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Tridatu Responsive Inquiry Adaptive Navigation to Enhance Acid-Base Titration Understanding in Bali Schools

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ABSTRAK

Pemahaman konseptual siswa pada materi titrasi asam-basa masih menjadi tantangan dalam pendidikan sains di tingkat sekolah menengah atas. Penelitian ini bertujuan untuk menilai efektivitas model TRIAN dalam meningkatkan hasil belajar kognitif dan kepuasan pengguna. Penelitian ini menggunakan pendekatan mixed-methods, dengan melibatkan 60 siswa SMA di Bali sebagai subjek penelitian. Data kuantitatif dikumpulkan melalui pre-test dan post-test, sementara data kualitatif diperoleh melalui observasi, wawancara, dan umpan balik pengguna. Penilaian efektivitas dilakukan menggunakan Model Evaluasi Kirkpatrick dengan fokus pada level Learning untuk mengukur peningkatan pengetahuan dan keterampilan siswa. Hasil penelitian menunjukkan peningkatan pemahaman konseptual siswa sebesar 50%, dengan peningkatan yang signifikan secara statistik berdasarkan analisis paired t-test ($p < 0,01$). Selain itu, hasil dari User Experience Questionnaire (UEQ) menunjukkan tingkat kepuasan yang tinggi, terutama pada dimensi daya tarik, stimulasi, dan efisiensi. Temuan ini mengindikasikan bahwa model TRIAN efektif dalam meningkatkan hasil belajar kognitif sekaligus mengintegrasikan nilai-nilai budaya ke dalam proses pembelajaran. Penelitian ini menyimpulkan bahwa model TRIAN yang didukung oleh TitraSee AR menawarkan pendekatan holistik dan menarik dalam pendidikan sains dengan menjembatani teknologi modern dan tradisi budaya lokal. Penelitian lebih lanjut dapat mengkaji penerapan model ini di berbagai konteks pendidikan dan budaya lainnya.

ABSTRAK

Students' conceptual understanding of acid-base titration remains a challenge in high school science education. This study aims to assess the effectiveness of the TRIAN model in improving cognitive learning outcomes and user satisfaction. A mixed-methods approach was employed, involving 60 high school students in Bali as research participants. Quantitative data were collected through pre-tests and post-tests, while qualitative data were gathered through observations, interviews, and user feedback. The effectiveness evaluation was conducted using Kirkpatrick's Evaluation Model, focusing on the Learning level to measure knowledge and skill improvements. The results indicated a 50% increase in students' conceptual understanding, with statistically significant improvements based on paired t-test analysis ($p < 0.01$). Additionally, findings from the User Experience Questionnaire (UEQ) revealed high satisfaction levels, particularly in the dimensions of attractiveness, stimulation, and efficiency. These findings suggest that the TRIAN model effectively enhances cognitive learning outcomes while integrating cultural values into the learning process. This study concludes that the TRIAN model, supported by TitraSee AR, offers a holistic and engaging approach to science education by bridging modern technology and local cultural traditions. Future research could explore the application of this model in various educational and cultural contexts.

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1. INTRODUCTION

The teaching of chemistry at the secondary school level often encounters challenges in conveying abstract and complex concepts, particularly acid-base titration. This topic requires an in-depth understanding of chemical reaction mechanisms, which are frequently difficult for students to grasp (Arztmann et al., 2022; Benawan et al., 2023; Jin et al., 2022; Kempke & Zeidler, 2023; Sarifah et al., 2025). Conventional teaching approaches, which predominantly rely on theoretical explanations, are often insufficient to motivate students, leading to low conceptual understanding and engagement (Benawan et al., 2023; Kartini, 2020; Siadari & Siddik, 2021). These challenges underscore the need for innovative pedagogical strategies that can effectively bridge the gap in student comprehension while enhancing learning experiences (Kulawansa & Mihirani, 2019; Naidu et al., 2023; Puggioni et al., 2021; Yıldırım, 2021). In response to these challenges, technology-enhanced learning has emerged as a promising solution. Educational tools like augmented reality (AR) have been shown to facilitate the visualization of complex chemical processes, making abstract concepts more accessible to students (Gasteiger, 2020; Mazzuco et al., 2023; Putra et al., 2021).However, most implementations of educational technology lack contextual relevance, particularly in regions with rich cultural heritages, such as Bali (Kartini & Putra, 2020). Bali's *Tri Datu* philosophy, which embodies the values of courage (red), truth (white), and resilience (black), offers a unique framework for integrating cultural wisdom into educational practices (A. T. Atmadja et al., 2017).

