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AI integration in education through the TMRC model: a Deweyan experimental approach

Adelfa Silor[1], Faith Stephanny Silor[2]
[1]Department of Technology Teacher Education, Mindanao State University-Iligan Institute of Technology, Iligan City, Philippines
[2]Office of the Vice Chancellor for Research and Enterprise, Mindanao State University-Iligan Institute of Technology, Iligan City, Philippines

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ABSTRACT

The integration of artificial intelligence (AI) in education must go beyond efficiency and automation. It must uphold humanistic values, preserve learner agency, and foster democratic, reflective classroom dynamics. This study introduces the technology-mediated reflective and collaborative (TMRC) model, an innovative pedagogical framework grounded in John Dewey's philosophy of experiential learning and democratic education. Employing a quasi-experimental design with 98 senior high school students divided into traditional and TMRC-integrated instructional groups, the study assessed the impact of the model on academic performance, student engagement, and reflective thinking across varied classroom contexts. Quantitative findings revealed statistically significant gains in the experimental group, particularly in engagement, critical thinking, and knowledge retention, while qualitative insights underscored increased learner autonomy and collaborative inquiry. The study's high-impact contribution lies in demonstrating that AI, when guided by pedagogical intentionality and rooted in human-centered design, can transform educational practices. It offers a scalable, adaptable model that bridges technological innovation and ethical, learner-focused education, advancing the global discourse on responsible AI integration in 21st-century learning.

Corresponding Author:

Adelfa Silor
Department of Technology Teacher Education, Mindanao State University-Iligan Institute of Technology
Iligan City, Philippines
Email: adelfa.silor@g.msuiit.edu.ph

1. INTRODUCTION

Artificial intelligence (AI) continues to reshape education by enabling adaptive feedback, personalized learning, and intelligent support systems. However, educators must integrate AI in ways that preserve the reflective, humanistic, and democratic nature of learning. Dewey's philosophy of experiential learning emphasizes that education should cultivate inquiry, participation, and reflection rather than automation or passive knowledge transfer.

Recent studies have shown how AI can foster reflective and self-regulated learning. Abdullah [1] found that AI chatbots help student teachers express themselves and improve reflective writing, supporting deeper self-awareness and communication. AI chatbots to help English as a foreign language (EFL) student teachers practice self-regulated learning, which improved their self-expression and reflective writing. This aligns with the metacognitive and reflective dimensions of the technology-mediated reflective and collaborative (TMRC) model, where learners plan, monitor, and evaluate their learning using AI support. Bate and Eberhard [2] reported that AI-driven anthropomorphic coaches enhance reflective practices in higher

education by promoting critical self-assessment and learner engagement. AI-supported anthropomorphic coaches enhance reflective practices in higher education. This supports the Reflective component of TMRC, emphasizing how AI can prompt students to think critically about their actions and progress. Greenberger *et al*. [3] further emphasized that reflective narratives enable students to construct meaning from their experiences, aligning with Dewey's idea that reflection transforms experience into understanding. Greenberger and colleagues applied Dewey's theory of reflection, showing that narrative construction helps learners interpret experiences meaningfully. Their concept supports the reflective inquiry aspect of TMRC, which values learning through experience and analysis. Greenberger and colleagues emphasized Dewey's reflective practice, showing that reflective narratives help learners construct and interpret experiences.

Collaborative and creative learning processes also benefit from AI integration. Bauters and Vesikivi [4] demonstrated that design thinking can serve as an effective collaborative learning design tool that encourages creativity and shared problem-solving. Bauters and Vesikivi used design thinking as a collaborative tool for teachers. Their approach connects with the collaborative and transformative aspects of TMRC, highlighting how cooperative innovation enhances problem-solving. Bauters and Vesikivi applied design thinking as a collaborative learning tool that enhances creativity and problem-solving among teachers. Cunska [5] revealed that technology-based interdisciplinary approaches accelerate learning by linking multiple domains of knowledge, fostering analytical and creative thinking across subjects. Cunska promoted technology-based interdisciplinary approaches to make mathematics learning faster and more engaging. Hangartner *et al*. [6] explored everyday uses of platform-mediated personalized learning in schools, showing that adaptive systems can respond to learners' diverse needs and contexts. Hangartner and co-authors studied everyday uses of AI-based platforms for personalized learning. Their findings align with the Metacognitive domain of TMRC, where learners use AI feedback to regulate and adjust their study habits.

