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Developing an Augmented Reality-Assisted Worksheet to Support the Digital Science Practicum

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Abstract: The purpose of this research is to develop a worksheet that can support a digital science practicum. Conducting a needs analysis comes first in the development of worksheets, then comes product creation. The product produced based on the needs test analysis is a worksheet with the help of science worksheet-augmented reality (SWAR). Two knowledgeable education professionals then evaluate the finished product and test it out on participants or students. The results of the study show that worksheets equipped with augmented reality media are necessary. Meanwhile, the resulting product is valid in an almost perfect category (Pe = 0.7219; Po = 0.9744; K = 0.9078). Student perceptions of the products produced are at an "excellent" level in each category (ME-Av, mean = 3.466; CO-Av, mean = 3.472; CT-Av, mean = 3.503; ST-Av, mean = 3,507; TA-Av, mean = 3.440; IN-Av, mean = 3.640; MO-Av, mean = 3.640). There is a significant inverse relationship between media features (ME-Av) and student interest (IN-Av) based on Pearson's correlation test with r = -.50 (p < .50). Further explanation is presented based on the data that has been collected.

Keywords: *Augmented reality, learning technology, digital science practicum.*

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Introduction

The 21st century learning requires students to have various skills that can be used to solve problems that arise through the role of technology (Wijaya et al., 2016). The learning process should be supported by a learning model that directs students to thinking skills such as critical thinking so that they are able to solve various problems that arise in the real world and decide on solutions (Butler et al., 2017). Regarding the skills that need to be mastered, learning media is important to help students master 21st century skills so that they can have good competitiveness in the world of work, especially in the post-pandemic situation of COVID-19, where learning media in digital form is increasingly developing for distance learning.

The type of learning in educational institutions is growing even though the pandemic is over. Various types of learning that utilize digital media vary greatly, for example, by applying blended learning (Hikmah & Chudzaifah, 2020), using WhatsApp groups (Susilawati & Supriyatno, 2020), and hybrid learning (Agustini & Ngarti, 2020). Thus, there will be a change in learning models that were previously based on direct instruction towards learning that involves digital learning media. The results of the study state that through digital media, students will have more positive learning outcomes and can increase their commitment to learning (Tabor & Minch, 2013). Thus, learning media has an important role because it can stimulate students' interests, thoughts, and attention so that they are better prepared to receive subject matter from the teacher (Akrim, 2018).

New digital technology is transforming the world of education, both in terms of formal and informal learning (Burbules et al., 2020). Previous studies suggest technological innovation in teacher education because teachers play an important role in designing learning (Laferrière et al., 2006). Thus, preparing future science teacher candidates needs to be accompanied by the utilization of digital media, including when online learning is implemented. Unfortunately, based on preliminary studies conducted by researchers, online learning process is still limited to using e-learning platforms, so the application of digital media needs to be optimized further. To optimize digital-based learning, one of the efforts that have been made by teacher educators is to enrich teaching materials from social media sites such as YouTube. The study of

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Noetel et al. (2021) revealed that videos embedded in learning at the tertiary level can have a positive influence on improving student learning. In addition, videos applied to learning provide greater benefits when students have high learning motivation compared to students with low motivation (Yang et al., 2021). However, research by Afify (2020) reveals that effective use of videos in class applies if the duration of the video presented is less than six minutes. Thus, we need a digital learning medium that can facilitate prospective science teachers' mastery of the material, both in terms of knowledge and psychomotor skills, as well as technology literacy.

Learning with technology integration for prospective teachers needs to be developed (Alelaimat et al., 2020). The types of learning technology offered today are very diverse, and one of the media that is trending and is expected to be able to facilitate learning activities, especially in science practicum activities, is augmented reality (AR) media. In learning activities such as science practicums, AR technology is able to present virtual information (Carmigniani & Furht, 2011) during practicum activities and results by simply scanning them using a smartphone, so that it is as if students are experiencing real practicum through 3D virtual information. Through AR that can be used with smartphone devices, it is possible for users to see real-life environments with digital augmentation overlays (Institute, 2023). Several previous studies revealed that AR media in science learning has a positive effect on student achievement and attitudes (Sahin & Yilmaz, 2020), as well as laboratory skills (Akçayır et al., 2016). In addition, (Petrov & Atanasova, 2020) investigated students' learning performance before and after using AR tools in science, technology, engineering and mathematics (STEM) education, and the results showed that there were substantial improvements in student understanding.