By aligning learning processes with these values, students can connect scientific concepts to their cultural context, fostering deeper engagement and understanding (Wale & Bishaw, 2020). Previous studies have highlighted the significance of culturally responsive education in increasing student motivation and academic achievement. Nevertheless, few studies have explored the integration of cultural values with emerging technologies, leaving a gap in the literature that this study aims to address. To address this issue, this study introduces the *Tridatu* Responsive Inquiry Adaptive Navigation (TRIAN) Learning Model. This framework integrates the inquiry-based learning approach with the *Tri Datu* philosophy and employs adaptive navigation tools such as TitraSee *AR*, an augmented reality-based application. TitraSee *AR* enables students to visualize complex titration processes interactively, promoting active participation and critical thinking during the learning process (Arztmann et al., 2022; Gasteiger, 2020; Zambri et al., 2022). The inquiry approach is structured around the *Tri Datu* values: fostering curiosity and exploration in the courage phase, guiding accurate analysis in the truth phase, and encouraging persistence in solving complex problems in the resilience phase (Nechypurenko et al., 2023; Septi et al., 2020; Tarng et al., 2022; Wen et al., 2023).

To evaluate the effectiveness of the TRIAN model, this study employs the Kirkpatrick Evaluation Model, focusing on the "Learning" level (Kirkpatrick, 2021). This evaluation framework assesses the improvement in students' knowledge, skills, and attitudes resulting from the integration of the TRIAN model into their learning process. The pre-test and post-test method, combined with user experience assessments and qualitative observations, allows for a comprehensive analysis of the model's impact on learning outcomes. By adopting a structured evaluation approach, this research not only measures learning improvement but also explores the alignment of the TRIAN model with the cultural context of Balinese students. By combining modern educational technology with culturally responsive pedagogy, this study seeks to address the limitations of traditional methods and contribute to the advancement of contextualized educational frameworks. Traditional approaches to education often lack engagement and fail to cater to the diverse cultural contexts of learners, leading to gaps in comprehension and motivation (Almuaqel, 2023; Cheng et al., 2024; Henim & Sari, 2020; Rini & Aldila, 2023). The integration of technology, such as augmented reality, with cultural elements like the *Tri Datu* philosophy, bridges these gaps by creating an immersive, relatable, and interactive learning environment. The novelty of this research lies in embedding the *Tri Datu* philosophy into an augmented reality-based learning model, offering a groundbreaking combination of cultural values and advanced technology. Unlike previous studies that often focus solely on technological innovations or cultural education, this research introduces a novel synthesis of both aspects, resulting in a holistic and contextually relevant educational model. This unique approach not only enhances students' understanding of complex scientific concepts but also fosters a deeper connection to their cultural heritage, thereby promoting both cognitive and emotional engagement. The integration of cultural pedagogy with augmented reality represents a pioneering effort to bridge modern technological tools with local cultural wisdom.

