Enhancing Ethnoscience Education Through AI: A Sustainable Learning Approach for Pre-service Teachers

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Abstract

A critical review in this study was used as a tool for analyzing the integration of artificial intelligence (AI) and ethnoscience into pre-service teacher education to promote sustainable learning. Ethnoscience, centered on indigenous knowledge systems (IKS), is essential in conserving cultural heritage and fostering culturally responsive teaching. Nevertheless, integration into formal education is not trivial because these are often standardized and rigid. This paper critically examines the literature related to all these issues and concludes that AI—an artefact capable of personalized learning and adaptive algorithms—has a newly created role as an important resource for pre-service middle school teachers in several ways. The paper reviews research works that have applied AI in ethnoscience education and provides a critical evaluation of them, pointing out possible advantages like personalized learning experience according to different cultural settings or better understanding sharpened by interactive tools. It also critically looks at the problems such as: how using an AI for cultural contexts can fail because it implicates into something called ethico-law mechanism; and that models of indigenous knowledge systems are made difficult to exist inside a binary logic outside some forms of performance via limitations upon adaptive learning communities in situations explained above. Despite these challenges, the review argues that integrating AI with ethnoscience can significantly contribute to sustainable learning by fostering long-term, meaningful engagement with knowledge and preparing pre-service teachers to create inclusive and culturally relevant educational environments. The review also identifies gaps in current research and suggests directions for future studies to explore the impact of AI on ethnoscience education more comprehensively.

Keywords: Artificial Intelligence, Ethnoscience, Teacher Education, Sustainable Learning, Indigenous Knowledge.

INTRODUCTION

Education relies on ethnoscience for providing local cultural knowledge to formalize scientific concepts so as to bring about learning and critical thinking. It actually inspires the students to love their cultural heritages while still connecting to science principles which makes the learning more real and contextual (Hasibuan, 2023; Fitri, 2023; Nurhasnah *et al.*, 2022). Besides promoting cognitive achievement, ethnoscience based education potentially renews students' values and attitudes to their environment so that they feel responsible and motivated learners [Sumarni *et al.*, (2020); Munawarah (2024); Wirama (2023)].

Furthermore, ethnoscience bridges traditional knowledge with the momentum of science so that students can see the scientific phenomenon in their culture view (Supiyati, 2024; Sarkingobir, 2024). In the result of this integration, the student can cultivate a moreediving environment that respects and values overcoming diversity, and will definitely be able to improve students' scientific literacy and critical thinking skills (Verawati *et al.*, 2022; Ansumarwaty, 2023). Educators can treat ethnoscience a medium in educating because through it, the learning experience to students will be more engaging and meaningful as well as resonant with their lived experiences and cultural backgrounds (Suciyati *et al.*, 2021; Fuadi, 2024).

The most serious challenge in integrating ethnoscientific methods in education has to do with curriculum development, the preparation of teachers, and engaging students. The lack of a solid framework for how local knowledge and cultural practice can be included in science curricula is a major issue because it results in uneven quality of educational outcomes

(Hasibuan, 2023; Yasir & Wulandari, 2020). In addition, teachers rarely are well prepared nor provided with the requisite training and resources to successfully incorporate ethnoscience with standard scientific concepts, a gap in pedagogical expertise (Zinyeka *et al*., 2016; Wirama, 2023). Furthermore, students can develop misconceptions and superficial understanding of both the ethnoscience and formal scientific principles by failing to make connections between the two (Sari *et al*., 2023). This disconnect can damage the students' development of critical thinking and scientific literacy as the students lack a view of the connection between ethnoscience and broader scientific context (Kasi *et al*., 2021; Nurhasnah *et al*., 2022). To address these challenges, educators, curriculum developers and communities are working collaboratively to come up with an integrated and culturally responsive educational framework as referred by Handayani *et al*. (2018) and Murwitaningsih (2023).