Finally, Hayashi *et al.* [7] found that collaborative learning with AI tutors and virtual learners promotes the co-construction of knowledge and enhances participation in digital environments. Hayashi and team investigated learning with AI tutors and virtual AI learners, emphasizing collaboration and co-construction of knowledge. This supports the collaborative and reflective components of TMRC, which value interaction and shared meaning-making. Ojeda-Ramirez *et al*. [8] expanded on this by examining "reflective AI partnerships," revealing how learners balance creativity and collaboration when co-creating with AI tools. Ojeda-Ramirez and colleagues found that students balance creativity and AI collaboration. This fits the transformative and collaborative aspects of TMRC, as AI inspires learners to co-create knowledge while enhancing creative inquiry.

AI in education has evolved rapidly under the frameworks of education 4.0 and education 5.0, both of which emphasize adaptability, personalization, and technology-driven pedagogy. Chinchorkar and Jadhav [9] conceptualized education 5.0 as the integration of artificial intelligence, automation, and human creativity to create responsive learning environments that promote flexibility, collaboration, reflective thinking, and innovation. This perspective supports the transformative dimension of the TMRC model, positioning AI as a catalyst for educational change and human advancement.

AI has transformed instructional design through intelligent tutoring systems, adaptive algorithms, and machine learning tools that improve learning outcomes and student autonomy. Gligorea *et al.* [10] demonstrated that adaptive AI systems can tailor instruction to individual learners, enhancing motivation and engagement. Gligorea and co-authors developed adaptive AI systems that adjust learning to student needs. This finding aligns with the Metacognitive principle of the TMRC model, which emphasizes personalized learning through feedback and self-regulation. Qian [11] further showed that generative AI in higher education supports learning analytics, automated feedback, critical thinking, and student engagement, while also raising concerns about data privacy, algorithmic bias, and equitable implementation. This supports the reflective and transformative elements of TMRC, where AI fosters higher-order thinking and continuous learning.

Scholars use behavioral and technology acceptance frameworks to understand how users interact with AI in education. Moradi [12] discussed technology acceptance frameworks, including the technology acceptance model (TAM) and the unified theory of acceptance and use of technology (UTAUT), as useful lenses for understanding users' willingness to adopt AI-supported technologies in education. Moradi [12] found that trust, perceived usefulness, and ease of use influenced ChatGPT acceptance among EFL students in China. These findings support the Transformative and Metacognitive dimensions of the TMRC model by indicating that positive perceptions of AI can encourage technology adoption and learner autonomy. Recent innovations focus on aligning AI with established pedagogical and cognitive frameworks. Almatrafi and Johri [13] extended Carrington's digital pedagogy wheel by mapping AI tools to Bloom's taxonomy. Almatrafi and Johri proposed the AI pedagogy wheel aligned with Bloom's taxonomy. This aligns with the metacognitive and reflective dimensions of TMRC by encouraging structured cognitive engagement using AI tools. This alignment ensures that AI supports outcome-based learning and promotes higher-order thinking skills. Saritepeci and Durak [14] found that AI-supported design-based learning promotes creativity, reflective

inquiry, and meaningful learner engagement. These findings align with the TMRC model by demonstrating how AI can support active, reflective, and creative learning experiences. Their concept fits the Transformative aspect of TMRC by encouraging innovation through reflective design processes.

The TMRC model includes four interconnected elements: technology enablement (T), mediation of knowledge (M), reflective inquiry (R), and collaborative construction (C). Together, these elements integrate Dewey's ideals of experiential learning, reflection, and social participation. The model views technology as a mediator that supports, not replaces, human learning. As stated by Das [15] "Integrating AI tools through the TMRC model positions learners as active experimenters—testing hypotheses, monitoring results, refining strategies, and revising understanding in iterative cycles—thereby embodying Dewey's vision of education as inquiry-driven growth." Das [15] also emphasized AI's role in rethinking pedagogy through creative media integration. This reflects the Transformative domain of TMRC, where AI expands the boundaries of traditional teaching.

