SACLA 2025
Programme, Abstracts & Work-in-progress Papers

Conference Theme: Innovation in CS, IS, and IT Education: Navigating the Next Frontier

Hosted by: Department of Computer Science & Informatics, University of the Free State

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Conference Programme

Day 1: Wednesday, 30 July 2025

Wednesday, 30 July 2025	
Time	**Description**
12h00 – 17h00	Registration (Tuscan Rose – Corporate Hall)
14h00 – 17h00	HoD Colloquium (Corporate Hall)
17h00 – 18h00	SACLA Executive Committee Meeting (Boardroom)
18h30 – 21h00	**COCKTAIL FUNCTION** **Tuscan Rose – Banquet Hall**

Day 2: Thursday, 31 July 2025 (Sessions 1A & 1B)

Thursday, 31 July 2025		
07h30 - 08h15	Registration & Coffee	
08h15 - 08h30	Opening & Welcome (Plenary session – Corporate Hall)	
08h30 - 09h15	Sponsor Talk: BBD (Plenary session – Corporate Hall)	
09h20 - 10h50	**Venue A – Corporate Hall**	**Venue B - Gallery**
	Session 1A: GenAI in Programming (Chair: Prof Liezel Nel)	**Session 1B: Equity, Accessibility & Literacy** (Chair: Ms Tlholohelo Nkalai)
	10: Leveraging Abstract Syntax Trees To Generate Instructive Hints In Programming *(Marc Levin, Herman Kandjimi, and Aslam Safla)* ***20: Evaluating AI-Generated C# Code in Computing Education: Implications for Academic Integrity*** *(Adewuyi Adetayo Adegbite and Eduan Kotzé)* ***27: Investigating the Internalization of Programming Code Obtained from Generative Artificial Intelligence*** *(Johan Prinsloo, Imelda Smit and Roelien Goede)*	***2: Learning and teaching computer programming: A systematic literature review of challenges faced by Deaf students in South Africa and beyond*** *(Alfred Hove Mazorodze)* ***16: Using assistive technology to improve independence in visually impaired students in higher education institutions: A systematic literature review*** *(Katlego Mfekane and Samwel Mwapwele)* ***21: Gender, Self-Efficacy, and Computer Literacy Acquisition in Marginalised South African Communities*** *(Wynand Nel and Rouxan Fouché)*
10h50 - 11h20	Coffee Break	
11h20 - 12h05	Sponsor Talk: Oracle (Plenary session – Corporate Hall)	

Day 2: Thursday, 31 July 2025 (Sessions 2A & 2B)

Thursday, 31 July 2025		
12h10 - 13h10	**Venue A – Corporate Hall**	**Venue B - Gallery**
	Session 2A: Inclusive Educational Practices (Chair: Prof Tanya Stott)	**Session 2B: Gender, Curriculum & Pedagogical Strategies** (Chair: Dr Ben Mase)
	11: Beyond Language Barriers: Programme-Specific Effects of English Medium Instruction in South African Computer Science Education *(Rouxan Fouché)* ***19: Quintuple Helix, the Informal Economy and Sustainable-Smart Innovations: Lessons to be learned from a transdisciplinary student project*** *(Carolien van den Berg and Belinda Verster)*	***15: A Bibliometric Analysis of Existing Literature on the Nexus between Gender and Introductory Computer Programming*** *(Sithandiwe Twetwa-Dube and Courage Matobobo)* ***25: Comparing South African Computer Science Curricula Structures using Graph-Theoretic Approaches*** *(Reolyn Heymann, Michael de Jager, and Japie Greeff)*
13h10 - 14h00	Lunch Break	

Day 2: Thursday, 31 July 2025 (Sessions 3 & 4)

Thursday, 31 July 2025		
	Venue A – Corporate Hall	**Venue B - Gallery**
14h00 - 15h30	**Session 3A: Innovative Pedagogy & AI Integration** (Chair: Dr Bennie Botha)	**Session 3B: Policy & Practical Implications of AI** (Chair: Mr Jay Vieira)
	1: A Phenomenographic Evaluation Approach for Inclusive UX Design Thinking Education *(Rennie Naidoo)* ***4: Contextualization, assessment, and generative AI in an online environment: An experiment with a hypothetical case study in Enterprise Architecture*** *(Wesley Moonsamy and Hugo Lotriet)* ***14: A Framework for Integrated Project & Context-Based ICT Education*** *(Jacqui Muller and Japie Greeff)*	***22: Students' Generative AI Use in Different Levels of Education: A Systematic Review*** *(Suzanne Sackstein and Mukelwe Mdluli)* ***18: The Networks between Students, Academics and Generative AI at a South African University: An Actor Network Theory Perspective*** *(Mikayla Suraya Seedat and Walter Ferreira Uys)* ***33: Adapting the Substitution Augmentation Modification Redefinition (SAMR) Model for Effective Classroom Integration of Generative Artificial Intelligence in a Distributed System Course*** *(Ijeoma Noella Ezeji, Sizakele Mathaba, Nombuso Sibeko and Matthew Adigun)*
15h30 - 16h00	Coffee Break	
16h00 - 17h00	**Session 4A: Educational Innovations & Industry Alignment** (Chair: Ms Reba Phuthi)	**Session 4B: Work-in-progress papers** (Chair: Prof Liezel Nel)
	13: A Model for Industry Advisory Boards' Effectiveness at Higher Education Institutions *(Estelle Taylor, Andre Calitz and Margaret Cullen)* ***23: Innovation in Information and Communication Technology Education: Navigating the Next Frontier by Using an Automated Grading System*** *(Dalize van Heerden and Leila Goosen)*	***28: Barriers to 4IR/AI Adoption in Zimbabwean Higher and Tertiary Education Institutions*** *(Fungai Nora Mukora, Nobert Rangarirai Jere, Tawanda Mushiri and Hilton Maverengo)* ***35: The use of Generative AI in Sign Language Interpretation to improve classroom engagement for Deaf students in IT education - A Literature Review*** *(Tichaona Chinyerere)*
18h30 – Late	**Gala Dinner (Tuscan Rose - Banquet Hall)**	

Day 3: Friday, 1 August 2025 (Sessions 5 & 6, Corporate Hall)

Time	Session
07h30 - 08h15	Arrival & Coffee
08h15 - 08h35	Sponsor Talk: IBM
08h40 - 10h10	**Session 5: Enhancing Programming through Debugging & AI** (Chair: Prof Tanya Stott)
	34: Overcoming Debugging Challenges: Expert Strategies for Novice Programmers *(Tipson Maleti and Liezel Nel)* ***24: Utilising Large Language Models for Automated Evaluation of Introductory HTML and CSS Assignments*** *(Jocelyne Smith, Eduan Kotzé and Liezel Nel)* ***8: Common Code Explaining Errors Made by Novice Programmers: Implications for the Teaching of Introductory Programming*** *(Mokotsolane Ben Mase and Liezel Nel)*
10h10 - 10h40	Coffee Break
10h40 - 12h00	**Session 6: Curriculum Development & Reflective Practices** (Chair: Dr Rouxan Fouché)
	17: Development of the GE-ARCS-E Model to Evaluate the Impact of Gamification on Programming Students' Motivation and Engagement *(Marisa Venter and Lizette de Wet)* ***9: Beyond Knowledge Transfer: A Framework for Creating Cybersecurity Qualifications that Meet Industry Expectations*** *(Tapiwa Gundu)* ***37: Delegates' Perceptions of the SACLA 2024 Conference*** *(André Calitz, Margaret Cullen and Liezel Nel)*
12h00 - 13h00	SACLA 2025 AGM
13h00 - 13h10	Closing Remarks & Thanks
13h10 - 14h10	Lunch & Departure

Paper Abstracts

Submission 1 (Springer publication)

A Phenomenographic Evaluation Approach for Inclusive UX Design Thinking Education

Rennie Naidoo

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Abstract. As computing education attracts increasingly diverse students, the need for adaptive and inclusive teaching approaches has become critical. Traditional pedagogical models often rely on standardized frameworks and evaluation methods that overlook the diversity of student experiences and learning styles, particularly in complex fields like UX design. This study employs a phenomenographic approach to evaluate and understand the range of student conceptions of UX design thinking in an undergraduate systems analysis and design course. Through the UX design thinking module, students engage with user-centred tools such as personas, customer journeys, and empathy maps. Analysis of student feedback reveals four experiential conceptions during the course—*scepticism, adjustment, practical utility, and user-centeredness*—showcasing the spectrum from surface-level understanding to deeper appreciation of UX principles. Findings demonstrate the effectiveness of phenomenography in capturing diverse learning experiences, underscoring its value as an evaluation tool for creating more inclusive and responsive UX design education. Future research should explore the effectiveness of the phenomenographic educational evaluation approach in fostering empathetic student development and enhancing inclusive teaching practices in computing education.

Submission 2 (Conference proceedings)

Learning and teaching computer programming: A systematic literature review of challenges faced by Deaf students in South Africa and beyond

Alfred Hove Mazorodze

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Abstract. South Africa has a shortage of computer programmers, and this gap could be closed by training more computer programmers from diverse groups of people. Considering that South Africa has more than 4 million Deaf and hard-of-hearing people, this paper reviews the challenges faced by Deaf students in learning computer programming, irrespective of the programming language and ultimately develops a learning and teaching strategy for the Deaf students. The study is guided by the Universal Design for Learning (UDL) theory, which emphasizes the creation of educational materials that are accessible to all students including those with special needs. The Web of Science, Elsevier and Scopus databases were used to search for relevant literature. A total of forty-six (46) peer-reviewed articles were analysed and the findings confirm that Deaf students learn computer programming better with multiple aids. The findings further confirm the lack of adequate human and technical resources to teach Deaf students coding. To improve the learning and teaching strategies, the study recommends teaching with guided practical activities because ultimately, the Deaf students must be able to develop and deploy working systems. The study recommends tailor-made courses for sign language interpreters to fully understand the coding terminology and ease the interpretation process. There is need for continuous collaboration between lecturers and sign language interpreters so that they can successfully deliver learning content to the Deaf students.

