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# Development of Electronic Student Worksheets Based on Multiple Representations for High School Students on the Topic of Buffer Solutions

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**Abstract:** The objective of this study is to develop an electronic student worksheet that utilizes multiple representations for high school students studying buffer solutions. This electronic student worksheet was created using the 4D development methodology, which encompasses the following stages: Define, Design, Develop, and Disseminate. The electronic worksheets underwent a validation process conducted by an expert validator. Field trials have been conducted and revised by developers, resulting in a valid and practical electronic student worksheet. The research outcomes indicate that the validity assessment by material and media validators falls under the category of highly valid. The practicality test conducted on six chemistry teachers from several high schools in Pekanbaru is categorized as highly practical. The small-group trial conducted with six 12th-grade science students from SMAN 5 Pekanbaru has been categorized as highly practical. Field trial on 30 12th-grade science students from SMAN 5 Pekanbaru resulted in the category of being highly practical. The conclusion drawn is that the electronic student worksheets based on multiple representations developed with a 4-D model is valid, practical, and it can be used in chemistry education at schools.

**Keywords:** Buffer solutions; Electronic student worksheets; Multiple representation

## Introduction

The advancement of science and technology signifies the progress of the era. Currently, technology has evolved into the digital stage. This includes Indonesia, where every field has embraced technology to facilitate tasks, including education. Technology in the realm of education aids in the execution of teaching and learning processes. This aligns with the perspective put forth by Tondeur et al., who assert that digital technology is increasingly penetrating the field of education, serving either as an information tool (for accessing information) or as a learning tool (facilitating learning activities and tasks) (Lestari, 2018). One of the readily available technologies nowadays is the smartphone. According to data released by the Ministry of Communication and Informatics, as many as 89 percent of the total Indonesian population has adopted smartphones (Bharata & Widyaningrum, 2021). However, in reality, this technology has not been used effectively in the field, resulting in less interesting learning and students becoming less active (Fadloli et al., 2019; So et al., 2019; Wati & Istiqomah, 2019). Instructional media that combine technology and instructional materials have a positive impact on learners, particularly for learning activities (Apriani et al., 2021). This is highly important for teachers to develop instructional materials supported by smartphone technology, which can be utilized in chemistry education.

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One of the instructional resources that can be employed in the educational process is student worksheets (Abdurrahman, 2015). Student worksheets comprise instructions, procedures, and exercises encompassing both theoretical and practical aspects. The use of student worksheets in the learning process has a positive impact. Students gain a more enjoyable learning experience, foster interactivity, provide opportunities for students to learn actively, and serve as motivation for students throughout their educational journey (Elviana et al., 2024). However, after the learning session is completed, these Student Worksheets can only be studied by students themselves without feedback from the instructor. Given this, there exists a necessity to create student worksheets that not only facilitate interaction between students and instructors within the school setting but also but also encourages interaction even beyond the classroom setting. The learning resources that are often used in learning only use limited print media and do not attract student motivation and independent learning (Nurkhasanah & Rohaeti, 2024). For this reason, appropriate learning media are needed to perfect it through electronic student worksheets. The expected benefit of using Student Worksheets is to facilitate students in directly responding to Student Worksheets questions within the device. Therefore, as technology advances, instructional materials need innovation, such as electronic Student Worksheets.

One distinguishing feature of chemical materials is their incorporation of three levels of representation: macroscopic, submicroscopic, and symbolic (Wiyarsi et al., 2019). The macroscopic representation encompasses observable and perceptible aspects that illustrate the properties of substances, such as variations in solution pH, the formation of precipitation, temperature changes, and so forth. Submicroscopic representation involves understanding and explaining observations of objects that are invisible and abstract, like the movement of electrons, particles, atoms/ions, and others. Symbolic representation is a form of representation that encompasses both quantitative and qualitative aspects, such as reaction equations, chemical formulas, mathematical formulas, mathematical calculations, and others (Baptista et al., 2019; Gabby et al., 2017). The lack of application of these three representations in learning is one of the factors causing chemistry material to be difficult for students to understand because in chemistry there are many abstract concepts (Sundami & Azhar, 2019). Kelly et al. (2017) state that when learning involves macroscopic, submicroscopic, and symbolic representations, Students attain a heightened level of comprehension. Therefore, these three levels should be explicitly taught to ensure that students easily comprehend the taught chemistry concepts.

