to generate innovative ideas. This approach promotes the production of many ideas that can be refined into ideal solutions. It facilitates consensus-building for a more informed path and introduces diverse perspectives that promote out-of-the-box innovations.

Digital technology, especially smartphones, is found to be crucial in students' brainstorming sessions. It enables them to explore new perspectives and refine ideas. This integration supports ideation and enhances collaborative learning, making it essential in design education. By utilizing these tools, educators can foster a creative environment that encourages innovation and effective problem-solving.

Mind Mapping

Liedtka and Ogilvie (2018) note that mind mapping illustrates how ideas relate to a central concept. It helps generate and classify ideas, revealing patterns that inform design criteria. This process improves students' understanding of the design brief and expands their ideation space during ideation. This makes mind maps an effective way for organizing thoughts.

Erdem (2017) highlights that mind maps enhance creativity, recall, problem-solving, focus, and thought organization. In design pedagogy, mind mapping helps learners visualize relationships between ideas, expand their design space, and explore creative solutions. This fosters an engaging ideation process, allowing students to use their imagination and systematically tackle design challenges.

The Mood Board

As stated by Diana (2018), a mood board is a collection of images, colors, and fonts that perfectly defines what a project is about, which can include a variety of things, such as photos,

illustrations, cutouts, color palettes, textures, words and anything that helps a designer to define the direction of a project.

The mood board serves as a vital source of design inspiration, helping designers refine their ideas and visualize how various elements fit together (Diana, 2018). As a physical or digital collage, it awakens creativity and acts as a useful visual aid for clearly communicating a designer's vision. This enables designers to present abstract concepts in a way that others can easily understand.

Idea Generation

It was gathered in literature that design involves human cognition, and the conclusion drawn after analyzing and synthesizing various literature (Chittka & Osorio, 2007; Chan, 2015; Pettersson, 2021) is that design activities can be regarded as thinking activities executed by cognitive operations. Design is therefore the end result of the cognitive process. While a designer's expressions may appear abstract to viewers, each stroke contains details understood only by the designer. Recognizing design as a cognitive process emphasizes the importance for educators to create spaces where students can freely express ideas and explore concepts without immediate judgment.

Idea generation, which is the creative stage of the ideation process where the designer externalizes concepts from the cognitive domain into the physical and observable forms that others can interact with, forms the second stage of Warr and O'Neill's (2005) generic model. At this stage, the quality of ideas is not of great importance. Rikke and Teo (2020) note that ideation focuses on generating many ideas to filter down to the best ones for better design solutions. Asana (2022) supports this, stating that more ideas increase the chances of finding one worth executing. This principle should guide educators to create tasks that motivate students to prioritize exploration and creativity over perfection in initial drafts.

McGlashan (2017) states that the use of paper sketches for capturing initial idea (idea generation) helps designers to build confidence and encourages good flow of ideas. These sketches were later transferred to digital devices for further illustration. According to ECLAC (2021), digital technologies have completely transformed how things are done. Incorporating digital tools into the curriculum can facilitate a more dynamic learning experience, enabling students to iterate on their designs rapidly and explore a broader range of possibilities.

Implications

There is little existing literature related to digital technology in the Ideation Process. While reducing the gap, this study presents significant theoretical implications for the field of design education and practice. It does this by highlighting the importance of digital technology in the ideation process. The study contributes to the discourse on enhancing creativity and efficiency in design by raising awareness among educators, students, and graphic designers about the importance of digital technology in idea generation. This awareness will encourage a

reassessment of instructional approaches, highlighting the need for a curriculum that integrates digital technologies to prepare students for the contemporary design industry. Additionally, it will advance academic discussions on the utilization of digital technology in design ideation, which will lead to a shift from a holistic reliance on the traditional approach to a more advanced, industry-accepted method of technology integration for outstanding ideation outputs that meet today's client expectations. This theoretical framework not only supports the integration of digital tools into design education but also sets the stage for future research on the impact of technology on creative processes.

