

Investigating the extent in which ecological systems help lecturers to enact Artificial intelligence strategies for adaptive teaching

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Abstract: The paper explores the influences Ecological Systems has in the growth of humankind and adaptation to technological changes. Institutes of learning are now adapting to the growth of Technology in which now is blown by AI immense growth as a teaching strategy (i.e., helping students to understand difficult and abstract mechanical concepts through AI.). This paper therefore explored how Ecological System helps lecturers to enact Artificial Intelligence strategies for adaptive teaching in Gauteng TVET Colleges that are offering Mechanical Engineering. Technical and Vocational Education and Training institutions find themselves as one of the critical sectors mandated with skills and manpower development roles in response to the needs of industry and commerce. It therefore follows that, the competence of lecturers who can effectively and efficiently transfer the relevant technical and vocational knowledge, and skills becomes a critical national imperative for analysis and discourse. The study was guided by Ecological System Theory framework in trying to give direction to study fundamentals. This study deployed qualitative research approach and further used interviews, observation and equipment analysis as a data collection instrument. Thematic analysis was a tool used to analyse the data obtained. The study found that Mechanical Engineering lecturers at TVET colleges lack training or development into the use of AI. Furthermore the study found that infrastructure is another stumbling block in most of the institutes as they don't have proper equipment of resources to enable lecturers to use AI strategies for adaptive teaching.

Keywords: Ecological Systems, AI, TVET, Mechanical Engineering, Adaptive Teaching

Introduction

Ecological Systems Theory (EST) by Urie Bronfenbrenner (1979), should be understood as a phenomenon where humans find better ways to cope with the speed of changes surrounding them such as lecturer' teaching. In other words, they should be in par with the innovations coming up and devise adaptive teaching plans to assist their students in delivering meaningful lessons (Biea et al., 2024). Almost every day of our lives we now learn how to live better with our surrounding environments. Our current environment forces us to become digital citizens especially in the education space. Looking at the role of Technical Vocational Education and Training (TVET), it emphasizes skills competitiveness globally, which are encapsulated by the technologies we see today. So, for lecturers to cope with these technologies, they should embody the ecological systems of their education sector.

Applying the principles of Ecological Systems Theory, lecturers can better manage the complexity of integrating AI into their teaching techniques in a diverse educational environment. Authors such as (Das et al., 2025; Chukhlomin, 2024; Regona et al., 2022; Cardona et al., 2023) explored the transformative potential of artificial intelligence (AI) in reshaping educational practices, particularly through adaptive learning technologies. These AI-driven systems, designed to act as personalized tutors, provide real-time, tailored support, adjusting to each student's unique learning needs and offering specific, timely feedback. Their findings shared positivity in the application of adaptive teaching

with AI but no specific focus in TVET colleges. It is a fair argument that not much has been done to understand mechanical engineering lecturers' pedagogies in TVET colleges, let alone how they use Artificial Intelligence to strategize their teaching, this is a research gap worth exploring.

Urie Bronfenbrenner (1979) proposed Ecological Systems Theory (EST), which provides a comprehensive framework for analysing human development in the context of numerous environmental systems. While originally used in psychology and sociology, it can now be used to describe the interactions between artificial intelligence (AI) systems and their environmental settings. Applying the EST framework to the usage of AI in colleges allows stakeholders to gain a deeper understanding of the intricate interactions between AI systems and the college environment. This comprehensive approach encourages careful consideration of technological, social, ethical, and cultural elements while designing, implementing, and evaluating AI-driven educational advances (Giannakos et al., 2024).

The incorporation of Artificial Intelligence (AI) within educational environments has seen significant growth in recent years, presenting innovative solutions for personalized instruction, especially within Technical and Vocational Education and Training (TVET) colleges. These institutions are essential in preparing students with the practical competencies necessary for various industries. The integration of AI into adaptive learning frameworks in TVET colleges can facilitate customized learning experiences that adapt to the individual requirements of students. Additionally, integrating ecological systems theories into these educational contexts offers a comprehensive, context-sensitive approach to examining the interactions between technology, learners, educators, and the educational ecosystem. The need for adaptive teaching is key in aligning ourselves with the current changes brought by AI.

