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Detecting Student Misconception in Chemical Bonding using a Virtual Reality Integrated Two-Tier Multiple-Choice Instrument within an Ethnochemistry Context

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Abstract: Two-Tier Multiple Choice Virtual Reality (TTMCVR) with ethnochemical content is used to measure the level of misconceptions and understanding of students on chemical bond materials that have good quality and tested. This development aims to test the readability and effectiveness of TTMCVR based on the results of validity and limited trials as a reference that the developed assessment is feasible to use to identify students' misconceptions and understanding of chemical bonding materials. This research method applies Research and Development (R&D) with the ADDIE model (Analysis, design, development, implementation and evaluation). This study used 18 students and 3 teachers in 3 public high schools in Surakarta. The sampling technique used purposive sampling. Data obtained in the form of instrument results include interview tests, TTMCVR assessments and open-ended questionnaires. The results showed that TTMCVR obtained validation based on aspects of context, language, and construction on the items and storyboard from 16 experts, namely 9 chemistry education lecturers from UNS, UNY and UM and 7 high school chemistry teachers in Surakarta resulting in 15 items and 16 valid storyboard indicators with Aiken index ≥ 0.73. The limited trial stage shows that TTMCVR is able to detect the level of understanding and misconceptions of students with criteria, namely understanding the concept of 26%, misconceptions 32% and not understanding 41% on ethnochemically charged chemical bonding material on ice gempol pleret. In addition, TTMCVR is classified as having a high level of readability and effectiveness as an assessment assessment from the material and media aspects of 90% from student responses and teacher responses. Therefore, it can be concluded that based on the validity and readability of TTMCVR, it is feasible to be further developed for assessment.

Keywords: chemical bonding, ethnochemistry, misconceptions, two-tier multiple choice virtual reality.

▪ INTRODUCTION

The low quality of education is a significant problem for one aspect of education, one of which is the results of student learning achievement. Based on data from the Program for International Student Assessment (PISA), Indonesia experienced a decrease in scores in numeracy, literacy, and science. However, the PISA score obtained by Indonesia, one of which is in science ability, has decreased by 13 points from the 2018 value. (PISA, 2022). Therefore, it can be said that the quality of education in Indonesia still shows low achievement results.

The level of learning achievement can also be obtained from the assessment results obtained by students. This is in line with the efforts made by the government to prepare students who can meet the demands of 21st-century learning by the 4C skills (Critical Thinking, Creativity, Communication, and Collaboration) by conducting authentic assessments. This assessment focuses on learning that involves students taking part in real learning activities, then conducting investigations, demanding that students play an active role in building knowledge from the surrounding environment (Paragae, I. P. N. S, 2023). Therefore, authentic assessment is critical because it is directly related to the stage

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of student progress and provides feedback to teachers to improve the planning and process of learning programs, one of which is chemistry.

Students often consider chemistry learning as abstract, complicated, complex and requires high scientific reasoning, thus causing learning difficulties that result in low learning outcomes (Soeharto & Csapó, 2021). Chemistry material is also directly related to the representation approach at three different levels, namely macroscopic (can be seen directly and tangibly), submicroscopic (cannot be seen directly, such as the arrangement of atoms, molecules and ions that interact), and symbolic (chemical equations, element symbols, formulas, reaction mechanisms) (Reiser et al., 2022). This is supported by research by Venessa et al (2020) explained that student learning difficulties can occur when students are unable to understand level 3 representation levels in chemistry, namely the chemical bond sub-topic, so that the potential for material misconceptions to arise in students.

Chemical bonding material discusses interactions in molecules, atoms, and ions in a compound. However, most students only apply theoretical concepts and memorize them without using them in everyday life (Zhao et al., 2019). The main difficulty of students lies in the inability to understand molecular interactions related to chemical bonds submicroscopically which often leads to misconceptions (Laohapornchaiphan & Chenprakhon, 2024). Misconception is a mismatch of understanding related to a concept that occurs between students and experts, giving rise to explanations that cannot be understood or accepted. So that the understanding of the concepts of students will be opposite to the existing scientific theory that has an impact on the learning process as well as learning outcomes (Assem et al., 2023). This is also supported by research by Rahayu et al. (2022) Related to the analysis of the level of difficulty of chemical bonding materials, it was found that the level of difficulty of chemical bonding materials ranged from 50-70% in covalent bonds, ionic bonds, and molecular shapes. Therefore, further development of instruments to detect students' understanding and misconceptions using diagnostic tests is needed.

Diagnostic tests as an instrument of assessment of the results of learner activities to collect information that will be used to make a decision on the knowledge that has been obtained (Adom et al., 2020). This test is usually only in the form of ordinary multiple-choice, reasoned multiple choice, matching, short form, and description (Butler, 2018). Based on observations in 3 public high schools in Surakarta, several teachers conducted evaluations on chemical bonding material only in the form of tests. The test questions used are in the form of essays and multiple choice questions with short answers that can only be applied to ordinary multiple choice questions. These questions use in-depth theory on chemical bonding material without being related to everyday life.

Observation data shows that ordinary multiple-choice tests and description tests have their shortcomings, namely the ease of students in shooting answers, allowing students to express different opinions, and making it difficult for teachers to analyze assessments of student understanding (Sakahuni & Ramadhanti, 2021). One of the tests that can be an alternative and developed is Two Tier Multiple Choice (TTMC). This test consists of two tiers of answers, where the first tier contains the questions asked and the answers, while the second tier is the reason for choosing the answer in the first tier (Rintayati et al., 2020). However, this test only focuses on macroscopic and symbolic

knowledge and measures cognitive understanding, so it needs to be associated with emerging technology, namely virtual reality (VR).