Generative AI tools, such as ChatGPT, have expanded discussions on reflective learning and cultural inclusion. Ward *et al.* [16] introduced the transmissional, transactional, and transformative (TTT) framework based on Deweyan principles and applied it in multicultural classrooms. This framework promotes narrative inquiry, cross-cultural dialogue, and transformative reflection using AI as a conversational partner. Ward and colleagues proposed the TTT framework to use ChatGPT for multicultural classrooms. This reinforces the collaborative component of TMRC, where dialogue across diverse learners promotes inclusivity and cultural understanding.

Freirean pedagogy also contributes to the debate on ethical AI integration. Majumdar [17] emphasized that AI must promote equity, inclusion, and critical consciousness rather than reinforce existing inequalities. Their work aligns with Dewey's and Freire's shared vision of democratic and participatory learning. Majumdar highlighted how AI fosters inclusion and equity in education. This aligns with the transformative and collaborative aspects of TMRC, advocating social justice and human-centered AI use. Lim [18] examined AI-enhanced feedback in ESL education and found that AI tools can provide immediate, formative, and ethical feedback that supports reflective language learning. Lim compared content-based instruction (CBI) and task-based instruction (TBI) using Bloom's taxonomy to assess AI-supported learning. This connects to the metacognitive and reflective principles of TMRC, showing how AI can enhance structured cognitive engagement.

Despite these advances, challenges remain. Scholars continue to warn about algorithmic bias, cultural insensitivity, and the misuse of AI-generated content. These issues highlight the need for ethical, transparent, and human-centered approaches. The TMRC model offers a pathway toward this goal by ensuring that AI serves as a partner in reflective inquiry and experiential learning, consistent with Deweyan principles of active, democratic, and transformative education. Building on these developments, the TMRC model provides a praxis-oriented framework for integrating AI into teaching and learning while remaining grounded in Deweyan principles. The model promotes experiential learning, collaboration, and reflection through the use of intelligent tutoring systems, generative AI tools, and interactive digital platforms. It views classrooms as democratic spaces where learners actively construct knowledge through inquiry and shared reflection.

This study examines the effectiveness of the TMRC model in fostering engagement, reflective thinking, and academic performance among senior high school students. It seeks to determine whether TMRC can enhance learning outcomes without compromising student agency and democratic participation. Ultimately, this research aims to establish the TMRC model as a human-centered and ethically grounded framework for AI integration in education.

Reflective thinking is central to both Deweyan pedagogy and the TMRC model. Philip H. Winne and Allyson F. Hadwin conceptualized metacognitive learning as a self-regulated process that involves planning, monitoring, and evaluating one's own understanding. AI platforms now embed these principles to help learners engage in self-reflection, metacognitive regulation, and deeper knowledge construction. This alignment strengthens the TMRC model's focus on reflection as a foundation for meaningful learning.

Despite these advancements, challenges remain. Scholars continue to warn about algorithmic bias, cultural insensitivity, and plagiarism risks. Addressing these issues is essential to ensure that AI promotes democratic, equitable, and multicultural learning environments. Recent literature supports the integration of reflective inquiry into AI-enhanced learning environments. Yuan and Hu [19] found that generative AI supports reflective learning by helping students examine their thought processes, assess the quality of their work, and deepen self-understanding, which aligns with the reflective domain of the TMRC model. Similarly, Lee and Bonk [20] showed that technology-mediated collaboration strengthens self-directed learning and reflective practice through peer interaction, reinforcing the reflective and collaborative dimensions of TMRC. Lei [21] further demonstrated that computer-supported collaborative environments enhance metacognitive awareness, critical reflection, and knowledge co-construction through interaction and feedback, supporting both the reflective and metacognitive dimensions of the model. Their findings align with the reflective and collaborative elements of TMRC, integrating peer dialogue with AI-assisted reflection. Similarly, Lei [21] highlighted that

computer-supported collaborative environments promote metacognitive awareness and critical reflection, allowing learners to co-construct understanding through interaction and feedback. Lei [21] described computer-supported environments that promote deep learning through reflection and assessment. This supports the reflective and metacognitive pillars of TMRC by combining digital tools with introspective learning.

