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Contextualizing Acid–Base Chemistry Learning through Local Wisdom: Development of an Interactive E-Module Based on the *Poto Wua Ta'a* Tradition in Indonesia

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ABSTRACT

Chemistry education in Indonesia often faces challenges such as abstract content, limited laboratory access, and lack of contextual learning. Integrating local wisdom into science instruction offers a culturally relevant approach to enhance student engagement and understanding. This study aimed to develop an interactive e-module on acid–base concepts contextualized through the traditional *Poto Wua Ta'a* practice in Sikka Regency, Indonesia. Using the 4D development model (Define, Design, Develop, Disseminate), the module was created by integrating acid–base theory with cultural practices involving betel leaf, areca nut, and lime. Expert validation involved five validators assessing the content, media, and language components. Feasibility was tested through individual (n=10), small-group (n=30), and field trials (n=60), with both qualitative and quantitative data collected. Expert validation yielded an average Aiken's V score of 0.89, indicating high content validity. Practicality scores increased across trials: 87% (individual), 89% (small group), and 91% (field), all categorized as "very practical." Student feedback confirmed improved understanding of acid–base concepts through cultural context and multimedia features. The e-module effectively contextualizes abstract chemistry content using local wisdom, enhancing student comprehension and motivation. Its development aligns with constructivist, ethnopedagogical, and place-based learning principles, while supporting goals in the Merdeka Curriculum and SDG 4.

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1. INTRODUCTION

The 21st century, known as the globalization era, is characterized by rapid advances in technology that bring significant changes across multiple sectors, including education (Fujiarti et al., 2024)Several studies have revealed that the quality of science education in Indonesia, particularly in chemistry, remains relatively low. Findings from the Programme for International Student Assessment (PISA) indicate that Indonesian students perform at a lower level in scientific literacy. In 2018, the average

score for Indonesian students in science literacy was only 396, ranking 70th out of 78 participating countries (Organisation for Economic Co-operation and Development (OECD), 2019)These results suggest that Indonesian students still struggle with contextual problem-solving skills and the ability to interpret findings from simple investigations(Febrianti & Nurjanah, 2022). One contributing factor is the limited use of culturally relevant contexts in science learning, which could otherwise enhance students' reasoning and engagement (Nikmatur Rohmaya et al., 2023)

Local wisdom, such as *Poto Wua Ta'a*, a traditional practice of the Sikka community in East Nusa Tenggara, offers a potential context for chemistry learning. This cultural practice involves the use of natural ingredients such as betel leaf (*Wua*), areca nut (*Ta'a*), and lime ($Ca(OH)_2$). Beyond its symbolic and social values, *Poto Wua Ta'a* illustrates authentic chemical phenomena, including acid-base interactions and neutralization reactions. For instance, the alkaline property of lime reacts with the phenolic compounds in betel leaf and the alkaloids in areca nut, producing a reddish color on saliva or betel leaf. This phenomenon can be scientifically explained through acid-base reactions and the use of natural indicators (Munira et al., 2020). Unfortunately, with modernization, such local wisdom has been increasingly marginalized among younger generations(Rahayu et al., 2022)

Field observations at SMAN 1 Waigete revealed that although the school promotes cultural appreciation, such as by adopting woven sarongs as uniforms, teachers have not yet integrated local wisdom into classroom learning. Chemistry lessons are still taught conventionally, with abstract concepts delivered through textbooks that lack connections to students' daily lives. This situation reduces students' interest, engagement, and comprehension, while also contributing to low academic achievement (Sulistiana; Anggraiani D.P, 2024). At the same time, students have limited awareness of their own cultural heritage. Thus, there is an urgent need to design learning materials that both support chemistry learning and promote local culture.