Virtual Reality (VR) as a support for teaching and learning activities that can visualize abstract chemical material that must be adjacent to 3 levels of representation in macroscopic, submicroscopic, and symbolic form (Hu-Au, E, 2024). In addition, VR can also be associated with ethnochemistry, a branch of science that will study chemistry based on a cultural perspective that becomes the content of the approach in learning (Rahmawati et al., 2023). One of the cultures used in this research is es gempol pleret as a typical Surakarta drink that will be included in learning content related to covalent bonding, ion bonding, hydrogen bonding, and molecular shapes. So, students will indirectly try how to directly visualize the manufacturing process related to chemical bonding material in 3 levels of representation.

This research will measure the validity and limited trial related to the VR-integrated TTMC assessment instrument with ethnochemical content on chemical bonding material using Aiken index analysis through the assessment of a number of instrument items by 16 assessors and 3 public schools in Surakarta city from teachers and students. While in the limited trial, students and teachers will use TTMCVR to determine the level of understanding and misconceptions based on categories such as understanding the concept, misconceptions and not understanding. In addition, the feasibility of the TTMCVR function based on teacher and student responses. Validity and limited trials of TTMCVR are indicators of assessment that are feasible to use to determine whether this assessment needs to be further developed.

▪ METHOD

Participants

In this study using participants, namely 18 XI grade students and 3 chemistry teachers who use 3 public high schools in Surakarta who will conduct limited trials and open questionnaires to see the readability and effectiveness of TTMCVR as an assessment of the level of understanding and misconceptions of students. The sampling technique used purposive sampling by using the daily test scores of chemical bonds that have been obtained based on low, medium and high. In addition, this study also involved 16 experts, namely 9 chemistry education lecturers from UNS, UNY and UM and 7 high school chemistry teachers in Surakarta who played a role in assessing the suitability of the question indicators with the TTMCVR indicators, the suitability of concepts and content in the items and VR storyboards, the suitability of the answer key, and the selection of words in the items and VR storyboards.

Research Design and Procedures

The type of research used is research and development (RnD) using the ADDIE model on ethnochemically charged TTMCVR on chemical bonding material in the form of reasoned multiple choice which aims to determine the level of validity and feasibility of assessments that can be used in learning. The ADDIE model is often used because it has the advantage of a systematic approach in producing teaching designs and learning materials so that the delivery of teaching will be more effective and efficient. This model is often also used in developing educational products such as learning strategies, learning methods, media learning materials (Adriani et al., 2020).

Analysis

This initial stage conducted needs analysis interviews with chemistry teachers in 3 high schools in Surakarta related to the problems and obstacles felt by teachers regarding the identification of student understanding and the level of conceptual errors that are often felt by students with the learning media used by teachers. The context of chemistry learning taken is on the sub-material, namely macroscopic, sub-microscopic and symbolic chemical bonds. At this stage the researcher also provided an initial design regarding the development of ethnochemically charged TTMCVR which included question instruments and storyboards to be developed. This is an important point in the early stages of TTMCVR design.

Design

After conducting the needs analysis stage, further in the design process which is a reference step for developing ethnochemically charged TTMCVR with etnochemistry on chemical bonding material. This design stage is designed using Unity and Canva which is tailored to chemical bonding material which is integrated with questions and storyboards for learning. This TTMCVR with etnochemistry was developed which will be able to display questions and experiments in 3D from chemical bond material in accordance with the 3-level representation approach. This development takes about 3 months.

Development

In the development process, researchers also made TTMCVR question instruments, TTMCVR storyboards, and open questionnaires regarding readability and effectiveness related to the use of TTMCVR. Then proceed with the validation process with the help of material and media experts using 16 experts including 9 chemistry education lecturers from UNS, UM and UNY and 7 chemistry teachers from Surakarta. TTMCVR with ethnochemical content developed needs to be analyzed related to content validity which is used to improve a test item while showing that the test can measure what should be measured (Ikhsanudin & Subali, 2018).

Implementation

TTMCVR after completion and revision from media and material experts, then limited product trials on 3 teachers and 18 grade XI students covering 3 public high schools in Surakarta. The results of using TTMCVR will get results regarding the level of understanding and misconceptions on chemical bonding material and an open questionnaire is given to see the readability, functionality and effectiveness of the developed assessment. The samples selected were students who had received chemical bonding material and took the daily test.

Evaluation

TTMCVR which has been carried out a limited trial of the product, then the evaluation stage to see the assessment of the function of TTMCVR based on the results of students and teachers based on the results of an open questionnaire. In addition, it also looks at how comments and suggestions from both teachers and students to later improve the performance of TTMCVR which functions more optimally.

Instruments

In this study using quantitative and qualitative research which includes data collection instruments as follows: (1) the validity of ethnochemically charged TTMCVR on chemical bonding material which is assessed by instruments, namely media and material expert validation sheets with 15 items question and 16 storyboard indicators on TTMCVR consisting of 4 simple simulation activities; (2) ethnochemically charged TTMCVR test instruments on chemical bonding material that have been adapted to learning in public high schools, especially class XI. This question contains multiple choice questions with direct simulation experiments. So that students are expected to answer questions by doing practicum first in making ethnochemically charged ice gempol pleret which later the questions and answers along with the reasons can be answered properly according to the chemical bond material; (3) Effectiveness and readability functions of using ethnochemically charged TTMCVR on chemical bond material assessed by teachers and students. The results of this data measure the practicality score of using TTMCVR on chemical bond materials using 5 indicators from the media and material aspects.