Literature

Artificial intelligence, or AI, is gaining popularity as a technique for mimicking human behavior. AI in education is the application of artificial intelligence technology, such as machine learning and natural language processing, to improve the learning experience (Alneyadi, Saif, Wardat, Yousef, Alshannag, Qasim, & Abu-Al-Aish, Ahmad., 2023). It entails the use of algorithms to evaluate data, discover patterns, and make predictions, allowing educators to tailor instruction for each student (Khan et al, 2022). Furthermore Fitria, (2021) defined Artificial Intelligence as the process of modelling human thinking and designing a machine so that it can behave like humans or other terms called cognitive tasks, namely how machines can learn automatically from programmed data and information.

A study by Zhu (2022) argues that the teaching mode of Basics of Mechanical Engineering has the purpose of improving the students' interest towards the course. The researcher found that integrating technological lessons into theoretical teaching can enhance students' interest in the course and thus motivate them. In this argument, it can be seen that for a Mechanical Engineering lecturer, they need to be effective and motivated with AI equipment or resources and be a practical person, meaning they must be in a position to confidently demonstrate the practical understanding of learning through technology.

Baser and Mutlu (2011) revealed that facilitators or teachers who make use of educational technologies as one of their teaching methods can engage more students in learning because of technology. While much of the early work in formal instructional design and teaching was based on objectivist philosophy, recent scholars believe constructivist learning is more effective since it fosters critical problem-solving skills (Renninger

Understanding Adaptive Teaching

Traditionally, the art of teaching has been connected with teachers' ability to lead classroom activities that assist students to learn. Furthermore, good teaching can be improved if lecturers and teachers are more introspective and disciplined in their judgment of what students need (Istiyono, et al. (2021). The end outcome is adaptive instruction. This style of instruction comprises monitoring students, procedures, and behaviors while you teach, carefully diagnosing pertinent components of the course content based on these monitoring activities, and changing the lesson accordingly.

In a larger sense, adaptive teaching refers to the teacher adjusting his or her teaching strategies and actions to improve student learning. A teacher's strategies may include encouraging students, providing feedback, assisting students with learning strategies, providing alternatives, summarizing and repeating, posing new questions, modeling, structuring how students should collaborate, and explaining why and how to repeat a concept. Teaching is most effective in developing self-monitoring, instructional decision-making, and teaching methods when new patterns are formed in a range of relevant settings. These strategies may be implemented during whole-class education, with higher and lower ability and minority students receiving additional approaches. At other times, adaptive methods will be used in one-on-one tutoring or cooperative peer interactions.

Adaptive teaching is regarded to address students' heterogeneity in schools and to individually support their learning (Sibley, et al. 2024). Technology may help to teach adaptively. However, it is still unclear whether realizing adaptive teaching with technology is a feasible teaching practice in real-world classrooms. Other researchers such as Parsons et al. (2018) believe adaptive teaching as a teacher's response to stimuli focused on supporting student needs. The researcher continued to allude that Teachers' adaptive instructional actions appear to lead to enhanced student learning, motivation, and behavior (Parsons et al., 2018).

Methodology

This study used qualitative research approach. Qualitative research approach refers to a systematic inquiry into social phenomenon in its natural environment (Henning, Van Rensburg & Smit, 2004). Exploratory case design was used, which is defined by Olawale, Chinagozi and Joe (2023), as research that involves acquiring informal and unstructured material.

Purposive sampling was deployed to understand the embodiment of ecological systems among Mechanical Engineering Technical Vocational Education and Training (TVET) College lecturers to use Artificial Intelligence strategies for adaptive teaching. Purposive sampling is defined as a process of selecting subjects to take part in a research investigation on the ground that they provide information considered relevant to the research problem (Green & Thorougood, 2018; Cohen, Manion, & Morrison, 2000). This study purposively sampled seven (7) TVET colleges across Gauteng province and 16 Mechanical Engineering lecturers, consisting of more than two mechanical engineering lecturers per college in the province offering the Mechanical Engineering scheme. Qualitative research standards, focusing on in-depth understanding rather than extensive data, guided the sample size for this study. The participant number provided detailed insights into how Mechanical Engineering TVET lecturers enact AI in their teaching. This sample size supported practical data collection and detailed analysis. Data saturation, was reached when interviews ceased to yield new insights, confirmed the suitability of the participant number for addressing the research questions.