Submission 4 (Springer publication)

Contextualization, assessment, and generative AI in an online environment: An experiment with a hypothetical case study in Enterprise Architecture

Wesley Moonsamy[1] and Hugo Lotriet[2]

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Abstract. Contextualization of questions has been suggested to deal with the capabilities of generative AI in an online environment. For this paper we experimented with contextualization to observe how generative AI (in this instance ChatGPT) deals with different elements of contextualization. The experiment used a hypothetical case study for a tailored course in Enterprise Architecture at postgraduate level and looked at contextualization along two axes: (1) Contextualized questioning, and (2) providing different learner contexts in the form of personas to ChatGPT and seeing whether ChatGPT adapted its responses. The contextualized questioning aspects used three different assessments. For the first assessment, individual questions on Enterprise Architecture were asked. For the second and third assessments the case study was used. In the second assessment a general essay that addresses certain elements of Enterprise Architecture was requested, while in the third assessment structured questions on the case study were asked. Responses for each of the assessments were independently marked by the authors, with marking results compared and discussed. The experiment found differences in the quality of responses generated by ChatGPT related to contextualization and degree of structuring in the questions, and in the responses provided to the different personas. Differences in responses to the personas were however not contextualized. It was observed that ChatGPT produced higher quality answers to individually structured questions but fared poorly when prompted for an essay. Educators should therefore contextualize and structure questions in the form of case studies which stimulate learner creativity and critical thinking skills.

Submission 8 (Conference proceedings)

Common Code Explaining Errors Made by Novice Programmers: Implications for the Teaching of Introductory Programming

Mokotsolane Ben Mase[1] and Liezel Nel[2]

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Abstract. Novice programmers often make unnecessary errors when they verbally explain code. These errors can be attributed to novices' lack of reasoning skills and fragile knowledge of programming concepts. The aim of this study is to identify typical code explaining errors made by a group of first-year Computer Science (CS) students at a South African university. This exploratory study used a mixed-methods approach grounded in the Frameworks for an Integrated Methodology. Data was gathered from seven novices enrolled in a first-year introductory programming course by means of asking questions, artefact analysis, and observation strategies. The narrative data (transcribed audio recordings and observation summaries) underwent a three-step coding process, while descriptive statistics were used to interpret the numerical data from observation checklists. Three recurring categories of errors emerged: Reliance on inductive reasoning, inability to perform deductive reasoning, and misunderstanding the working process of loops and arrays. Participants frequently guessed the purpose of a piece of code based on specific values, failed to abstract high-level functionality, and struggled with foundational control structures, particularly for loops and arrays. The findings underscore the need for instructional strategies that focus on both conceptual knowledge and reasoning. By scaffolding tasks to foster abstract thinking, encouraging systematic code reading, and providing more examples of loops and arrays, facilitators can help novices overcome common pitfalls. This study lays a foundation for future research on how structured interventions may strengthen code explaining skills and ultimately improve the programming competencies of novice programmers.

Submission 9 (Conference proceedings)

Beyond Knowledge Transfer: A Framework for Creating Cybersecurity Qualifications that Meet Industry Expectations

Tapiwa Gundu

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Abstract. Cybersecurity is always evolving requiring agile cybersecurity specialists. The knowledge-based qualifications seem to be insufficient in equipping graduates with the agility required to address emerging threats. This studies conceptual analysis examines how cybersecurity education should shift from rote knowledge transfer to fostering critical thinking, adaptability, and lifelong learning. The study analyses existing literature on cybersecurity curricula, industry requirements, and pedagogical frameworks to propose a model that aligns academic offerings with dynamic industry expectations. The findings highlight the need for experiential learning, problem-solving approaches, and continuous skill development to ensure graduates remain relevant in the field. The paper further then concludes by giving future directions.

Submission 10 (Springer publication)

Leveraging Abstract Syntax Trees To Generate Instructive Hints In Programming

Marc Levin[1], Herman Kandjimi[1,2], and Aslam Safla[1]
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Abstract. Introductory programming education is constantly challenged with how to provide effective, personalized guidance to struggling novices. AST-based hints generation emerges as a potential solution, marrying abstract syntax tree analysis with generative AI to offer tailored, instructive feedback for Python learners. Existing hint generation systems like ITAP and GPT4Hints-GPT3.5Val have approached hint generation through path construction and generative models, respectively. Both approaches to hint generation have shown promise in generating human-like hints, but each has its own limitations. These approaches either provide highly instructive hints that are often too explicit or more abstract but may lack the specificity necessary for effective guidance. Our study combines the strengths of both approaches to provide students with hints that are both instructive and abstract but do not give away the solution. We provide a detailed overview of the AST-based hints system, including requirements gathering, the system architecture and features. The system is evaluated through path construction testing and A/B testing with speculative analysis. The results from path construction and A/B testing demonstrate that AST-Hints is moderately effective at generating human-like hints, faster than human tutors, with its success strongly related to the quality of the goal solution and hint relevance.

Submission 11 (Springer publication)

Beyond Language Barriers: Programme-Specific Effects of English Medium Instruction in South African Computer Science Education

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Abstract. In South African higher education, English serves as the primary medium of instruction despite only 24 percent of undergraduate students citing English as their first language. This study investigates how language difficulties affect first-year Computer Science students' perceived module difficulty and engagement patterns across different technical disciplines at the University of the Free State. Analysis of survey data from 226 first-year IT students revealed distinct patterns across different module types: programming courses showed no significant difficulty differences between language groups, challenging assumptions about language barriers in technical education; business computing modules demonstrated the most pronounced challenges, while mathematical modules unexpectedly showed lower perceived difficulty among students with language difficulties. Student engagement analysis revealed higher classroom participation and increased informal peer learning engagement among students with language difficulties, suggesting compensatory learning strategies. Based on Cognitive Load Theory and Linguistic Relativity Theory, these findings show that the unique requirements of each subject area influence the cognitive load experienced during technical learning. Programming's universal syntax provides natural support that reduces unnecessary cognitive load, while business modules' contextual demands increase it. These insights advance theoretical frameworks for understanding multilingual technical education and provide evidence-based guidance for developing differentiated support strategies in post-colonial educational contexts.

Submission 13 (Conference proceedings)

A Model for Industry Advisory Boards' Effectiveness at Higher Education Institutions

Estelle Taylor[1], Andre P. Calitz[2] and Margaret Cullen[3]

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Abstract. Industry Advisory Boards (IABs) provide valuable feedback to academic departments relating to topics, such as industry graduate requirements, Information Technology (IT) trends, programme quality and curriculum relevance. IABs can ensure compliance with international curriculum standards, such as the ACM curricula recommendations. The academic literature provides general guidelines on the role and responsibilities, membership, composition and the functioning of IABs. However, no empirically tested model for IAB effectiveness presently exists, covering the IAB tasks, roles, member characteristics and the effects of these factors on the successful operation of an IAB. Accreditation bodies, such as ABET, provide guidelines for implementing and functioning IABs at Higher Education Institutions (HEIs). Many theories relate to Advisory Boards, including theories such as resource dependency theory, stakeholder theory, institutional theory and board capital theory. The aim of the study was to evaluate a proposed IAB model that Computer Science, Information Systems, Information Technology and other related departments at HEIs can use for effectively managing their IABs. An IAB questionnaire was compiled and sent to the Head of Departments (HODs) of 32 universities in Southern Africa. A total of 36 Heads of Department or representatives at 26 HEIs in Southern Africa completed the survey. The data were statistically and thematically analysed. The results of the study indicate that the proposed IAB model can be used, in association with guidelines and best practices for departments managing IABs. HODs of departments who managed an IAB provided advice on the effective management of an IAB. This research study will assist academic departments in implementing and maintaining IABs according to accreditation body requirements and standards.

Submission 14 (Springer publication)

A Framework for Integrated Project & Context-Based ICT Education

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Abstract. The evolving landscape of Information and Communication Technology (ICT) education necessitates innovative teaching methodologies that bridge the gap between academic theory and industry practice. This study proposes the Integrated Project & Context-Based Learning (IPCBL) framework, which integrates project-based learning (PBL), context-based learning (CBL), and Integrated Learning (IL) interdisciplinary approaches to enhance student engagement, competency development, and real-world application of skills. Using Design Science Research (DSR) methodology, the study iteratively develops and evaluates the IPCBL framework to ensure its effectiveness in fostering deep learning and problem-solving skills. The framework is tested within an ICT module focusing on the Internet of Things (IoT), where students engage in capstone projects that progressively build technical and analytical skills while aligning with industry requirements. Through an industry-aligned curriculum incorporating external certifications, the IPCBL framework successfully enhances student motivation, critical thinking, and professional readiness. The study further explores technical considerations, assessment methodologies, and scalability of the framework within higher education. Results indicate that IPCBL fosters a structured learning approach that aligns academic outcomes with workforce expectations. Future research will focus on refining the framework, incorporating structured curriculum rubrics, and optimizing external training integration. Ultimately, the IPCBL framework contributes to ICT education by promoting an integrated, skill-based, and industry-relevant learning experience.