Data Analysis

This study uses data analysis techniques which include validity tests, TTMCVR product trials and TTMCVR effectiveness and readability tests. The validity test uses the Aiken index which is assessed by experts and media which aims to see the feasibility of a product based on the results of analysis from experts. Validity assessment is carried out by giving a score of 1 - 4 on each item with the aspects measured, namely the content aspect, language aspect, and question presentation aspect. The content aspect of the question includes the suitability of the material used with the truth of science, the development of science, and real life. The language aspect consists of the language used is communicative, the sentences used are easy to understand with Indonesian language rules and the readability of the questions used. The presentation aspect includes aspects of the clarity of the sequence and consistency of the problem structure, including the instructions for working on the questions submitted, which are easy to understand and do not cause many interpretations and the visual appearance of the questions used must also be clear.

Validity analysis of the TTMC assessment instrument integrated with VR-based assessment with ethnochemistry content of chemical bonds in this study used Aiken's formula (1985) with the following formula:

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

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)

TTMCVR assessment with ethnochemical content on chemical bonding material is declared to have a good level of validity if the validity level is at least valid with a V

Table index of more than 0.73 which is calculated based on the number of experts (Aiken, 1985). If the level of validity achievement is below valid, it is necessary to make revisions based on the input provided by the validators. The TTMCVR product trial was used to determine the level of understanding and misconceptions of students. The categories of TTMCVR assessment answers that have been done by students and teachers will be determined based on the categories listed in Table 1.

Table 1. Answer categories on TTMC (Humaidi et al., 2023)

Answer Type	Explanation	Category	Skor
B-B (correct- correct)	Wrong answer. wrong reason	Understand	3
S-B (false-correct)	Wrong answer. right reason	Misconception	2
B-S (true-false)	Correct answer. wrong reason	Misconception	1
S-S (false-false)	Correct answer. correct reason	No understanding	0

The above results aim to determine whether the TTMCVR can be read properly as an assessment in terms of students' level of understanding and misconceptions. These results can be used as an initial form of providing information about the suitability of the material with students to prevent conceptual errors and the latest knowledge with an ethnochemical approach. The results of the percentage of answers to students can be categorized as the level of student misconceptions divided into three options namely low, medium and high which can be seen in Table 2.

Table 2. Percentage level of misconception (Humaidi et al., 2023)

Percentange(%)	Misconception Category
0-30	Low
31-60	Medium
61-100	High

The effectiveness and feasibility tests were carried out by calculating the scores obtained from the questionnaire results from students and teachers using a 1-4 Likert scale questionnaire with answer descriptions. This scale ranges from 4 – 1 by indicating “strongly agree” to “disagree”. Researchers use even choices to avoid respondents who tend to give neutral or middle or undecided category assessments, so that they will obtain certainty of information or answers (Kusmaryono et al., 2022). The results of teacher and student response data were calculated to determine the percentage of positive responses to ethnochemically charged TTMCVR on chemical bonding materials. Teacher and student responses were measured by dividing the total score by the maximum score, then multiplying the result by 100%. The results of the questionnaire indicators can be seen in Table 3, while the percentage score of effectiveness and feasibility adjusted to the category can be seen in Table 4.

Table 3. TTMCVR learner assessment aspects and indicators

No	Aspect	Indicator	Item
1	Material	Understand material	1.2
		Presentation material	3.4.5
2	Media	Readability and Language use	6.7.8

	Graphic display of media	9.10.11.12
	Characteristics of Ethnochemical-based VR integrated TTMC	13.14.15.16

Table 4. Criteria for teacher and student response to TTMCVR

Percentange(%)	Category
90-100	Very good
80-89	Good
60-79	Good enough
0-59	Not good

▪ RESULT AND DISSCUSSION

TTMCVR With Etnochemistry Chemical Bonding

Analyze

At the analysis stage as a preliminary step to develop ethnochemically charged TTMCVR on chemical bonding material using Unity and Canva. This stage is important because it has to ensure the suitability of learning assessments with student characteristics, technology and curriculum. In addition, it also functions in identifying problems that often occur in schools which are the basis for developing this learning assessment. Based on the results of observations and interviews in 3 high schools in Surakarta, there are several problems related to the learning process, especially in chemical bonding material such as constraints in visualizing the occurrence of macroscopic, sub-microscopic and symbolic intermolecular bonds which are very abstract, introductory material is still in the form of books that do not provide real understanding, teachers only use the lecture method, the assessment questions used by teachers in conducting evaluations on chemical bonds are mostly only tests. In addition, assessments other than tests are also carried out by giving assignments, assessments during practicum and when making reports in practicum. The types of test questions used are essay questions, multiple choice with short answers that can only be applied to ordinary multiple choice questions. Then, the process of making questions also still uses an in-depth theoretical basis that is not related to the application of chemical bonding material in everyday life and teachers often experience difficulties in preparing tools and materials to conduct face-to-face practicum.