In practice, AR technology cannot stand alone because a marker is needed so that a 3-dimensional virtual view can appear on the user's smartphone screen. To support and guide students during practicum, worksheets can be an alternative that is applied to achieve the objectives of learning activities (Kaymakci, 2012). Several previous studies have developed worksheets equipped with AR media, for example, on optical materials (Bakri, Ervina, et al., 2019) and heat experiments (Bakri, Pratiwi, et al., 2019), and the resulting products are in the very good category. Herliandry et al. (2021) also mentioned that AR-assisted worksheets can be used to practice critical thinking skills on science concepts. Based on previous research, there is a gap in developing integrated science worksheets equipped with augmented reality that aim to train students' critical thinking skills. Previous studies reveal that AR has advantages in improving or stimulating students' critical thinking skills (Bakri, Ervina et al., 2019; Elmunsyah et al., 2022; Zuniari et al., 2022).

In addition, the combination of AR in worksheets aims to optimize the role of worksheets in the learning process. The worksheet itself, which is a learning tool, does not always have a positive impact on students. Prior study regarding the reasons for not using worksheets in learning can be caused by several weaknesses that worksheets have, such as inhibiting learning through play, restricting freedom of movement by desk-bound activity, ignoring gross motor skill development, and restricting curiosity (Simsek, 2023). Therefore, combining AR technology with worksheets is expected to optimize the role of worksheets in learning. Based on this background, researchers aim to know students' responses and perceptions of AR-assisted worksheets, or what in this research is called science worksheet-augmented reality (SWAR), which was developed in science practicum activities. Referring to this information, the research questions formulated are as follows:

RQ 1: How do students respond to AR-assisted worksheets as a learning media?

RQ 2: How are students' perceptions of the product being developed, and what is the relationship among categories about perception of SWAR?

Methodology

Research Design

The descriptive analysis method (Kemp et al., 2018) was used to obtain information about the results of needs analysis, validity, and students' perceptions (prospective science teachers) of a product that will be used in the teaching and learning process in school science practicum courses. The product being developed is an integrated science worksheet equipped with AR media accompanied by critical thinking questions on the theme of acid rain and ecosystem balance, hereinafter referred to as SWAR. The developed SWAR also applied the science, technology, engineering, and mathematics (STEM) approach to the learning stages section of the worksheet.

Participants

Students or prospective science teachers are the main participants in this study. There were three groups of participants involved in this study. The first are the participants involved in the product needs analysis process, which was conducted on 71 prospective science teachers in the second-year undergraduate program (n=71). Second, the participants are experts who have sufficient ability to assess the product being developed, namely two observers (n=2) who are academic staff in the science education study program. Third, the participants involved in this study were 25 science teacher candidates who had tried the SWAR products that had been developed (n=25).

Procedures

This research begins with conducting a needs analysis of the product being developed. After the needs analysis data was collected, product component designs are carried out based on the results of the needs analysis. The design stage consists of compiling the components that must exist in the developed SWAR. The next stage was the development or production of SWAR based on the designs that have been made. During the development phase, SWAR was validated by multiple experts in their respective disciplines to determine the level of SWAR's validity and then revised until the product is valid. Products that have been validly implemented (pilot tested) to determine student perceptions of the product being developed. At the implementation stage, researchers conducted an analysis of students' perceptions of SWAR to produce an overview of the resulting product. An overview of the procedure flow in SWAR development can be seen in Figure 1.