Chemistry is a compulsory subject for high school students majoring in the Science stream in Indonesia. Chemistry comprises numerous abstract concepts (Kirik & Boz, 2012). Abstract chemistry topics such as the concept of moles, chemical formulas, chemical laws, and principles make chemistry lessons difficult for students to understand (Ristiyani & Bahriah, 2016; Şendur et al., 2010). Buffer solutions constitute a chemistry subject typically covered in the 11th-grade high school curriculum. The buffer topic is filled with theory and mathematical calculations, necessitating clear analysis and conceptual understanding (Sariati et al., 2020). Hence, it is essential to devise appropriate strategies and teaching materials to address students' difficulties in comprehending buffer materials.

Buffer solutions are one of the topics that largely involve abstract concepts. These abstract concepts can lead to misconceptions. Understanding a concept is not merely achieved through rote memorization; it requires comprehension so that the learned concepts are not easily forgotten (Marsita et al., 2010). Based on the research outcomes of Yakina et al. (2017), students' learning outcomes regarding buffer topics were unsatisfactory. This is attributed to students memorizing concepts and formulas only. Furthermore, chemistry education tends to focus solely on the macroscopic and symbolic levels, often neglecting the submicroscopic level (Sunyono et al., 2013). Ignoring one aspect of multiple representation, students only memorize the material without fully understanding the concept, reducing the quality of chemistry learning in schools (Syam & Louise, 2023). Therefore, a method is needed to enhance students' understanding of buffer materials by employing multiple representations that can depict buffer concepts, enabling students to observe occurring phenomena, analyze them, and draw well-founded conclusions (Li & Arshad, 2014; Sari et al., 2023). It's crucial for educators to choose an appropriate model to address students' difficulties in comprehending chemistry topics, particularly regarding buffers (Sari & Seprianto, 2018).

Based on the preliminary research conducted at SMAN 5 Pekanbaru, It is widely acknowledged that educators continue to employ the discovery learning model in alignment with the directives outlined in the 2013 curriculum. Instructors believe that this model is easily applicable and comprehensible for the learners. However, the recommended general teaching model under the K-13 curriculum doesn't explicitly demonstrate the instructional stages leading to the three chemistry levels and their interconnections. This is in line with Tasker & Dalton's viewpoint, who assert that science education generally involves there exist two tiers of representation, specifically the macroscopic and symbolic levels (Sunyono, 2015).

Previously, scholars have undertaken the creation of student worksheets grounded in multiple representations. Meutia et al. (2021) focused on the topic of factors influencing reaction rates, stating that their developed material was suitable for instructional use and received highly positive responses from both students and teachers. Yanni et al. (2021) worked on the topic of colligative properties of solutions, affirming the effectiveness of their multipel-representation-based teaching materials in enhancing scientific process skills. Pratiwi et al. (2018) worked on solubility and solubility products, creating practical materials deemed suitable and valid for laboratory activities to enhance scientific process skills. In this ongoing research endeavor, the creation of Student Worksheets employing multiple representations will be undertaken to enhance students' comprehension of buffer solution concepts.

## Method

The research methodology applied in this study is Research and Development (R&D). Electronic Student Worksheets, founded upon multiple representations, are crafted using the 4D development model introduced by Thiagarajan. The stages utilized within the 4D development model encompass definition, design, development, and dissemination (Mulyatiningsih, 2016). The steps to be carried out are shown in Figure 1. The research cohort comprises two validators (experts in materials and media), six chemistry educators, and 12th-grade science students from a senior high school located in Pekanbaru. Validity analysis is the data analysis technique employed in this research. The instruments used consist of materials validation sheets, media validation sheets, readability sheet for student, and practicality sheets for teacher. The items in the validity instrument for Electronic Student Worksheets are modified from the National Education Standards Agency (BNSP), encompassing content appropriateness, presentation appropriateness, language, and graphics.