Submission 15 (Conference proceedings)

A Bibliometric Analysis of Existing Literature on the Nexus between Gender and Introductory Computer Programming

Sithandiwe Twetwa-Dube and Courage Matobobo

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Abstract. This bibliometric analysis explores the intersection of gender and introductory programming education by analysing existing literature. The review synthesizes studies from diverse academic sources to understand how gender dynamics influence learning outcomes, engagement, and participation in introductory computer programming courses. Key themes identified include gender inequalities in confidence, access to resources, learning styles, and the impact of group stereotypes on students' performance. The review also highlights the effectiveness of various pedagogical strategies to reduce these disparities, such as inclusive curricula, mentorship programs, and collaborative learning environments. To highlight gaps and inconsistencies in the current literature, identifying areas where further research is needed to better understand the nexus between gender and introductory programming. Despite progress, the literature reveals ongoing challenges in achieving gender equity in introductory programming. To provide evidence-based recommendations for educators, academics, and researchers to address gender-related barriers further and promote an inclusive learning environment in computer science. Furthermore, on how to address gender disparities in introductory programming courses, informed by the systematic review. The relationship between gender and success in introductory programming courses has been widely discussed, yet existing literature presents conflicting findings and lacks a comprehensive synthesis. This research paper seeks to systematically review existing studies to identify patterns, gaps, and underlying factors that influence gender inequality in introductory programming, to provide a clearer understanding of how gender impacts student outcomes in these courses, and to inform future educational interventions.

Submission 16 (Conference proceedings)

Using assistive technology to improve independence in visually impaired students in higher education institutions: A systematic literature review

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Abstract. Tertiary education has its own set of obstacles, and the visually impaired have a particular set of challenges. Studies categorize these difficulties as attitudinal, institutional, physical, and environmental. The current gap is that no body of literature analyses the numerous problems beyond navigational challenges that visually impaired students confront, which may hinder their ability to have an independent student life. This review looks at how these difficulties affect the sense of independence among visually impaired students. During August and September 2023, systematic searches were undertaken utilizing ProQuest, Scopus and Google Scholar. Peer-reviewed articles published in English between 2010 and 2023 were included for analysis. The sixteen included articles were subjected to inductive thematic analysis. Key findings revealed that assistive technologies exist to assist students with visual impairments; however, their availability to students is dependent on their institution, their policies and strategies. Furthermore, there are differences in the needs of students with complete blindness and those with low vision that need strategic technological view. Lastly, students are unaware of the assistance they can receive at the university, which leads to a lack of self-esteem and mental well-being that affects their academic well-being. The study contributes to theory by developing a conceptual framework on challenges hindering independence among visually impaired students. The practical contribution is that adopting assistive technology would foster an inclusive environment for students with visual impairments and allow them to complete tasks independently. The study contributes to policy by providing evidence on reducing inequality, which aligns with the sustainable development goal 8.

Submission 17 (Springer publication)

Development of the GE-ARCS-E Model to Evaluate the Impact of Gamification on Programming Students' Motivation and Engagement

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Abstract. Programming modules in higher education often face challenges such as low student motivation and engagement, exacerbated by traditional, teacher-centred methods that limit active participation. Gamification offers a transformative solution, enabling educators to redefine programming education through innovative, gamified learning activities and software applications. This approach fosters engagement, addresses existing challenges, and creates a dynamic learning environment, empowering students to succeed in their programming endeavours. This study aimed to develop and empirically evaluate a theoretical model to assess the influence of gamification elements on the motivation and engagement of first-year higher education internet programming students. Using the Stimulus-Organism-Response (S-O-R) framework, the GE-ARCS-E theoretical model was developed. Findings revealed that students' interaction with achievement-related and social-related game elements significantly predicted the attention and satisfaction dimensions of motivation. Additionally, the interaction of students with social-related game elements and the relevance dimension of motivation significantly predicted the confidence dimension of motivation. Lastly, confidence and satisfaction dimensions of motivation significantly predicted the academic engagement of first-year programming students. The study's scientific contribution lies in presenting a statistically validated theoretical model that measures the interaction of students with game elements and its predictive impact on ARCS motivation, while also quantifying the influence of motivation on academic engagement. A key recommendation is that institutions should invest in the development of customisable gamification tools and platforms tailored to programming education, enabling educators to design and adapt gamified learning experiences that align with specific course objectives and student needs.

Submission 18 (Conference proceedings)

The Networks between Students, Academics and Generative AI at a South African University: An Actor Network Theory Perspective

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Abstract. This paper reports on the usage and integration of generative artificial intelligence at a South African university. The study explored the relationship between students, academics, support staff, and artificial intelligence tools using an actor-network theory perspective. Thematic data analysis was used to code the insights and findings from the interview data based on the theoretical perspective. The study found that there were strong networks between students, academics, support staff, generative artificial intelligence tools, Turnitin, and academic policies. Future research needs to explore these networks in a broader context.

Submission 19 (Springer publication)

Quintuple Helix, the Informal Economy and Sustainable-Smart Innovations: Lessons to be learned from a transdisciplinary student project

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Abstract. This paper explores how the informal economy can act as a catalyst for sustainability and digital innovation through student-led interventions in marginalised communities. Drawing on a transdisciplinary project situated in the informal settlement of Dunoon, Cape Town, we apply the Quintuple Helix (QH) framework to examine how collaborative innovation unfolds across academia, government, industry, civil society, and the natural environment. The study investigates how student teams co-designed context-specific digital solutions in partnership with community and institutional actors. Our research is guided by the question: What insights does the QH framework offer for guiding transdisciplinary student projects focused on the informal economy? Using thematic analysis of student artefacts, reflections, stakeholder feedback, and researcher observations, we evaluate how knowledge co-creation contributes to sustainable-smart innovation. Findings highlight the importance of community engagement, inter-institutional collaboration, and sustainability-oriented design, while also identifying challenges such as limited industry involvement and scalability.

Submission 20 (Springer publication)

Evaluating AI-Generated C# Code in Computing Education: Implications for Academic Integrity

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Abstract. The rapid integration of Generative Artificial Intelligence (GenAI) tools, such as ChatGPT, Blackbox.AI, and Microsoft Copilot, into computing education has transformed how students learn programming languages like C#. These tools enhance learning by offering immediate code generation and support; however, they challenge academic integrity by facilitating potential misuse, such as submitting AI-generated code as original work. This study explores the use of GenAI in C# programming courses through four research questions, utilising a mixed-methods approach with 368 questionnaire responses, code examination, and grade comparisons. Results reveal that ease of use drives model preference, with ChatGPT being the most favoured. GenAI code exhibits detectable structures, and grading analysis shows it consistently outperforms human-written code, with Blackbox.AI leading, followed by ChatGPT and Microsoft Copilot. However, GenAI accessibility poses integrity risks, necessitating robust detection and assessment strategies. This research contributes to computing education by thoroughly examining GenAI C# code and proposing practical measures, such as code interviews and process documentation, to balance GenAI benefits with equitable evaluation, ensuring students develop authentic programming skills. These findings offer actionable insights for educators adapting to AI-driven education landscapes.

Submission 21 (Conference proceedings)

Gender, Self-Efficacy, and Computer Literacy Acquisition in Marginalised South African Communities

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Abstract. In South Africa's marginalised communities, the digital divide perpetuates socio-economic exclusion, with gender potentially shaping access to and success in computer literacy education. Guided by Social Cognitive Theory, which emphasises self-efficacy as a key driver of learning, this study explores how gender influences adult computer literacy acquisition through a 10-week service-learning intervention in Bloemfontein. The study population (N=157) revealed a gender imbalance, with females comprising 73.90% of participants, indicating potentially greater technology access barriers or stronger motivation for skills development among females. A pre- and post-test design assessed participants' attitudes towards computers, basic computer skills, and self-reported proficiency in MS Word and MS Excel through a questionnaire with 50 Likert-scale and binary items. Statistical analyses, including Repeated Measures ANOVA for Likert data and Chi-Square tests for binary responses, revealed significant improvements across all domains. No significant Time × Gender interactions emerged, indicating comparable gains across genders despite higher self-efficacy in males. These findings highlight self-efficacy as a key mechanism driving learning outcomes, with the intervention equalising confidence gains despite initial gender disparities. For educators and program designers, these results suggest incorporating pre-program confidence-building activities for females, ensuring equitable mastery opportunities, and maintaining post-intervention technology access to sustain skill development across genders.

Submission 22 (Conference proceedings)

Students' Generative AI Use in Different Levels of Education: A Systematic Review

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Abstract. Generative AI (GenAI) is transforming education with applications of AI powered toys in preschool, to writing assistance for tertiary students. Despite the benefits GenAI offer, concerns around students' ethical behaviour and reduced critical thinking exist. Furthermore, as needs and aims vary between educational levels, exploring GenAI use at all levels is essential, so that its potential can be leveraged and risks of integration better understood. Using a systematic literature review, relevant articles were selected to provide an overview of GenAI use, benefits, challenges and policies across educational levels. Thematic Analyses were used to construct codes and themes. Findings indicate that while GenAI is used across all levels to scaffold learning and simplify content, preschools' use is limited as formal assessment, writing skills and research tasks are not needed at this level. Similarly, GenAI benefits such as personalised learning, greater accessibility, improved knowledge acquisition and creativity are universal across levels, however automation of feedback is not relevant for preschools. Likewise, challenges of biased data, privacy and depersonalisation, unequal access, and misleading information are common to all levels, but academic dishonesty and reduced work quality are not early childhood education concerns. For policies, major gaps exist in current policies governing GenAI use from primary to tertiary education. Furthermore, GenAI training and skills development is lacking, and copyright GenAI content copyright needs more exploration. In conclusion, as GenAI becomes pervasive, challenges must be addressed, and policies developed to ensure sustainable and responsible GenAI use across educational levels, specifically from primary to tertiary contexts.

Submission 23 (Conference proceedings)

Innovation in Information and Communication Technology Education: Navigating the Next Frontier by Using an Automated Grading System

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Abstract. This paper is placed against the background of innovation in Computer Science (CS), Information Science (IS), and Information Technology (IT) education in terms of navigating the next frontier. By using an automated grading system, an Information and Communication Technology (ICT) course is navigating the next frontier in assessment. A large contingent of programming students at Comprehensive Open Distance e-Learning (CODeL) institutions and time constraints have always impeded the way programming courses are assessed. Grading programming assessments can be time-consuming as the grading must be done by a person. Human graders with specialized skills are required to grade programming assessments and they often spend a lot of time reviewing and understanding the code. This results in delays in providing feedback, which can be potentially biased or subjective, thus hampering the learning process. Automated grading systems can help alleviate this issue to some extent. This paper will investigate and report on the use of the CodeGrade automated grading system that was adopted in a first-year programming course to assist students in improving their coding skills. Programming instructors and the e-learning community in general will have the opportunity to decide to which extent they can use the automated grading system discussed in their particular setting based on the experiences presented in this paper.