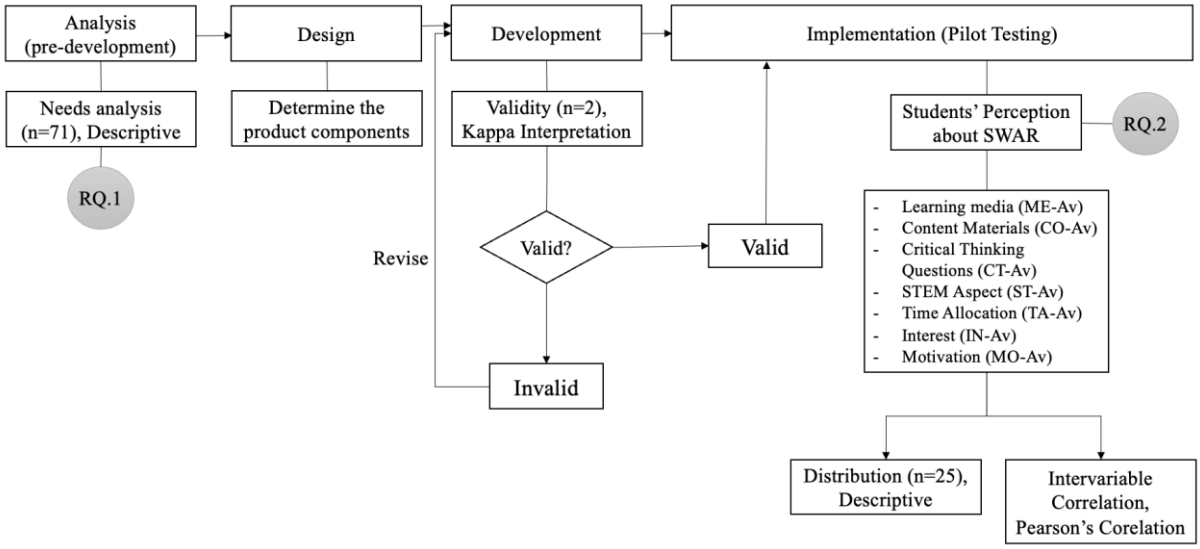

Figure. 1. Research Procedure Based on the Research Questions (RQ)

Instrumentation

This study has three research questions about the SWAR product development process. The instrument used examine needs analysis questionnaire (hereinafter referred to as IN-1), which consists of 11 statement items using the Gutman Scale with the "Yes/No" dichotomy format (Engelhard, 2005), which was classified into 2 categories, namely needs of worksheets during learning (NW) and needs of AR (NA). Like IN-1, the validity questionnaire (hereinafter referred to as IN-2) that was developed consists of 39 item statements about SWAR consisting of aspects of content feasibility (6 items), language (3 items), content presentation (3 items), graphics (6 items), STEM content (1 item), critical thinking content (3 items), and AR media (17 items) and used the Guttman Scale with a "Yes/No" dichotomy format (Engelhard, 2005). Meanwhile, the student perception questionnaire (hereinafter referred to as IN-3) used a Likert scale with a choice of 4 points (1=poor, 2=fair, 3=good, 4=excellent) (Bernstein, 2005) to analyze student perceptions of SWAR. IN-3 consists of 33 items stating students' perceptions about SWAR, which were grouped into seven categories or aspects, consisting of features of media (ME-Av, n=9), feasibility of content and materials (CO-Av, n=5), critical thinking questions (CT-Av, n=7), STEM aspects (ST-Av, n=3), time efficiency (TA-Av, n=2), students' interest (IN-Av, n=3), and motivation (MO-Av, n=4).

Data Analysis

Based on the instruments that have been determined, data analysis on IN-1 was carried out by calculating descriptive statistics in the form of percentages presented per item based on NW and NA categories. Furthermore, data analysis on the IN-2 instrument was carried out by calculating the Kappa coefficient, which was interpreted based on the agreement range generated by the Kappa value, K (< 0.0=less than chance agreement; 0.01-0.20=slight; 0.21-0.40 = fair; 0.41-0.60=moderate; 0.61-0.80=substantial; 0.81-0.99=almost perfect) (Viera & Garrett, 2005). Meanwhile, to analyze the data on IN-3, two analyses were carried out: calculating the perception index of each category descriptively and calculating the correlation using JASP software (JASP Team, 2023) to investigate the relationship between various categories of student perceptions that had been determined using Pearson's correlation. The perception index of the IN-3 instrument is interpreted using the Likert four-point scale interpretation (Nee & Yunus, 2020) as follows: 1.00-0.99=poor, 1.99-1.00=fair, 2.99-2.00=good, and 4.00-3.00=excellent.