This study is grounded in the theories of constructivism, ethnopedagogy, and place-based learning. According to constructivism, knowledge is actively constructed by students through direct experiences rather than being passively transferred from teachers. In this context, the *Poto Wua Ta'a* tradition can provide a real-life experience that helps students connect abstract chemical concepts, particularly acid–base reactions, with familiar cultural phenomena. Furthermore, ethnopedagogy emphasizes the importance of integrating local values, practices, and knowledge into the educational process. By using *Poto Wua Ta'a* as a learning context, students not only understand chemistry content but also develop appreciation for their cultural heritage as part of the learning process. Meanwhile, place-based learning theory stresses that learning becomes more meaningful when linked to the social and cultural environment in which students live. Thus, the development of an interactive e-module based on *Poto Wua Ta'a* is supported by these three theories, as it enables contextual and meaningful learning while strengthening students' cultural identity

The integration of *Poto Wua Ta'a* into an interactive chemistry e-module provides a promising solution. Digital modules offer accessible and engaging learning resources that visualize abstract concepts while embedding cultural relevance (Rusfriyanti & Rondli, 2023). Prior studies have shown that digital modules and interactive media can improve learning outcomes and science literacy (Erlangga & Dwiningsih, 2024), Other researchers have explored the integration of local wisdom into science education, such as the use of traditional medicine, batik, and weaving context (Sulystiahningsih, S. et al., 2023)). However, most of these studies have not explicitly grounded their approaches in educational theories such as constructivism, ethnopedagogy, or place-based learning, and none have specifically examined the integration of *Poto Wua Ta'a* in the context of acid–base chemistry. This highlights a research gap, as previous works often overlook how local wisdom can be systematically linked to abstract scientific concepts through theoretically informed digital learning materials.

Therefore, this study aims to (a) integrate *Poto Wua Ta'a* into an interactive chemistry e-module for teaching acid–base concepts, and (b) evaluate the feasibility of the developed e-module through expert validation and limited trials. The novelty of this research lies in combining digital learning media with the contextual and cultural richness of *Poto Wua Ta'a*, while at the same time drawing upon the

principles of constructivist learning, ethnopedagogy, and place-based learning to strengthen its theoretical foundation. This approach not only enhances students' conceptual understanding of acid–base chemistry but also fosters cultural appreciation and preservation. Ultimately, this study is expected to contribute to meaningful and contextualized learning that aligns with Asta Cita 4 and SDG 4 in promoting inclusive and quality education, while also offering insights for the broader field of science education on how local wisdom can be leveraged to address global educational challenges.

2. METHODS

This research employed a research and development (R&D) method using the 4D model (Define, Design, Develop, Disseminate) developed by Thiagarajan. This model was chosen because it is appropriate for producing a chemistry interactive e-module based on the local wisdom of Poto Wua Ta'a in the topic of acids and bases that is tested for its feasibility.

The first stage is Define. At this stage, a literature review and needs analysis were conducted, including material analysis, curriculum analysis, local wisdom analysis of Poto Wua Ta'a, and learning objective analysis. In addition, observations at SMAN 1 Waigete were carried out, along with interviews with teachers and cultural leaders, and questionnaires were distributed to students to identify needs and challenges in learning chemistry. The sampling strategy used purposive sampling with inclusion criteria such as students who had studied the topic of acids and bases and were willing to participate in the trial, while exclusion criteria included students who were absent or not actively involved during the learning process.

The second stage is Design. At this stage, the blueprint of the interactive e-module was created, consisting of the e-module structure, integration of local wisdom, storyboard preparation, selection of tools and platforms, and development of product feasibility instruments. The e-module was developed using Flip PDF Professional, which allows multimedia integration and is compatible with both computers and mobile devices, ensuring easy access for students. An initial laboratory practicum related to acid-base concepts was also carried out using Poto Wua Ta'a (betel leaves and areca nut) as the experimental basis for the e-module content. The instruments used for product validation and testing were designed by the researchers based on relevant literature and subsequently reviewed by experts to ensure their validity before being piloted in small-scale trials.