This study used TWO (2) methods in collection of data, namely semi-structured Interviews, and Observation. Data collection is defined as the technique which is geared to systematically collect information about objects of the study including people and phenomena, and the setting where data is collected (Tracy, 2024). This study chose a qualitative research approach, other than quantitative and mixed methods, because it allowed the researcher to go beyond surface data and uncover deeper insight that would have been lost in numerical data. This depth was essential for a clear understanding of the distinctions of the embodiment of ecological systems among Mechanical Engineering TVET lecturers to use AI strategies for adaptive teaching.

In order to minimize internal bias, reflexive journaling was utilized, along with triangulation, member checking, and maintaining an audit trail. Each of these steps was necessary to ensure that my personal views did not inform the data and that participants' voices remained central throughout the study.

Findings and Discussion

This study found that ecological systems helped lecturers to:

Adaptation To Technological Changes

Adapting to emerging technologies has become a necessity of the TVET environment, particularly because the TVET Colleges are in the frontline in producing competitive industrial skills (Yusvana, 2024). It is thus expected that TVET lecturers associate themselves with all emerging technologies that could aid their technological pedagogy. In addition, these technologies should complement the readily available technologies that are geared to accelerate skills capacity to their students (Angel-Urdinola & Chinen, 2025). As such, lecturers were asked to register their views on how ecological systems helped them to enact Artificial intelligence strategies for adaptive teaching, see extracts below:

In my mechanical class when I teach the topic Hydraulics, I use AI tools in lesson preparation. I used a software (google form) to make quizzes and organize material better. It makes teaching administration easier, but I still like to guide the content.- Interview (Lecturer 2).

In support of lecturer 2's view, Lecturer 4 said that: "

I occasionally use AI tools to plan lecture slides, for my Mechanotechnics – interview (Lecturer 7).

Drawing from the positives of the above responses of the TVET lecturers, there are other lecturers who reported challenges in the adaptation to the use of technologies in teaching their respective Mechanical Technology modules.

The lecturers registered their views as indicated in the extract below:

I have not really used AI tools to great lengths in my teaching so far. The department has provided some resources, but I think I do need more training. The technology is there, but I do feel a bit overwhelmed with possibilities - interview (Lecturer 1)

Resonance with lecturer 1 was also identified with lecturer 3 assertions who indicated a challenge in using AI tools to assist in employing adaptive teaching strategies, see excerpt below:

AI? To be honest, I do not apply anything like that to my teaching. The curriculum is already rigid enough, and I do not know where the AI would fit in. My students do not appear to need it either – interview (Lecturer 3)

Indeed, lecturer 3 words were verified by the setting of his classroom, see figure 4.2 below:



Figure 1 : Lecturer 3 Mechanical lesson

Image taken by the researcher: Mhlanga P.T

The above figure depicts the classroom for lecturer 3 in support of the no application of AI tools for students' enhancement. It is surprising that in this day and age, engineering lessons are still taught in a way that any other module is taught. A study by Eshkoraev (2024) demonstrates that mechanical concepts should be taught in a way that knowledge-based approach is used simultaneously with skills-application approach. This enables students to consume strong foundational mechanical concepts where both theory and laboratory work serves equal purpose. However, in the case of lecturer 3, it seems a textbook and lecture method approach were overused to the detriments of students' psychomotor skills. Indeed, there is an unbalanced scholarship of teaching and learning from the lecturer 3's side. The views of lecturer 3 were also echoed by the response of lecturer 6 who stated that:

I do not use AI resources. I do not believe that they can replace the human touch in the classroom - interview (Lecturer 6).