This study aims to develop and evaluate a culturally responsive learning model that integrates advanced educational technology with local traditions, specifically the *Tri Datu* philosophy. The primary objective is to enhance students' conceptual understanding of acid-base titration while fostering cultural appreciation through the integration of augmented reality and culturally relevant pedagogy. By aligning technological innovation with cultural values, the research seeks to address gaps in traditional teaching methods and provide a framework for contextually adaptive educational practices. The expected outcomes

include the establishment of a scalable model that enriches learning experiences through inclusivity, engagement, and cultural relevance. This framework is anticipated to serve as a reference for future research and practice, emphasizing the importance of integrating cultural context with innovative teaching tools to improve educational outcomes. Furthermore, the findings aim to contribute to the broader discourse on localized solutions to global educational challenges, underscoring the potential of culturally adaptive learning models to enhance educational equity while preserving cultural heritage.

2. METHOD

This study employs a qualitative descriptive research design, following the guidelines of Ritchie and Lewis (Ritchie et al., 2021), to explore the effectiveness of the *Tridatu* Responsive Inquiry Adaptive Navigation (TRIAN) Learning Model in enhancing students' understanding of acid-base titration. Data collection methods were grounded in recent educational research methodologies and included pre-test and post-test assessments, user experience evaluations, observations, and interviews. The pre-test and post-test assessments were designed to measure improvements in students' conceptual understanding, focusing on theoretical knowledge, procedural skills, and problem-solving abilities, based on the revised Bloom's taxonomy framework (Krathwohl, 2021).

To evaluate the usability and effectiveness of the TitraSee AR application as part of the TRIAN learning model, this study utilized the User Experience Questionnaire (UEQ), as updated by (Schrepp, 2023). The UEQ measured six dimensions: attractiveness, perspicuity, efficiency, dependability**,** stimulation, and novelty, ensuring a comprehensive analysis of user interaction and satisfaction. Observations and semi-structured interviews, as outlined in (Flick, 2022), were conducted to gather in-depth qualitative insights into students' learning experiences and perceptions of the TRIAN model. These mixed-method approaches provided a robust framework for evaluating both quantitative outcomes and qualitative feedback, enabling a holistic understanding of the model's impact on student learning and its alignment with culturally responsive pedagogy. The *Tridatu* Learning Model can be seen in Figure 1.

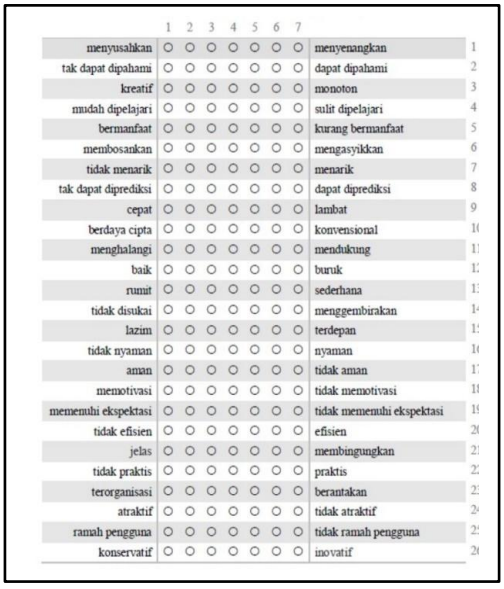
Figure 1. *Tridatu* Responsive Inquiry Adaptive Navigation Learning Model

The *Tridatu* Responsive Inquiry Adaptive Navigation (TRIAN) Learning Model is a culturally grounded educational framework that integrates the *Tri Datu* philosophy—courage (red), truth (white), and resilience (black)—into an inquiry-based learning process. This model aims to provide a meaningful and holistic learning experience by aligning the learning stages with the cultural values symbolized by the *Tri Datu* bracelet. Each stage in the TRIAN model corresponds to a specific phase of inquiry-based learning, supported by adaptive navigation tools like augmented reality applications. The first stage, Orientation & Exploration (Courage), symbolized by the red color, is designed to stimulate curiosity and encourage students to actively explore new concepts. This stage embodies the value of courage, motivating learners to step beyond their comfort zones, question existing knowledge, and engage in critical inquiry. It provides an open environment where students feel empowered to investigate and generate initial hypotheses. By