The development of this learning assessment is motivated by various kinds of problems faced in schools, such as constraints in the difficulty of visualizing the material, there are still few media that support learning and the use of comprehension questions that are still in the form of tests. Therefore, the researchers conducted an in-depth needs analysis to ensure that the development of ethnochemically charged TTMCVR on chemical bonding material was very relevant to the curriculum, material content and also answered the problems that occurred in the school environment. This TTMCVR present in schools can be expected to be able to help improve student understanding and identify misconceptions early so that they do not continue further while creating interesting, innovative and interactive assessments with an ethnochemical approach.

Design

At the design stage as a form of continuation of steps from analyzing needs within the school scope by designing in the development of ethnochemically charged TTMCVR on chemical bonding material which is compiled based on the results of analysis, learning outcomes as well as indicators on chemical bonding material. The beginning of making TTMCVR starts with making a simple practicum learning storyboard starting from basic concepts to interactions in VR to exploration and answering questions using Unity which can be seen in Figure 1.

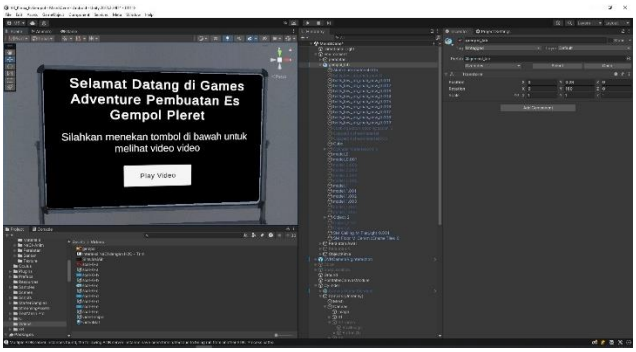


Figure 1. Creation of TTMCVR using unity

TTMCVR is made by paying attention to the material of chemical bonds in theory which includes covalent bonds, ion bonds, and molecular forms that are applied in everyday life on ice gempol pleret which are interrelated to each other. The following is a TTMCVR design that will be used by students to perform simple practicum and answer questions with a simulation of making ice gempol pleret as a learning assessment on this instrument which can be seen in Figure 2, 3, 4, and 5.

Figure 2. First experiment on TTMCVR

In the initial stage, students will be presented with a laboratory room to conduct a simple experiment on the making of ice gempol pleret which is related to chemical bonds. Then students will be directed with instructions during the learning process. Before conducting the experiment, students are first presented with a lighter video related to the making of gempol pleret ice and the tools and materials that will be used to simulate a simple experiment. Then students continue the experiment integrated with TTMCVR questions that are in accordance with the experiments that have been carried out to match what has been learned, after completion will continue with the second experiment.

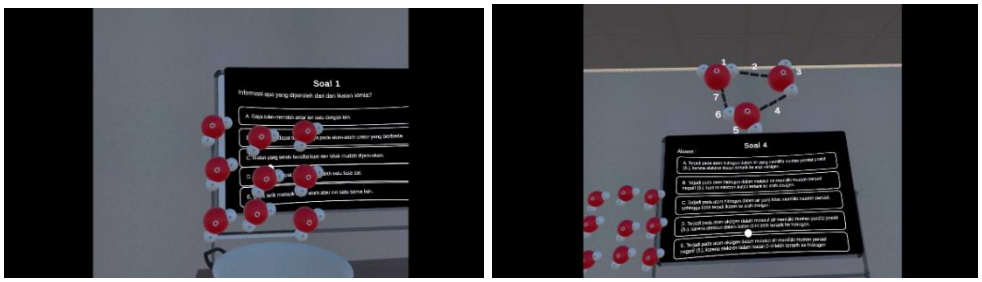


Figure 3. Second experiment on TTMCVR

In the second experiment, students will continue the practicum in making ice gempol pleret in the water treatment process such as students will understand how covalent bonds are formed in H2O, how the interaction and shape of H2O molecules in the liquid phase and how the form of hydrogen bonds that occur between H2O molecules with H2O. This is closely related to ice gempol pleret and chemical bonding material focused on in-depth understanding and detecting misconceptions whether the theory understood by students is correct or there are conceptual errors regarding covalent bonds and hydrogen bonds using multiple choice questions.