Research in active and inquiry-based learning also complements the reflective dimension of the TMRC model. Kori [22] demonstrated that inquiry-based learning in higher education strengthens learner autonomy, critical thinking, and reflective reasoning, supporting the reflective and self-directed learning principles of the TMRC model. This connects with reflective inquiry in TMRC, which follows Dewey's view that learning emerges from questioning and exploration. Žerovnik and Šerbec [23] identified project-based learning as a vehicle for experiential knowledge building. Žerovnik and Šerbec implemented project-based learning to enhance engagement and practical understanding. This supports the collaborative and transformative parts of TMRC by promoting teamwork and authentic learning experiences. These pedagogies resonate strongly with Dewey's vision of education as learning through experience and reflection. Carvalho and Bauters [24] emphasized that technology-supported active learning encourages engagement and practical problem-solving, aligning with Dewey's experiential learning theory. Carvalho and Bauters integrated technology-supported active learning, promoting creativity and reflection. Their approach relates to the transformative and reflective elements of TMRC, emphasizing active participation. In parallel, Vesikivi *et al*. [25] showed that integrating agile methodologies with design thinking promotes adaptability, collaboration, reflective practice, and iterative inquiry, which are consistent with the collaborative and reflective principles embedded in the TMRC framework. This aligns with the collaborative and transformative dimensions of TMRC, supporting flexible and reflective innovation.

Recent studies explore AI's role in supporting self-regulated learning, reflective practice, and collaborative engagement, but several gaps remain. Most research focuses on individual elements, such as AI for reflection, metacognition, or collaboration, rather than integrating AI within the full TMRC model. There is limited evidence showing how AI can enhance all four TMRC domains simultaneously. Although AI tools encourage reflection and collaboration, few studies frame their interventions within Dewey's experiential learning philosophy, where knowledge emerges through active experience and reflective inquiry. Researchers have not fully explored the connection between AI-mediated learning and Deweyan principles of reflection, transformation, and social engagement. Most studies are descriptive, theoretical, or exploratory and lack experimental validation of AI's effectiveness in structured learning models like TMRC. There are a few experimental studies assessing AI's impact on self-regulation, reflective thinking, creativity, and collaborative engagement. Additionally, research rarely examines how AI integration through TMRC addresses diverse learner needs across disciplines and educational contexts. Studies also provide limited evidence linking AI-driven creative tasks to transformative learning outcomes, which are central to TMRC and Dewey's philosophy. These gaps highlight the need for a comprehensive experimental study that integrates AI fully within the TMRC framework, applies a Deweyan experiential approach, provides empirical evidence on metacognitive, reflective, transformative, and collaborative outcomes, and explores AI's role in promoting inclusivity, creativity, and interdisciplinary learning. This research will bridge theoretical, pedagogical, and practical gaps, offering actionable insights for AI-integrated education in the 21st-century.

Despite evidence that AI supports reflection, metacognition, collaboration, and creativity, studies rarely integrate AI across all TMRC domains, apply Dewey's experiential principles, or provide experimental validation. Research also lacks investigation of AI's role in fostering inclusivity, equity, and interdisciplinary learning. To address these gaps, this study aims to examine the effects of AI integration on students' transformative, metacognitive, reflective, and collaborative learning, using a Deweyan experiential approach. This approach provides empirical evidence and practical insights for 21st-century education.

This study aims to investigate the effects of AI integration on students' learning through the TMRC model using a Deweyan experiential approach. Specifically, it seeks to integrate AI tools across all four TMRC domains—transformative, metacognitive, reflective, and collaborative—while applying Dewey's principles of experiential learning. The study will measure AI's impact on students' self-regulation, reflective thinking, creativity, and collaborative engagement. It will also examine how AI integration promotes inclusivity, equity, and interdisciplinary learning. Finally, the research aims to provide empirical evidence and practical insights for implementing AI in 21st-century education.

2. METHOD

This study adopted a quasi-experimental design utilizing a pre-test and post-test comparison framework to evaluate the effects of the TMRC model. The research was structured to compare an experimental group exposed to the TMRC-integrated instruction with a control group receiving traditional teaching methods. The independent variable was the instructional model employed, while the dependent variables included

student engagement, academic achievement, and reflective thinking. This design enabled the researchers to measure the learning gains and behavioral changes attributable to the TMRC model while controlling for extraneous variables that might influence the outcomes.