Submission 24 (Conference proceedings)

Utilising Large Language Models for Automated Evaluation of Introductory HTML and CSS Assignments

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Abstract. Rising student enrolments at tertiary institutions are creating significant grading bottlenecks. Educators are struggling to manage increasing workloads, resulting in an inability to provide personalised feedback. This issue is particularly pronounced in universities constrained by budgetary limitations. This study investigates the use of artificial intelligence, specifically large language models, for the automated grading of first-year HTML and CSS assignments. The study employed a two-phase approach. The first phase focused on developing an automated grading pipeline utilising advanced AI techniques, including Tool Use, Multi- Agent Collaboration, and Prompt Engineering. In the second phase, we compared API-inference and local-inference large language models using a dataset of 30 assignments, in terms of processing time, computational cost, and accuracy to determine their suitability in providing personalised feedback. Our findings demonstrate that API-inference models,
specifically ChatGPT, outperform others likely due to large-scale infrastructure, large, diverse datasets, and advanced reasoning capabilities. This research highlights ChatGPT-4o-mini as the most effective model for providing scalable and cost-effective grading solutions in educational settings. If implemented, such systems could significantly reduce grading workloads and improve educational outcomes, especially at institutions with limited budgets.

Submission 25 (Conference proceedings)

Comparing South African Computer Science Curricula Structures using Graph-Theoretic Approaches

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Abstract. The variability in South African Computer Science curricula presents challenges in comparing and designing competitive degree programs, particularly in the absence of a standardized accreditation process. This paper investigates a graph-theoretic approach to objectively compare curriculum structures across eight South African universities ranked in the Times Higher Education (THE) 2024 listings for Computer Science. By modelling curricula as network flow diagrams, where modules are represented as nodes and prerequisite relationships as directed edges, structural differences in curriculum design are analysed. Key graph properties, including path lengths, degree distributions, and connectivity, are used to evaluate the hierarchical complexity and modular dependencies of each curriculum. Findings indicate significant disparities in curriculum structures, elective module availability, and information flow. The results underscore the need for objective comparative methodologies in curriculum design, aiding institutions in optimizing program structures for better educational outcomes.

Submission 27 (Conference proceedings)

Investigating the Internalization of Programming Code Obtained from Generative Artificial Intelligence

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Abstract. Recent developments in Generative Artificial Intelligence promise massive potential for using this technology in education. However, the use of Generative Artificial Intelligence in the educational setting is not without its challenges, as many re-searchers are concerned that Generative Artificial Intelligence could pose a substantial threat to academic integrity due to its ability to generate content that is difficult to differentiate from that created by humans. This concern is not just in the context of text but also in programming since this new technology is quite adept at generating unique code. This study explores both the opportunities and challenges associated with the use of Generative Artificial Intelligence, as highlighted in literature, by reflecting on realizations from its use in formative programming assessment. The study utilizes the TPACK framework to inform the integration of Generative Artificial Intelligence as technology, assessment as pedagogy and programming using data structures as content. It examines the use of Generative Artificial Intelligence in formative assessment as a collaborative partner and reports on students' perspectives regarding its use and the quality of submitted assessments. Re-evaluations are employed as a mitigating strategy to re-evaluate students in a supervised environment. The submitted formative assessment and the supervised evaluation are compared to determine the level of internalization reached by the students.

Submission 33 (Conference proceedings)

Adapting the Substitution Augmentation Modification Redefinition (SAMR) Model for Effective Classroom Integration of Generative Artificial Intelligence in a Distributed System Course

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Abstract. The integration of Generative Artificial Intelligence (AI) in education presents significant potential for transforming teaching and learning experiences. Generative AI tools like ChatGPT can support tasks such as research, coding, and writing, enabling greater efficiency and personalized support. However, without guided integration, these tools may lead to unintended consequences where students may become overly reliant on them, which may diminish their motivation, critical thinking, creativity, and problem-solving skills. To address these challenges, this paper explores the application of the Substitution, Augmentation, Modification, and Redefinition (SAMR) model as a pedagogical framework for integrating Generative AI into classroom settings to enhance, rather than hinder, student learning. The study employs a qualitative case study approach, drawing on structured instructor observations and aggregated group-level reflections from a Distributed Systems course assignment. AI tools such as ChatGPT and GitHub Copilot were allowed to be used for the assignment to support tasks such as system design, coding, and debugging. The study analyzes these interactions through the adapted SAMR lens, identifying both instructional benefits and pedagogical challenges. Insights from the study indicates that Generative AI enhances efficiency and fosters innovation, but it also introduces challenges related to output verification, over-reliance on automation, and uneven AI literacy. The paper concludes by offering practical strategies for responsible integration of AI in computer science education and proposes ways educators can scaffold AI use to promote active learning and critical engagement. It also outlines directions for future research to better understand the cognitive and ethical implications of Generative AI in the classroom.

Submission 34 (Springer publication)

Overcoming Debugging Challenges: Expert Strategies for Novice Programmers

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Abstract. Debugging, a critical yet challenging programming skill, remains problematic for novice programmers due to their ineffective, unstructured approaches. Previous research emphasizes that novices frequently struggle with semantic and logical errors, relying primarily on inefficient trial-and-error methods. This approach contrasts with experts who are more inclined to employ structured debugging strategies. Additionally, an individual's self-theory (i.e. beliefs about the malleability of their intelligence) has been shown to significantly impact their debugging behaviours, with growth-oriented individuals demonstrating greater persistence and adaptability. This paper reports on an experiment (as one phase of a multi-phase study) addressing a specific debugging bottleneck, namely: Novices' inability to plan and execute structured debugging strategies. Using Steps 2 and 3 of the Decoding the Disciplines (DtD) framework, the implicit mental processes of six expert debuggers (selected using random sampling based on their mindset classifications) were made explicit through decoding interviews, structured interviews, and think-aloud debugging exercises. Data analysis by means of a Narrative Data Analysis Framework (NDAF) revealed seven explicit debugging steps followed systematically by experts. Additionally, findings illustrated a notable connection between experts' self-theories (fixed vs. growth) and their debugging effectiveness, with growth-minded experts demonstrating more resilient and adaptive strategies. These results underscore the importance of explicitly modelling structured debugging processes for novice programmers. The developed model holds significant potential for instructional use, supporting novices in adopting structured debugging strategies and fostering growth-oriented self-theories to enhance their overall debugging proficiency.

Submission 37 (Conference proceedings)

Delegates' Perceptions of the SACLA 2024 Conference

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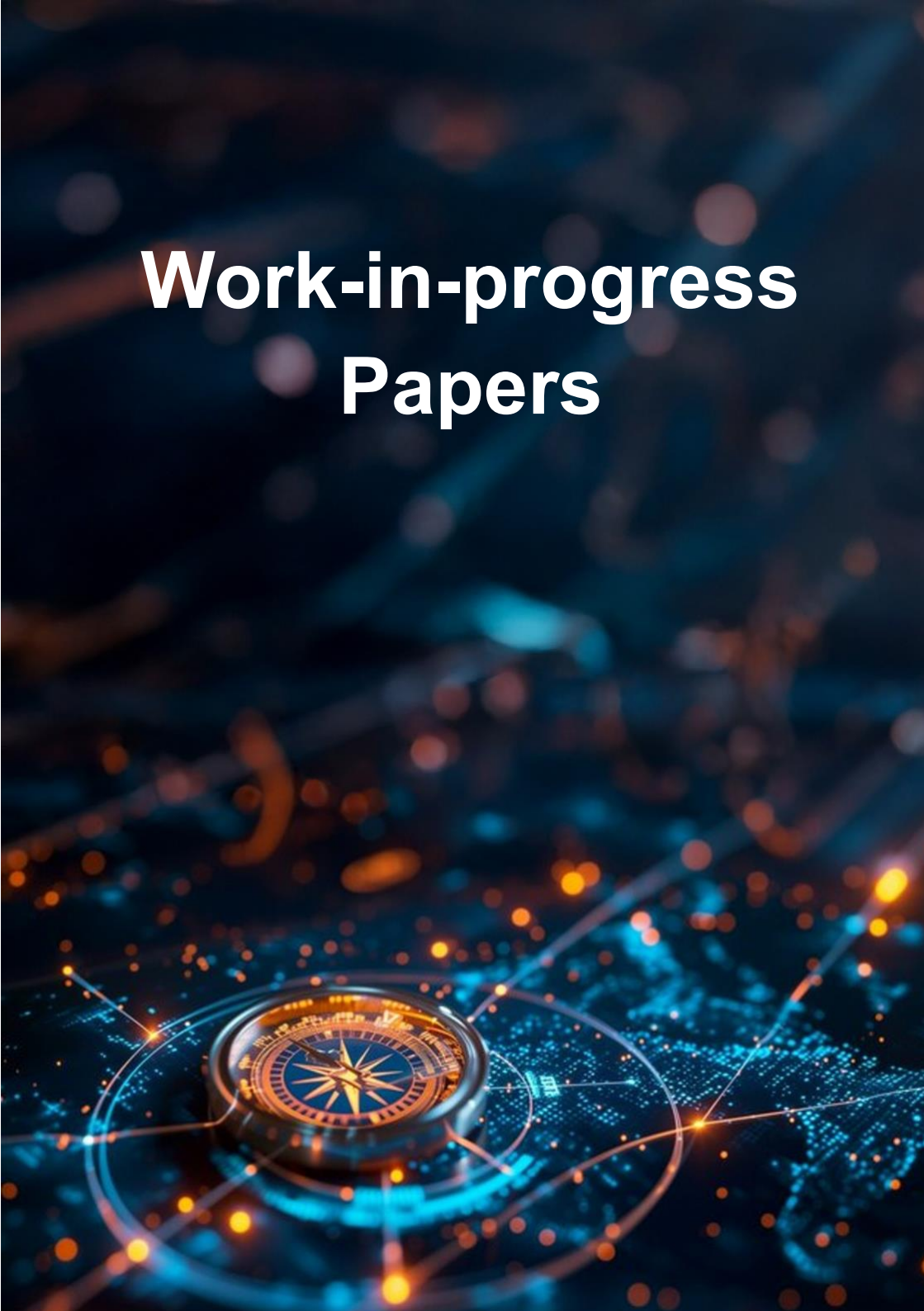
Abstract. Academic conferences serve as a platform to present recent research, remain current with the latest developments in a specific study field and engage in meaningful dialogue with professional colleagues. The Southern African Computer Lecturers' Association (SACLA) is a formal academic association involved in teaching Computer Science (CS), Information Systems (IS) and related Information Technology (IT) at universities throughout Southern Africa. The SACLA conference has been hosted annually for the past 53 years in different locations in Southern Africa and has been attended by over 500 academics and researchers over the past 10 years. The theoretical basis for successful conference organisation and management is grounded in the Theory of Events and the use of the academic conference model. It is recommended that conference organisers regularly request delegates to evaluate the conference they attended. SACLA conferences have not been formally evaluated by delegates. The aim of this study was to assess delegates' satisfaction with the SACLA 2024 conference held in July 2024 in Port Elizabeth, South Africa and to provide recommendations for organisers of future SACLA conferences based on delegate feedback. An online survey was conducted using QuestionPro and the findings were statistically and thematically analysed. The findings indicate that delegates enjoyed the location, found the conference well-organised and appreciated the Springer publication. The conference provided networking opportunities and younger academics valued the opportunity to present their research findings. Delegates also expressed interest in having more workshops, panel discussions and excursions included in the conference fee. The study identifies key factors SACLA conference organisers should consider when planning and organising future SACLA conferences.

