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Content Validity of Three-Tier Multiple Choice Virtual Reality-Based Assessment with Embedded Ethno-SSI Concepts on Acid-Base Topics

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Abstract

Research on acid-base misconceptions at the high school level is extensive, but studies at the university level remain limited. Due to the prevalence of these misconceptions, developing accurate instruments for early detection is crucial. This study developed a three-tier multiple-choice virtual reality-based assessment integrating the ETHNO-SSI concept for acid-base topics. The study employed the Borg and Gall R&D model to evaluate content validity. The study used a developmental design, with face validation by six expert reviewers using a rubric to evaluate content validity, construct relevance, clarity and contextual integration. Processing of the data involved the use of Aiken's V index. The results also evidenced a high content validity for all the dimensions studied (V > 0.80), indicating that the instrument is pedagogically sound and culturally relevant. By embedding Ethno-SSI in immersive VR platforms, this assessment approaches represents a new path in the pursuit of students' conceptual challenges when dealing with sociocultural decision making in real-world conditions. This study provides valuable information to the development of multidimensional chemical assessment instruments to link sociocultural innovation, recover notions of acid-base misconceptions, and incorporate cultural relevance in chemistry education.

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INTRODUCTION

The difficulty of learning chemistry as a course stems from the very nature of the abstractness of the science and the various levels of representation involved. These challenges arise from its foundation in the study of the composition, structure, properties, and transformation of matter. According to Hendry, (2016) Kean & Middlecamp (1985), suggest that such attributes include its abstract nature, hierarchically-organized yet ever-changing content, and its wide-ranging and interconnected subject matter. Gulacar et al (2020) and Johnstone et al (1977) suggested that understanding chemistry needs to develop at the three levels: macroscopic, submicroscopic, and symbolic. Chemical ideas are thus problematic due to the fact that students are required to connect macroscopic experiences (what they can see) with submicroscopic processes (what they can't see) and symbolic representations (Barke et al., 2009; Keiner & Graulich, 2021).

Of these topics, acid-base chemistry is the most challenging for students because of its abstract character and the problem of bridging the macroscopic evidence with the molecular scale and the symbolism (Barke et al., 2009; Gkitzia et al., 2020). The situation is even more complicated by the availability of several often-contradictory theories of acid-base behavior, like Arrhenius, Brønsted, Lowry, and Lewis. Such different models can confuse learners' minds as they try to associate several models in different contexts (Barke et al., 2009; Santos & Arroio, 2016). These

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misconceptions have a detrimental effect on future learning of chemistry because they introduce misinformation that is a barrier to acquiring scientifically accepted ideas and interferes with learning (Yamtinah et al., 2023). This misconception occurs not only at the school level but also at the university level.

Many studies have addressed acid–base misconceptions at the high school level, but research at the tertiary level remains limited. Nonetheless, these misconceptions persist in university students. For example, many students mistakenly believe that pH measures acidity while pOH measures basicity, or that strong acids only partially ionize (Kala et al., 2013; Nahadi et al., 2023; Siswaningsih & Chandratika, 2020). Misunderstandings about neutralization reactions and the use of indicators are also common, as students struggle to connect theory with practice (Hadinugrahaningsih et al., 2021; Shaafi et al., 2025). This may be due to the assumption that university students have already mastered these basic concepts, leading researchers to focus on more advanced topics (Osman et al., 2016). Such misconceptions often arise from rote memorization divorced from a scientific context (Romine et al., 2016). They continue in higher-level courses like biochemistry and organic chemistry, where students confuse ionization with hydrolysis or misunderstand the Lewis acid–base model essential for learning reaction mechanisms (Dood et al., 2018). These issues do not vanish at the college threshold; instead, students often carry them forward, limiting their ability to grasp more complex concepts in higher education (Jiménez-Liso et al., 2020; Shaafi et al., 2025).

Given the prevalence of acid–base misconceptions, accurate instruments are needed for early detection. Confidence-based assessments, such as Three-Tier Multiple Choice tests, offer deeper insights into students' understanding (Mubarak & Yahdi, 2020). Many researchers have adopted the Three-Tier Multiple Choice format, incorporating the third tier Certainty of Response Index (CRI) to detect misconceptions (Hakimah et al., 2021; Mubarak & Yahdi, 2020; Ristanto et al., 2023). Still, there are some unresolved issues concerning CRI's reliability and validity in different contexts and disciplines. The reliability of CRI-based tests is problematic; these tests do not consistently differentiate lack of knowledge from misconceptions (Arslan et al., 2012; Diani et al., 2019). The accuracy of CRI disproportionally depends on how well an individual interprets his or her self-claimed levels of certainty (Chen et al., 2023). Students' overestimation or underestimation leads to inaccurate identification of non-diagnosed Confident Misconceived Forms due to failure to fully grasp the expression of confidence. To summarize, CRI accuracy heavily relies on students' ability to self-evaluate their confidence regarding their chosen answers. If learners find it hard to reflect on or rate their confidence, then CRI outcomes may be less useful in separating misconceptions from a lack of information (Wu et al., 2021).

In this research, a different version of the three-tier multiple-choice question is made, where Tier 3 measures the confidence level but also asks for reasoning behind Tier 2. This progress can be reconciled with Johnstone's framework, in which he considers macroscopic representation, submicroscopic (which may be verbal or visual), and symbolic forms equally important in depicting a scientific phenomenon (Banawi et al., 2022). Considering the previously mentioned misconceptions related to acid-base concepts, there need for an approach where the three-tier multiple choice test can both pinpoint misunderstandings and offer context that prompts students toward deeper exploration of the concepts. The incorporation of Ethno-SSI (Ethno Scientific Socio Issues) strives to link these scientific concepts with learners' culture and surroundings, thus broadening its impacts and relevancy (Febu et al., 2017; Rahayu, 2019). Students become more engaged and interested when they study chemistry through a cultural lens because they feel an attachment to the material on some personal level (Sumarni et al., 2023). The ethnoscience issue raised is centered on the tradition of batik making from Kampung Batik Laweyan. Furthermore, this instrument examines the socioscientific aspects of batik production with a focus on its environmental consequences regarding dye pollutants to the Bengawan Solo River. This innovative strategy not only promotes early identification of misconceptions but also a better understanding of core chemistry concepts alongside active learning through related cultural and environmental phenomena(Paristiowati et al., 2019; Rodriguez et al., 2020).

The implementation of paper-based testing formats for the Three-Tier Multiple Choice tests is documented in Cetin-Dindar & Geban (2011), and more recent adaptations using Google Classroom and Google Forms can be found in Hakimah et al. (2021) and Julaeha et al. (2020). The application of Virtual Reality in assessment practices is virtually unexplored. Assessment conducted through VR is more valid because it simulates testing situations better than traditional methods (Krajčovič et al., 2021; Sudarmin et al., 2023; Vlah et al., 2021). Social situation simulations are useful for psychological and behavioral assessments. These evaluations can be done from controlled settings, which provides a more comprehensive evaluation than conventional methods (Finken & Wölfel, 2023). Implementing virtual reality (VR) technology in teaching chemistry aligns with the constructivist theories of learning (Duca et al., 2024; Jiang et al., 2024; Kounlaxay et al., 2022;Liu et al., 2017), as students develop knowledge through activities that require their physical presence. Moreover, VR has been shown to make education more appealing and capture attention at other levels (Rashid et al., 2021;Makransky & Lilleholt, 2018). Understanding abstract concepts is made easier when learners are able to visualize the molecular structures and chemical processes in three dimensions. This aligns with systematic reviews Guruloo & Osman (2023), which revealed the prevalence of VR tools such as Unity 3D for educational content development pertaining to chemistry. The overview in Figure 1 shows a major omission related to assessment in the field of chemistry education VR.