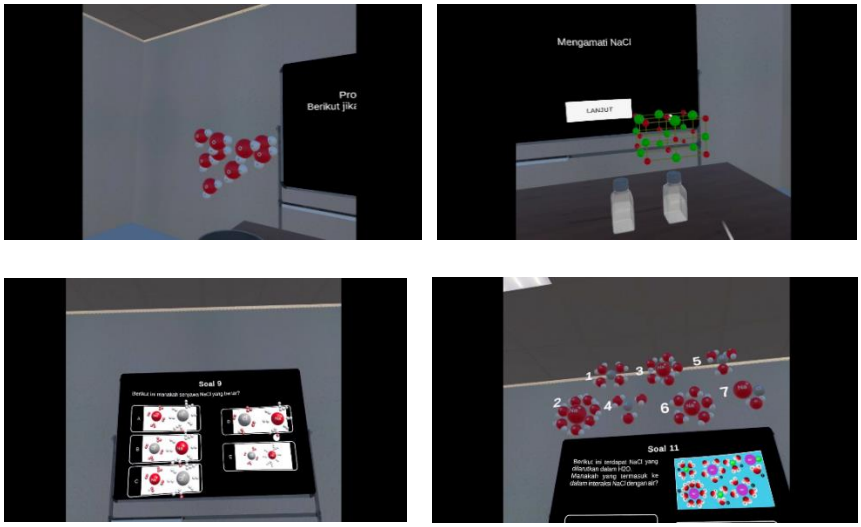


Figure 4. Third experiment on the TTMCVR

In the third experiment, students will be associated with ionic bonding material and the interaction between covalent bonds and ionic bonds in the process of heating water dissolved with salt. Students will be presented directly how the interaction of H2O molecules when given heat energy whether it changes treatment or not macroscopically, then students will know how the initial formation of NaCl ionic bonds until they are formed based on atomic electronegativity. In addition, students can also directly see how the dissolution interaction between H2O and NaCl supports learning in 3 levels of representation macroscopically, sub-microscopically and symbology. Therefore, from the interaction of direct experiments students will also be faced with reasoned multiple choice questions to determine the level of understanding and whether or not misconceptions arise from material related to chemical bonds.

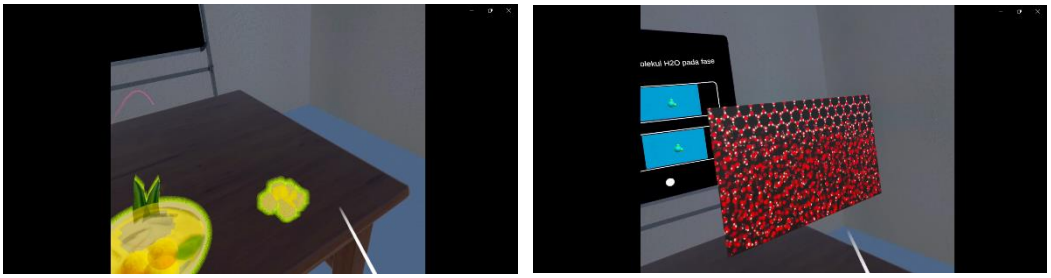


Figure 5. Four experiment on the TTMCVR

In the last stage, students will be faced with problems on the interaction of H2O molecules in the solid phase, so that students will directly see how interactions occur submicroscopically. In addition, students also conduct a finalization stage regarding the making of ice gempol pleret which will answer multiple choice questions given reasons to see the level of understanding and the possibility of misconceptions arising in chemical bonding material that has followed the learning from beginning to end. After the experiment of making ice gempol pleret is complete, students will get a final score on each question which will be able to determine the level of student understanding and identify misconceptions that occur in students. The following are the results of the TTMCVR score after conducting the experiment which can be seen in Figure 6.

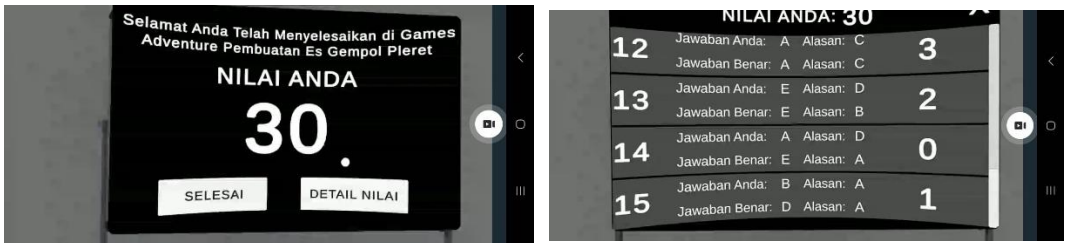


Figure 6. Results of the TTMCVR score

Based on the results of the final score of the TTMCVR, it will be easier to analyze the understanding and misconceptions on each number using the answer categories including understanding with a score of 3 when the first statement and reason are correct, misconception with a score of 2 when the first statement is correct and the reason is wrong, misconception with a score of 1 when the first statement is wrong and the reason is correct, and not understanding when the statement is wrong and the reason is wrong. Therefore, TTMCVR is able to assist teachers in identifying student understanding and providing final conclusions on chemical bonding material while for students it can prevent misconceptions that are understood from chemical bonding material during the learning process. This is supported by the research of Kounlaxay, K., et al (2022) that simulations with VR systems in laboratory settings can improve student learning outcomes in experimental chemistry. In addition, it reduces potential hazards in real laboratory environments and accidental exposure to chemicals due to lack of experience that can cause major and minor safety accidents.

Development

The TTMCVR development stage is carried out after completing the design of the assessment that has been developed. This stage is through a validation analysis to ascertain whether this TTMCVR is included in the valid and feasible category for use and application in high schools, especially in class XI. The validity value is analyzed based on each item with the aspects measured, namely the content aspect, language aspect, and presentation aspect by giving a score of 1 - 4 on each item. The results of the validity analysis of this research instrument are based on the agreement of experts. This is because the use of agreement from these experts to determine the level of content validity because a test or non-test instrument will prove more valid if the experts believe that the instrument developed can measure the ability to be measured. Aiken's validity index is used in determining the level of agreement of experts (Retnawati, 2016). Based on the results of the focus group discussion (FGD) that has been conducted, the results of the content validity value obtained from 16 assessors including 9 item experts and 7 other experts on the storyboard from the media and material aspects using Aiken's formula can be seen in Table 5 and Table 6.