*Analysis of Validation Sheets for Electronic Student Worksheets*

The validity of electronic worksheets founded on multiple representations is determined through the application of Aiken's equation (as presented in Bashooir & Supahar, 2018) as follows:

$$V = \frac{\sum(r_i - l_o)}{[n(c-1)]} \quad (1)$$

Information:
ri = the value obtained from the assessor
c = highest validation number
lo = lowest validation number
n = the number of experts and practitioners who assess
The criteria for expert validity scores are presented in Table 1.

**Table 1.** Criteria for Expert Validity Value

| Validity results | Validity criteria |
|---|---|
| Highly valid | $0.80 < V \leq 1.00$ |
| Valid | $0.60 < V \leq 0.80$ |
| Quite valid | $0.40 < V \leq 0.60$ |
| Less valid | $0.20 < V \leq 0.40$ |
| Invalid | $0.00 < V \leq 0.20$ |

*Readability and Practicality Analysis*

The feasibility of Electronic Student Worksheets centered on multiple representations can be evaluated through quantitative data using a 1-5 Likert Scale. To compute the average scores, the following equation can be employed based on the quantitative data collected (Arikunto, 2009).

$$\bar{x} = \frac{\Sigma X}{n} \quad (2)$$

Information:
$\bar{x}$ = Average score
ΣX = Sum of scores for each aspect
n = Total respondents

Next, calculate the percentage of results using the following equation:

$$Percentage\ of\ Yield = \frac{Score\ obtained}{Maximum\ score}\ x\ 100\% \quad (3)$$

The criteria for product suitability can be observed in Table 2.

**Table 2.** Criteria for the Suitability of Electronic Student Worksheets (Riduwan, 2013)

| Category | Score (%) |
|---|---|
| Very practical | 81-100 |
| Practical | 61-80 |
| Quite practical | 41-60 |
| Less practical | 21-40 |
| Not practical | <21 |

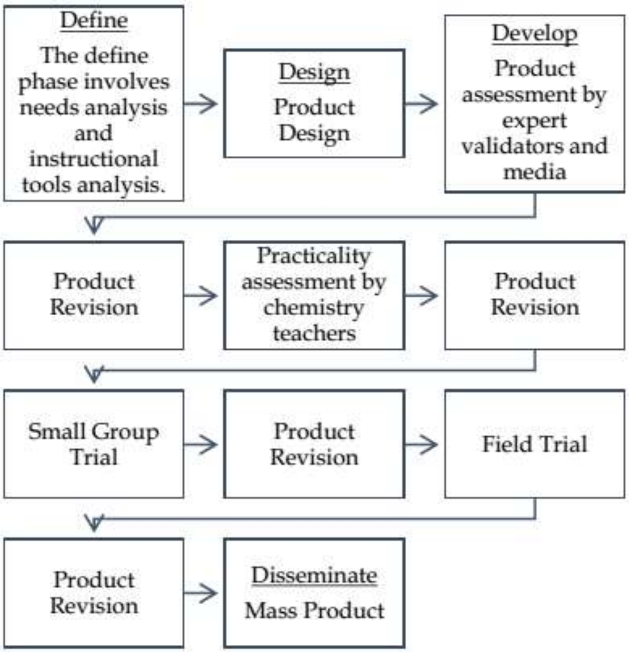


**Figure 1**. Research flow

## Result and Discussion

Electronic student worksheets grounded in multiple representations have been devised for senior high school students following the 4D development model, which encompasses the phases of definition, design, development, and dissemination. These electronic learning materials can be accessed on both smartphones and laptops.

The define phase involves needs analysis and instructional tools analysis. The needs analysis encompasses an examination conducted among teachers and students in the school. Drawing upon the outcomes of interviews with teachers, it was found that the developed buffer solution student worksheet lack the microscopic aspect. However, this element is crucial for students to overcome their difficulties. Interviews with students revealed that they find the buffer solution material challenging due to its incorporation of concepts, experiments, and calculations. Hence, instructional materials are required that incorporate multiple representations (microscopic, macroscopic, and symbolic) through animated content and videos. Student worksheets are teaching materials that can develop students' overall abilities (Yulkifli et al., 2019). Students can use student worksheets to better understand the material (Fitri et al., 2019; Yunitasari & Pratama, 2024).