The study involved 98 grade 12 students enrolled in a public senior high school. The participants were divided equally into two groups: 49 students in the experimental group and 49 in the control group. Both groups were carefully matched based on their previous academic performance and socio-demographic characteristics such as age, gender, and socioeconomic status to ensure comparability and reduce selection bias. This matching process helped establish a baseline of equivalence between the two groups, enhancing the reliability and validity of the study's findings.

The intervention spanned six weeks, during which the experimental group engaged in instruction utilizing the TMRC model. This model was characterized by the integration of AI tools such as ChatGPT for collaborative writing, real-time feedback, and problem-solving activities. Students maintained weekly digital reflection journals, which promoted metacognition and deeper learning. Additionally, collaborative group tasks were facilitated using AI content-generation platforms, allowing students to co-construct knowledge in meaningful ways. In contrast, the control group followed conventional instructional methods, including teacher-centered lectures, textbook reading, and completion of worksheets, with no digital or AI-enhanced tools involved. This contrast allowed for a clear assessment of the added value brought by the TMRC approach.

To assess the outcomes of the intervention, the study employed three key instruments. Student engagement was measured using the student engagement was measured using an adapted 20-item engagement scale based on the multidimensional framework of Fredricks *et al*. [26], which evaluates behavioral, emotional, and cognitive engagement through a Likert-scale format. Academic performance was assessed using a 30-item multiple-choice achievement test that was content-validated and aligned with senior high school curriculum standards to ensure content relevance and reliability. Reflective thinking was analyzed using the four-category reflective thinking rubric developed by Kember *et al.* [27], which assesses levels of non-reflection, understanding, reflection, and critical reflection. Together, these instruments enabled a multidimensional evaluation of the TMRC model's effects on students' engagement, academic performance, and reflective thinking.

To comprehensively assess the effectiveness of the TMRC model, a mixed-methods approach was employed in analyzing both quantitative and qualitative data. Quantitative data derived from pre-test and post-test scores on engagement, academic achievement, and reflective thinking were analyzed using paired t-tests to determine within-group differences and analysis of covariance (ANCOVA) to evaluate between-group differences while controlling for baseline scores. These statistical procedures, conducted using SPSS version 28, enabled a rigorous evaluation of the TMRC model's impact while accounting for initial disparities between groups. In parallel, qualitative data gathered from students' digital reflection journals and post-intervention interviews were subjected to thematic coding. This process involved identifying recurring patterns, insights, and emergent themes related to student experiences, perceptions of AI integration, and changes in reflective practices. The integration of both statistical and thematic analysis provided a more nuanced understanding of how the TMRC model influenced learners both cognitively and affectively, thereby enriching the interpretation of results and supporting the study's validity.

3. RESULTS AND DISCUSSION

3.1. Engagement outcomes

As shown in Table 1, students in the TMRC group demonstrated significantly higher engagement across all categories compared with those in the comparison group. The results indicate that the TMRC approach positively influenced students' behavioral, emotional, and cognitive engagement. Table 1 presents the detailed engagement outcomes of the participants.

Table 1. Students in the TMRC group showed significantly higher engagement across all categories

Type of engagement	Control group	TMRC group	p-value
Behavioral	3.45	4.12	0.001
Emotional	3.22	4.10	0.003
Cognitive	3.30	4.35	0.000

As illustrated in Figure 1, the TMRC group demonstrated higher levels of behavioral, emotional, and cognitive engagement than the control group. The figure provides a visual comparison of the three engagement dimensions between the two groups. These results further highlight the positive influence of the TMRC approach on students' overall engagement.