Recommendations

The design ideation models presented in this study represent the ideation processes that were widely adopted several decades ago. The models do not fully capture the significant shift within current design processes that rely on digital tools for dynamic explorations of creative ideas. While these models are not entirely deviations from current practices, they need modification to include digital idea exploration to accurately reflect the modern ideation process.

The new models should embrace modern design ideation, where digital technology enhances collaboration, mind mapping, and iterative processes. Developing these models is essential to align design education and practice with the digital age. They will serve as frameworks that encompass the entire ideation process, integrating both traditional methods and current digital practices. This ensures that ideation remains relevant, effective, and reflective of the diverse approaches in contemporary design.

Educators should adapt the curriculum to integrate digital tools and internet resources, aligning with contemporary design practices to prepare students for industry demands. Teaching methods should emphasize online research and digital ideation, enhancing digital literacy through training in design software and online resources. Additionally, educators can encourage creative exploration by urging students to use the internet not only to find existing solutions but also to generate new ideas and concepts.

Limitations of the Study

The study has some limitations that should be acknowledged. Firstly, it focuses exclusively on graphic design students at the university level, omitting insights from graphic design professionals. Including a broader range of participants, such as those from other educational levels and practicing designers, could have provided a better representation of ideation practices among Ghanaians.

Again, the study focused on the idea generation processes of design students, using a qualitative approach with a sample of 24 students and 4 lecturers, which may limit generalizability. Combining qualitative and quantitative methods with a larger, diverse sample could strengthen conclusions and better represent graphic design ideation in the country. These limitations

indicate the need for further research to gain deeper insights into the practices and expectations within the field.

Conclusion

The conclusion is governed by the two research questions of the study and these are: 1. What are the activities that charaterise the design ideation stages among students? and 2. How does digital technology influence the preparation and the idea generation stages of the ideation process? Design students researched briefs to better understand their tasks. Mind mapping and brainstorming were key activities during ideation, promoting collaboration and problem-solving, which led to diverse ideas (Mindmanager, 2019). They sought design inspiration, generating a variety of quality and creative ideas through pencil and digital illustrations.

Among designers today, ideas are not only cognitively conceived but are also digitally inspired. Designers' choice of colour, font type, and idea organization are greatly influenced by digital technology. Ng (2015) states that technology has improved over the years, transforming how tasks are executed (ECLAC, 2021). Digital technologies have significantly impacted designers' ideation processes, aiding students in research, idea exploration, and creation using vector software. These tools help student designers understand briefs, gain inspiration, and generate diverse ideas for creative solutions. This stands to reason that digital technologies played pivotal roles throughout the design ideation process; hence, the call for the development of an ideation model with digital technology integration to project how students navigate creative thinking and technology during learning. This will guide design education for effective design ideation outputs.

Teaching strategies like project-based learning, collaborative learning, workshops, and interactive digital tools should be adopted. Project-Based Learning engages students in real-world projects using digital tools, fostering creativity and critical thinking while building their portfolios. Collaborative Learning promotes teamwork through group projects and peer reviews, mirroring industry practices and developing essential communication skills. Periodic workshops with industry professionals will offer insights into current trends that will inspire students and enhance their technical competencies. Using tools like Adobe Creative Suite, Sketch, or Figma ensures students are proficient and competitive in the job market.

It is necessary to develop a new Graphic Design curriculum that focuses on integrating digital technologies into graphic design practices. This approach will ensure that students are equipped with the essential skills and knowledge required to meet the expectations of today's clients.

Declaration of Generative AI and AI-assisted Technologies

The authors would like to acknowledge the use of artificial intelligence (AI) tools in the preparation of this manuscript. Grammarly was used for checking grammatical errors, Quillbot for paraphrasing, and Poe for rephrasing and arranging the reference list.

All AI-edited text was thoroughly reviewed and revised by the authors to ensure accuracy, clarity, and adherence. AI tools were not used for other purposes, including data generation, data analysis, methodology, or interpretation of findings or conclusions. The authors take full responsibility for all aspects of the final manuscript.

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Corresponding Author: Folasayo Olalere
Email: folasayo.olalere@open.ac.uk

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Email: murielle.elhajj@hotmail.com

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