The analysis of instructional tools encompasses the learning resources employed in chemistry education. The learning resources utilized consist of textbooks and printed student worksheets. The description of the buffer solution material can be found in Table 3.

**Table 3**. Buffer Solution Material

| Basic competencies | Subject matter |
|---|---|
| | Buffer solutions: |
| 3.12. Explain the working principle, pH calculation, and role of buffer solutions in the body of living things | -Properties of buffer solutions<br>-pH buffer solution |
| 3.14. Creating a buffer solution with a certain pH | -The role of buffer solutions in the body of living things and industry (pharmaceuticals, cosmetics) |

The design phase is executed through the creation of electronic student worksheets pertaining to the topic of buffer solutions. This electronic student worksheet comprises a cover, electronic student worksheets user guide, instructional guidelines, basic competencies, core competencies, learning objectives, concise content, session 1 on the properties of buffer solutions, session 2 on the pH of buffer solutions, session 3 on the role of buffer solutions, laboratory activities, questions, answer key following the questions, and a bibliography.


**Figure 2.** Partial presentation of the electronic student worksheets content

The development stage involves assessing the feasibility of electronic student worksheets using multiple representations, utilizing a modified validation sheet from the National Education Standards Agency

(BSNP). The suitability of these electronic student worksheets is evaluated by subject material experts and media experts as validators. Both validators are faculty members within the Faculty of Mathematics and Natural Sciences at the University of Yogyakarta. The dissemination phase involves acquainting students and teachers at a high school in Pekanbaru with the electronic student worksheets based on multiple representations. The interface of the electronic student worksheet grounded in multiple representations is depicted in Figure 2.

*Results of Content Validation for Electronic Student Worksheets*

Content validation centers on assessing the content of the electronic Student Worksheets through evaluation by expert validators in the field of chemistry. The outcomes of content validation for the electronic Student Worksheets (LKPD) are presented in Table 4.

**Table 4.** Results of Content Validation for Electronic Student Worksheets

| Aspects | $\sum (r_i-l_o) / n(c-1)$ | Category |
|---|---|---|
| Learning objectives | 0.94 | Highly valid |
| Fill | 0.81 | Highly valid |
| Language | 0.83 | Highly valid |
| Average score | 0.86 | Highly valid |

Table 4 reveals that the average score for the content validation results of the electronic Student Worksheets is 0.86, classifying it as "very high." The learning objective obtained a score of 0.94, the content scored 0.81, and the language aspect scored 0.83. According to the evaluation by the material validator, the student worksheets centered around multiple representations on buffer solution materials for senior high school students are considered highly valid. Suggestions and comments from the material validator include improving the writing in accordance with the Standard Indonesian Language (EYD).

*Results of Media Validation for Electronic Student Worksheets*

The objective of media validation is to ascertain the effectiveness of the electronic student worksheets in supporting the learning process. The outcomes of Expert Media Validation are outlined in Table 5.

**Table 5.** Findings from the Expert Media Validation

| Aspects | $\sum (r_i-l_o) / n(c-1)$ | Category |
|---|---|---|
| Serving | 0.88 | Highly valid |
| Multiple representations | 0.81 | Highly valid |
| Graphic design | 0.81 | Highly valid |
| Software engineering | 0.84 | Highly valid |
| Average score | 0.84 | Highly valid |

Table 5 shows that the average score of the validation results for the electronic student worksheets media is 0.84, categorized as highly valid. Suggestions and comments from material validators include slowing down the pace of videos and intonation to facilitate students' understanding of the conveyed material. Student worksheets are suitable for use if all components meet the minimum valid criteria (Suryanti & Festiyed, 2023).

*Results of Practicability Test by Chemistry Teachers*

The revised product, based on validator feedback, was subsequently subjected to a practicability test. The practicability test was carried out as a product development trial involving chemistry teachers on the electronic student worksheets grounded in multiple representations. The chemistry teachers involved in the research amounted to six individuals. These six chemistry teachers were from SMAN 5 Pekanbaru (3 individuals), SMAN 6 Pekanbaru (1 individual), SMAN 11 Pekanbaru (1 individual), and SMAN 14 Pekanbaru (1 individual). The outcomes of the feasibility test are displayed in Table 6.