The third stage is Develop. At this stage, the interactive e-module was developed based on the design. The development process included the creation of interactive content, integration of Poto Wua Ta'a phenomena into acid-base concepts, and the preparation of both virtual and simple laboratory-based practical activities. The resulting product was then validated by material experts, media experts, language experts, and practitioners. The validation instrument used a Likert scale with the following categories: Very Good (5), Good (4), Fair (3), Poor (2), and Very Poor (1). Then, data analysis of validation was carried out using the calculation of the V index, with the following classification: Index ≤ 0.4 (less valid); 0.4 – 0.8 (moderately valid); and > 0.8 (highly valid). Furthermore, improvements were made based on the suggestions of the validators.

The next stage was product trials, conducted in stages: individual trials (10 students), small-group trials (30 students), and field trials (60 students). Each trial produced data in the form of student and teacher responses to the product. Qualitative data were obtained in the form of improvement suggestions, while quantitative data were presented as product feasibility percentages, which were analyzed to determine the level of feasibility of the interactive e-module. The range of scale values and levels of achievement of teaching material feasibility can be described as follows: Very Good (scale 5) with an achievement level of 81%–100%; Good (scale 4) with an achievement level of 61%–80%; Fair (scale 3) with an achievement level of 41%–60%; Poor (scale 2) with an achievement level of 21%–40%; and Very Poor (scale 1) with an achievement level of less than 20%. Ethical clearance for this research was obtained from the institutional review board, and informed consent was secured from participating students, teachers, and cultural leaders prior to data collection.

The final stage is Disseminate. At this stage, the chemistry interactive e-module based on the local wisdom of Poto Wua Ta'a was distributed on a limited scale to students at SMAN 1 Waigete to obtain further feedback regarding the effectiveness of the product.

3. FINDINGS AND DISCUSSION

3.1 Findings

3.1.1 Define

The definition (define) stage was carried out to formulate the needs and requirements before developing an interactive chemistry e-module based on the local wisdom of *Poto Wua Ta'a* on the topic of acids and bases. The analysis showed that chemistry learning at SMA N 1 Waigete still relied on conventional methods such as lectures and assignments, using textbooks and worksheets that were mainly theoretical, resulting in students being less motivated, having difficulties in understanding concepts, and perceiving chemistry as a difficult subject. The analysis of grade XI science students indicated varied levels of understanding, namely high (13.88%), medium (27.7%), and low (58.3%). Students also expressed the need for technology-integrated learning, the use of videos, laboratory practices, as well as contextual approaches by integrating chemistry with local wisdom to make the material easier to understand and remember. In addition, interviews with local community members in Sikka Regency regarding the *Poto Wua Ta'a* tradition revealed that this cultural practice contains both symbolic and chemical values, such as the use of betel leaves, areca nut, and lime, each of which has different acid-base properties. This shows a direct connection between local wisdom and the concept of acids and bases, which can be used as real contexts in chemistry learning. Based on curriculum analysis, relevant Basic Competencies (KD) and Learning Outcomes (IPK) were determined as the foundation for media development, while the acid-base material was described in indicators that were then structured into a concept map. From this analysis, the learning objectives were formulated, namely that students would be able to explain the properties of acids and bases according to the theories of Arrhenius, Brønsted-Lowry, and Lewis; calculate the concentration of H^+/OH^- ions and pH values; predict the pH of solutions and explain acid-base reactions through laboratory practice; as well as analyze the effect of pH on solutions through interactive discussions based on the local wisdom of *Poto Wua Ta'a*.

3.1.2 Design

After completing the defining stage, the researchers proceeded to the initial design stage of the product in the form of an Interactive Chemistry E-Module integrated with the local wisdom of "Poto Wua Ta'a" on the topic of Acids and Bases at SMAN 1 Waigete. This product was developed using Microsoft Word 2019 and is structured into three main sections, namely General Information, Core Activities, and Appendices.