Work-in-progress Papers



Submission 28

Barriers to 4IR/AI Adoption in Zimbabwean Higher and Tertiary Education Institutions

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Abstract. The Fourth Industrial Revolution (4IR) and the integration of Artificial Intelligence (AI) present transformative opportunities for higher education, yet they also pose significant challenges, particularly in developing countries like Zimbabwe. There is a scarcity of comprehensive studies addressing the barriers to 4IR and AI adoption within Zimbabwean Higher and Tertiary Education Institutions (HTEIs), necessitating a focused investigation into this area. The main objective of this qualitative study was to explore the challenges faced by tertiary education institutions in Zimbabwe with regards to adopting 4IR technologies and AI, emphasizing institutional readiness and infrastructural limitations. Data was generated through a qualitative desk review, examining existing literature and reports on the subject. For data analysis, the study employed textual analysis to identify recurring themes and insights. The analysis revealed that the challenges include inadequate digital infrastructure that hampers access to necessary technologies, resistance to change among educators and administrators due to fear of job displacement, and socio-economic disparities that create a digital divide among students. The findings suggest that addressing these challenges is key for policymakers and educational leaders to effectively integrate 4IR technologies and AI into the curriculum, thereby enhancing educational outcomes and preparing students for a rapidly evolving job market.

Keywords: 4IR, Higher and Tertiary Education, Barriers to Adoption.

1. Introduction

The integration of the Fourth Industrial Revolution (4IR) and Artificial Intelligence (AI) into higher education institutions in Zimbabwe presents a complex landscape of opportunities and challenges. Global education systems are changing because of the Fourth Industrial Revolution (4IR) and the emergence of artificial intelligence (AI). Nevertheless, implementing these technologies presents some difficulties for Zimbabwe's HTEIs. These difficulties vary from the need for curriculum reform and ethical issues to weaknesses in digital competence and infrastructure. As the global educational paradigm shifts towards digitalisation, Zimbabwean Universities must navigate various obstacles, including outdated infrastructure, limited access to technology, and resistance to change among faculty and students [1].

The urgency of this transition is underscored by the need for educational systems to prepare students for an increasingly competitive job market that demands digital literacy and technological proficiency. Despite these challenges, there is significant potential for 4IR technologies to enhance learning experiences through innovative teaching methods and improved access to educational re-sources [2].

This study aims to explore barriers and provide a comprehensive analysis of the challenges associated with 4IR/AI adoption in Zimbabwe's higher education institutions. The main argument centres on the assertion that while the adoption of 4IR technologies in Zimbabwean HTEIs holds transformative potential, it is fraught with significant hurdles that must be addressed. Resistance from educators who fear job displacement, inadequate technological infrastructure, and socio-economic disparities are among the primary obstacles hindering effective implementation [3]. Additionally, the lack of a coherent policy framework governing technology use in education exacerbates these challenges and limits the ability of institutions to fully leverage available resources [4]. This article posits that overcoming these barriers is essential not only for enhancing educational outcomes but also for fostering national development in a rapidly evolving global landscape. By focusing on these critical issues, this article seeks to contribute valuable insights into how Zimbabwe can better position itself within the context of global educational advancements.

The paper is structured as follows: Following this introduction, the literature review synthesises existing research on the challenges and influencing factors of AI-based learning in developing regions. The methodology details the research design, data collection and analysis techniques employed. The findings section presents the study's key results, followed by the discussion that interprets these findings in relation to existing scholarship. Finally, the conclusion and recommendations appropriate for higher education.

2. Literature Review

In developing countries, artificial intelligence (AI) integration in higher education faces a lot of challenges that hinder its full potential. Literature reveals that concerns surrounding data privacy, security, and ethics are at the forefront of these challenges [5], with the promise of AI and blockchain in education being tempered by issues related to accessibility, efficacy, and risk management [6]. Additionally, significant obstacles such as inadequate technological infrastructure, extensive training and support demands, and resistance to change further complicate AI adoption [7]. The implementation of Education 4.0 in these regions is additionally burdened by barriers like cybersecurity risks, skills gaps, and limited resources. This review synthesises current research to highlight the pervasive challenges within higher education institutions in developing countries, aiming to identify critical areas for policy intervention and strategic development to harness AI's transformative potential effectively.

2.1 4IR and AI Integration in African Higher Education

Integrating 4IR technologies in South African higher education institutions faces multiple obstacles, including conflicting global perspectives, difficulties in conceptualising 4IR, and a persistent digital skills gap [8]. [9] added that financial constraints and outdated infrastructure further limit adoption. Across Africa, the lack of skilled AI professionals, inadequate data protection infrastructure, and weak regulatory oversight exacerbate these challenges, making seamless AI integration difficult [10]. Similarly, higher education institutions in Nigeria struggle with curriculum misalignment, insufficient funding, limited training, and weak academia-industry collaboration, all of which slow the adoption of AI and 4IR technologies [11].

Beyond financial and regulatory barriers, cultural and social factors also shape 4IR adoption. [12] emphasised that a key challenge for Africa is bridging the gap between new technological cultures and traditional African cultures. [13] further highlights the hurdles faced by educators, including the need for continuous upskilling, resistance to change, and ensuring equitable student access to technology. Similarly, [14] specified that Kenyan universities attempt to implement e-learning and face negative perceptions, inadequate policies, and budget constraints, making it difficult.

The readiness of African education systems for the 4IR remains a pressing issue. [15] argue that Africa's education sector is largely un-prepared for the digital revolution, necessitating substantial curriculum improvements and investments to enhance student experiences. Ugandan university graduates, for instance, exhibit only basic knowledge of the Fourth Industrial Revolution, highlighting the need for curricula that better address technological advancements [16]. [17] underscores the importance of embedding entrepreneurship education into university programs to prepare students for the demands of IR 4.0.

Despite these challenges, AI integration offers substantial benefits. In South Africa, AI has enhanced learning environments by fostering collaboration, promoting active learning, and improving pedagogical systems [18]. Similarly, in academic libraries, AI holds immense potential for improving information service delivery, making it a crucial tool for 4IR transformation [19]. [20] note that while some South African institutions have successfully incorporated 4IR technologies into both virtual and in-person instruction, further efforts are needed for full-scale adoption. However, awareness of AI's potential remains moderate among tertiary students, with concerns centered around technical difficulties, privacy risks, and inadequate training and support [21].

For AI and 4IR technologies to drive meaningful change in African higher education, systemic improvements are essential. [22] argue that successful AI integration requires addressing issues such as inadequate infra-structure, socio-economic disparities, and ethical concerns related to data privacy and algorithmic bias. [23] envision AI as a transformative force capable of fostering industrialization and innovation, ultimately contributing to Africa's economic development. While the path to AI and 4IR adoption in African higher education

is fraught with challenges, strategic investments in digital infrastructure, policy frameworks, and capacity building can unlock their full potential.

3. Methodology

This study adopts a qualitative research approach, employing a predominantly desk review methodology to examine the challenges associated with artificial intelligence and the barriers to the Fourth Industrial Revolution in higher education. The research design emphasises the systematic analysis of secondary data, with sources including books, policy documents, government reports, newspapers, and other relevant literature. Data was retrieved using reputable search engines such as Google Scholar, Scopus and Web of Science. A Boolean search strategy was implemented, utilising operators “AND” and “OR” to effectively filter and refine the search results. The review process exclusively considered articles written in English to maintain consistency in language and interpretation. Key words employed during the search included “AI challenges,” “4IR barriers,” “universities,” and “institutions of higher learning.” This comprehensive approach allowed for the aggregation of diverse perspectives and insights, facilitating a critical examination of existing policies and academic debates. This method ensured a rigorous, transparent, and replicable analysis, establishing a solid basis for discussing the implications of emerging technologies in education.