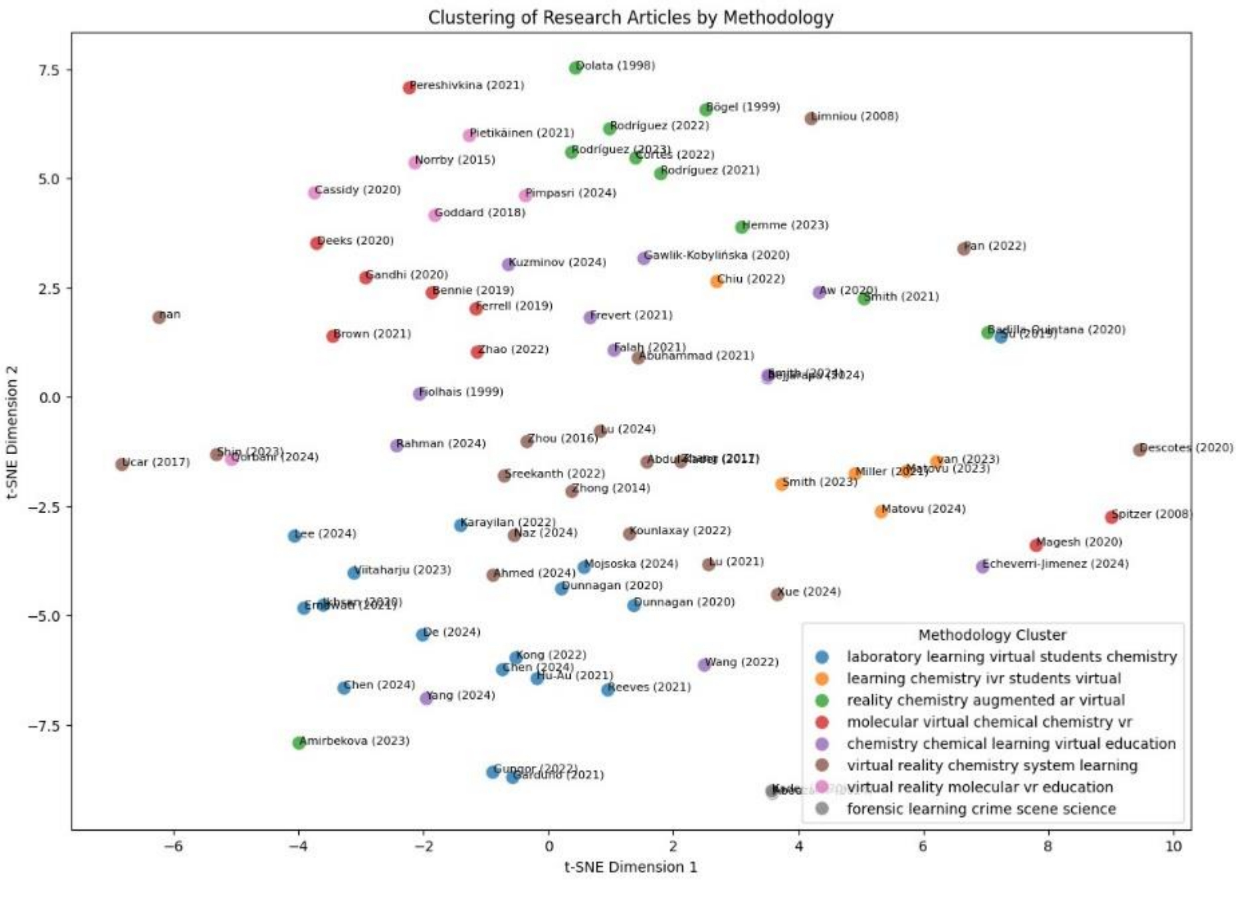


Figure 1. Trends in Virtual Reality Research

While researchers have focused extensively on the benefits of VR technology for learning and student engagement, little attention has been paid to the use of VR in assessment programs. For example, (Di Natale et al., 2020) studied learning with VR but did not consider how it could be harnessed to assess understanding in chemistry. Undoubtedly, VR can strengthen a learner's grasp of challenging concepts within the discipline of chemistry through three-dimensional imaging. Unfortunately, its role as an evaluative tool has not been given sufficient attention. Hence, this research constructs a framework for the early detection of misconceptions using ETNO-SSI elements within acid-base chemistry delineated by a three-tier multiple-choice VR-based test. This study is framed under two guiding inquiries: What is the content validity concerning three-tier levels of a multiple-choice instrument infused with ethnosocio-scientific issues?. What is the content validity concerning the storyboard for Virtual Reality (VR)?. These all closely relate to how effectively and suitably the tools designed for measuring students' learning outcomes in acid-base chemistry are anchored into sharp concepts. The first question considers whether or not the three-tier multiple-choice items capture respondents' understanding of critical concepts, misconceptions, and Ethno-SSI-relevant cultural dimensions. Verification of VR storyboard validity, as covered by its learning objectives, clarity of visuals, and fidelity to chemistry concepts, focuses on validation in the second question. In pursuing these research questions, this study intends to construct reliable assessments that blend traditional with contemporary methods in teaching chemistry.

METHOD

Research Design

This study employed a research and development (R&D) method using the Borg and Gall development model (Borg & Gall, 1983). However, this study is limited to focusing on the review and refinement of the educational product (the VR storyboard and three-tier multiple-choice items) based on expert feedback. Field trials, as part of the full R&D process, are not conducted in this article, as it represents preliminary research. Figure 2 presents a flow diagram of the process of developing a Three-Tier Multiple Choice Virtual Reality Based Assessment that integrates the Ethno-SSI concept.