The General Information section contains several key components that form the foundation of the e-module. The module identity includes the title, subject, grade or semester, time allocation, and author, which provide an overview of the learning product. Furthermore, the Core Competencies (KI) are formulated to describe the essential abilities students must achieve in the domains of attitudes, knowledge, and skills, while the Basic Competencies (KD) are specified as indicators of achievement for the acids and bases topic in accordance with the Merdeka Curriculum. To clarify the interconnection of concepts, a concept map is provided to illustrate the systematic flow of the material. In addition, the module description presents a brief explanation of the content, objectives, and advantages of the product, particularly the integration of *Poto Wua Ta'a* as a cultural context to make chemistry learning more meaningful.

The Core Activities section is designed to include components that support the implementation of the learning process, such as learning objectives, meaningful understanding, types of assessment, triggering questions, learning activities, and reflections from both students and teachers. The entire sequence of activities is aimed at facilitating students to understand acid–base concepts in an interactive and applicable manner by connecting them with the cultural practice of *Poto Wua Ta'a* that exists within the community.

Meanwhile, the Appendices section consists of teaching materials, student worksheets (LKPD), assessment instruments, enrichment, remedial activities, glossary, and references. These appendices are provided to enrich students' understanding and to reinforce the link between chemistry learning and daily life based on local wisdom. Through this design, it is expected that students will not only master the concepts of acids and bases but also be able to apply their knowledge in real-life situations while appreciating the cultural values embodied in *Poto Wua Ta'a*.

3.1.3 Development

The validation results from material, media, and language experts, as well as practitioners, show that the interactive Chemistry E-Module on Acid-Base material integrated with the local wisdom *Poto Wua Ta'a* has met the criteria of very good feasibility. The material aspects, including content, learning, and language, obtained Aiken's V values ranging from 0.83 to 0.9, indicating a high level of agreement among validators. This finding demonstrates that the content of the E-Module is aligned with the curriculum requirements, comprehensible, and relevant to the learning needs. That good quality material should be evaluated in terms of content accuracy, alignment with learning objectives, and clarity of language(Alim et al., 2025)

Furthermore, the media aspects, including cover design, content layout, images, illustrations, and graphic elements, achieved Aiken's V values above 0.85. This result shows that the visual design of the module supports readability, is aesthetically appealing, and facilitates understanding of abstract concepts. This finding aligns with the multimedia learning theory, which emphasizes that combining text, images, and illustrations enhances comprehension by engaging dual cognitive channels. Practitioner assessments also confirmed this, with an average Aiken's V score of 0.86, indicating that the E-Module is not only theoretically valid but also practically relevant in the classroom context (Mayer, 2024)

The effectiveness of the module was further examined through three stages of trials. In the individual trial involving 10 students, they used the E-Module independently, and the analysis showed a feasibility score of 87% (very good). Some students suggested adding more contextual questions to provide greater variation in exercises. This finding supports the idea that user feedback is essential in the development of interactive learning media(Ukenova & Bekmanova, 2023)

In the small group trial involving 30 students, the feasibility score increased to 89% (very good). Most students reported that the interactive module was easy to use, had an attractive design, and that the *Poto Wua Ta'a* illustrations helped them to better understand the acid-base concepts. The integration of local wisdom into learning was shown to enhance student engagement. This is consistent with recent findings that integrating local wisdom into early-childhood and school curricula revitalizes ethnopedagogical practices and increases students' motivation and conceptual understanding by connecting learning to their daily-life contexts(Sakti et al., 2024)

Stronger results were obtained during the large-scale field trial involving 60 students. At this stage, the feasibility score reached 91% (very good). Students highlighted that the integration of local wisdom not only made learning more enjoyable but also helped them connect acid-base theory with real-life experiences. This finding resonates with the principles of *contextual teaching and learning* (CTL), which emphasize the importance of linking academic concepts with real-world contexts to make learning more meaningful (Semilarski et al., 2021)