Table 5. Results of aiken index analysis of TTMC items integrated with ethnochemistry VR on chemical bonding

Question	Value V	V Table	Conclusion
1	0.94	0.73	Valid
2	0.80	0.73	Valid
3	0.86	0.73	Valid
4	0.80	0.73	Valid
5	0.93	0.73	Valid
6	0.91	0.73	Valid
7	0.91	0.73	Valid
8	0.88	0.73	Valid
9	0.88	0.73	Valid
10	0.93	0.73	Valid
11	0.96	0.73	Valid
12	0.93	0.73	Valid
13	0.93	0.73	Valid
14	0.94	0.73	Valid
15	0.89	0.73	Valid

Table 6. Results of aiken index analysis of TTMC storyboard integrated with ethnochemistry VR on chemical bonding

No	Indicator	Value V	V Table	Conclusion
	Media Aspect			
1	The images in the storyboard are interesting and easy to understand	0.90	0.73	Valid
2	The sentences used are easy to understand	0.90	0.73	Valid
3	The suitability of the size of the writing in the storyboard is appropriate in each section	0.90	0.73	Valid

4	The suitability of the size of the images in the storyboard has been balanced and arranged as well as possible	0.81	0.73	Valid
5	The images and videos used in the storyboard match the theme	0.90	0.73	Valid
6	The images used in the storyboard are interesting	0.86	0.73	Valid
7	The typeface in the storyboard is easy to read	0.95	0.73	Valid
8	The combination of text and background in the storyboard is balanced and attractive	0.90	0.73	Valid
9	The color degradation used in the storyboard is appropriate	0.90	0.73	Valid
10	The images and videos already provide ethnochemistry reinforcement	0.95	0.73	Valid
	Material Aspect			
11	The suitability of material with misconception indicators	1.00	0.73	Valid
12	The orderly organization of the material presented	0.90	0.73	Valid
13	The easy to understanding the material presented	0.90	0.73	Valid
14	The subject matter presented as a question narrative is by the ethnochemistry approach	1.00	0.73	Valid
15	The images and videos can visualize material concepts	0.86	0.73	Valid
16	The systematic presentation of misconception questions is good	0.95	0.73	Valid

The level of content validity is closely related to the suitability between question items and indicators of the ability of TTMC integrated with ethnochemistry VR on chemical bonding material. This research uses four types of answers in determining validity such as irrelevant (TR) score 1, less relevant (KR) score 2, moderately relevant (CR) score 3, and relevant (R) score 4, so that each expert chooses from the four types of answers on each question instrument.

The validity of a question item is said to be a good measuring instrument based on Aiken with nine expert assessors who use four types of answers, namely if the Aiken index results are greater than or equal to the V table value of 0.73 (Aiken, 1985). It can be seen that the Aiken index value (V index) is an index of appraiser agreement regarding the suitability of the question items related to the indicators that need to be measured using these question items (Retnawati, 2016). Based on the results of the analysis of the calculation of content validity with Aiken's formula, that the TTMC assessment instrument integrated with VR with ethnochemistry content on chemical bonding material produces 15 question items that are said to be valid.

The calculation results can be seen in Table 5 and Table 6 related to the Aiken index on the question items and storyboard of the VR-integrated TTMC with ethnochemistry content on chemical bonding material, 2 question items and 2 storyboard indicators of media aspects have moderate validity and 13 question items 14 storyboard indicators of media and material aspects have high validity. This can be seen based on the Aiken validity index obtained from the assessment of experts can be declared low level, if a score below 0.4 is obtained. The index obtained is moderate ranging from 0.4 - 0.8 and the validity obtained is high if a score above 0.8 is obtained (Aiken, 1985). Therefore, when an Aikes index value is obtained closer to a score of 1.0, it can be said that a question item is getting better because it is more relevant in accordance with the predetermined indicators (Retnawati, 2016).

Validation results based on the FGD results also obtained suggestions and input from 16 assessors. Suggestions and input from the question items are as follows: (1) Pictures and treatments on molecular interactions are more clarified, so as not to cause misperceptions; (2) Include one of the narratives in the question based on simulation activities carried out coherently and clearly; (3) The material (content) used in the stimulus must consider related to the achievement of learner competencies; (4) Editorial in writing stimulus and questions must be in accordance with PUEBI; (5) The text of the question and stimulus is recommended not to cause student misconceptions; (6) Questions and answer choices must be relevant to the stimulus; (7) Question indicators and question items are required to be relevant according to the correct material concept. While suggestions and input on storyboards from media and material aspects include: (1) Visualization of molecules does not cover other parts; (2) Narration in the storyboard needs to be adjusted clearly; (3) The suitability of font size and typeface is monotonous; (4) Representation of the size of Na+ and Cl- is corrected according to the size of the atom; (5) Submicroscopic images need to be clarified and adjusted to the interaction of experimental activities.

Therefore, based on the validation results from the content aspect, language aspect, and presentation aspect, TTMCVR as a learning assessment has a valid category and is suitable for application in high schools in class XI to be used by students. The overall score is included in the index results are greater than or equal to the V table value of 0.73 with a valid category. This is supported by the research of Sejati et al (2021)which states that when a product is developed, it can be declared feasible when it obtains valid results with predetermined categories based on the aspects to be measured based on the results of the experts. In addition, based on Mardhiyah et al (2022) that when content validity as a form of product needs to be obtained from what is to be measured in the learning process. However, before being tested on students, there was input and suggestions from experts to improve TTMCVR in order to obtain optimal and maximum results.