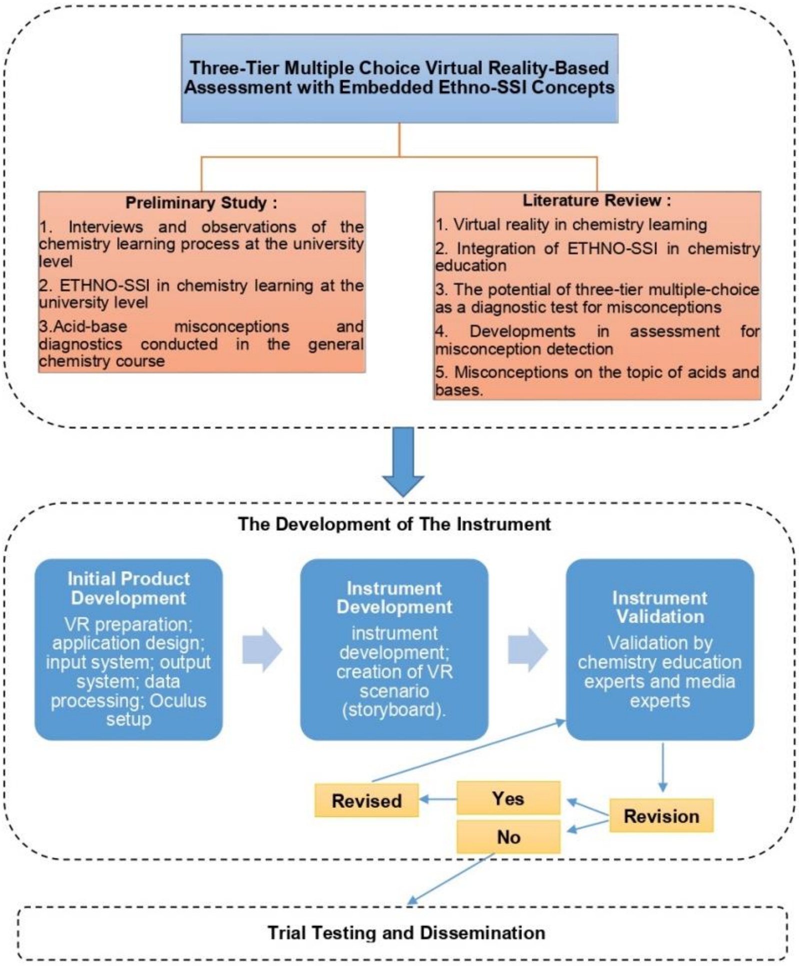


Figure 2. Flowchart of the Development Process for the Three-Tier Multiple Choice Virtual Reality-Based Assessment with Embedded Ethno-SSI Concepts

This study focuses on detecting misconceptions at the undergraduate level. However, literature concerning misconceptions among school students remains relevant, as many university students exhibit similar misunderstandings due to rote memorization of rules disconnected from their scientific context (Romine et al., 2016). In Misconceptions in Chemistry, Barke et al (2009) revealed that many students experience misconceptions regarding pH values, Brønsted-Lowry theory, and the concept of neutralization in acid-base chemistry. Based on these acid-base misconceptions, this study develops several indicators to identify students' misunderstandings, as presented in Table 1.

Table 1. Indicators of Acid-Base Misconceptions

Subtopic	Misconception
Acid-Base Theory	Any compound containing H^+ is an acid, and any compound containing OH^- is a base. Molecules containing hydrogen are always acidic (based on the Arrhenius definition).
Neutralization	All ions in a solution participate in the neutralization reaction. Salt is formed as a solid or crystal from neutralization reactions. Neutralization always results in a neutral pH (pH 7), even for weak acids and bases. Neutralization only occurs when acids and bases have equal concentrations.
pH	At pH = 0, compounds are neither acidic nor basic. Highly concentrated acids have high pH values, while dilute acids have low pH values. Soil cannot be acidic because plants are able to grow in soil.

Sample and Data Collection

The data in this study were obtained from validation results involving seven validators, consisting of content experts (chemistry education specialists) and media experts, during a Focus Group Discussion (FGD). The content experts evaluated the accuracy of the concepts and the relevance of the content, while the media experts assessed the visual, technical, and presentation aspects of the media. The aim was to ensure that the instrument met appropriate academic and media quality standards before its broader use.

Analysis of Data

Validators from the content and media areas validated the instrument test. Using Aiken's formula, 7 validators assessed 15 questions on content, language, and presentation, yielding a mean score out of Z0.76 threshold for validity per item, which subsequently pass V=0.76 threshold under evaluation by the remaining validators, contingent scoring yielded positive outcome for the rest authored value schemes counters. Equally rigorous validation was performed where VR storyboards were cross-checked against set indicators evaluated broadcast scoring scheme employing the same criteria as Aiken's formula, including 1-4 rating leading known metric schemas confirming bounds described previously(Aiken, 1985).

Aiken's formula (Aiken, 1985), applied to calculate the content validity index, is as follows:

$$V = \sum S / [n(C-1)]$$
$$S = R - Lo$$

Description:
V = Aiken index
S = the score given by the rater minus the lowest score in the category
R = score given by the rater
Lo = lowest assessment score (1)
C = highest assessment score (4)
n = number of validators (raters).

Both media and content specialists validated the three-tier, 15-item multiple-choice assessment. Aspects such as content, language, and the overall presentation were analyzed for each item. Validation of the VR storyboard was also done from content and media perspectives. The media evaluation emphasized image aesthetics, typeface clarity, text-background balance, ratio of text to visuals, design synergy, coherence with ethnoscience-SSI themes, and inter-image harmony beyond surface-level artistry. For the storyboards relevant to ethnoscience SSI themes, under consideration for these criteria had justification alongside material relevance and organization, including apportionment of essential images and videos along with clarity in expression for structured presentation grade.

The analyses were based on transcriptions from focus group discussions. All comments received from participants and experts within panels were analyzed in a round robin style exchange across the defined structured steps per discipline that occurred post discussion among designated leaders per theme stream on devising instructional blocks corresponding to levels context, meaning, metadatateric structuring interconnections towards building holistic cohesive seamless integrated multi-layered narratives through convergence arcs balance driven circuits responsive spike activations adaptive intelligence ripple flow coherence arrangements centered upon emergence process feedback dynamics system spiral wholonomically. The data above were processed first by clustering them into notions that reflect topics central for axes or precis based on stubs defined under instrument development attributes. Following the analysis, revisions resulted from expert consultations so as to improve the content and structure of the instrument. Consequently, completing the final version of the instrument was possible after integrating all changes proposed during the FGD.

RESULTS AND DISCUSSION

Three-Tier Multiple Choice with Embedded Ethno-SSI Concept on Acid-Base Material

The content validity values for the question items evaluated by 7 experts using Aiken's formula are presented in Table 2. This validation step took place in a focus group discussion (FGD) wherein specialists were asked to critique item relevance and accuracy aligned with predefined goals

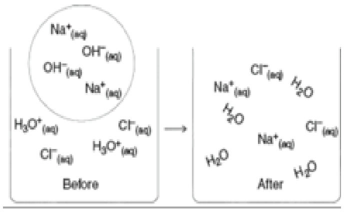
Table 2. Results of Aiken Index Analysis of Three-Tier Multiple Choice with Embedded Ethno-SSI Concept on Acid-Base Material

Question	Value V	V Table	Conclusion
1	0.95	0.76	Valid
2	0.97	0.76	Valid
3	0.92	0.76	Valid
4	0.95	0.76	Valid
5	0.95	0.76	Valid
6	0.92	0.76	Valid
7	0.97	0.76	Valid
8	0.97	0.76	Valid
9	0.95	0.76	Valid
10	0.98	0.76	Valid
11	0.97	0.76	Valid
12	0.98	0.76	Valid
13	0.98	0.76	Valid
14	1.00	0.76	Valid
15	0.97	0.76	Valid

The development of a diagnostic instrument sought to target misconceptions related to acid-base concepts through a three-tier multiple-choice format (3-TMC) integrated with Ethno-SSI (Ethno-Scientific and Socio-Cultural Integration), aiming at enhancing science education in a comprehensive manner that considers cultural context. The content validity analysis conducted using Aiken's Index (Aiken, 1985) showed strong reliability across participants with all question items (Q1-Q15) scoring between 0.92 and 1.00, which exceeds Aiken's recommended minimum of 0.76 benchmark, suggesting these items are credible alongside relevant, precise, and accurately structured towards diagnosing misconceptions precisely within acid-base chemistry. This indicates that the items are verified as relevant, accuracy flawless, and well fit towards the goals of diagnosing misconceptions within the study concerning acid-base chemistry. The expert validation, which was carried out in a focus group discussion FGD showed affirmation around item accuracy, both on the central context fulfillment (conceptual accuracy) as well as local cultural integration appropriateness about the acid-base content. An illustration of a tier multiple choice 3-TMC item alongside Ethno-SSI is presented in Figure 3. This argument portrays local cultures used as frameworks for identifying learners' misconceptions while retaining core concept fidelity.