fostering a sense of intellectual bravery, this phase lays the foundation for deeper learning and prepares students to approach subsequent stages with a stronger understanding and confidence. The second stage, Collect Data and Analyze (Truth), represented by the white color, focuses on guiding students in collecting accurate, relevant information and analyzing it systematically. This stage emphasizes the importance of evidence-based reasoning, where students critically evaluate data and draw logical conclusions grounded in scientific principles. By aligning with the value of truth, this phase reinforces the need for accuracy, objectivity, and analytical rigor in the learning process. It ensures that students develop a methodical approach to problem-solving, equipping them with the skills necessary to interpret and synthesize information effectively. The third stage, Problem Solving & Reflection (Resilience), depicted by the black color, is centered on training students to address complex challenges and engage in reflective practices. This stage integrates the value of resilience, encouraging learners to persist through difficulties and refine their understanding through iterative problem-solving. Students are guided to critically assess their learning journey, identify areas for improvement, and apply their knowledge to real-world scenarios. By promoting resilience, this phase not only strengthens students' problem-solving capabilities but also cultivates a mindset of continuous growth and adaptability, which are essential for long-term academic and personal success.

Together, these three stages form a cohesive and iterative learning framework that integrates cultural values with educational practices, enabling students to navigate the learning process with curiosity, integrity, and perseverance. This alignment with the *Tri Datu* philosophy ensures that the learning model is not only pedagogically effective but also culturally meaningful, fostering a holistic development of learners. The circular arrangement of the stages in the TRIAN model signifies an iterative learning process, where students continuously refine their understanding and skills through repeated cycles of exploration, analysis, and reflection. The *Tri Datu* bracelet at the center of the model serves as a visual representation of the cultural philosophy that underpins the learning process, emphasizing the integration of traditional values with modern educational approaches. This model not only enhances cognitive learning outcomes but also embeds cultural relevance, making it particularly effective in contexts where local values and traditions play a crucial role in education. Qualitative data were gathered through classroom observations, where student engagement and interaction with the learning model were documented. Semi-structured interviews with selected students provided in-depth insights into their learning experiences, particularly the cultural relevance of the *Tri Datu* framework and the integration of augmented reality into the learning process. The research sample consisted of 60 high school students purposively selected from SMA Negeri 4 Denpasar, SMA Negeri 1 Singaraja, and SMA Lab Undiksha Singaraja, representing diverse academic backgrounds and cultural contexts.

The collected data were analyzed using both quantitative and qualitative approaches. Pre-test and post-test scores were statistically analyzed using paired t-tests to determine significant improvements in learning outcomes. The *User Experience Questionnaire (UEQ)* results were processed using standardized tools to produce descriptive statistics for each dimension, including attractiveness, perspicuity, efficiency, dependability, stimulation, and novelty can see on Figure 2.



	1	2	3	4	5	6	7		
menyusahkan	○	○	○	○	○	○	○	menyenangkan	1
tak dapat dipahami	○	○	○	○	○	○	○	dapat dipahami	2
kreatif	○	○	○	○	○	○	○	monoton	3
mudah dipelajari	○	○	○	○	○	○	○	sulit dipelajari	4
bermanfaat	○	○	○	○	○	○	○	kurang bermanfaat	5
membosankan	○	○	○	○	○	○	○	mengasyikkan	6
tidak menarik	○	○	○	○	○	○	○	menarik	7
tak dapat diprediksi	○	○	○	○	○	○	○	dapat diprediksi	8
cepat	○	○	○	○	○	○	○	lambat	9
berdaya cipta	○	○	○	○	○	○	○	konvensional	1(
menghalangi	○	○	○	○	○	○	○	mendukung	1:
baik	○	○	○	○	○	○	○	buruk	1:
rumit	○	○	○	○	○	○	○	sederhana	1:
tidak disukai	○	○	○	○	○	○	○	menggembirakan	1•
lazim	○	○	○	○	○	○	○	terdepan	1:
tidak nyaman	○	○	○	○	○	○	○	nyaman	1(
aman	○	○	○	○	○	○	○	tidak aman	1:
memotivasi	○	○	○	○	○	○	○	tidak memotivasi	1:
memenuhi ekspektasi	○	○	○	○	○	○	○	tidak memenuhi ekspektasi	1:
tidak efisien	○	○	○	○	○	○	○	efisien	2(
jelas	○	○	○	○	○	○	○	membingungkan	2:
tidak praktis	○	○	○	○	○	○	○	praktis	2:
terorganisasi	○	○	○	○	○	○	○	berantakan	2:
atraktif	○	○	○	○	○	○	○	tidak atraktif	2•
ramah pengguna	○	○	○	○	○	○	○	tidak ramah pengguna	2:
konservatif	○	○	○	○	○	○	○	inovatif	2(