Artificial intelligence (AI) in education when combined with ethnoscience holds tremendous promise in empowering pre service teachers with sustainable learning practices. Ethnoscience that involves incorporation of local knowledge and cultural background in scientific education brings better critical thinking and problem solving to students (Wahyuningtyas, 2023; Haulia *et al*., 2022; Hikmawati *et al*., 2020). In addition to involving the students; it also stimulates a superior understanding of Scientific Concepts through culturally appropriate samples (Dewi *et al*., 2021; Sari, 2024). This integration can be further augmented with AI to personalize learning experiences and supply live feed back, which matches the dispersed needs of pre-service educators (Kamruzzaman, 2023; Aggarwal, 2023). For example, AI driven platforms may assist in developing collaborative learning environment where its being used to engage in ethnoscientific content and to improve the level of science literacy and cultural awareness (Aggarwal, 2023; Dewi *et al*., 2021). By adopting this double methodology, not only do pre service teachers get ready to teach effectively, but they get to form a sense of responsibility to sustainable practices in the community (Sari, 2024; Parmin & Fibriana, 2019).This synergy between ethnoscience and AI in education is instrumental in having a future educator learn how to create sustainable learning spaces that consider and incorporate local cultures. This review aims to review the status of the integration of AI in ethnoscience education, specifically taking look at implementations within pre service teacher education. This review synthesizes existing research to assess what AI could bring to ethnoscience teaching and how it could support sustainable learning practices of teacher education. It also aims to identify gaps of the existing research and propose directions of future studies to conduct further exploration regarding the integration of AI and ethnoscience in educational settings.

METHODS

The analysis on the intersection of Artificial Intelligence (AI) and ethnoscience in pre service teacher education is conducted using a critical approach. This methodology is devised for critical appraisal of the available literature, mapping the scope of this gap and related trends, and also for identification of the interlinkages between the sources of ethnoscience education and the AI technologies. The choice of critical analysis method is due to its capacity to synthesize complex information and offer a sophisticated comprehension concerning the feasible and critical conditions surrounding the integration of these two scopes.

This study's data is derived from a broad literature review based on peer reviewed journal papers, conference papers and relevant books published over the last two decades. Working

from criteria selection that included works that explore the use of AI in education, the utility of ethnoscience in teacher training and the sustainability of learning practice, the research determined that while there has been significant scholarship on the topic and a variety of practical applications of AI in education, the perspective towards teachers, and through them, learning practices is lacking in a deep way. Relevant sources were taken from databases such as Scopus, Web of Science and Google Scholar. Special critical review process has critical evaluated all selected literature, and has rated each source by relevance, the methodological rigour and contribution towards the field. The findings are categorised according to their alignment with the three core aspects of the analysis framework: 1) Ethnoscience Education: AI integration; 2) Ethical and Cultural Considerations; 3) Sustainability in Teacher Education. A thematic analysis is also used to determine recurring patterns, strengths and weaknesses in existing research.

The study employs a reflexive approach for the validity and reliability of the findings to ensure their validity and reliability. It includes a continuous review of the analysis process and multiple perspectives of literature. Additionally, the study is strengthened with strategies of peer debriefing as well as member checking.

RESULTS AND DISSCUSION
Integrating AI with Ethnoscience

Integrated artificial (AI) and ethnoscience offers great potential for changing how traditional knowledge systems are taught and preserved in educational settings. AI can be a powerful tool to bring learning with ethnoscientific knowledge to life for students and educators alike. For example, AI-powered platforms can render immersive learning: for example, via the use of virtual simulations of historical practices or interactive databases of indigenous knowledges. Because of these technologies, students can explore ethnoscientific concepts in imaginative ways, which support modern preferred learning, resulting in a deeper understanding of real cultural knowledge (Luckin *et al*., 2016).

AI's capability of personalizing learning experiences can be very useful for ethnoscience. AI can adapt content to fit diverse cultural backgrounds and student learning paces of which ethnoscientific material will then resonant more deeply with learners. In addition to providing further engagement, this tailored approach also promotes a deeper concept of ethnoscientific concepts that can be complicated and contextually specific (Holmes *et al*., 2019). Moreover, AI offers educators an opportunity to enhance more productive pedagogical practices through drawing upon data regarding the performance of students, and monitoring how ethnoscientific content can best be integrated into existing curricula (Zawacki-Richter *et al*., 2019).