Narrative on Batik Wastewater Treatment:

In the Bengawan Solo River, batik wastewater containing various chemical compounds can pollute the river water. One method to reduce this pollution is by neutralizing acidic or basic waste used in the batik dyeing process. During this neutralization process, acids and bases present in the wastewater react with each other, so that the discharged waste is no longer strongly acidic or basic.



Tier 1:

In the process of neutralizing batik wastewater, NaOH is used to neutralize an acidic solution containing HCl. When NaOH is added to the HCl solution, what happens to the ions in the solution?

a. All ions in the solution react to form new compounds.
b. H^+ ions from HCl and OH^- ions from NaOH react to form NaCl (salt) and water.
c. Na^+ ions from NaOH and Cl^- ions from HCl react to form solid NaCl at the bottom of the solution.
d. H^+ ions from the acidic solution containing HCl react with OH^- ions from NaOH to form water (H_2O), while Na^+ and Cl^- ions remain in solution.
e. H_3O^+ ions from the acidic solution containing HCl react with OH^- ions from NaOH to form water ($2H_2O$), while Na^+ and Cl^- ions remain in solution.

Tier 2:

What is your reason for choosing the answer in Tier 1?

a. All ions in the solution react because, in chemical reactions, ions typically react with each other to produce new products.
b. H^+ and OH^- ions form NaCl and water because acid-base neutralization produces salt and water.
c. Na^+ ions from NaOH react with Cl^- ions from HCl to form solid NaCl, which is a typical property of salts formed through neutralization.
d. H^+ ions from HCl react with OH^- ions from NaOH to form water (H_2O), because acid-base neutralization produces water.
e. H_3O^+ ions from HCl react with OH^- ions from NaOH to form water ($2H_2O$), while Na^+ and Cl^- ions remain in the solution as spectator ions.

Tier 3:

Why did you choose that answer in Tier 2?

a. Na^+ and Cl^- ions are spectator ions that do not undergo chemical changes and only serve to maintain charge balance in the solution.
b. All ions in the solution will react with each other to form new compounds, according to the principles of chemical reactions.
c. The result of a neutralization reaction between an acid and a base always forms a salt in solid form.
d. The reaction between H^+ ions from HCl and OH^- ions from NaOH forms water, while the other ions do not participate.
e. H^+ ions in the acidic solution are converted into Na^+ ions after reacting with the base solution containing NaOH.

Figure 3. One Example of a Developed Three-Tier Multiple Choice (3-TMC) Item with Embedded Ethno-SSI Concepts on Acid-Base Topics

A notable aspect of this diagnostic tool is the application of Ethno-SSI principles (See Table 4) that connect scientific concepts to students' socio-cultural environments. In this case, the batik industry's wastewater treatment techniques and the Kampung Batik Laweyan Surakarta region are used to demonstrate the relevance of acidity and basicity in chemistry. This local context shifts the understanding of science from an abstract discipline to one more relatable to daily life, enabling students to grasp fundamental chemical principles more profoundly. Studies indicate that using local culture and environment in science teaching enhances student interest and understanding (Rahayu, 2019; Zidny & Sjöström, 2021). Moreover, by embedding these cultural elements into the diagnostic tool, the study demonstrates awareness of culturally responsive teaching approaches that have been associated with heightened motivation and improved understanding of concepts among students. (Widarti et al., 2025)

Though the validators ensured that the items had high validity, they notified us of concerns regarding the clarity and uniformity of terms used. One of the key issues noted by validators concerns discrepancies in the usage of the term "ion." Some items equated "ion" to mean acid-base species, while others were more vague. It was brought up that the definition of polarity as well as the terms 'H^+ ions' versus 'protons', together with 'OH'- ions' versus 'hydroxide', needed to be addressed equally throughout the instrument, which would help achieve a uniform criterion throughout all questions without loss of precision. Such recommendations are advocated for in chemistry education, where precision in advocating for anti-education confusion is vital (Reina et al., 2022). The focus on mastery and precision advocacy fosters students' capability to accurately grasp concepts, communicate effectively, think critically, and reinforce their understanding of subjects ranging beyond its motto logic (Azamat et al., 2024). Using terminology precisely mitigates risks linked to vague phrasing or poor terminology, which leads to inaccurate chemical concept comprehension (Azamat et al., 2024).

Another Validator suggestion focused on the chemical equations' clarity in both readability and presentation, as some were considered overly intricate or poorly formatted. This concern means students would struggle to interpret the reactions precisely. The validators recommended that the chemical equations be notated properly to simplify them so that students can understand more easily the processes being evaluated. These validations emphasize the universal principle of communication and clarity, particularly in chemistry teaching, where notions are incomprehensible, like reactions (Hammer & Avram, 2024). Well-organized chemical equations alongside sound explanations help learners deal with abstract chemical concepts and counter frequent chemistry misconceptions effectively. (Herunata et al., 2024; Hoai et al., 2024)

Virtual Reality Storyboard with Embedded Ethno-SSI Concept on Acid-Base Material

Table 3 includes data from seven experts using Aiken's method to assess content validity for the VR storyboard, which is further highlighted in this table. This validation was conducted during the focus group discussion (FGD), where the experts reviewed both the media and content aspects of the storyboard to ensure its effectiveness in conveying the intended message and aligning with the learning objectives.

Table 3. Results of Aiken Index Analysis of VR Storyboard

No	Indicator	Value V	V Table	Conclusion
	Media Aspect			
1	The images in the storyboard are engaging and easy to understand	0.90	0.76	Valid
2	The sentences used are clear and comprehensible	0.95	0.76	Valid
3	The text size in each section of the storyboard is appropriately proportioned	0.81	0.76	Valid
4	The images are well-balanced and arranged optimally	0.86	0.76	Valid
5	The images and videos used in the storyboard align with the theme	1.00	0.76	Valid
6	The images used in the storyboard are interesting	0.95	0.76	Valid
7	The typeface is legible and enhances readability	0.86	0.76	Valid
8	The combination of text and background is visually appealing and well-balanced	0.90	0.76	Valid
9	The color gradient in the storyboard is well-applied and visually suitable	0.86	0.76	Valid
10	The images and videos effectively reinforce the ETHNO-SSI concept	1.00	0.76	Valid
	Material Aspect			
11	The material aligns with misconception indicators	1.00	0.76	Valid
12	The content is organized in a structured and coherent manner	0.90	0.76	Valid
13	The material is presented in a way that is easy to understand	0.95	0.76	Valid
14	The subject matter presented as a question narrative is in accordance with the ETHNO-SSl concept	1.00	0.76	Valid
15	The images and videos effectively visualize key material concepts	0.81	0.76	Valid
16	The misconception-related questions are presented in a structured and systematic manner.	0.90	0.76	Valid