Implementation

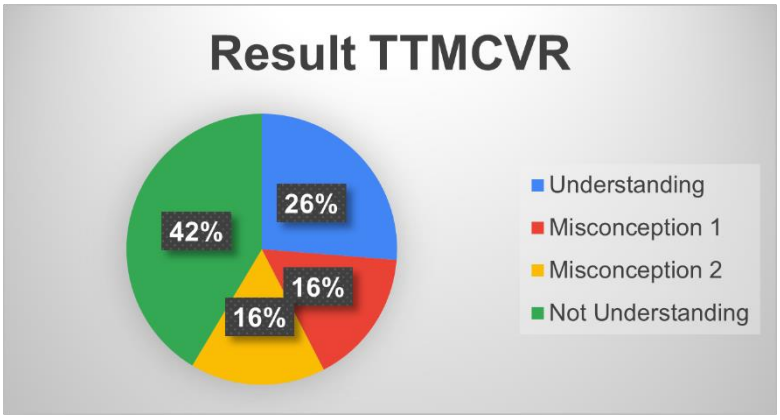
The TTMCVR has been developed and revised after getting input and suggestions from experts to improve the learning assessment. Furthermore, the implementation stage was carried out on 18 students and 3 teachers covering 3 public high schools in Surakarta. In this implementation using class XI who have received chemical bonding material and took the daily test, so it only takes one meeting to conduct a limited trial in each school.

This stage the teacher as an observer in the meeting to see how the effectiveness and feasibility with the application of ethnochemically charged TTMCVR on chemical bond material is feasible to use in learning. According to (Aldoobie, 2015) that in the trial stage, it is necessary to pay attention to preparing students such as knowing the initial information of the device used and how much time it takes to use the device. Therefore, researchers have made plans to prepare oculus, classrooms and wifi so that this TTMCVR can function optimally when used by students.

Students conducted experiments using TTMCVR with an average of each learner spending 15-20 minutes with a total of 15 questions and 4 experiments in chemical bonding material. Students widely tried in-depth to do a simple practicum in making ice gempol pleret which has been integrated with multiple choice questions and their reasons. The use of each oculus lasts for 3 hours in one experiment with an average use of 6 students without stopping. In addition, researchers prepared around 3 oculus along with other supporting devices, so that students did not wait for each other in conducting TTMCVR simulation experiments. The following are the results of limited trials conducted by teachers and students which can be seen in Figure 7.

Figure 7. Results of limited trials TTMCVR

Based on the limited trial of TTMCVR in 3 public high schools in Surakarta. Figure 8 presents the TTMCVR results for 18 students for both comprehension and misconception levels.



Fiture 8. Result TTMCVR

Based on the results of answers from students using ethnochemically charged TTMCVR tested using four cognitive statuses including: Understanding, Type 1 Misconception, Type 2 Misconception, and Not Understanding. This division aims to

identify students' understanding and misconceptions more deeply and definitively. Understanding: with details of correct answers with appropriate reasons; 26.8% of the total. This contrasts with the most common response of 41% (Don't Understand), which very clearly shows that there are some major problems in terms of understanding. The remaining responses were evenly split between two versions of Type 1 Misconception (16%) and Type 2 Misconception (16%), indicating that there were common reasoning errors in participants' answers and reasoning. Therefore, it was found that the level of misconception in the limited trial was in the medium range around 32% with the use of TTMCVR.

Based on the results of the TTMCVR analysis, it is revealed that students still mistake intermolecular H-bonds with intramolecular forces, so there is still a need for further development of submicroscopic structures (Chen et al., 2023). In addition, problems in applying the rules of polarity and solubility, which indicate difficulties in connecting formal learning with real-world situations. This is in line with cognitive load theory as simultaneous processing of macroscopic and submicroscopic information is likely to overload working memory and cause conceptual gaps (Johnstone, 1993). In addition, students had difficulty forming a correct submicroscopic model of the hydrogen bond network. This error often occurs due to an incorrect exchange between intermolecular hydrogen bonds and intramolecular forces, an error consistently noted in the chemistry education literature (Bruce et al., 2022) It is likely that some of these results are at least partly due to the abstract nature of hydrogen bonds, ionic bonds, covalent bonds and molecular shapes that require imagining submicroscopic interactions. These difficulties highlight the cognitive difficulties in connecting macroscopic phenomena with molecular-level explanations.

Therefore, the TTMCVR simulation is an alternative to early identification of students' understanding and misconceptions by creating an interactive environment for eliciting and deeply exploring the submicroscopic structure of molecules. Furthermore, when combined with more traditional scaffolding approaches, including lectures and problem-solving tasks, VR activities can also help deepen views on concepts and more systematically address misconceptions. Through this dual approach, which links macroscopic properties of materials, such as density and phase change, with the submicroscopic underpinnings of those same properties. Students can then develop further understanding and impact on the broad application of chemical bonding materials.

Based on the results of the effectiveness assessment obtained from an open questionnaire from teacher and student responses given to 3 teachers and 18 students who have used ethnochemically charged TTMCVR on chemical bonding material, a positive response to the developed learning assessment can be seen in Table 7.