Overall, the validation and trial results confirm that the interactive Chemistry E-Module integrated with *Poto Wua Ta'a* meets the quality standards expected in the Merdeka Curriculum while

also providing a contextual, relevant, and engaging learning experience. The integration of local culture into science education has been proven to strengthen conceptual understanding while fostering students' appreciation of their cultural heritage, as recent research shows that small science and early engineering learning in culturally valued, play-based experiences help shape children's cultural identity alongside improving STEM conceptual understanding(Sikder, 2024)

Table 1. Comparative Results of Product Trials

Trial Stage	Number of Students	Mean Score (%)	Feasibility Category
Individual Trial	10	87%	Very Good
Small-Group Trial	30	89%	Very Good
Field Trial	60	91%	Very Good

3.1.4 Dissemination

In this study, the dissemination stage was carried out on a limited scale. The final product, an interactive Chemistry E-Module based on the local wisdom *Poto Wua Ta'a* for Acid-Base material, was distributed only to students at SMAN 1 Waigete as the primary target users. This limited dissemination aimed to provide students with the opportunity to try and utilize the product in the learning process. In addition, feedback was collected from the students regarding the strengths, weaknesses, and potential improvements of the developed E-Module. The feedback served as valuable input for further refinement of the product in subsequent development stages.

3.2 Discussion

The development of an interactive Chemistry E-Module based on the local wisdom of *Poto Wua Ta'a* for the topic of acids and bases has demonstrated promising results in enhancing both the quality and relevance of chemistry learning for students at SMAN 1 Waigete. Initial analysis revealed that conventional instructional methods, which largely rely on lectures, textbooks, and worksheets, often fail to actively engage students, leading to difficulties in conceptual understanding and the perception of chemistry as a difficult subject. These findings are consistent with recent studies indicating that teacher-cantered approaches tend to limit students' motivation and active participation. To address these issues, technology-enhanced constructivist learning and attention to contextual and individual factors are needed to create more meaningful learning resources and experiences(Maican et al., 2024)(Fırat et al., 2021)

The design stage of the E-Module was carried out by aligning with curriculum requirements while integrating local cultural contexts. The module's structure—comprising general information, core activities, and appendices—offers a systematic and student-centered learning experience. The use of concept maps, clearly defined learning objectives, and contextualized activities through local wisdom enables students to connect scientific concepts to their daily lives. This aligns with the principle that new information is more easily understood when linked to learners' prior knowledge, as supported by recent research on meaningful learning in science education(Melgarejo et al., 2024). The integration of *Poto Wua Ta'a*—involving betel leaves, areca nut, and lime—provides a tangible example of acidic and basic properties that enrich conceptual understanding. Local wisdom–based learning not only enriches learning content but also cultivates students' cultural appreciation, ensuring that education remains globally relevant while locally rooted(Sakti et al., 2024).

Validation results showed high feasibility and quality of the module. Material, media, and language experts rated the module with Aiken's V coefficients ranging between 0.83–0.9 for content and above 0.85 for media aspects. This indicates that the module met the standards of accuracy, relevance, and clarity. Practitioner evaluations, with an average score of 0.86, further confirmed that the module was not only theoretically sound but also practically relevant in classroom settings,

supporting recent findings that practicality is a critical factor in instructional product development(Garay Abad & Hattie, 2025)

Trial results reinforced the module's effectiveness. In the individual trial, the module received an 87% feasibility rating (very good), although students suggested the addition of more contextualized questions. This highlights the importance of user feedback in instructional product development . In the small-group trial with 30 students, feasibility increased to 89% (very good), with positive feedback on ease of use, appealing design, and the *Poto Wua Ta'a* illustrations that facilitated understanding. In the large-scale trial involving 60 students, feasibility reached 91% (very good), with students noting that the integration of local wisdom not only made learning more engaging but also helped them connect acid–base theory with real-life applications. These findings resonate with recent studies emphasizing that local wisdom–based learning can enhance motivation, conceptual understanding, and student engagement(Sakti et al., 2024)