The media aspects of the VR storyboard, including the images, text, and layout, received high validation scores, indicating that these elements are visually engaging and accessible for students. Notable strengths included the alignment of images and videos with the theme (1.00), the clarity of the text (0.95), and the balance between text and background (0.90). These attributes contribute to making the content visually appealing, clear, and easy to understand, which is crucial in engaging students and supporting their comprehension of complex scientific concepts, particularly those involving acid-base reactions in the context of Ethnochemistry (Zidny & Eilks, 2022; Zidny & Sjöström, 2021). Figure 4 presents the virtual reality storyboard that incorporates these validated media elements, illustrating how the visual and textual components are integrated to support student engagement and understanding of acid-base concepts within an ethnochemical and socio-scientific issue context.

Figure 4. Virtual Reality Story Board

Despite these strengths, the expert feedback suggested some areas for refinement, particularly regarding color degradation (0.86) used in the storyboard. While the overall color scheme was deemed appropriate, it was noted that the contrast between colors could be further optimized to improve clarity and visual appeal. The importance of appropriate color contrast cannot be overstated in educational media because it aids students in identifying and distinguishing the critical elements of the content (Zamudio et al., 2024). Having a sharper contrast as a visual cue where important concepts are highlighted can improve not just the text appraisal but also enhance imagery so that no significant visual information is missed by students. This would improve the storyboard's accessibility for students with color vision deficiencies, making engagement with content available without challenges (Elford et al., 2022).

Another issue raised by raters was image-text proportion balance within the storyboard, which scored at 0.86. Although there was an acceptable general image-text balance, some areas required refinement towards achieving better equilibrium where neither element dominates. Appropriateness of text size relative to storyboard layout affects readability, especially for lengthy explanations or descriptions, thereby underscoring design usability concerns like cognitive load that obstruct learning (Elford et al., 2022).

High validity scores were achieved for the alignment of the content area's learning goals, addressing learners' misconceptions, and the holistic structural quality of the VR storyboard. For instance, alignment with the indicator relating to material clarity (1.00), content presentation (0.95), and systematic order of misconception-question presentation (0.90) all support that the content structure in acid-base chemistry is tailored to accurately assess and remediate basic misconceptions inscribed within common problem-solving strategies. As a prompt for further considerations, Ethno-SSI reinforcement was appreciated at the level of 1.00 because it goes beyond superficial consideration by embedding local students' cultures along with socio-scientific issues into their learning processes, which captures their attention more readily (Rahayu, 2019; Sudarmin et al., 2023; Zidny & Sjöström, 2021). The ethno-SSI topics used in this study are presented in Table 4.

Table 4. Ethno-SSI Topics

Aspect	Ethno-science	Socioscientific Issue (SSI)	ETNO-SSI
Definition	Connecting local wisdom or culture with scientific concepts (Febu et al., 2016; Kurniawan & Basuki, 2024; Muyassaroh et al., 2016).	Science-based issues that are difficult to define, involving moral and ethical choices (Johnson et al., 2022; Sparks et al., 2022; Viehmann et al., 2024).	Integrating local culture with scientific and social issues to support learning (Febu et al., 2016; Kurniawan & Basuki, 2024; Nisa' et al., 2024).
Educational Goals	Helping students understand science by incorporating local culture (Febu et al., 2016; Kurniawan & Basuki, 2024).	Developing critical thinking, interdisciplinary learning, and scientific literacy (Chen et al., 2022; Johnson et al., 2022; Viehmann et al., 2024).	Making learning more engaging by connecting science to cultural and social contexts (Febu et al., 2016; Kurniawan & Basuki, 2024; Nisa' et al., 2024).
Topic	This study focuses on batik, particularly the dyeing process as part of ethno-science. The focus is on traditional and modern dyeing techniques. The relationship with acid-base concepts lies in the role of solutions in the dyeing process, for instance: natural dyes require alkaline solutions (lime water) for extraction, while synthetic dyes often need acidic solutions to adjust pH.	This study addresses batik waste as a socioscientific issue, focusing on the neutralization process of batik waste. The liquid waste from the dyeing process often has extreme acidic or basic properties, requiring neutralization using acid or base solutions to reduce environmental pollution impacts.	This study integrates local culture in batik dyeing processes, linking it to the batik waste dilemma. The relationship with acid-base concepts includes: acid-base theory, neutralization of batik waste to normalize pH, and pH measurement to ensure waste safety before disposal into the environment.

The validators also suggested that the storyboard include more detailed, dynamic visualizations that represent the submicroscopic behavior of ions and molecules. Incorporating interactive or animated elements that allow students to observe these processes in real-time would provide them with a more accurate and intuitive understanding of the chemical reactions. Research has shown that dynamic visualizations, such as molecular animations, can significantly improve students' understanding of abstract concepts in chemistry (Coduto et al., 2024; Stieff, 2019). These enhancements would not only improve the clarity of the material but also deepen students' conceptual understanding by allowing them to visualize the atomic and molecular-level processes behind the reactions (Maksimenko et al., 2021). Figure 5 displays the initial interface of the developed virtual reality (VR) application, providing a visual overview of the user experience at the entry point of the simulation.

Figure 5. The Initial Interface of the Developed Virtual Reality (VR) Application

The use of Virtual Reality (VR) can enhance students' motivation, but may result in cognitive overload when they engage in complex science tasks. This research incorporates a three-tier diagnostic structure into the VR environment to increasingly scaffold students' thinking (Rashid et al., 2021;Makransky & Lilleholt, 2018). Moreover, another finding demonstrated that VR could stimulate students' understanding of chemistry concepts. Our approach includes ethno-socioscientific contexts to enhance not only conceptual knowledge but also cultural meaning (Duca et al., 2024; Jiang et al., 2024; Kounlaxay et al., 2022;Liu et al., 2017). Thus, our research makes an input to the field by combining cognitive diagnosis, immersive technology, and cultural contextualization in a single assessment model.

The newly developed tool has multiple merits in improving chemistry education. As a three-tier assessment instrument, it provides insight into students' comprehension of issues far more complex than mere confidence, to the level of their actions in real time within a virtual reality (VR) setting, and their actual behavior via feedback. Moreover, in ethnoscientific socio-scientific issues (ethno-SSI), it uses interwoven context-based problem solving to foster culturally responsive pedagogy, which is aimed at learners' identity by respecting them and aiming at understanding their culture while assessing learning. Also, VR enables the visualization and manipulation of chemical phenomena that are often abstract and challenging on a submicroscopic scale. Perhaps the most notable disadvantage is that developing such advanced instruments entails high costs, limiting adoption associated with widespread use. Regardless of this limitation, the advocacy for innovative assessment approaches in chemistry teaching remains remarkable within the prism of this research work, where the intention was to design models aimed at integrating technology within rich contextual frameworks alongside profound diagnostics blended with tech context-tailored precision aimed at sharpening learners' performance.