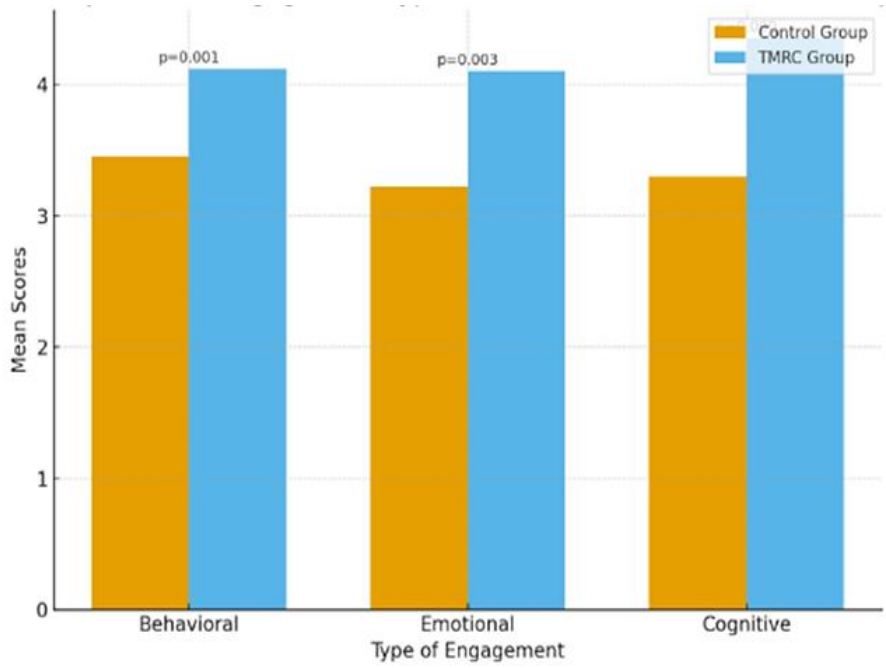

Figure 1. Comparison of engagement types between control and TMRC groups

3.2. Academic achievement

Analysis of the post-test results showed a significant increase in academic performance among students in the experimental group who were treated with the TMRC model. The experimental group recorded a 13.5% increase in performance, which was significantly higher than the control group, which recorded a 5.8% increase. This was verified by the ANCOVA test, which showed that the model had a statistically significant effect on the performance of students ($F(1.95)=9.27$, $p=0.003$). The results of the study indicate that the TMRC model, which incorporates AI tools in a reflective and collaborative learning environment, is effective in enhancing academic performance. The study is expected to have a significant positive impact on the global community, which is increasingly focusing on technology-infused pedagogy, learner-centered education, and AI integration in education.

3.3. Reflective thinking

A close examination of 294 reflective journal entries by students further supported the TMRC model's effectiveness in promoting reflective thinking, with implications that reach beyond the specific educational environment and are beneficial for a global audience. Students in the experimental group used significantly more evaluative and metacognitive language than those in the control group. Themes that emerged in their reflective journaling included critical evaluations of the accuracy of AI tools, ethical implications of data privacy, and learnings from peer collaboration—issues that are of concern to a wide range of educational institutions around the world that are increasingly incorporating artificial intelligence into the educational process. The reflective journal entries not only reflected higher-order thinking but also pointed to the TMRC model's effectiveness in developing globally relevant skills such as ethical digital literacy, critical thinking about emerging technologies, and self-regulation. In this way, the results of this study indicate that the TMRC model is a transferable teaching model that can be used to promote reflective and responsible AI use among students in a variety of global educational environments.

3.4. Discussion

3.4.1. TMRC as a humanistic and pedagogically informed AI model

The results clearly show that the TMRC model has a number of advantages in improving learning and engagement for students through the reflective and collaborative use of artificial intelligence. The TMRC model is positioned on the philosophy of experiential learning, as espoused by John Dewey. This positioning of the model is important in that it differentiates the model from other uses of artificial intelligence, which are more technocratic and focused on efficiency rather than pedagogy. The positioning of the model is humanistic and student-centered.

3.4.2. Student engagement and learning outcomes

The empirical findings suggest that TMRC has a positive impact on behavioral, emotional, and cognitive engagement, implying that AI-based learning environments have the potential to go beyond the boundaries of passive content transfer. Students were more actively engaged in collaborative activities, showed a deeper level of conceptual understanding, and experienced better academic outcomes. These findings are in line with the global research that claims the educational potential of AI is best realized when it is integrated with constructivist and reflective learning approaches and not used as a replacement for human interaction.

3.4.3. Reflective thinking, ethics, and metacognition

One of the major strengths of the TMRC model is its ability to encourage reflective thinking and ethics. The students showed a marked increase in the use of evaluative and metacognitive language, critical evaluation of AI outputs, and an increased awareness of ethical issues in the use of technology. These skills are becoming increasingly important for students using AI-mediated knowledge environments around the globe. By incorporating reflective thinking and ethics into AI-supported learning, TMRC is able to integrate technological innovation with global educational priorities.