**Table 6.** Results of Practicability Test by Chemistry Teachers

| Aspects | Average | Practicality (%) | Category |
|---|---|---|---|
| Material | 4.83 | 96.67 | Very practical |
| Serving | 4.72 | 94.44 | Very practical |
| Multiple representations | 4.25 | 85.00 | Very practical |
| Graphic design | 4.72 | 94.44 | Very practical |
| Software engineering | 4.72 | 94.44 | Very practical |

Table 6 demonstrates that all aspects evaluated by the six teachers fall within the highly practical category. Teaching materials are said to be in the practical category if the product produced is easy for users to use (Kurniasih & Rahayu, 2017). Apart from that, the practical criteria for electronic worksheets are that they are easy to learn and understand (Magdalena et al., 2021). This assertion finds support in the study conducted by Rusmansyah et al. (2023) which posits that educational outcomes can be improved when learning is contextualized within everyday life.

*Results of Small Group Trial*

The revised product, based on feedback from teachers, was subsequently subjected to a small group trial involving six students from SMAN 5 Pekanbaru. The results obtained from the small group trial are presented in Table 7.

**Table 7.** Results of Small Group Trial

| Aspects | Average | Practicality (%) | Category |
|---|---|---|---|
| Material | 4.67 | 93.33 | Very practical |
| Serving | 4.64 | 92.78 | Very practical |
| Graphic design | 4.67 | 93.33 | Very practical |
| Functions and benefits | 4.50 | 90.00 | Very practical |

Table 7 indicates that all assessed aspects fall under the category of highly practical. Subsequently, the electronic student worksheets underwent a field trial. In the aspect of impact on users during small group trials, participants assessed that electronic student worksheets had a positive impact on them because they could better understand the material presented in the various multimedia content and electronic worksheets provided. They are also easy to use and suit the mindset of educational participants (Artika et al., 2024).

*Results of the Field Trial*

A field trial of the electronic student worksheets was conducted with 30 participants from 12th grade at SMAN 5 Pekanbaru. The data from the field trial results are presented in Table 8.

**Table 8.** Results of Field Trial

| Aspects | Average | Practicality (%) | Category |
|---|---|---|---|
| Material | 4.18 | 83.61 | Very practical |
| Serving | 4.26 | 85.28 | Very practical |
| Graphic design | 4.25 | 85.00 | Very practical |
| Functions and benefits | 4.38 | 87.59 | Very practical |

Table 8 demonstrates that all assessed aspects in the field trial obtain a highly practical qualification. The results stemming from the development of electronic student worksheets can be integrated into chemistry education within school settings. Student responses to multiple representation-based teaching materials showed a positive response (Helsy et al., 2017). The multiple representation-based teaching materials developed were well received responses from teachers and students (Noor et al., 2019). In accordance with the research findings, the development of electronic student worksheets seeks to provide learners with guidance in engaging in various activities essential for improving learning outcomes (Asma et al., 2020; Haryanto et al., 2020).

Printed worksheets tend to be informative yet less engaging due to their inability to incorporate sound, video, and animations that can provide clear explanations of the intended concepts. electronic student worksheets are more flexible, encompassing a wide array of information in the form of videos, images, and audio, thereby enhancing the learning experience (Costadena & Suniasih, 2022). Based on Lafifa et al. (2022) outcomes, the utilization of electronic student worksheets can heighten students' learning motivation. Moreover, electronic student worksheets have a favorable influence on the learning process, free from constraints related to space and time. The development of electronic student worksheets should be pursued to foster effective and efficient learning. Consequently, student worksheets based on multiple representations can stimulate students' learning independence (Meutia et al., 2021).

## Conclusion

Electronic worksheets founded on multiple representations for high school students, covering the topic of buffer solutions, have been effectively crafted and can be put into practice, as evidenced by the results of validator evaluations and practicality testing. The electronic student worksheets based on multiple representations developed with a 4-D model is valid, practical, and it can be used in chemistry education at schools.

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Tengku Afdhaluz Zikri, contributed designing research, conducting research, and writing article. Sri Handayani, plays a guiding role in the process of carrying out research and writing articles.

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**Conflicts of Interest**

There is no conflict of interest.

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