LIMITATIONS

Construction of the assessment instrument was limited to acid-base content, and testing was limited to this specific topic in chemistry, which made generalization to other parts of the subject or other learning settings difficult. Second, content validity analysis was only conducted on expert answers via the Aiken formula, which, while useful, does not consider potential biases or varying views of various experts.

CONCLUSION

Content validity of the three-tier multiple-choice instrument and the Virtual Reality (VR) storyboard, both infused with Ethno-Socio-Scientific Issues (Ethno-SSI) for acid-base chemistry, was determined in this research. The results of the validation of the three-tier multiple-choice instrument were very content valid, as each item ranked between Aiken's validity of 0.92 and 1.00, which is higher than the critical cut score of 0.76. This means that the instrument's content is valid, reliable, and consistent with the intended educational objectives, able to effectively merge both scientific principles and local cultural environments in assessing students' knowledge of acid-base reactions. Similarly, the content validity of the VR storyboard was also tested, and validation results showed scores ranging from 0.81 to 1.00, also more than the acceptable value. Media components such as images, text, and structure, and material components such as alignment of content with misconception indicators and inclusion of the Ethno-SSI approach were all found appropriate and valid. This implies that the content of the storyboard is well-organized and properly communicates the messages to be conveyed in a way that incorporates cultural appropriateness, making it an effective tool for enriching students' comprehension of concepts.

We encourage future researchers and practitioners in chemistry education to conduct further studies on incorporating Ethno-SSI into assessment tools and teaching to enable deeper immersion into scientific concepts through local culture. Practitioners must also consider the role of technology, particularly virtual reality, as an interactive media to portray complex scientific concepts such as acid-base reactions in a more interactive and engaging manner. With VR, learners may be offered an unparalleled, experiential learning experience that integrates theoretical concepts with real cultural practice. This can also be piloted in different education settings to see if it is effective in reducing misconceptions and promoting more inclusive and culturally responsive science education.

AUTHOR CONTRIBUTIONS

H contributed to data collection, analysis, and manuscript writing. Y gave the conceptual framework, design, and general supervision of the study. S helped in reviewing, editing the manuscript, and supervising in addition.

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REFERENCES

Aiken, L. R. (1985). Three coefficients for analyzing the reliability and validity of ratings. *Educational and Psychological Measurement*, *45*(1), 131–142. https://doi.org/10.1177/0013164485451012

Arslan, H. O., Cigdemoglu, C., & Moseley, C. (2012). A three-tier diagnostic test to assess pre-service teachers' misconceptions about global warming, greenhouse effect, ozone layer depletion, and acid rain. *International Journal of Science Education*, *34*(11), 1667–1686. https://doi.org/10.1080/09500693.2012.680618

Azamat, J., Khodadust, M. R., & Bahrami Maddah, A. M. (2024). The role of technical english proficiency in chemistry education. *Chemical Review and Letters*, *7*(8), 731–741.

Banawi, A., Sopandi, W., Kadarohman, A., & Solehuddin, M. (2022). Five-tier multiple-choice diagnostic test development: Empirical evidences to improve students' science literacy. *Proceedings of the International Conference on Madrasah Reform*, *633(1)*, 131–138. https://doi.org/10.2991/assehr.k.220104.020

Barke, Hazari, A., & Yitbarek, S. (2009). Misconceptions in chemistry. In *Misconceptions in*

Chemistry. Springer Berlin Heidelberg, 15-20. https://doi.org/10.1007/978-3-540-70989-3
Borg, W. R., & Gall, M. D. (1983). *Educational Research: An Introduction*. Longman.
Cetin-Dindar, A., & Geban, O. (2011). Development of a three-tier test to assess high school students' understanding of acids and bases. *Procedia - Social and Behavioral Sciences*, *15*, 600–604. https://doi.org/10.1016/j.sbspro.2011.03.147
Chen, C.-W., Andersson, B., & Zhu, J. (2023). A factor mixture model for item responses and certainty of response indices to identify student knowledge profiles. *Journal of Educational Measurement*, *60*(1), 28–51. https://doi.org/10.1111/jedm.12344
Chen, L., Hui, C., Qun, H., Jianbo, X., & and Teng, H. (2022). Absorption, metabolism and bioavailability of flavonoids: a review. *Critical Reviews in Food Science and Nutrition*, *62*(28), 7730–7742. https://doi.org/10.1080/10408398.2021.1917508
Coduto, J. R., Lazicki, A., & Leddy, J. (2024). Visualizing 3D objects in analytical chemistry. *Journal of Chemical Education*, *101*(1), 77–87. https://doi.org/10.1021/acs.jchemed.3c00821
Di Natale, A. F., Repetto, C., Riva, G., & Villani, D. (2020). Immersive virtual reality in K-12 and higher education: A 10-year systematic review of empirical research. *British Journal of Educational Technology*, *51*(6), 2006–2033. https://doi.org/10.1111/bjet.13030
Diani, R., Alfin, J., Anggraeni, Y. M., Mustari, M., & Fujiani, D. (2019). Four-Tier diagnostic test with certainty of response index on the concepts of fluid. *Journal of Physics: Conference Series*, *1155*(1). https://doi.org/10.1088/1742-6596/1155/1/012078
Dood, A. J., Fields, K. B., & Raker, J. R. (2018). Using lexical analysis to predict lewis acid-base model use in responses to an acid-base proton-transfer reaction. *Journal of Chemical Education*, *95*(8), 1267–1275. https://doi.org/10.1021/acs.jchemed.8b00177
Duca, A., Constantinescu, G.-G., & Iftene, A. (2024). Future education: Experimenting with chemical reactions in virtual reality. *18th International Conference on INnovations in Intelligent SysTems and Applications, INISTA 2024*. Institute of Electrical and Electronics Engineers Inc, 1(1), 1-6. https://doi.org/10.1109/INISTA62901.2024.10683861
Elford, D., Lancaster, S. J., & Jones, G. A. (2022). Fostering motivation toward chemistry through augmented reality educational escape activities. A self-determination theory approach. *Journal of Chemical Education*, *99*(10), 3406–3417. https://doi.org/10.1021/acs.jchemed.2c00428
Febu, R., Sudarmin, M, N., & W, S. (2016). Development of ethnoscience approach in the module theme substance additives to improve the cognitive learning outcome and student's entrepreneurship. *Journal of Physics: Conference Series*, *755*(1). https://doi.org/10.1088/1742-6596/755/1/011001
Finken, J., & Wölfel, M. (2023). Influence of immersive virtual reality on cognitive and affective learning goals. *Lecture Notes in Networks and Systems*, *581(1)*, 510–521. https://doi.org/10.1007/978-3-031-21569-8_48
Gkitzia, V., Salta, K., & Tzougraki, C. (2020). Students' competence in translating between different types of chemical representations. *Chemistry Education Research and Practice*, *21*(1), 307–330. https://doi.org/10.1039/C8RP00301G
Gulacar, O., Milkey, A., & Eilks, I. (2020). Exploring cluster changes in students' knowledge structures throughout general chemistry. *Eurasia Journal of Mathematics, Science and Technology Education*, *16*(6), 1850. https://doi.org/10.29333/EJMSTE/7860
Guruloo, T. N. M., & Osman, K. (2023). Integrating virtual reality laboratories (VRLs) in chemistry education: A systematic literature review. *International Journal of Education*, *15*(4), 127. https://doi.org/10.5296/ije.v15i4.21372
Hadinugrahaningsih, T., Ridwan, A., Rahmawati, Y., Allanas, E., Cahya N., G., & Amalia, R. (2021). An analysis of chemistry student's laboratory jargon in acid-base material using a 3E learning cycle. In M. M., R. Y., D. M., & F. E. (Eds.), *AIP Conf. Proc.* 2 April 2021; 2331 (1): 040035. https://doi.org/10.1063/5.0045512
Hakimah, N., Muchson, M., Herunata, H., Permatasari, M. B., & Santoso, A. (2021). Identification student misconceptions on reaction rate using a Google forms three-tier tests. In S. H., H. H., & R. D. (Eds.), AIP Conf. Proc. *2 March 2021; 2330 (1): 020020.* https://doi.org/10.1063/5.0043114
Hammer, M., & Avram, E. M. G. (2024). Online interactive activity: Using a web-based multimedia