Using case studies, the successful integration of AI in ethnoscience education has already been demonstrated. AI driven tools have been used to digitize and preserve endangered languages so that students can learn and practice these languages interactively. Like these AI powered platforms, traditional ecological knowledge has been documented and shared as a dynamic resource for students and researchers. These examples demonstrate some of the great potential of AI in helping preserve and spread ethnoscientific knowledge in school contexts (Tsai *et al*., 2020).

However, doing so is not without challenges and limitations as shall be discussed below when analysing the integration of AI with Ethnoscience. One of the main concerns is inacknowledgment of the specific hardship that AI systems themselves experience as far as

encompassing and interpreting the culturally related concepts inherent to the ethnoscientific subject matter. These constraints are due to the fact that the AI technologies, which are developed by and large in conformity with the idioms of the Western science paradigms, may fail to capture and interpolate the context reduced local knowledgeatient of ethnoscience (Aikenhead & Ogawa, 2007). This limitation leads to a worry that the information AI provides about culture is at best reductionist and at worst constructive of an inaccurate, ahistorical stereotype (Eubanks, 2018).

A third important limitation is the issue of ethical practice within an AI-IKM framework particularly for indigenous populations. The sharing of ethnoscientific knowledge within the digital systems by utilizing A.I may endanger a chance of promoting cultural knowledge within the wrong section of the population without the permission of the knowledge owners. This issue presents a vicarious case of why there must be high ethical standard and cooperation with the native people in the use of AI in ethnoscience education (Tuck & Yang, 2012). Also, the investment cost, time, and technical expertise needed to design and regularly update AI tools relevant to ethnoscience instruction may be unaffordable in low-resource learning environments. This limitation could worsen the current disparity in the availability of education technology thereby a situation that could push aside ethnoscience's objective of helping minority and marginalized groups.

In summary, while AI seems to hold potential to foster the improvement of ethnoscience education, such improvements are again threatened by such disadvantages and limitations. These need to be discussed among educators, technologists, and indigenous nations so that true to the spirit of ethnoscience and cultural maintenance, effects of AI learned can be normatively applied.

Sustainable Learning in Teacher Education

Sustainable learning, as an aspect of sustainable education therefore means enhancement of learning in a manner that makes it possible for the learner to effectively apply knowledge gained in different situations and over a long period of time (Sterling, 2011). Unlike other successful practices focused on information memorization and acquisition, sustainable learning concentrates on enhancing performer's capabilities in the problem-solving process and mastering knowledge that can be effectively applied if necessary. As for the principles of sustainability in learning, Wals & Jickling (2002) found learner orientation, relevance, and build-up of sustainability relevant competencies. Zeicherung eines langlebigen Lehrens ist sowohl im Zusammenhang mit der Lehrerinnen- und Lehrerbildung besonders wichtig, da diese das Wissen in der erzieherischen Praxis benötigen, um ähnliche Vorgehensweisen in Klasse weiterzugeben.

The infusion of AI and ethnoscience into teacher education is a rich opportunity to develop a model that augments sustainable learning through the harmonisation of indigenous knowledge and contemporary technology. Thus, AI, which can learn and adapt to the learner and providelearner-centric content, can facilitate sustainable learning the context of program needs of pre-service teachers. As an instance, the AI-powered theory can offer individual feedback, progress progression, and further resources that match a teacher's learning objectives to promote the acquisition of core skills for life-long learning (Holmes *et al.*, 2019).

Ethnoscience however, enhances sustainable learning since education promoted is based on a cultural context. When the cultural paradigms of the Indigenous people are introduced to the pre-service teachers, this allows them to expand perspectives on how people make sense of

the world around them and this honing of the teacher candidates' culturally responsive teaching pedagogical repertoires (Barnhardt & Kawagley, 2005). Another way of arguing that cultural clarity is a part of sustainable practice is to point out that it helps create an accepting and diverse classroom environment (Aikenhead & Ogawa, 2007). Studies have shown that AI-enhanced ethnoscience curricula can significantly improve pre-service teachers' engagement with complex cultural content, leading to a deeper and more sustained understanding of the material (Tsai *et al.*, 2020). Additionally, the use of AI to facilitate access to ethnoscientific resources empowers teachers to incorporate culturally relevant content into their teaching, promoting sustainable learning practices that extend beyond the classroom (Smith, 2016). This integration of AI and ethnoscience not only enhances the educational experience but also prepares pre-service teachers to create more inclusive, adaptable, and culturally responsive learning environments.