4. Findings

The findings show that there are challenges that are experienced in Zimbabwe to fully implement 4IR. The challenges are presented in the Table 1, Table 2, Table 3, and Table 4.

Table 1

Technology	Integration in Curricula	Remarks
Artificial Intelligence	Limited	Not part of core academic programs
Robotics	Limited	Innovation hubs exist but not embedded in teaching
Blockchain	Limited	Lack of structured curriculum integration
Nanotechnology	Not integrated	Not widely taught
Machine Learning	Limited	No comprehensive training strategy
Additive Manufacturing	Largely absent	Requires equipment and skills development

Table 2

Challenge	Description
Lecturer capacity gaps	Lack of training and exposure to 4IR tools
Absence of industry collaboration	No formal engagement with instructional designers
Digital divide	Students from rural backgrounds lack devices like smartphones and laptops
Poor internet connectivity	National internet penetration at only 34.8%
Frequent power outages	Power cuts lasting up to 19 hours disrupt education and operations
Infrastructure and administrative constraints	Lack of standard policy, insufficient digital resources, high data costs, low parental involvement, etc.

Table 3

Barrier	Description
Lack of standardized technology policy	No consistent guidelines across institutions
Inadequate digital infrastructure	Universities lack sufficient computers and servers
Household digital exclusion	Limited access to computers in homes
High internet costs	Unaffordable for many students
Limited administrative support	Few support structures for students and staff
Low parental involvement	Particularly in rural settings
Unstable internet connectivity	Disrupts learning and assessment

Table 4

Aspect Affected	Impact Description	Source
Assignment submissions	Missed deadlines due to lack of power	Benon Ncube, ZINASU
Learning delivery	Interruptions in both remote and in-person classes	Parliamentary Committee, 2023
Examination conditions	Exams conducted in poor lighting or transitional power periods	UZ Registrar, UWN (Dec 15, 2022)
University operations	Increased operational costs due to generator reliance	UWN, Parliamentary Reports

5. Discussion

Inadequate technology infrastructure is one of the greatest issues. A lack of adequate technology infrastructure makes it difficult for many Zimbabwean tertiary institutions to successfully adopt online learning. Both students and professors have limited access to modern devices and dependable internet connection. Teachers frequently turn to asynchronous online learning methods because of these constraints, as [27] make evident. Although it allows for flexibility and self-pacing, students can also choose online education due to data difficulties.

Furthermore, having little funds makes the issue worse. Insufficient financial resources impede the successful adoption of online education [4]. Institutions find it difficult to acquire up-to-date, compatible IT infrastructure, which is necessary for digital transformation. The provision of internet data and enhanced connectivity are also impacted by these budgetary constraints, which significantly hinders access to online resources. The study reveals that inadequate digital infrastructure is a significant barrier to the adoption of 4IR technologies and AI in Zimbabwean HEIs. This finding aligns with the work of [1] who argue that outdated technological frameworks hinder educational progress in developing regions. The lack of reliable internet access and modern computing facilities restricts both educators and students from fully engaging with digital tools that could enhance learning experiences. Furthermore, this infrastructural deficit exacerbates the digital divide, leaving many students without the necessary resources to compete in a technology-driven job market.

Addressing these infrastructural challenges is essential for creating an environment conducive to the successful integration of AI and 4IR technologies, as emphasised by [28], who highlights the urgency of equipping educational institutions with modern technological capabilities.

Socio-economic disparities significantly contribute to the challenges faced by higher education institutions in Zimbabwe regarding AI adoption. The findings indicate that these disparities create a digital divide among students, limiting access to essential learning resources and technologies. This observation aligns with the literature reviewed by [7], which highlights how socio-economic factors can hinder equitable access to educational opportunities in developing countries. As students from lower socio-economic backgrounds struggle to access digital tools, their educational outcomes are adversely affected, perpetuating cycles of inequality. Policymakers must prioritise initiatives aimed at bridging this gap by investing in affordable technology solutions and providing targeted support for underprivileged students. Such efforts are crucial for ensuring that all learners have equal opportunities to benefit from advancements in AI and 4IR technologies.

In Zimbabwe, having both lecturers and students with digital competencies is crucial. The low level of digital competency among instructors and students is a major barrier to the implementation of online learning [4]. Their comprehension and acceptability of online learning are impacted by the fact that many instructors and students lack the necessary skills to use online technology [29]. Hence, to enhance these competencies and assure the efficient use of technology in teaching and learning, extensive training and education are required.

More generally, ICT uptake and use in the public sector are impacted by skill gaps. In order to improve service delivery and modernise the public sector, these issues must be resolved. According to [28] this entails making investments in both technical and soft skills for ensuring efficient service delivery. In order to effectively address these abilities, the curriculum must incorporate pedagogy, technology, knowledge, and skills. An analytical structure that emphasises complexities at the interface of curriculum architecture, pedagogy, delivery, and context must be established to direct pre-service curriculum.

Furthermore, policymakers must be aware of gender equity and cultural and language diversity in order to promote socioeconomic inclusion. With the aim to prevent weakening marginalised populations, [31] stated that AI deployments in Africa must take these important factors into account. As a way ensure that AI benefits everyone in society, proactive steps must be taken to eliminate current inequalities. For Zimbabwe to reap the benefits of the 4IR, entrepreneurial education must be improved. This involves modifying educational regulations to align with the 4IR. Developing skills that are relevant to emerging markets, like products-as-services, the sharing economy, and digital services exports, should be a top priority, according to [32].

The lack of a coherent policy framework governing technology use in education further complicates the adoption process for 4IR technologies in Zimbabwean higher education institutions. The study's findings suggest that without clear guidelines and strategic direction, institutions may struggle to implement effective technology integration initiatives. This situation resonates with insights from [32], who emphasise that coherent policies are essential for guiding educational institutions through technological transitions. Policymakers must develop comprehensive frameworks that outline best practices for technology adoption while addressing potential risks associated with AI use, such as data privacy concerns highlighted by [5]. By establishing robust policies, stakeholders can create an environment where technology is not only integrated but also used responsibly and ethically.

6. Recommendations

The study reveals several critical findings. Inadequate digital infrastructure emerged as a primary barrier, significantly limiting access to necessary technologies for both educators and students. Resistance to change among faculty, driven by fears of job displacement and lack of confidence in new tools, further complicates the integration process. Socio-economic disparities create a digital divide, exacerbating inequalities in educational opportunities. The absence of a coherent policy framework governing technology use in education restricts institutions' ability to leverage available resources effectively. Furthermore, fostering collaboration between educational institutions and industry stakeholders is essential for aligning curricula with market demands. Addressing these challenges requires a holistic approach that involves all stakeholders, including policymakers, educators, and industry leaders, to create an inclusive environment conducive to innovation.

The recommendations in this article are grouped into three key clusters: investment in digital infrastructure, policy formulation for inclusivity and governance, and fostering collaboration and innovation in higher education institutions.

7. Conclusion

Zimbabwe's higher and tertiary education institutions face numerous obstacles in using 4IR technology and artificial intelligence. These difficulties include deficits in digital proficiency, strategic and policy shortcomings, ethical issues, educational adjustments, and infrastructure constraints. A diverse strategy is needed to address these issues, which includes:

- Investing in resources and infrastructure related to technology.
- Progressing digital competencies through thorough instruction and training.
- Establishing procedures and guidelines for integrating AI and online education.
- Concentrating on moral issues with partiality, academic honesty, and job security.
- Adjusting courses to integrate the 4IR and digital transformation.
- Encouraging cooperation between industry partners, students, librarians, and academics, among other stakeholders.
- Advancing social inclusion and gender parity during the digital transformation process.

Higher education institutions in Zimbabwe can use the 4IR and AI to improve learning results, encourage innovation, and support socioeconomic development by taking steps to address these issues.

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Submission 35

The use of Generative AI in Sign Language Interpretation to improve classroom engagement for Deaf students in IT education - A Literature Review.

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Abstract. This study examines how Generative AI can transform sign language interpretation technologies to improve classroom engagement for deaf students. Conventional supports, such as human interpreters and captioning, often face issues with both availability and accuracy. GenAI provides real-time translation of spoken language into text or sign language, effectively closing communication gaps, especially in areas such as computer science, information systems, and information technology education. Our systematic literature review and archival document analysis were informed by Universal Design for Learning, Technological Pedagogical Content Knowledge, Cognitive Load Theory, and Community of Practice. The findings show that GenAI-powered tools improve content delivery and personalised learning, but struggle with translation accuracy, contextual interpretation, and teacher readiness for AI integration. Although GenAI enhances accessibility, it's essential to acknowledge that it should augment, not replace, human interactions in the classroom. This reinforces the continued importance of human educators in the learning process. This study greatly improves our understanding of how GenAI tools can be incorporated into education. It offers concrete evidence on both the benefits and drawbacks of these technologies in educational settings. The findings are particularly relevant for educators, policymakers, and tech developers, highlighting the need for comprehensive teacher training on AI use and identifying practical challenges such as translation accuracy issues and institutional support problems. Overall, the study proposes future research directions aimed at improving translation accuracy, exploring collaboration between humans and GenAI, and developing scalable solutions for institutions with limited resources. These recommendations provide vital insights for stakeholders seeking to optimise GenAI tool use in inclusive education.

Keywords: Generative AI, Sign Language Interpretation, Information Technology, Deaf Student Accessibility

1. Introduction

Artificial Intelligence (AI) technologies play a crucial role in promoting inclusive learning in today's educational environment, particularly for students who are deaf [1]. Effective communication plays a vital role in ensuring academic success and social inclusion for deaf learners. However, traditional support methods, such as human interpreters and captioning services, often face challenges including limited availability, accuracy issues, and scalability constraints [2]. These challenges hinder deaf students' participation in classroom discussions and their interaction with peers and instructors [3]. AI-based sign language interpretation technologies, such as GenAI, are revolutionising education in various fields and are paving the way for a more inclusive and accessible future. Their impact in Computer Science (CS), Information Systems (IS), and Information Technology (IT) education is increasing, promising to enhance the learning experiences for deaf students significantly [2]. GenAI offers innovative solutions for overcoming communication barriers by providing real-time translations of spoken content into written text or sign language. With GenAI-based sign language interpretation tools, classroom interactions become more dynamic and accessible, significantly improving comprehension and engagement [4].