The limited dissemination stage also yielded valuable insights. The final product was distributed only to students at SMAN 1 Waigete, and their feedback confirmed the strengths of the module while also identifying areas for improvement, such as including a greater variety of contextualized exercises. This is consistent with recent studies indicating that continuous evaluation is essential to maintain the relevance and sustainability of instructional products. Furthermore, the module's emphasis on contextual and interactive learning aligns with the principles of the *Merdeka Curriculum*, which promotes independence, meaningfulness, and student-centeredness (Amiruddin et al., 2023).

However, this study also acknowledges potential biases and threats to validity. Since the dissemination and trials were conducted only in a single school context, the generalizability of findings is limited. In addition, the possibility of a Hawthorne effect—where students may perform differently simply because they are aware of being observed in a study—cannot be fully ruled out. Moreover, while the overall results showed high feasibility, there were also contradictory or unexpected findings, such as a small number of students reporting difficulties in adapting to digital interactive media or expressing the need for additional contextual questions beyond those provided. These aspects highlight the need for more critical reflection and further studies to ensure the robustness and sustainability of the developed e-module.

From a practical standpoint, this research contributes significantly to overcoming the limited laboratory facilities that often constrain chemistry learning in schools. By incorporating *Poto Wua Ta'a* as a cultural medium, students were able to explore acid–base concepts in a contextual manner even without access to fully equipped laboratories. This strategy not only improved the accessibility of learning but also ensured that education remained relevant to students' sociocultural environments. Similar approaches have been proven effective in other contexts, where local culture was used as a bridge to scientific understanding(Wahyu et al., 2025)(Atmojo et al., 2025).

Nevertheless, this study has limitations, as dissemination was restricted to a single school, which limits the generalizability of findings. Further research should involve broader implementation across multiple schools and regions to test the adaptability of the module in diverse contexts. Longitudinal studies are also needed to evaluate the long-term effects of local wisdom–based learning on students' academic achievement, critical thinking skills, and cultural identity. Moreover, future development could focus on integrating the module into digital platforms or learning management systems to increase accessibility, particularly in blended and online learning contexts(Elmabaredy & Gencel, 2024).

Overall, this study underscores that integrating local wisdom into interactive learning media is a powerful pedagogical strategy. Such an approach not only enhances student engagement, supports meaningful learning, and fosters cultural appreciation, but also aligns with the demands of modern curricula. As recent research shows, culture-based education serves as a bridge between scientific knowledge and traditional values, creating a holistic learning experience that shapes students not only into competent learners but also into individuals grounded in their cultural identity(Suprapto et al., 2024).

4. CONCLUSION

This study clearly answers the research questions by demonstrating that the Interactive Chemistry E-Module based on Poto Wua Ta'a local wisdom for the topic of acids and bases is valid, practical, and effective. Expert validation obtained an average Aiken's V score of 0.89 (very valid). Individual trials with 10 students yielded a practicality score of 87% (practical), small-group trials with 30 students increased to 89% (very practical), and large-scale field trials with 60 students further improved to 91% (very practical). These results confirm that the developed interactive module meets the criteria of a feasible and high-quality learning medium.

The implications highlight that integrating local wisdom into science education not only enhances students' conceptual understanding but also strengthens their learning motivation and cultural appreciation. The main contribution of this study is advancing contextual learning practices by bridging scientific knowledge with cultural values, while simultaneously supporting the Merdeka Curriculum and SDG 4 on quality education.

For future directions, further research should focus on implementing the module across different schools and regions, conducting longitudinal studies to examine its long-term impact on students' scientific literacy, critical thinking, and cultural identity, as well as integrating the module into digital platforms or learning management systems to increase accessibility and ensure sustainability, especially in hybrid and online learning contexts.

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