The above findings indicates that some lecturers are aware of the possibilities of AI in enriching lesson delivery, insufficient institutional support, training and opposition to a shift in traditional teaching methods are still emerging as the core factors in preventing widespread use of AI in classrooms. This supports claims by Mutanga et.al (2025) who postulate that some lecturers continue to resist the change brought by AI in their environment because of varied micro-ecological factors such as classrooms and online learning platforms, in line with the Micro Systems from EST framework by Bronfenbrenner (1979). Nevertheless, some lecturers have been exposed to the AI tools but never had a chance or experience to apply it into their adaptive teaching, see extract below:

I do have knowledge of learning management system (LMS) such as Moodle and MyUnisa, that includes some AI-capabilities, like recommending reading assignments based on student performance, but that is about it. I do believe more integration of AI would be useful but would be reliant upon institutional support. I only got the experience of it from UNISA when I was studying there – interview (Lecturer 5)

Another lecturer shared similar sentiment with lecturer 5, see below:

I had minimal contact with AI in instruction, but I believe it might be helpful for grading or spotting gaps in student

performance. I just have not had the opportunity to explore those avenues thoroughly - interview (Lecturer 4)

The above reflects mixed feelings from lecturers when it comes to the adoption of AI in classroom for adaptive teaching in Mechanical Engineering. In resonating the findings from the lecturer's responses, a study by Tondeur et al. (2017) highlighted the importance of institutional efforts that include digital literacy and AI teaching skills in academic growth programs. AI integration works best when it is paired with ongoing professional development, mentoring, and a supportive community (Tomaskinova & Tomaskin, 2024). The findings of this theme revealed the need for lecturer development and training in line with the use of AI in classroom.

Most lecturers seem to lack the third component, and this deficit bars adoption.

Looking at the lecturers' responses, several of the most significant themes were identified that explain how ecological systems influence adoption in teaching with AI. The major supporting themes that were identified were Limited Exposure to AI, Institutional Support and Resources, Independence in Pedagogy, Perceived Value of AI, and Technological Comfort.

The mixed feelings of the lecturers is not due to a resistance to AI but due to systemic constraints and exposure. This parallels the model of "technological pedagogical content knowledge" (TPACK), which suggests that effective integration of technology (including AI) requires integrated knowledge of:

Content knowledge (mechanical engineering), Pedagogical knowledge (how to teach) and Technological knowledge (how AI can be effectively used).

Overall, the findings suggest the possibility of a will among lecturers to explore AI applications in the classroom, given adequate institutional investment, teacher development, and supportive policy incentives. To move interest into practice, higher education institutions must make the creation of both the technical platforms and human capacity necessary to actualize the full potential of AI in Mechanical Engineering education an academic imperative.

Pedagogical Autonomy

Pedagogical autonomy is considered to be one of the most liberating teaching dividends in the TVET environment, where lecturers get freedom to make decisions about their teaching methods and curriculum execution (Nikisi, Mashologu, Bwowe & Masha, 2025). In order to diffuse innovation into TVET Colleges, pedagogical autonomy ought to be promoted. This is supported by Liew (2024) who propound that for many years lecturers' morale and motivation has been declining due to leadership restrictions on their teaching methods. As a result, it was refreshing to see this theme emerge in participants' responses as a critical insertion into the promotion of Artificial intelligence strategies for adaptive teaching discourse.

Lecturers across all the TVET colleges visited described autonomy at the microsystem level, including classroom-level decisions and with students. A number of participants reported that they had autonomy to choose and apply AI tools best suited for their pedagogical requirements. For instance, one participant said:

"I believe that in my own classroom, I have the option to use AI to track student participation or adjust the content in real-time. The college do not require that. That's up to me." Interview (Lecturer 2)

The views of lecturer 2 aligns with Paulsrud and Wermke (2020) description of teacher autonomy not so much as the power to decide about teaching approaches but also as having the capacity to reflect critically and be accountable for pedagogy. With regard to the use of AI, this reflection often entailed ethical issues and a desire to maintain human-centered learning environments (Holmes et al., 2019).

But the evidence also confirmed that this autonomy is not total. Many of the participants made clear the way in which the exosystem institutional policy, technological infrastructure, and administrative priorities determined the boundaries of their autonomy. As one respondent put it:

"I have the freedom to play around with AI tools, but without institution support or a clear framework, you are in effect walking in the dark. You can do it, but you are not sure if it is the right path." Interview (Lecturer 4)

The views of lecturer 4 were not unique that of a study by Erichsen and Reynolds (2020) which argues that institutional environments empower or suppress innovation depending on the way resources, professional development, and administrative discretion are organized. Furthermore, Trust et al. (2016) highlight that training access and policy transparency significantly influence whether autonomy results in significant innovation or compliance.