GenAI serves as both a tool and a transformative force in education, enhancing educators' abilities to create personalised learning experiences, speed up students' learning processes, and deliver tailored lessons and feedback [4]. Technologies like SignAll and DeepASL utilise computer vision and natural language processing to convert sign language into spoken or written formats. Additionally, tools such as ChatGPT and GitHub Copilot provide personalised, text-based learning support, making programming and technical subjects more accessible without reliance on auditory input. Meanwhile, multimodal platforms like Sora and Microsoft's Seeing AI produce adaptive visual content that accommodates various learning styles in emerging tech domains, such as computer science (CS), information systems (IS), and information technology (IT) [3]. GenAI has substantially transformed learning environments by providing innovative solutions to traditional barriers, fostering inclusive educational experiences that were once unavailable to marginalised groups, including deaf students [3, 5]. The provision of sign language interpretation exemplifies this shift, granting deaf students real-time access to information and

bolstering their participation in classroom discussions, activities, and social integration promises.

Although GenAI sign language interpretation technologies show great potential, deaf students still encounter difficulties in accessing spoken content and participating in classroom activities. As educational institutions aim to foster inclusive environments, the demand for more effective communication tools intensifies. This highlights the significance of our research question: “How are GenAI sign language interpretation technologies utilised in education to enhance deaf students' classroom participation”?

2. Literature review

2.1 The Role of GenAI in CS, IS, and IT Education

AI and GenAI technologies are at the forefront of reshaping CS, IS, and IT education, from enhancing content delivery to enabling personalised learning experiences [4]. GenAI is disrupting traditional teaching methods, offering new possibilities for student engagement, academic achievement, and professional development [6]. The facilitation of developing more innovative tools that address the complex needs of diverse student populations, including deaf students who rely on sign language as a primary mode of communication, can never be overemphasised enough [6].

GenAI-based sign language interpretation technologies are an innovative solution to accessibility challenges in educational settings. Aligning GenAI with CS, IS, and IT curricula, the next frontier of innovation in education can help break down communication barriers in diverse learning environments, fostering a more inclusive educational ecosystem for students with disabilities.

Recent advancements in computer vision and NLP have led to the development of systems capable of translating sign language into spoken or written language [7]. Among these, SignAll and DeepASL have emerged as pioneering solutions.

2.2 Sign Language Interpretation Technologies

GenAI has significantly empowered deaf students through advancements in natural language processing (NLP), speech recognition, and sign language generation. These innovative tools facilitate real-time communication translation, as shown by [8]. They can either generate sign language from

spoken words or provide real-time text transcription, allowing deaf students to engage more fully in academic and social environments [9]. This empowerment represents a hopeful development, offering resources tailored to the specific communication needs of deaf students, thereby enhancing their engagement with content and interaction with their peers.

The influence of GenAI is noteworthy and promising, creating enhanced opportunities for students in learning, collaboration, and innovation. For example, GenAI-powered sign language interpreters could be employed in software development courses, enabling deaf students to share ideas, write code, and participate in group projects without the limitations of traditional communication methods. Additionally, GenAI can assist lecturers in interpreting code and facilitating debugging discussions, allowing deaf students to engage effortlessly in IT-related coursework and projects [8]. This ability to create new opportunities showcases GenAI's progressive role in education.

Technologies like SignAll and DeepASL merge computer vision with NLP to translate sign language into spoken or written forms. Utilising computer vision, a branch of GenAI, these technologies help machines comprehend visual data. As sign language is both visual and gestural, it involves intricate combinations of hand shapes, movements, spatial orientation, and facial expressions [10]. Accurate capture and interpretation of these visual components are crucial for effective translation.

The evolution of GenAI-driven sign language translation systems such as SignAll and DeepASL signifies a significant advancement in inclusive communication technology.

3. Theoretical Background

Various theoretical frameworks offer concrete suggestions to support educators in ensuring that all learners, particularly deaf students, can access and participate in meaningful and challenging learning opportunities. The integration of GenAI-based sign language interpretation technologies in educational settings can be informed by several key theories related to learning, accessibility, and technology, each contributing to understanding how these technologies can enhance classroom participation and engagement for deaf students [4, 9, 11].

Due to the ethical constraints encountered during the empirical data collection process, the study realised that adopting existing frameworks would help in extracting meaningful insights from the existing literature. Thus, grounding the paper in existing theories would enable the extraction of these insights based on various factors.

The Universal Design for Learning (UDL) framework, derived from the universal design architecture concept, strongly emphasises developing adaptable learning environments that meet the various needs of every student [12]. It is based on the notion that, wherever possible, products and environments should be designed to be usable by all people without needing adaptation or specialised design [12]. UDL provides multiple means of representation, engagement, and expression, ensuring that all students, including those with disabilities, can access and participate in learning experiences [13]. This enables deaf students to engage more fully in classroom discussions and activities, ultimately supporting their academic success [14, 15].

However, the UDL framework faces challenges in integrating technology, pedagogy, and content knowledge. This integration can be complex, requiring educators to have a deep understanding of both the subject matter and the technology. Ensuring that the technology is accessible to all students and that assessments are flexible and inclusive can be a significant challenge. The Technological Pedagogical Content Knowledge (TPACK) framework can effectively address these challenges. TPACK offers a practical framework for integrating technology into teaching strategies, ensuring that it enhances content delivery and engages students, making it a valuable tool in educational settings [16, 17]. The framework is designed to incorporate technological knowledge, building upon the pedagogical content knowledge (PCK) concept presented in [5]. For technology-assisted instruction to be effective, teachers must build TPACK. Therefore, TPACK is essential in sign language interpretation, as educators include GenAI's technological function in their teaching methods. The integration helps make learning more accessible and meaningful for deaf students, ensuring that GenAI tools are used effectively in the classroom to promote engagement and comprehension [18].

However, the UDL and TPACK diverge from addressing the burden associated with conceptualising the impacts on the mental health of deaf students [14, 19].

The UDL provides adaptable learning environments, and the TPACK concentrates on integrating technology use into teaching [20, 21].

The Cognitive load theory (CLT) posits that learning is most effective when optimising the cognitive load and mental effort required [22]. The CLT suggests that traditional methods of communication, such as reading captions or waiting for human interpreters, can impose an additional cognitive load as they require processing spoken language and its interpretation [23]. CLT lessens learning difficulties by concentrating cognitive energy on schema development. It has been noted that CLT addresses artificial learning and problem-solving challenges that can be influenced by instructional design. On the other hand, the intrinsic cognitive load remains constant for a specific area because it is a fundamental aspect of the subject matter [24]. Since it is noted that CLT addresses learning and problem-solving difficulties, understanding can be facilitated through instructional design, thereby reducing cognitive load considerably when learning the interactions between numerous aspects is required, primarily for deaf students [23]. Utilising GenAI sign language technologies can streamline this process by providing immediate access to information in a format that is easier for deaf students to process. This reduces cognitive load, empowering students to focus more on the taught content and improve their information processing and learning outcomes [22, 23].

However, because deaf students are not learning in their isolated environments, including their social spheres in the discussion would provide a wholesome approach to informing the study's requirements. The Community of Practice (CoP) theory, developed by Lave and Wenger, emphasises the social nature of learning and how individuals acquire knowledge through community participation [25]. The CoP emphasises the importance of engaging with peers and instructors to create a sense of belonging and shared knowledge in the classroom setup [26]. GenAI can facilitate mixed classroom engagements, enabling classroom discussions and active collaboration amongst peers, promoting inclusive interactions, and fostering a sense of community that encourages social integration, which is crucial for the academic and social success of deaf students [25].

These four theories are among the several theoretical frameworks that support the integration of AI-based sign language interpretation technologies in education to enhance accessibility and engagement for deaf students. The UDL

summarises adaptable learning environments by providing multiple means of representation, engagement, and expression. However, its effectiveness can be enhanced by TPACK, which integrates technology into teaching strategies to improve content delivery and student engagement. TPACK ensures that AI-driven tools, like sign language interpretation, are effectively implemented to make learning more accessible. The CLT highlights the importance of minimising extraneous cognitive effort to optimise learning. Traditional captioning and interpreter-based methods can increase cognitive load for deaf students. In contrast, AI-driven sign language interpretation, a key component of GenAI technologies, provides immediate access to information, reducing cognitive strain and improving learning outcomes. However, since learning is inherently social, the CoP theory emphasises the role of peer engagement and collaboration in fostering inclusive learning environments. AI tools, including GenAI technologies, can support these social interactions by enabling real-time discussions, enhancing participation, and fostering a sense of belonging among deaf students.

This combination offers valuable insights into understanding the impact of GenAI sign language technologies in promoting inclusive learning environments for deaf students. This combination provides a comprehensive understanding and opens new possibilities for inclusive education, which was previously hindered by ethical issues. For the same reason, our research methodology opted to utilise literature from archival documents, systematically reviewed, as interviews were discarded due to the sensitive nature of the research involving deaf students.

4. Research Methodology

The research methodology is guided by a two-fold approach integrating a systematic literature review for literature collection with archival document analysis. This approach was chosen to ensure a comprehensive extraction of literature guided by the UDL, TPACK, CLT, and CoP frameworks presented above. By utilising these frameworks, the study aimed to utilize existing reviewed literature to provide the required depth.