This study reveals that the adoption of AI and ethnoscience in teacher education has potential pathways for enhancing sustainable learning in teaching practices that require consideration to reach fruition.
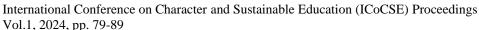
The value of this integration lies in extending the cultivation and diffusion of ethnoscience knowledge, advancing the ways in which artificial intelligence supports and enhances our teaching practices, but significant challenges need to be analysed to enhance the sustainability of this advancement in teacher education. One task is to address the cultural relevance and validity of AI technologies that reproduce ethnoscientific knowledge without stereotyping or misinterpreting culturally subtle forms (Eubanks 2018). The other difficulty is in preparing pre-service teachers and educators for their capacity to implement AI tools and the ethnoscientific content of knowledge creation in their classrooms practices (Hermes *et al.*, 2012). Furthermore, there are ethical issues about digitalisation and publicising the indigenous knowledge because such information can be misused or misappropriated (Tuck & Yang 2012). In tackling these issues it is crucial to engage indigenous peoples in the formulation and the use of AI ethnoscience based curricular, which is culturally sensitive and appropriate (Smith, 2016). Therefore, the integration of AI and ethnoscience in teacher education seeks to provide a natural way of improving sustainable learning outcomes among preservice teachers through acquisition of appropriate knowledge, skills, and worldview that would enable them to embrace change in meeting educational needs sexually. Nevertheless, the identified potential demands critical analysis of the noted difficulties and sufficient emphasis on the ethic and culturally sensitive education approaches.

Synthesis of Literature

a. Key Findings

As this paper will show through reviewing the available literature on integration of AI and ethnoscience, several important findings regarding teacher education exist. First, research suggests that AI is likely to improve the delivery of ethnoscience by providing learners with unique and individualized learning environments that can address the cultural and learning diversity of learners (Luckin *et al.*, 2016, Holmes *et al.*, 2019). Ethnoscientific knowledge is more comprehensible and fascinating when imported through AI tools such as virtual reality simulators and interactive databases to enhance pre-service teachers' embodied learning, (Zawacki-Richter *et al.*, 2019).

Second, the literature highlights the appreciable aspect of ethnoscience in the enhancement of cultural sustainability in the educational facilities. Thus, ethnoscience makes it

possible to preserve and transmit indigenous forms of knowledge, increasing pre-service teachers' cultural-related suitability, and hence improving the ways in which each student will fit into and interact with their new context as teachers (Barnhardt & Kawagley, 2005). Ethnoscience being introduced into the teacher education programs has been noted to enhance the curriculum to make future teachers culturally aware and ready to infuse ethnoscence into practice (Aikenhead & Ogawa, 2007).

Further, works indicate that the interrelation between AI and ethnoscience could help promote green learning in teacher education. AI, through the adaptiveness in the instructional approaches of techniques and ethnoscience interest for component cultural knowledge, improve the teacher education programs to promote the stable culture of learning and practices. Not only does this intersection improve the educational arena for all, but it also prepares pre-service teachers with the knowledge necessary for building flexible learning communities (Smith, 2016).

b. Identifying Gaps

However, these provide an avenue for major improvements in the current status of the literature based on existing studies. This means that, there is a rich research void where ethnoscience education within the domain of teacher training and AI is concerned, and there are several areas deserving of further specification and research. There has been a considerable amount of literature on the incorporation of AI in education and ethnoscience individually, but a paucity of literature on its integration, especially in pre-service teacher education program. This gap hinders the determination of the specific ways in which AI can be adopted to support ethnoscience instruction as well as scale up these developments in the teacher education programmes (Hermes *et al.*, 2012).