Figure 2. UEQ Question List in Bahasa Indonesia (Juniantari et al., 2021)

In the UEQ, students rated their experiences across various bipolar dimensions, such as "difficult–easy," "complicated–clear," and "conventional–innovative," on a 7-point Likert scale. The scale allowed students to express their perceptions ranging from highly negative to highly positive. Each item on the scale contributed to measuring specific aspects of user experience, such as how intuitive the application felt (e.g., "complicated–clear") or how engaging it was (e.g., "boring–exciting"). The qualitative data from observations and interviews were analyzed thematically, with a focus on patterns related to student engagement, cultural alignment, and the usability of the TRIAN model. These thematic analyses were triangulated with the quantitative results to provide a deeper understanding of the factors influencing the model's effectiveness. The findings were synthesized to provide a comprehensive understanding of the TRIAN model's effectiveness, highlighting its integration of cultural values with modern educational tools. This combination created a holistic and meaningful learning experience, as evidenced by students' consistently positive feedback across multiple UEQ dimensions.

3. RESULT AND DISCUSSION

Results

The results of this study indicate that the AR-based learning model combined with the inquiry approach and *Tri Datu* cultural values significantly improves students' understanding and engagement in learning. These findings are discussed as follows. Improved Conceptual Understanding through AR Technology Integration The results show a Table 1. improvement in students' conceptual understanding, as indicated by the pre-test and post-test scores. The average score increased from 65 to 85, representing an improvement of 30.77%. The maximum score rose from 70 to 95, an increase of 35.71%, while the minimum score increased from 50 to 75, showing the most substantial improvement at 50%. This data highlights the effectiveness of the AR-based learning model in enhancing students' comprehension of acid-base titration. By leveraging AR technology through the *TitraSee AR* application on Figure 3, students were able to interactively visualize and understand complex concepts, overcoming barriers often associated with abstract topics.

Table 1. Average Score Pre-Test and Post-Test

No	Metrics	Pre-test	Post-test	Improvement
1	Average score	65	85	30.77%
2	Maximum score	70	95	35.71%
3	Minimun score	50	75	50%