Table 7. TTMCVR feasibility and effectiveness assessment result

No	Question	Skor
1	TTMCVR gave me an understanding of chemical bonding and molecular shapes	83%
2	Application of chemistry in daily life using TTMCVR according to the material studied	89%
3	The information contained in the TTMCVR is easy to understand	89%
4	The material presented in TTMCVR is easy to understand	90%

5	The TTMCVR experiment simulation instructions are easy to understand.	92%
6	The writing on the TTMCVR is legible	88%
7	The images and question text in TTMCVR are clearly visible	93%
8	The language in TTMCVR is simple and easy to understand	89%
9	The images in TTMCVR are attractive, clear and easy to understand.	90%
10	The voice of the practicum simulation in the TTMCVR is clearly audible	94%
11	The color composition in TTMCVR is interesting	94%
12	The appearance and layout of TTMCVR looks neat and attractive	90%
13	TTMCVR is simple to use	93%
14	TTMCVR can improve my understanding of chemical bonding materials	88%
15	I feel happy in learning when using TTMCVR	88%
16	I would like to have a TTMCVR for me to study at home	88%
	Average	90%

Based on the results of the questionnaire, an average of 90% was obtained which included 16 questions which can be seen in Table 7. This questionnaire contains assessment criteria with details, namely strongly agree (4), agree (3), disagree (2) and disagree (1) which includes the development of TTMCVR with ethnochemical content on chemical bonding material seen from the material and media aspects. Therefore, from the results of the questionnaire, TTMC is suitable for use as an alternative assessment integrated with ethnochemical virtual reality with very good criteria.

In addition to filling out the questionnaire on the instrument that has been given, teachers and students also provide comments and suggestions for further development related to ethnochemically charged TTMCVR on chemical bonding materials. The following input and suggestions can be seen in Table 8 from teachers while Table 9 from students

Table 9. TTMCVR feedback and suggestions from chemistry teachers

No	Comments	Addive
1	The use of Virtual Reality in learning can make it easier for students to understand chemical bonding material in real terms and be able to visualize the shape of molecules macroscopically and real	It needs to be developed again for other materials and other local cultural approaches and also think about the affordability of purchasing power for users, especially in the scope of schools
2	A cultural approach can help students to learn more about the application of chemical bonds in everyday life	The continuous use of VR can make students feel dizzy, alternative tools that can visualize VR can be considered
3	The use of TTMC is also a new breakthrough for students in order to reduce the assumption of answers that should see the experiment first in order to answer the question	Features in VR need to be added more deeply regarding student needs such as providing material, practice questions, and practicum so that it has many functions
4	VR as a tool that can and has the potential to be applied as a virtual practicum for students to practice like playing games and fun for learning.	

Table 10. TTMCVR feedback and suggestions from students

No	Comments	Addive
1	The use of virtual reality (VR) can create a more immersive and interesting learning experience so that students are more actively involved in the learning process. Visualization of molecules and chemical processes in VR can help students understand abstract concepts better	The use of VR is quite heavy when used for too long so it is quite uncomfortable, so a lighter alternative can be provided when used for learning
2	Good and interesting, because practicum using VR is not troublesome because the tools and materials have already been prepared and do not pose a dangerous risk when working	After practicing and answering questions, a discussion and correct answers can be given
3	Chemistry learning becomes fun and not monotonous when using VR integrated TTMC becomes clearer and easier to understand	The controls during the experiment were made smoother and easier to slide to retrieve materials and tools
4	The instructions for using VR with TTMC are easy to use, and can find out more about multiple choices that have reasons so that it makes us think more critically to find answers according to the experiments that have been carried out	VR goggles may be further reduced and can be adapted to various head sizes of students in conducting practicum There is an additional feature about
5	TTMC-based VR is interesting to use in learning, making it easier for students to visualize the molecular shape of chemical bonds in 3D	There is an additional feature about returning to the previous question and being able to correct the answer before moving on to the next trial and question

Based on the results of the open questionnaire regarding TTMCVR, there are several comments and suggestions for further improvement of the developed assessment. Teachers and students have an interest in the use of TTMCVR with the advantages of real visualization and helping to increase understanding which in schools cannot be taught directly, so the presence of TTMCVR is very positive and has the potential to be used in the continuation of other learning. In addition, it is also expected that TTMCVR can be applied to materials related to the 3 levels of representation and other ethnochemical approaches to review the usefulness of the assessment development.

Evaluation

This evaluation stage aims to see how the effectiveness and readability of the development of ethnochemically charged TTMCVR on chemical bonding material where overall this assessment is able to detect the level of misconceptions and understanding of students who offer real images, designs, colors and animations. In addition, chemical bonding material associated with ethnochemistry is able to increase knowledge for students and is supported by the results of product trials which obtained mixed results regarding the criteria for understanding, not understanding and misconceptions as well as

positive responses from teachers and students and input and suggestions can later be used to improve further development of TTMCVR.

▪ CONCLUSION

Based on the results of the Aiken index validity of ethnochemically charged TTMCVR on chemical bonding material, both 15 question instruments and 16 storyboard indicators show the level of validity with the Aiken index ≥ 0.73. This category indicates that TTMCVR has feasibility in terms of media, content and use which has suggestions and input from experts to make improvements. In addition, related to the use of TTMCVR as an assessment conducted on a limited trial with 3 teachers and 18 students in 3 public schools in Surakarta that TTMCVR is able to detect the level of understanding and misconceptions of students with criteria, namely understanding the concept of 26%, misconceptions 32% and not understanding 41% on etnochemistry chemical bond material. In addition, TTMCVR as an alternative assessment from the material and media aspects of 90% from students and 95% from chemistry teachers. Therefore, based on the results of the validity and effectiveness of TTMCVR, it shows that this assessment is suitable for use in learning.

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