This is consistent with Guy-Evans (2020) hypothesis, that broader ideological and cultural values influence indirectly

the decisions made at the classroom level. As one of the interviewees explained:

"Autonomy is great, but there is sometimes an unspoken expectation since AI is the name of the game right now, you're supposed to do it, even if you're not aware that it is your best solution for your topic." Interview (Lecturer 8)

Moreover, much recent research on AI in learning such as Luckin et al., (2016); Holmes et al., (2019) emphasizes that without enabling ecosystems technical, ethical, and pedagogical enactments of AI are likely to be performative rather than transformative. Overall, pedagogical autonomy in enacting AI plans is facilitated as well as restricted by the encompasses ecological systems. While lecturers typically feel free in their local contexts, such autonomy is highly contingent on institutional and cultural systems' support (or lack thereof). Where the ecological layers are congruent, autonomy facilitates innovation and reflective practice. Where they are out of alignment, it leads to ambiguity, resistance, or superficial utilization of AI tools.

This viewpoint underlines the earlier criticisms by acknowledging incremental reforms but, on the other hand, exposing ongoing lack of essential teaching technology. Together, these responses reveal a broader trend of institutional underinvestment in teaching technology, with lecturers across departments both frustrated and defeated. The responses also reveal a disconnect between infrastructure enhancements (e.g., campus-wide Wi-Fi) and actual tools necessary for technology-enabled teaching.

Observation

Observational data across various TVET college campuses revealed that physical and technological setup in most lecture halls is poorly geared towards enabling the effective use of Artificial Intelligence (AI) resources in teaching and learning. Three broad themes emerged: traditional classroom layouts with low connectivity, heterogeneous technological infrastructure across engineering workshops, and small numbers of digitally equipped learning facilities.

Firstly, most classrooms have conventional layouts of fixed seating, blackboards, and restricted access to computers or internet connections. Such settings are naturally at odds with the flexible, interactive, and networked learning environments required for AI-supported learning (UNESCO, 2021). Restrictions on basic infrastructure such as projectors, reliable Wi-Fi, and sufficient power points hinder the integration of AI tools like intelligent tutoring systems or computerized testing programs.

Second, the observations showed that engineering workshops comparatively have improved access to technology like desktops, simulation software, and diagnostic tools. While these workshops can incorporate AI most notably in machine learning simulations or smart diagnostics their hardware is typically outdated, inadequately serviced, or offline. This supports the findings of Zhang and Aslan (2021), who point out that isolated technological enhancements do not meet needs in the absence of networked digital convergence and connectivity.

Lastly, there were some institutions that had created digitally enabled learning spaces with smart boards, mobile desks, internet access, and audio-visual devices. These spaces held promise for AI-enriched education but were few in number, largely underutilized, and not available for routine pedagogy. This is in agreement with Holmes et al. (2021), who argue that while more classrooms are being made digitally-enhanced, access and equity continue to be serious problems in under-resourced learning spaces.

Discussion

The findings of this study provide critical understanding of how ecological systems influence the capacities of lecturers to apply AI approaches to adaptive teaching. Adaptation to Technological Changes and Pedagogical Autonomy are two general themes emerging from the interviews with participants. Together, they reflect both enabling and constraining roles of ecological structures at various system levels.

Adaptation to Technological Changes highlights the ongoing changes that lecturers must deal with as AI becomes more ubiquitous in tertiary learning. Participants noted increasing pressure to keep up with evolving technologies, much of which was driven by institutional, societal, and policy-level factors. The mesosystem and macrosystem a level including professional development systems, interdepartmental collaboration, and national education policies weighed strongly in influencing lecturers' willingness and capacity to adapt. Where such systems existed, lecturers were emboldened to try out AI tools for adaptive teaching. Where such environments did not exist, with no evident strategies, training, or infrastructure, such adaptation was more difficult, and reluctance or surface use of AI technologies was observed.