Findings/Results

The data was obtained based on data analysis on the IN-1, IN-2, and IN-3 instruments. First, percentage calculations using the Gutman scale with the format "yes" and "no" were carried out on IN-1 to analyze the need for teaching materials in

digital-based practicums. Second, expert validation was carried out by assessing the SWAR product by two experts who directly test and try it and then provide an assessment on the IN-2 questionnaire sheet. Data regarding the level of validity was then calculated using the Kappa agreement interpretation formulation. Third, students' perceptions of SWAR products that had been developed to find out whether the resulting products can be properly categorized and identify student perceptions of the products produced using IN-3.

The Responses of Students (Prospective Science Teachers) for Worksheets Assisted by Digital-based Learning Media in the Form of AR (RQ 1)

As seen in Table 1, which is the result of data processing from IN-1, in the NW category, 90% of respondents (n=71) knew what a worksheet was [NW1], and 77.10% had used a worksheet as a medium in carrying out their practicum [NW2]. Based on the data, it is known that 98.6% of students have an interest in learning [NW3] and have high motivation (97.10%) when the practicum is equipped with a worksheet [NW4]. Regarding the need to learn to use worksheets, 94.30% of respondents stated that worksheets were needed when science practicums were carried out [NW5]. In the NA category, more than half of respondents (61.40%) already know what AR is [NA1]. 85.70% of respondents expressed interest [NA2] and 80.00% were motivated [NA3] if the practicum was equipped with AR technology. In addition, 85.70% of students stated that a technology-assisted practicum using AR was necessary [NA4]. Respondents stated that when compared with e-learning learning, 60% were more interested in using AR [NA6], but when compared with direct practicum in the laboratory, only 11.40% of respondents stated that they were interested [NA5].

Table 1. Students' Response for Worksheets Assisted by AR

	Items	Response (%)	
		Yes	No
NW	**Student responses of worksheet**		
NW1	I know what worksheet is.	90.00	10.00
NW2	I have used the worksheet in practicum.	77.10	22.90
NW3	I am interested if the practicum using worksheet.	98.60	1.40
NW4	I am motivated when I used worksheet during practicum.	97.10	2.90
NW5	I need a worksheet to run my practicum	94.30	5.70
NA	**Student responses of AR**		
NA1	I know what AR is.	61.40	38.60
NA2	I am interested if the practicum is equipped with AR.	85.70	14.30
NA3	I am motivated if the practicum using AR.	80.00	20.00
NA4	Technology-assisted practicum using AR is needed.	85.70	14.30
NA5	I am interested to do the digital practicum than conventional practicum.	11.40	88.60
NA6	I am more interested to use the AR than e-learning when practicum.	60.00	40.00

Validation is the process of determining whether or not a product feature meets the needs of the user (Dunbar, 2019). Validation was used to determine the feasibility of a product and measure its feasibility, which was reviewed by experts (n=2). Validation was carried out by two observers to assess SWAR products based on several criteria using the IN-2 instrument. Experts carry out an assessment by examining the worksheets developed and testing the AR features combined with these worksheets. Table 2 shows that the developed SWAR product has a K value of 0.9078 (almost perfect), meaning that the SWAR product is valid according to the expert. SWAR products reviewed by experts have sufficient validity and show that they can be tested.

Table 2. Interobserver Variation of Product Validity

		Observer 1			Pe	Po	Kappa, K	Interpretation
		Yes/ Valid	No/ Invalid	Total				
Observer 2	**Yes/ Valid**	32	1	33	0.7219	0.9744	0.9078	almost perfect
	No/ Invalid	0	6	6				
	Total	32	8	39				

Students' Perception Analysis of the SWAR and Its Relationship (RQ 2)

The SWAR that has been validated were then given to students (n=25) to be tested. Students assessed the SWAR from the user's point of view. Table 3 shows that respondents gave positive responses to the seven categories of IN-3 items. The interest and motivation categories showed the highest average scores, both of which were 3.640. The respondent's perception data shows that SWAR are interesting and can increase learning motivation. Meanwhile, the lowest perception is in the category of media use (3.466). Examples of statement items in IN-3 that are used to capture student perceptions of SWAR products can be seen in Table 4.