The first gap is a problematic area; the ethical dimension of AI application in connection with indigenous knowledge. Despite the awareness that misrepresentation of cultural content, data privacy and respect for indigenous people's consent are areas of controversy, there is hardly any research that discusses these issues in detail. This lack of concern points towards the necessity of future research aimed at working out the ethical standards and effective practices of the AI incorporation into ethnoscience without eradicating culture, on which Tuck & Yang (2012) have focused.

c. Implications for Future Research

For these gaps, the future research should be directed at carrying out quantitative investigations that discuss the effects of AI on ethnoscience learning in teachers' colleges. These kinds of research should explore how AI tools can be used in teaching Ethnoscience: how they should be developed and utilized and the culture and ethical concerns this learning entails. Further, study should investigate the impact of the implemented ethnoscience, enriched by AI applications, on the pre-service teachers' readiness and readiness to promote sustainable learning environment in classrooms they are to teach (Smith, 2016).

Moreover, there is an urgent need for joint endeavor between developers of AI, teachers, and indigenous people in order to create culturally appropriate AI applications that better respond to the goals of ethnoscientific content representation and tutorial. More such studies must be conducted in the future to determine the implementation level of these innovations in terms of the required resources and staff training for scaling up in teacher education (Zawacki Richter *et al.*, 2019).

d. Implications for Practice

Based on the literature review, there are major practical implications for teacher education. Schools of education ought to incorporate AI-enabled applications into ethnoscience courses for improvement of pre-service teachers learning. These tools may hold potential for the provision of differentiated knowledge, where the teachers are able to apply ethnoscientific knowledge in a way that is best suited to their cultural experience and learning (Capability) (Luckin *et al*., 2016). Accordingly, teacher education programs must target the ethnoscience pedagogy to aware the upcoming teachers about how to teach effectively in culturally diverse classrooms (Barnhardt & Kawagley, 2005).

Lastly, there is a desperate need to launch professional development initiatives that will help the teacher educators to learn how to use AI and ethnoscience in their practice properly. Hermes *et al*. (2012) noted that such programs would enable educators to appreciate how both fields work so they can apply the two fields to enhance students learning for sustainable teachers education with ease.

CONCLUSION

This review focused on the application of artificial intelligence and ethnoscience in pre-service teacher education and the opportunities and limitations of an integration between the two fields for constraining sustainable learning. The literature shows that traditional knowledge systems alive and thriving all over the world can be enriched by AI and fostered for teaching and learning of ethnoscience by using a range of approaches like making it more interactive, engulfing, and even tailored. Ethnoscience in its turn, is a critical element in promoting cultural sustainability, as well as the diversification of education, both of which are vital to the education of the teacher. Nevertheless, for the integration of AI and ethnoscience to be successful consideration of cultural, ethical, and practical issues will be important. These are of representation of indigenous knowledge, data privacy ethical issues, and appropriate sensitization of indigenous people to fit the implementation.

AI integration with the ethnoscience is considered to be a useful method of preparing future educators to foster an atmosphere of equity-sensitive learning environments. This combined method enhances the learning achievement of the pre-service teachers and promotes culture responsive education practices. The essay argues that the development of ethical principles will keep AI applications from undermining the legitimate practices created by the indigenous people, hence the need to sustain culture the cultures of the indigenous people.

SUGGESTION

Thus, to base future investigation on the current findings, the author of the essay proposes to engage in empirical research that is aimed at investigating the effects of AI integration into the process of ethnoscience learning with specific regard to PST formation. It encourages more investigation on how more of such AI innovations can be scaled up or introduced where resources are limited, and also the need for sustained inter-disciplinary work to chart the future course of how ethnoscience education enhanced by artificial intelligence would look like in the service of sustainable and culturally sensitive teaching.

Summing up, the implementation of the ideas of AI and ethnoscience in the context of developing a teaching education can be considered as important further development that could contribute to the enhancement of the idea of teacher education in the context of current

tendencies of transforming education. Nevertheless the application of knowledge based on such relations exposes significant ethical cultural and practical concerns and therefore the necessity for further research and cooperation is obvious. With these measures, AI and ethnoscience may be levered to enhance the equality, environmentalism and cultural relevancy of education.

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