Pedagogical Autonomy was a tacit but significant factor in shaping lecturers' experiences of AI integration. The majority of the participants felt they were enabled at the microsystem level to make decisions rooted in their teaching

contexts, particularly in leveraging AI to personalize learning experiences. This autonomy was felt as the door to substantial AI adoption. Yet, it was also subject to the limitations of the exosystem, like institutional policy, funding structures, and administrative demands. While autonomy made lecturers classroom innovators, its effectiveness was contingent on systemic support and alignment at ecological levels.

In direct response to the research question, the study concludes that ecological systems facilitate and constrain AI strategy implementation based on the interaction between systemic support and individual agency. The capacity of lecturers to deploy AI for adaptive teaching is strongest when:

Institutional and policy environments (exosystem and macrosystem) offer consistent guidance and support;

Lecturers have the opportunity to develop technological competence (mesosystem); and they retain pedagogical freedom and trust at the classroom level (microsystem).

Thus, the introduction of AI solutions to adaptive teaching is not solely a technological problem, but also systemic and pedagogical, requiring ecological alignment, continuous professional development, and a respectful balance between innovation and teacher autonomy.

Overall, the study reports a broad gap between existing physical infractions in TVET colleges and physical infractions necessary to facilitate effective integration of AI. Most learning environments remain traditional and not well equipped and thus a hindrance to advancement in AI-based pedagogy. Absent much investment in infrastructure and credible access to digital facilities, AI in TVET teaching will remain in patches and intermittently applied.

Findings

The condition of lecture rooms and workshop facilities in the TVET colleges being monitored is in harmony with broader concerns expressed in the literature on the digital divide in vocational education. Different research studies (OECD, 2019; Kivindu, 2024) name the lack of infrastructure as one of the most persistent barriers to the adoption of AI and other cutting-edge technologies in technical education. This echoed with the findings of this study.

Mhlanga & Moloi (2020) note that for AI to be incorporated meaningfully into the classroom, there must be a threshold level of technological readiness, both in terms of hardware, software, and internet connectivity. Without these fundamental foundations, incorporation of AI proves to be difficult, if not impossible. Moreover, David et al. (2024) argues that education for the Fourth Industrial Revolution demands not only exposure to technology but even re-engineering of learning spaces for advancing digital literacy, automation, and data-driven thinking. Traditional workshop configurations with retrogressive machinery do not catch this imagination.

The findings from the classroom observation in response to research question number 3, clearly indicated that *most learning environments for mechanical engineering in TVET colleges are quite unready to accommodate AI technologies* (observation data). While some have progressed to digitization by installing computer labs or projectors, the general setup is still mostly analog, especially in workshops. A study by Olawale, et al. (2023) echoed that to enhance the integration of AI, there should be systematic investment in equipment modernization and infrastructure. The workshops should be modernized to include digitally enabled and AI-compatible equipment, and the lecture halls should be equipped with internet facilities and smart technologies that enable adaptive, data-driven styles of teaching. Ultimately, barring a catch-up by the physical learning and teaching spaces to evolving technology needs, adoption of AI in TVET learning will be a mirage.

These findings are similar to the findings of the study conduct by Ralushai (2021), that indicated that infrastructure remains a huge challenge in south African settings of colleges. Moreover, the study further indicated that in some of their findings they have also produced some serious problems like old equipment, lack of equipment, and more. Almost all the TVET colleges interviewed reported Wi-Fi availability problems. Respondents in interviews showed irregular internet connection or non-activated Wi-Fi. ICT problems otherwise include the need for servers, hardware space for loading learning materials and video lessons, and suitable software. This study found similar results with majority of the colleges having little to no WIFI connections.

The findings further revealed that majority of South African TVET colleges experiences similar challenges in Artificial Intelligence use as an adaptive teaching strategy. The challenges go as far as infrastructural, whereby most TVETs structure aren't ready to accommodate the use of AI in teaching Mechanical Engineering modules. These findings were similar to the findings of United States of America education technology report by Cardona, et al. (2023), which alluded that some uses of AI may be infrastructural and unseen, which presents concerns about transparency and trust. AI typically emerges in new applications with the aura of magic, but lecturers and procurement

policies insist that educational technology establish efficacy. One college in Mpumalanga have some equipment in place but still under full construction to allow ICT integrated into the teaching and learning. However, lecturer development or training for the use of AI as an adaptive teaching strategy remains in shamble. The study also found the Ecological Systems, such as the MESO is the main stumbling block into the embodiment and infusion of AI integrated tools into teaching and learning.