Table 3. Descriptive Statistics for Students' Perception in Each Category

	ME-Av	CO-Av	CT-Av	ST-Av	TA-Av	IN-Av	MO-Av
Valid	25	25	25	25	25	25	25
Mean	3.466	3.472	3.503	3.507	3.440	3.640	3.640
Std. Error of Mean	0.029	0.040	0.041	0.064	0.073	0.051	0.043
Std. Deviation	0.146	0.199	0.206	0.322	0.363	0.255	0.217
Variance	0.021	0.040	0.042	0.104	0.132	0.065	0.047
Minimum	3.220	3.000	3.000	3.000	3.000	3.330	3.250
Maximum	3.780	3.800	3.860	4.000	4.000	4.000	4.000

Overall, the data shows that students' perceptions of the AR media being developed are in the range above 4.00, which means they are in the excellent range. Students' good perception of AR media features (ME-Av, mean = 3.466), which were developed, makes this product suitable for use in the learning process. In addition, in terms of the material (CO-Av, mean = 3.472) presented in SWAR, respondents stated that the material contained in the worksheet was in accordance with the required competencies and presented clear material. Students' perceptions of critical thinking questions (CT-Av, mean = 3.503) and STEM aspects (ST-Av, mean = 3.507) in the media also show that SWAR has reached the predetermined categories. Furthermore, in the time efficiency category (TA-Av, mean = 3.440), the developed media are considered very good and efficient. Students' perceptions in the categories of interest (IN-TV, mean = 3.640) and motivation (MO-Av, mean = 3.640) were excellent.

Table 4. The Example of Questionnaire Items of Students' Perception About SWAR

Category	Code	Items
Media features	ME-Av	I can understand the instructions for using the application (media) well. The application (media) is easy to download and install.
Feasibility of content and materials	CO-Av	The material contained in the worksheet and the application (media) contains the competencies I need. The material contained in the worksheet and the application (media) application is clearly explained.
Critical thinking questions	CT-Av	Questions on the Worksheet require me to make assumptions. Questions on the Worksheet require me to provide solutions.
STEM aspect	ST-Av	The worksheet already presents a systematic learning syntax. The syntax or learning stages are clear.
Time efficiency	TA-Av	I can learn using the application (media) according to my learning speed. My study time has become more efficient using the application (media).
Interest of media	IN-Av	I enjoy learning to use the application (media) of Acid Rain and Ecosystem Balance. I am interested in using the application (media) of Acid Rain and Ecosystem Balance.
Learning motivation	MO-Av	The application (media) can increase my motivation in learning.

In addition, intervariable correlation testing is used to see the relationship between categories and student perceptions. Figure 2 shows a diagram of the intervariable test results using Pearson's correlation. Based on the results of the analysis in Figure 2, it is known that there is a significant correlation between students' perceptions of AR media features (ME-Av) and students' learning interest (IN-Av) with $r = -.50$ ($p < .50$). However, the correlation value is negative. This means that when students' perceptions of the media features being developed are in the good category, their perceptions of student interest are low. In contrast, positive student perceptions of the developed media indicate that the products can be used and applied in learning so that digital-based practicums can be carried out.