4.1 Systematic Literature Review

We systematically reviewed relevant literature from esteemed sources to evaluate the integration of AI-based sign language interpretation technologies

in educational environments. The review examined studies that applied UDL, TPACK, CLT, and CoP frameworks. We focused on how these frameworks facilitated the integration of AI-based sign language technologies, explicitly emphasising the reduction of barriers for deaf students and promoting engagement and participation in the classroom. The review followed a structured search protocol, identifying sources that provided peer-reviewed articles, conference proceedings, and institutional reports from reputable academic databases, including Google Scholar, IEEE Xplore, Springer, and PubMed.

The search terms used included “AI sign language interpretation, “GenAI sign language interpretation, “inclusive education and technology,” “UDL, TPACK, CLT, CoP frameworks in AI and education,” and "assistive technologies for deaf students."

We included studies focusing on AI-based sign language interpretation tools in educational settings. We examined the application of UDL, TPACK, CLT, and CoP frameworks in technology integration and provided empirical evidence that AI tools enhance classroom accessibility for deaf students.

We excluded studies that lacked empirical evidence or focused solely on theoretical discussions, addressed AI applications unrelated to sign language interpretation, and were published before 2010 unless they provided foundational insights into GenAI and education.

The systematic literature review considered GenAI-powered tools, including real-time sign language translation systems, speech-to-text applications, automated captioning technologies, and gesture recognition systems. The focus was on evaluating their effectiveness in fostering accessibility, engagement, and participation of deaf students in mainstream educational settings. Additionally, the review explored how GenAI technologies were integrated into inclusive education programs and how various pedagogical frameworks supported their implementation.

To broaden our insights, we also incorporated archival documents from institutional reports, project evaluations, and case studies from schools and universities that had implemented AI-based sign language tools in their classrooms. These documents examined how these institutions addressed accessibility issues and the outcomes of their GenAI initiatives. Government

reports and educational policy papers were also included to assess the broader regulatory context for employing GenAI technologies in inclusive education.

We argue that this archival analysis approach offers a deeper understanding of the practical challenges faced by institutions and users in real-world educational contexts, underscoring the importance of continuous evaluation and refinement of GenAI-based tools.

4.2 Data Analysis

We employed a deductive coding approach, informed by the reflective thematic analysis framework [27], to extract insights from the dataset. Our analysis was limited to themes guided by and relevant to our research question: “How are GenAI sign language interpretation technologies utilised in education to enhance deaf students' classroom participation?” By objectively extracting only relevant insights, we minimised the necessity to include emerging themes [27]. Following our inclusion and exclusion criteria, we uploaded the 18 remaining articles into NVIVO version 15, where we coded the data.

The bar graph in Fig. 1 highlights key themes explored in the study, with "GenAI sign language" being the most referenced (10 mentions), followed by "students' classroom participation" (7 mentions). "Language interpretation technologies" is mentioned 6 times, while "AI and education" has the fewest references (5 mentions). This suggests a strong focus on AI-driven sign language solutions and their impact on student engagement in the classroom.

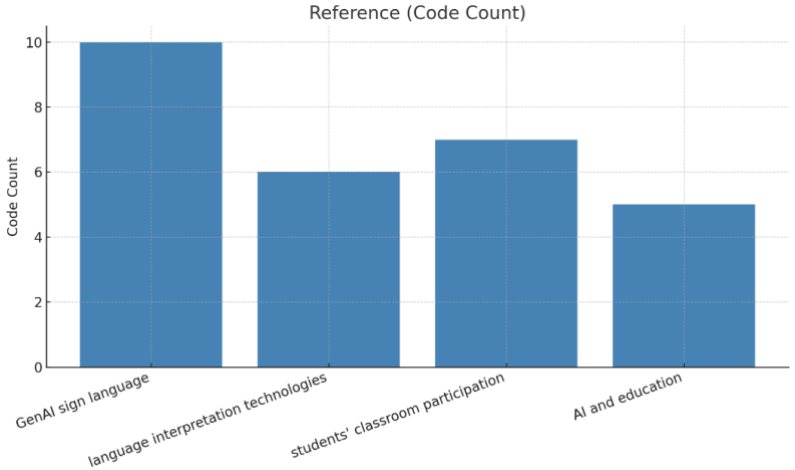

Fig. 1. This process involved classifying the data into key themes.

5. Findings

An analysis of the literature, conducted through a systematic literature review approach, draws insights from archival documents into GenAI sign language interpretation technologies and their significance in inclusive learning environments. The themes were shaped by theoretical constructs, alongside our primary question: "How can Gen AI sign language interpretation technologies be used in education to improve deaf students' participation in the classroom?" The findings emphasise both the potential and limitations that affect the use of GenAI technologies. Several results are presented in Table 1.

The thematic analysis of data regarding the implementation of GenAI-based sign language interpretation technologies in educational settings for deaf students revealed five central themes. Each theme is underpinned by specific theoretical frameworks that help to contextualise and explain the findings.

Table 1. Insights into the successful incorporation of GenAI-based tools in classrooms.

Theme (Data Analysis)	Code Count	Findings Summary	Theoretical Constructs
GenAI Sign Language	10	GenAI enhances access to spoken content for deaf students, promoting fuller classroom participation, though real-time translation accuracy varies.	UDL, CLT
Students' Classroom Participation	7	Improved classroom participation is observed when GenAI is effectively integrated; however, poor translation and lack of human nuance can cause isolation.	CoP, UDL
Language Interpretation Technologies	6	These technologies help bridge communication gaps, but often fall short in understanding non-verbal cues, such as facial expressions and spatial gestures.	TPACK
AI and Education	5	While GenAI facilitates learning, its full potential is hindered by institutional resistance, infrastructure limitations, and concerns about accuracy.	TPACK
Impact on Classroom Participation	9	GenAI tools, when used effectively, support engagement; however, inconsistency in performance may impact student inclusion.	UDL, CoP

The utilisation of GenAI technologies significantly improves access to spoken content for deaf students, promoting their active involvement in classroom activities. However, inadequate translation accuracy and the absence of human nuance can result in feelings of exclusion. This theme is fundamentally linked to CoP theory, highlighting the social dimensions of learning and the significance of community interaction [28]. The UDL advocates for equitable access and participation in educational environments [21].

Although AI-driven interpretation technologies help close communication gaps, they often fail to accurately convey non-verbal elements, such as facial expressions and spatial gestures. This shortcoming emphasises the necessity

for a pedagogically informed strategy for integrating technology, which is more comprehensively understood through the TPACK framework.

TPACK provides a valuable framework for the effective and contextual integration of new technologies into educational practices [20].

6. Discussion

GenAI has witnessed advancements that have made real-time translation increasingly viable in classroom settings, where immediate access to instructional content is essential. GenAI technologies now provide near-instantaneous captions and translations, enhancing the flow of information for deaf students.

Despite these improvements, some challenges persist, particularly in dynamic classroom interactions. Issues with translation accuracy arise during fast-paced discussions, specialised vocabulary, and informal discourse, leading to communication breakdowns. [29]. This underscores the necessity for continuous enhancements in GenAI's natural language processing capabilities to capture contextual and cultural nuances better, highlighting the need for improved NLP capabilities [29]. We were surprised to discover that while students valued real-time access to classroom content, many reported issues with the accuracy of GenAI translations and the absence of human-like nuance in sign language interpretation [8]. As [6] stated, faculty members expressed concerns about the need for more practical training to effectively integrate AI tools, emphasising the importance of teacher preparedness in incorporating GenAI. While GenAI can provide real-time captions and translations, it struggles to capture the emotional subtleties, tone, and non-verbal cues that are essential for inclusive learning. Thus, AI should be a support tool rather than a standalone solution [4].

7. Contributions

This study significantly contributes to the discussion on inclusive education by enhancing our understanding of how GenAI technologies can boost classroom engagement for deaf students. It introduces a conceptual framework based on four essential theoretical constructs, UDL, TPACK, CLT, and CoP, that together underpin the pedagogical, technological, cognitive, and social aspects of integrating GenAI into inclusive education [17, 30].

The findings, which extend to emerging themes, also highlight the importance of teacher training. Educators equipped with GenAI-specific skills demonstrate more effective classroom integration of these tools, a conclusion that aligns with the principles of TPACK [20]. The study further underscores the socio-emotional impact of AI-mediated learning. The reduced interpersonal interaction associated with GenAI interpretation can lead to student disengagement and social isolation, which are effectively interpreted through CoP, as it emphasises the role of social participation and collaborative engagement in learning [31].

The study establishes a comprehensive theoretical foundation for the deployment of GenAI in inclusive classrooms. Addressing pedagogical effectiveness, cognitive accessibility, technological competence, and social connectedness, the findings inform future practice, policy, and design for more equitable and responsive educational technologies.

8. Future Research

Future research should focus on enhancing the accuracy and contextual comprehension of GenAI-driven sign language translation, as well as investigating human-GenAI collaboration to promote more effective communication. Additionally, developing teacher training programs for successful integration in classrooms is essential [8, 9, 29]. As GenAI technologies continue to advance, assessing their long-term effects on student engagement, social inclusion, and academic achievement through empirical research is critical. Gaining insights into how these technologies influence learning outcomes will help educators and policymakers refine their implementation strategies.

There is a significant need for evidence-based approaches when integrating GenAI technologies in education. By understanding the impact of these technologies on learning outcomes, educators can adjust their teaching methods to maximise benefits for students, particularly those who are deaf or hard of hearing.

Exploring methods to scale GenAI tools across varied educational environments, especially in under-resourced institutions with limited access to qualified interpreters and assistive technologies, is crucial. Assessing the cost-effectiveness and sustainability of these technologies can provide valuable insights into their practicality for broad adoption [8]. Furthermore, it is vital to

develop policies that ensure the ethical incorporation of GenAI, addressing issues such as bias in translation models and the potential consequences of over-reliance on automated tools. Implemented policies and guidelines for GenAI use in classrooms will aid in overcoming institutional resistance and guaranteeing fair access to GenAI-driven educational resources, promoting inclusive learning environments for every student.

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