3.4.4. Dialogic learning and democratic knowledge construction

In line with the dialogic and emancipatory approach advocated by Paulo Freire, the TMRC approach promotes dialogic and collaborative knowledge construction. Instead of treating AI as a source of knowledge, TMRC promotes dialogue among learners and between learners and technology. This is especially important in multicultural and international settings, where participation and respect for diversity are essential.

3.4.5. Implications for inclusive and global education

The implications of the study are the need for ethical and inclusive design of AI, particularly in multicultural educational settings. If AI technologies are not carefully pedagogized, they have the potential to perpetuate inequities. The TMRC approach shows how AI can be used to promote equitable, reflective, and participatory learning. For educators around the world, the TMRC approach provides strategies for using AI to promote collaboration, reflection, and active knowledge construction, which are principles that can be applied across borders.

3.4.6. Contribution to global educational discourse

In general, the TMRC model makes a contribution to the global discourse in education by providing a theoretical and empirical framework for the integration of AI in education. The model shows that AI, when integrated with humanistic and reflective approaches to education, can improve learning outcomes while promoting awareness and inclusivity. This is particularly beneficial for the global community as it provides a balanced approach to AI in education that takes into account both technological and humanistic considerations.

3.5. Recommendations

Based on the findings and implications of the research study, the following recommendations have been made to ensure effective and sound integration of Artificial Intelligence in education using the TMRC model, based on Dewey's principles of experiential and reflective learning. These recommendations have been made to be applicable in various educational settings, thus increasing their relevance for the global audience.

3.5.1. Recommendations for educators

Educators are advised to adopt AI tools in a manner that emphasizes inquiry, reflection, and collaboration over rote and mechanical learning. AI-based teaching practices should be developed to encourage reflective questioning, formative feedback, and learner agency in accordance with the TMRC framework. Professional development workshops should aim to provide educators with the pedagogical skills required to utilize AI for metacognitive scaffolding, creative problem-solving, and reflection. This will help ensure that AI serves as a cognitive and ethical aid for learning rather than a replacement for human judgment.

3.5.2. Recommendations for educational institutions

Educational institutions, such as schools and universities, should develop institutional policies that encourage the ethical, inclusive, and sound use of AI. Curriculum designers should aim to develop learning outcomes, teaching practices, and assessments in accordance with the TMRC framework to ensure that AI applications are used for transformative and reflective learning experiences.

3.5.3. Recommendations for learners

Learners should be encouraged to employ AI resources responsibly as facilitators of self-directed, reflective, and collaborative learning. Learning programs should focus on the cultivation of critical digital

literacy competencies, empowering learners to critically assess AI-produced content, identify biases, and engage in reflective learning practices. The promotion of reflective conversation and collaborative learning in AI-mediated contexts can help learners develop autonomous thinking, ethical insight, and lifelong learning skills that are fundamental to Deweyan educational thought.

3.5.4. Recommendations for policymakers

Policymakers are urged to create holistic frameworks that promote equal access to AI technology while maintaining high standards of ethics, data protection, and equity. Policymaking efforts should concentrate on teacher professional development, inclusive digital literacy, and ethical innovation that aligns with global and national agendas for quality education. Public funds should be allocated to support initiatives that combine AI innovation with humanistic and reflective approaches to learning, which can help mitigate digital inequities and cultivate responsive education systems.

3.5.5. Recommendations for future research

Future research studies should examine the long-term effects of AI-supported reflective learning on students' performance, creativity, moral judgment, and well-being. Future research studies can also explore the use of the TMRC model in technical-vocational education, online learning, and lifelong learning programs. Interdisciplinary research studies that combine education, philosophy, learning sciences, and technology studies can help to strengthen the theoretical and empirical connections between Deweyan principles of experiential learning and the emerging AI-enabled learning technologies.