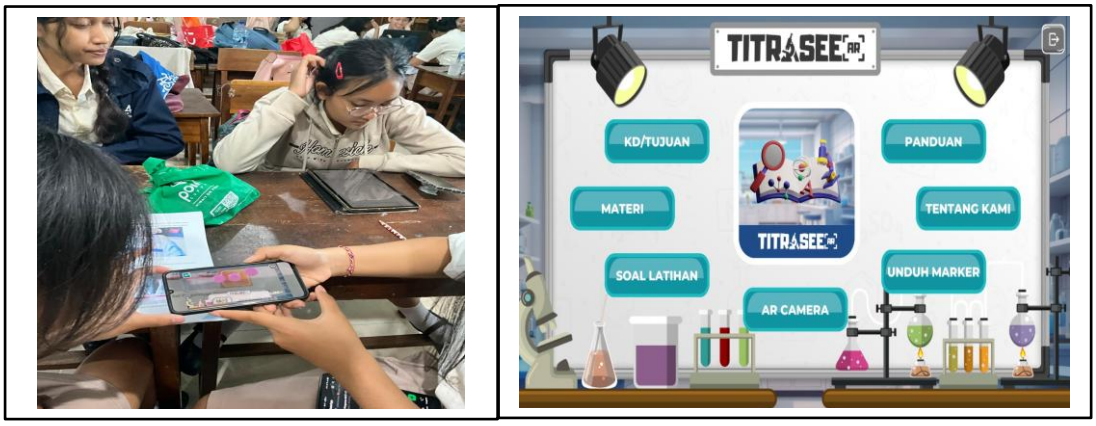
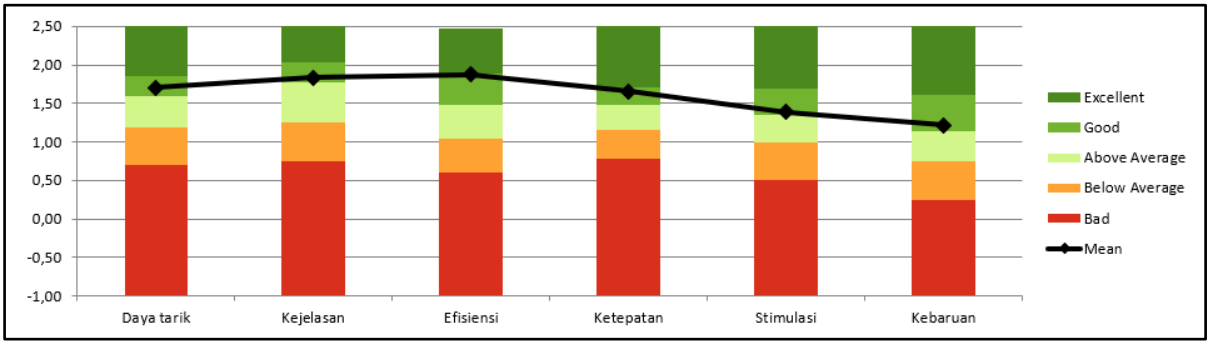


Figure 3. Students Learn using the Titration AR Application

In Figure 3, students are actively engaging with the TitraSee AR application during a classroom session. The application enables them to visualize complex concepts in acid-base titration interactively using augmented reality. Students can observe simulated chemical reactions, manipulate virtual objects, and follow guided steps to enhance their understanding. This hands-on approach not only simplifies abstract concepts but also promotes active learning and collaboration among peers. The image reflects the immersive nature of the learning process facilitated by modern educational technology. The interface of the TitraSee AR application demonstrates a user-centered design that integrates various features to support a comprehensive and engaging learning experience in chemistry education. The main menu provides

structured options tailored to different stages of the learning process, including Learning Objectives (*KD/Tujuan*), Materials (*Materi*), Practice Questions (*Soal Latihan*), AR Camera, and Download Marker (Unduh Marker). Each feature is strategically designed to enhance students' conceptual understanding and interaction with the learning material. The Learning Objectives section outlines the competencies and goals that students are expected to achieve, providing clarity and direction for their learning journey. This feature helps students contextualize their activities and align their efforts with the intended outcomes. The Materials section offers detailed content on acid-base titration, supported by interactive visuals, diagrams, and explanations, allowing students to explore theoretical concepts in an engaging and accessible manner. The Practice Questions feature includes interactive quizzes and exercises that reinforce students' understanding through active recall and application. Immediate feedback is provided to help students identify gaps in their knowledge and improve their performance. The AR Camera, a core component of the application, allows students to activate augmented reality experiences by scanning markers. This feature provides immersive 3D simulations of titration processes, enabling students to visualize and interact with abstract concepts in real time, bridging the gap between theoretical understanding and practical application. The Download Marker option ensures that students can access the necessary resources to fully utilize the AR functionality, enhancing the application's accessibility. Additional features, such as the Guide (*Panduan*) and About Us (*Tentang Kami*) sections, support ease of use and provide background information about the application's purpose and development. These elements ensure that both students and educators can navigate the application effectively, promoting its adoption in diverse educational settings. The intuitive design, complemented by visually appealing icons and a well-organized layout, emphasizes usability and ensures that users of varying technological proficiency can engage with the tool seamlessly. Overall, the TitraSee AR application exemplifies a thoughtfully designed educational platform that combines modern technology with pedagogical principles. Its integration of augmented reality, interactive content, and structured learning activities provides a holistic approach to education, making it particularly effective for addressing complex topics such as acid-base titration. The interface's focus on usability, functionality, and engagement aligns with best practices in educational technology, ensuring its relevance and impact in modern chemistry education. User Experience Questionnaire Results showed in Figure 4.