activity to teach balancing chemical equations. *Journal of Chemical Education, 101(10),* 4510-4516. https://doi.org/10.1021/acs.jchemed.4c00786

Hendry, R. F. (2016). Structure as abstraction. *Philosophy of Science*, *83*(5), 1070–1081. https://doi.org/10.1086/687939

Herunata, H., Wijaya, I., Sulistina, O., & Nazriati, N. (2024). The development of teaching materials based on conceptual understanding, chemical representation, and representational competence in chemical kinetics. In H. H. & R. T. (Eds.), *AIP Conference Proceedings*, *American Institute of Physics,* 3106, (1), 040014. https://doi.org/10.1063/5.0214803

Hoai, V. T. T., Son, P. N., An, D. T. T., & Anh, N. V. (2024). An investigation into whether applying augmented reality (ar) in teaching chemistry enhances chemical cognitive ability. *International Journal of Learning, Teaching and Educational Research*, *23*(4), 195–216. https://doi.org/10.26803/ijlter.23.4.11

Jiang, G., Xia, X., Li, Y., Liang, H.-N., & Hui, P. (2024). ChemistryVR: Enhancing educational experiences through virtual chemistry lab simulations. In S. S.N. (Ed.), *Proceedings - SIGGRAPH Asia 2024 Educator's Forum, SA 2024*. Association for Computing Machinery, Inc. 1(1), 1-5 https://doi.org/10.1145/3680533.3697068

Jiménez-Liso, M. R., López-Banet, L., & Dillon, J. (2020). Changing how we teach acid-base chemistry: A proposal grounded in studies of the history and nature of science education. *Science and Education*, *29*(5), 1291–1315. https://doi.org/10.1007/s11191-020-00142-6

Johnson, M. D., Lavner, J. A., Mund, M., Zemp, M., Stanley, S. M., Neyer, F. J., Impett, E. A., Rhoades, G. K., Bodenmann, G., Weidmann, R., Bühler, J. L., Burriss, R. P., Wünsche, J., & Grob, A. (2022). Clinical psychology: Science and practice commentary. *Personality and Social Psychology Bulletin*, *48*(4), 534–549. https://doi.org/10.1177/01461672211016920

Johnstone, A. H., Macdonald, J. J., & G Webb. (1977). Misconceptions in school thermodynamics. *Physics Education*, *12*(4), 248. https://doi.org/10.1088/0031-9120/12/4/011

Julaeha, S., Hidayat, T., & Rustaman, N. Y. (2020). Development of web-based three tier multiple choice test to measure student's tree thinking; Try out. *Journal of Physics: Conference Series*, *1521*(4), 39-40. https://doi.org/10.1088/1742-6596/1521/4/042024

Kala, N., Yaman, F., & Ayas, A. (2013). The effectiveness of predict-observe-explain technique in probing students' understanding about acid-base chemistry: A case for the concepts of ph, poh, and strength. *International Journal of Science and Mathematics Education*, *11*(3), 555–574. https://doi.org/10.1007/s10763-012-9354-z

Kean, E., & Middlecamp, K. (1985). *Panduan belajar kimia dasar*. Erlangga.

Keiner, L., & Graulich, N. (2021). Beyond the beaker: Students' use of a scaffold to connect observations with the particle level in the organic chemistry laboratory. *Chemistry Education Research and Practice*, *22*(1), 146–163. https://doi.org/10.1039/D0RP00206B

Kounlaxay, K., Yao, D., Ha, M. W., & Kim, S. K. (2022). Design of virtual reality system for organic chemistry. *Intelligent Automation and Soft Computing*, *31*(2), 1119–1130. https://doi.org/10.32604/iasc.2022.020151

Krajčovič, M., Gabajová, G., Matys, M., Grznár, P., Dulina, Ľ., & Kohár, R. (2021). 3D Interactive learning environment as a tool for knowledge transfer and retention. *Sustainability (Switzerland)*, *13*(14), 1–23. https://doi.org/10.3390/su13147916

Kurniawan, W., & Basuki, F. R. (2024). Ethnoscience learning: How do teacher implementing to increase scientific literacy in junior high school. *International Journal of Evaluation and Research in Education (IJERE)*, *13*, 1719. https://doi.org/10.11591/ijere.v13i3.26180

Liu, D., Bhagat, K., Yuan, G., Huang, R., & Chang, T. (2017). *The potentials and trends of virtual reality in education.* 105–130. https://doi.org/10.1007/978-981-10-5490-7_7

Makransky, G., & Lilleholt, L. (2018). A structural equation modeling investigation of the emotional value of immersive virtual reality in education. *Educational Technology Research and Development*, *66*(5), 1141–1164. https://doi.org/10.1007/s11423-018-9581-2

Maksimenko, N., Okolzina, A., Vlasova, A., Tracey, C., & Kurushkin, M. (2021). Introducing atomic structure to first-year undergraduate chemistry students with an immersive virtual reality experience. *Journal of Chemical Education*, *98*(6), 2104–2108. https://doi.org/10.1021/acs.jchemed.0c01441

Mubarak, S., & Yahdi. (2020). Identifying undergraduate students' misconceptions in understanding acid base materials. *Jurnal Pendidikan IPA Indonesia*, *9*(2), 276–286. https://doi.org/10.15294/jpii.v9i2.23193

Muyassaroh, I., Amiroh, A., Maryadi, M., & Masruroh, N. (2016). Integrasi kearifan lokal dalam kurikulum sains di sekolah dasar: Tinjauan literatur sistematis. *Kalam Cendikia: Jurnal Ilmiah Kependidikan*, *12*, 1–23. https://doi.org/10.20961/jkc.v12i3.93360

Nahadi, N., Siswaningsih, W., Firman, H., Dewi, E. P., Lestari, T., & Rahmawati, T. (2023). Development and application of a two-tier acid-base misconception diagnostic test based on pictorial to identifying student misconceptions in chemistry. *Journal of Engineering Science and Technology*, *18(1)*, 207–223.