4. CONCLUSION

This research makes it clear that the TMRC model is an effective, humanistic, and viable approach to incorporating artificial intelligence into modern education. The TMRC model is based on Deweyan philosophies of experiential learning, reflection, and collaboration and asserts that technology should be a catalyst for human development, not a replacement for it. In the context of addressing the objectives of the study, the results have confirmed that the TMRC model makes a significant impact on the academic performance of students. The strategic use of AI tools in a constructivist learning environment has helped to encourage active engagement, conceptual understanding, and learning outcomes. The students were not only exposed to digital technologies but also to reflective inquiry and knowledge construction, leading to effective and lasting learning experiences.

In addition to academic outcomes, the TMRC model has made a significant impact on engagement and reflective thinking among students. The students were encouraged to question, collaborate, articulate their understanding, and evaluate their learning processes. The focus on reflective thinking has helped to encourage metacognitive awareness, learner agency, and ethical use of AI, which is becoming increasingly important in the context of a globally interconnected and technology-driven learning environment.

Notably, the flexibility of the TMRC model in different classroom settings underscores its scalability. The successful implementation of the TMRC model in both traditional and online settings indicates that the model can be applied in different educational settings and cultures. This scalability makes TMRC a universally applicable model for institutions that aim to integrate AI technology while preserving educational integrity and inclusivity. In conclusion, this study extends Dewey's educational vision by showing how AI technology, when informed by Dewey's principles of reflection and collaboration, can improve critical thinking, creativity, and self-regulation. The TMRC model provides a sustainable approach for institutions to align technological innovation with humanistic values. By developing reflective, collaborative, and transformative thinkers, the AI-enhanced TMRC model makes a significant contribution to future-ready education in both local and global settings.

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AUTHOR CONTRIBUTIONS STATEMENT

This journal uses the Contributor Roles Taxonomy (CRediT) to recognize individual author contributions, reduce authorship disputes, and facilitate collaboration.

Name of Author	C	M	So	Va	Fo	I	R	D	O	E	Vi	Su	P	Fu
Adelfa Silor	✓	✓		✓	✓	✓		✓	✓	✓	✓			
Faith Stephanny Silor	✓	✓		✓	✓	✓		✓	✓	✓	✓	✓		

C : **C**onceptualization
M : **M**ethodology
So : **So**ftware
Va : **Va**lidation
Fo : **Fo**rmal analysis
I : **I**nvestigation
R : **R**esources
D : **D**ata Curation
O : Writing - **O**riginal Draft
E : Writing - Review & **E**diting
Vi : **Vi**sualization
Su : **Su**pervision
P : **P**roject administration
Fu : **Fu**nding acquisition

CONFLICT OF INTEREST STATEMENT

The authors declare that there are no conflicts of interest related to this research. The authors state no conflict of interest.

INFORMED CONSENT

The authors confirm that informed consent was obtained from all individuals included in the study. The privacy and confidentiality of all participants were respected by ethical research standards.

ETHICAL APPROVAL

The research involving human participants was conducted in full compliance with all applicable national regulations and institutional policies. It adhered to the ethical principles outlined in the Declaration of Helsinki, ensuring the rights, safety, and well-being of all participants were protected throughout the study.

DATA AVAILABILITY

The authors confirm that the data used in this study are available in the article and/or its supplementary materials.

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BIOGRAPHIES OF AUTHORS

Adelfa Silor is a professor VI at Mindanao State University-Iligan Institute of Technology (MSU-IIT), Philippines. Her research interests encompass education, gender studies, inclusive pedagogies, literacy, and the integration of technology in teaching and learning. She has published extensively in Scopus-indexed and peer-reviewed journals, contributing to scholarship in gender-responsive education and transformative, culturally grounded pedagogical practices. As a committed academic leader, she actively promotes inclusive and gender-equitable education both locally and globally. She can be contacted at email: adelfa.silor@g.msuiit.edu.ph.

Faith Stephanny Silor is a research assistant at Mindanao State University-Iligan Institute of Technology, where she supports research in education, gender studies, and sustainable development. She holds a Bachelor of Science in Hotel and Restaurant Management and has completed the academic requirements for the Master of Science in Hotel and Restaurant Management. Her research interests focus on inclusive education, gender-responsive policies, youth leadership, and community-based development in the hospitality and education sectors. She has co-authored five journal publications and presented eight research papers at regional and national conferences. She can be contacted at email: faithstephanny.silor@g.msuiit.edu.ph.