Figure 4. User Experience Questionnaire Results



Feedback from the User Experience Questionnaire (UEQ) evaluation further supports the effectiveness of the TRIAN model. The results, as illustrated in Figure 4 (UEQ Results), indicate that students consistently rated the AR-based learning tool highly across six dimensions: attractiveness, perspicuity (clarity), efficiency, dependability (accuracy), stimulation, and novelty. The highest scores were observed in the dimensions of attractiveness and efficiency, reflecting that students found the tool engaging and intuitive to use. These results highlight the ability of the TRIAN model, supported by TitraSee AR, to create a user-friendly and enjoyable learning experience. The graph in Figure 4 shows a breakdown of feedback across performance categories, from "Bad" to "Excellent." Most dimensions received ratings in the "Good" to "Excellent" range, with minimal feedback in lower categories such as "Below Average" or "Bad." The dimension attractiveness achieved the highest mean score, emphasizing the appealing and interactive design of the TitraSee AR application. Meanwhile, novelty scored slightly lower compared to other dimensions, suggesting opportunities for further innovation to enhance the experience. The overall mean score across dimensions exceeded 1.5 (on a scale where 2.0 indicates "Excellent"), demonstrating a strong positive perception of the tool.

Disscussion

The integration of augmented reality (AR) technology with the *Tridatu* Responsive Inquiry Adaptive Navigation (TRIAN) model has proven effective in simplifying complex chemistry topics, such as acid-base titration, while fostering active student participation and engagement. The interactive and immersive visual features of AR allowed students to explore abstract concepts in a tangible and relatable manner, enhancing their understanding (Hidayat et al., 2021; Kaur et al., 2020; Silva et al., 2023). Additionally, the cultural alignment of the TRIAN model with local Balinese values strengthened students' connection to the material, fostering a greater sense of belonging and motivation. The key finding of this study is the combination of AR technology with local cultural values through the TRIAN model, creating an innovative and culturally relevant learning approach. The model not only utilizes AR as a modern teaching tool but also integrates the *Tri Datu* philosophy, symbolizing courage, truth, and resilience as a pedagogical framework. This demonstrates that integrating local cultural values can improve students' understanding while fostering a deeper connection to the learning material (Fuad et al., 2020; Putri & Ananda, 2020; Sumarni et al., 2022; Zeng & Onlamul, 2023). The results show that students expressed high levels of satisfaction with the interactivity, visual appeal, and cultural relevance of the TRIAN model. This highlights the significant impact of combining advanced technological tools with culturally responsive approaches in creating meaningful learning experiences. The positive reception of the TRIAN model underscores its potential as an innovative method in chemistry education, seamlessly integrating modern technology with local cultural values. This synergy not only enhances cognitive learning outcomes but also promotes emotional and cultural engagement, ultimately delivering a holistic and impactful educational experience (Fuad et al., 2020; Ngazizah & Laititia, 2022; Putri & Ananda, 2020; Shufa, 2018; Sumarni et al., 2022; Zeng & Onlamul, 2023).