Challenges Identified

Exposure to AI Tools

Unfamiliarity with AI tools was one of the overarching themes throughout the responses. Lecturers such as Lecturer 1 were daunted by what AI has to propose, while others, such as Lecturer 3, had a tangible feeling of alienation and stated that “*they could not conceptualize how AI would be integrated into their teaching*”.

Institutional Support and Resources

The other prominent strand was the absence of institutional support for introducing AI. Lecturer 5 talked of utilizing AI-enabled functions within a Learning Management System but emphasized the need for further institutional support. Similarly, Lecturer 4 listed the potential for applying AI to grading and identifying student performance gaps but noted a requirement for additional times to trial such tools.

The responses show an ecological environment where frameworks of an institution are not yet providing training, tools, or incentives for integrating AI as a standard tool in teaching. Majority of the TVET colleges have not yet incorporated their infrastructure in line with technology. There’s still poor development that reinforces the need to be technological inclined which one can therefor relate it to Ecological System such as MESO System that focuses on the communication between the institution, department and the lecturers.

Insufficient Proper Training and Professional Development

Lecturers require not merely generic ICT support but tailored, ongoing professional development to acquire expertise using next-generation technologies. Research emphasizes that the training content needs to blend essential topics (Office tools, LMS use) with exposure to advanced 4IR technologies (robotics, CAD, simulations), and a focus on pedagogical strategies for integration (Brennan & Prediger, 1981). Similarly, Ugandan academics transitioning to technology-mediated education mention time constraints and a mismatch between training offered and their personal requirements (Uzorka et al., 2023).

Perceived Value of AI

Others also had perceived value of AI tools but were hesitant to fully commit to them since they had no personal experience and no full institutional or departmental support. For instance, Lecturer 4 & 9 admitted that AI might be useful for grading and the detection of performance gaps in students but had not yet investigated these uses. The usefulness of AI was seen, but environmental conditions like lack of training or time to practice using AI could deter lecturers from utilizing such tools completely.

Pedagogical Resistance and Ethical Concerns.

Table1 Summary Table of Key Barriers

Barrier Category	Description
Lack of familiarity	Few teachers lack or have minimal experience with AI tools in their subject (Teis & Els, 2021)
Inadequate training	Training is often generic, intermittent, or misaligned with practical needs
Poor infrastructure	Colleges lack computational and network facilities for AI usage
Cost concerns	AI tools and supporting structures are costly and underfunded
Ethical and quality concerns	Worries about bias, data privacy, and reliability discourage use
Cultural resistance	Educators resist shifts in pedagogy and question AI’s legitimacy in teaching.

Source: researcher (Mhlanga, et.al)

Conclusion

Collectively, these conditions describe a context within which exposure to AI tools by TVET teachers is nonexistent. They call for collective effort in the form of: raising awareness through deliberate communication, developing customized professional development programs, investing in access and infrastructure, setting clear governance and ethics mechanisms, and building confidence and cultural readiness for AI facilitated pedagogy.

Drawing these conclusions required caution to minimize internal bias and to keep the interpretations connected to what the participants actually experienced. Strategies enhancing the credibility of the findings included reflexive journaling, triangulation of data sources, and member checking. These measures ensured that the conclusions had been derived in a systematic and transparent manner, reflecting the authentic views of the lecturers themselves, rather than assumptions of the researcher.

Summary of the Ecological System theory findings

The findings align with the different levels of Bronfenbrenner's ecological systems:

- **Macrosystem:** National AI policies are yet to be put in place as it also raises concerns of ethical consideration to facilitate the use of AI tools, but institutional readiness lags behind.
- **Exosystem:** Lecturers lack access to external training and professional development opportunities.
- **Mesosystem:** Weak communication between home, work, and peer environments inhibits adoption.
- **Microsystem:** Individual classrooms lack exposure, resources, and support to embed AI tools effectively

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