Nisa', F. N., Widodo, W., Roqobih, & Dian, F. (2024). Pembelajaran inkuiri terbimbing untuk meningkatkan hasil belajar siswa pada materi pencemaran lingkungan. *BIOCHEPHY: Journal of Science Education*, *4*(1), 330–336.

Osman, S. A., Razali, S. F. M., Shokri, S. N. S. M., Othman, A., Badaruzzaman, W. H. W., Taib, K. A., & Khoiry, M. A. (2016). Effectiveness of pre-Test in determining students' achievement in department fundamental courses. *Pertanika Journal of Social Sciences and Humanities*, *24*(1), 49–62.

Paristiowati, M., Zulmanelis, Z., & Nurhadi, M. F. (2019). Green chemistry-based experiments as the implementation of sustainable development values. *JTK (Jurnal Tadris Kimiya)*, *4*(1), 11–20. https://doi.org/10.15575/jtk.v4i1.3566

Rahayu, S. (2019). *Socio-scientific Issues (SSI) in chemistry education : Enhancing both students ' chemical literacy & transferable skills*, *1227(1), 012008* https://doi.org/10.1088/1742-6596/1227/1/012008

Rashid, S., Khattak, A., Ashiq, M., Rehman, S. U., & Rasool, M. R. (2021). Educational landscape of virtual reality in higher education: Bibliometric evidences of publishing patterns and emerging trends. *Publications*, *9*(2), 17. https://doi.org/10.3390/publications9020017

Reina, M., This, H., & Reina, A. (2022). Improving the understanding of chemistry by using the right words: A clear-cut strategy to avoid misconceptions when talking about elements, atoms, and molecules. *Journal of Chemical Education*, *99*(8), 2999–3006. https://doi.org/10.1021/acs.jchemed.2c00411

Ristanto, R. H., Suryanda, A., & Indraswari, L. A. (2023). The development of ecosystem misconception diagnostic test. *International Journal of Evaluation and Research in Education*, *12*(4), 2246–2259. https://doi.org/10.11591/ijere.v12i4.25200

Rodriguez, J.-M. G., Hunter, K. H., Scharlott, L. J., & Becker, N. (2020). A review of research on process oriented guided inquiry learning: Implications for research and practice. *Journal of Chemical Education*, *97*(10), 3506–3520. https://doi.org/10.1021/acs.jchemed.0c00355

Romine, W. L., Todd, A. N., & Clark, T. B. (2016). How do undergraduate students conceptualize acid–base chemistry? measurement of a concept Progression. *Science Education*, *100*(6), 1150–1183. https://doi.org/10.1002/sce.21240

Santos, V. C., & Arroio, A. (2016). The representational levels: Influences and contributions to research in chemical education. *Journal of Turkish Science Education*, *13*(1), 3–18. https://doi.org/10.12973/tused.10153a

Shaafi, N. F., Yusof, M. M. M., Ellianawati, E., Subali, B., & Raji'e, M. H. H. (2025). Investigating misconceptions about acids and bases among pre-service science teachers. *Journal of Education and Learning*, *19*(1), 460–477. https://doi.org/10.11591/edulearn.v19i1.21803

Sparks, B., Zidenberg, A. M., & Olver, M. E. (2022). Involuntary celibacy: A review of incel ideology and experiences with dating, rejection, and associated mental health and emotional sequelae. *Current Psychiatry Reports*, *24*(12), 731–740. https://doi.org/10.1007/s11920-022-01382-9

Siswaningsih, W., & Chandratika, V. (2020). Profile of misconception in senior high school students on the concept of acid-base strength. *Proceedings of the 7th Mathematics, Science, and Computer Science Education International Seminar, MSCEIS 2019*. European Alliance for Innovation. https://doi.org/10.4108/eai.12-10-2019.2296380

Stieff, M. (2019). Improving learning outcomes in secondary chemistry with visualization-supported inquiry activities. *Journal of Chemical Education*, *96*(7), 1300–1307. https://doi.org/10.1021/acs.jchemed.9b00205

Sudarmin, S., Pujiastuti, R. S. E., Asyhar, R., Tri Prasetya, A., Diliarosta, S., & Ariyatun, A. (2023).

Chemistry project-based learning for secondary metabolite course with ethno-STEM approach to improve students' conservation and entrepreneurial character in the 21st century. *Journal of Technology and Science Education*, *13*(1), 393. https://doi.org/10.3926/jotse.1792

Sumarni, W., Sumarti, S. S., & Kadarwati, S. (2023). Blended inquiry learning with ethno-stem approach for first-semester students' chemical literacy. *Jurnal Pendidikan IPA Indonesia*, *12*(3), 439–450. https://doi.org/10.15294/jpii.v12i3.45879

Viehmann, C., Fernández Cárdenas, J. M., & Reynaga Peña, C. G. (2024). The use of socioscientific issues in science lessons: a scoping review. *Sustainability (Switzerland)*, *16*(14), 5827. https://doi.org/10.3390/su16145827

Vlah, D., Čok, V., & Urbas, U. (2021). Vr as a 3d modelling tool in engineering design applications. *Applied Sciences (Switzerland)*, *11*(16), 7570. https://doi.org/10.3390/app11167570

Widarti, H. R., Wiyarsi, A., Yamtinah, S., & Shidiq, A. S. (2025). Analysis of content development in chemical materials related to ethnoscience : A review. *Journal of Education and Learning (EduLearn)*, *19*(1), 422–430. https://doi.org/10.11591/edulearn.v19i1.21210

Wu, Q., Vanerum, M., Agten, A., Christiansen, A., Vandenabeele, F., Rigo, J. M., & Janssen, R. (2021). Certainty-based marking on multiple-choice items: Psychometrics meets decision theory. *Psychometrika*, *86*(2), 518–543. https://doi.org/10.1007/s11336-021-09759-0

Yamtinah, S., Susanti VH, E., Saputro, S., Ariani, S. R. D., Shidiq, A. S., Sari, D. R., & Ilyasa, D. G. (2023). Augmented reality learning media based on tetrahedral chemical representation: How effective in learning process? *Eurasia Journal of Mathematics, Science and Technology Education*, *19*(8), 2313. https://doi.org/10.29333/ejmste/13436

Yang, H. M., & Hwang, S. Y. (2016). Reliability and validity of the assessment tool for measuring communication skills in nursing simulation education. *Korean Journal of Adult Nursing*, *28*(1), 95-96. https://doi.org/10.7475/kjan.2016.28.1.95

Zamudio, J. O., Miguel-Gómez, J. E., Santiago, A., Montaño-Hilario, J. M., Franco-Bodek, D., García-Ortega, H., Reina, A., & Reina, M. (2024). Chemical element lotto: A captivating guessing and cultural game inspired by the mexican lottery. *Journal of Chemical Education*, *101*(11), 4820-4829. https://doi.org/10.1021/acs.jchemed.4c00759

Zidny, R., & Eilks, I. (2022). Learning about pesticide use adapted from ethnoscience as a contribution to green and sustainable chemistry education. *Education sciences*, *12*(4), 227. https://doi.org/10.3390/educsci12040227

Zidny, R., & Sjöström, J. (2021). A multi-perspective reflection on how indigenous knowledge and related ideas can improve science education for sustainability. 29, 145–185. https://doi.org/10.1007/s11191-019-00100-x