The integration of *Tri Datu* cultural values, symbolizing courage, truth, and resilience, significantly enhanced student engagement and learning outcomes. These values provided a culturally resonant framework that connected abstract scientific concepts to students' daily lives, fostering a deeper understanding and relevance of the learning material (Atmadja et al., 2016; Fuad et al., 2020; Putri & Ananda, 2020; Sumarni et al., 2022; Zeng & Onlamul, 2023). Observations revealed that the value of courage (red) encouraged students to step out of their comfort zones and explore critically during inquiry activities. The value of truth (white) promoted a disciplined, evidence-based approach, enabling students to analyze data systematically. Lastly, the value of resilience (black) supported students in overcoming challenges and developing persistence, resulting in a growth mindset. These findings underline the importance of culturally responsive pedagogy in enhancing not only cognitive but also emotional and cultural engagement. In comparison with previous studies, the findings of this study align closely with the body of research emphasizing the transformative role of culturally responsive education, underscored the critical importance of embedding cultural values into educational frameworks to enhance student engagement and contextual relevance, particularly in regions with rich cultural traditions such as Bali (Atmadja et al., 2017; Kusumayani et al., 2019; Prastya et al., 2022). This study extends their findings by demonstrating how the integration of the *Tri Datu* philosophy representing courage, truth, and resilience into the TRIAN model provides students with a culturally meaningful context that strengthens their emotional connection to the learning material.

Furthermore, the effectiveness of contextualized learning approaches that combine cultural frameworks with advanced technologies to foster deeper learning outcomes (Jones & Sharma, 2021; MacKenzie et al., 2022). This study builds on their research by illustrating how augmented reality (AR), when paired with culturally significant values, not only simplifies complex scientific concepts such as acid-base titration but also nurtures critical thinking and emotional engagement. The dual impact of enhancing cognitive understanding and emotional resonance is a novel contribution to the field. Moreover, this study corroborates the findings, which identified AR's potential to create immersive and interactive educational experiences and emphasized the importance of cultural relevance in educational models to increase their effectiveness (Engerman & Otto, 2021; Wale & Bishaw, 2020). By explicitly demonstrating how the TRIAN model bridges modern technology and cultural practices, this study provides empirical evidence for the synergistic effects of combining AR with local cultural philosophies. This unique integration highlights the potential of culturally responsive AR-based frameworks to transform both the cognitive and affective dimensions of learning, offering a comprehensive solution for regions seeking to balance traditional values with technological advancements.

The implications of these findings extend to the development of inclusive, impactful learning environments. The TRIAN model, guided by *Tri Datu* values and supported by AR, serves as a blueprint for designing globally adaptable yet culturally rooted educational frameworks. It underscores the potential of technology to bridge global advancements with local traditions, fostering both academic success and cultural identity. Furthermore, the inquiry-based approach embedded within the TRIAN model effectively

develops critical thinking and problem-solving skills, as supported by recent studies methods (Almuaqel, 2023; Carolina, 2022; Devesh & Nanjundaswamy, 2023; Rasna et al., 2021).This holistic integration of cultural values and AR technology contributes to the advancement of culturally responsive and innovative pedagogy. Despite its strengths, the study has notable limitations. The research was conducted with a limited sample size in Bali, which may restrict the generalizability of the findings. Future studies should validate the TRIAN model in diverse cultural settings to assess its broader applicability. Additionally, the AR technology employed in this study was limited to basic simulations. Advanced AR platforms with more interactive and immersive features could further enhance the learning experience. These recommendations suggest avenues for future research, including long-term studies on the model's impact on academic achievement and cultural identity development, as well as its potential applications in various educational and cultural contexts.

4. CONCLUSION

The significant improvement in pre-test and post-test scores, along with positive feedback from the User Experience Questionnaire (UEQ), highlights the model's ability to simplify complex concepts such as acid-base titration while fostering an interactive and enjoyable learning environment. The incorporation of *Tri Datu* values—courage, truth, and resilience—provides a culturally responsive dimension that connects students to their learning context, further motivating them and deepening their understanding. The AR-based application TitraSee AR played a crucial role in enabling students to visualize abstract concepts interactively, reinforcing its value as a modern educational tool.

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