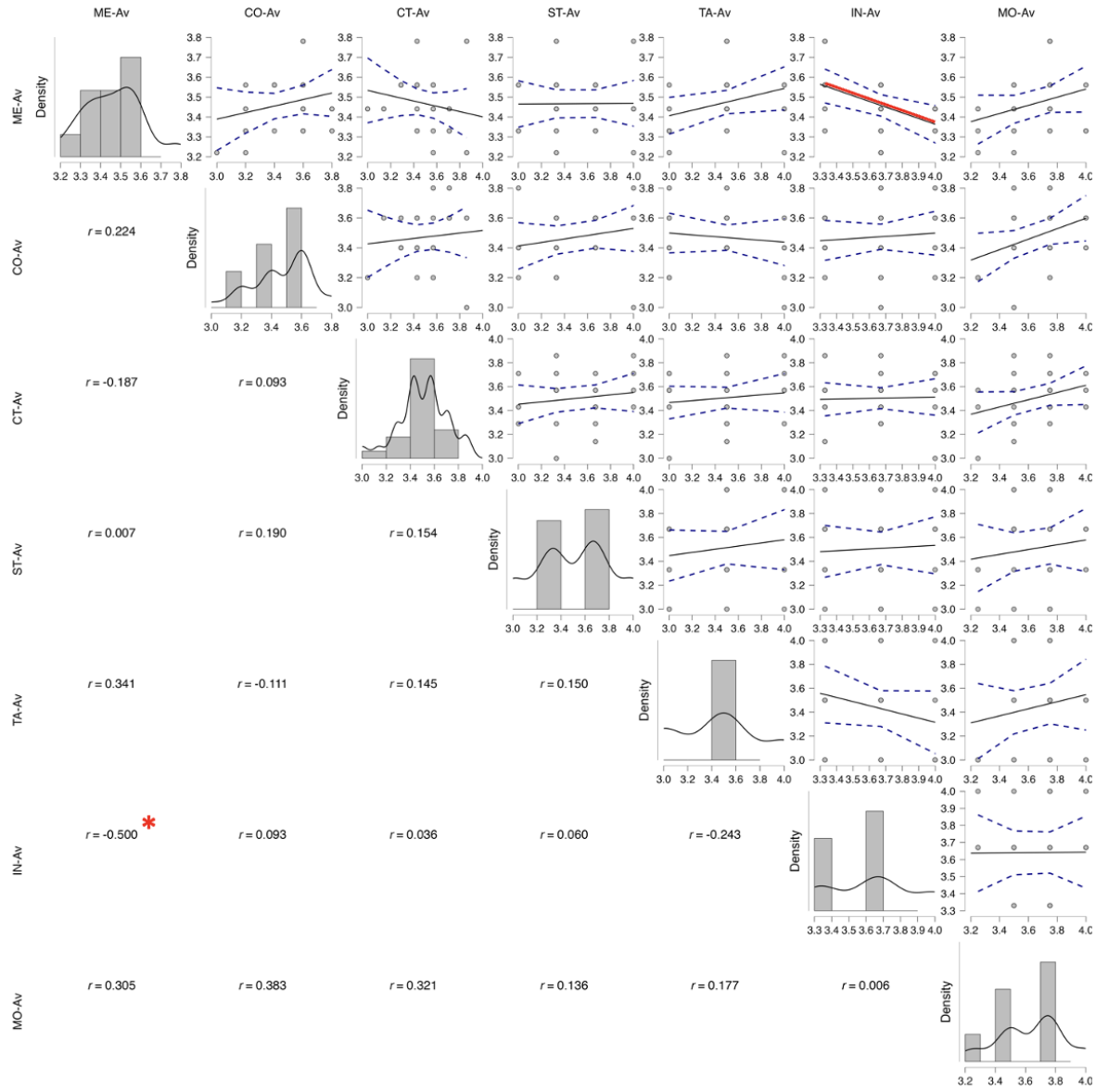

Figure 2. Matrix Plot of Students' Perception in Each Category

Discussion

Based on the findings, the responses of students on SWAR were positive regarding the application of worksheets and AR in science practicum activities. Therefore, worksheets have an important role, especially to support 21st century learning, such as critical thinking (Muskita et al., 2020). Most students already know and use worksheets in the learning process they have experienced. This can be assumed to be a learning pattern that has been carried out so far. As a result, the use of worksheets during the learning process needs to be implemented so that students can focus on giving attention to assignments that are specific in nature (Ratliffe, 1982). In addition, the findings show that by using worksheets during science practicum, students are more interested and motivated to learn. Making students interested and motivated when learning activities take place can provide various benefits to students. The research results also found that students' interest in practicum was in line with students' need for worksheets in practicum. This finding is consistent with prior study, which revealed that worksheets can increase students' interest in the learning process because they facilitate students being able to learn in various conditions, provide teaching materials that are concise, clear, interesting, and easy to understand, and can be combined with learning media (Sutarto et al., 2020). Therefore, the results of this research highly recommend the use of worksheets in science practicum activities to be implemented because they can increase students' interest and motivation in carrying out practicum activities.

Online learning activities provide students with the opportunity to carry out science practicum independently. In the practicum that I did previously, online practicum was carried out by simply uploading worksheets to the e-learning portal and assigning students to do it personally with practicum tools and materials that had to be prepared by the students. Thus, the development of AR in this research aims to make it easier for students to carry out practicum activities from anywhere. When students were asked about AR, more than half of the respondents stated that they knew what AR was

and felt interested and motivated if AR was used in science practicum. Most students also stated that the use of technology-based practicum was very necessary. However, a unique finding from this research is that although students have a good response regarding the use of technology in practicum, most students still choose to carry out practicum directly at laboratory when compared to digital practicum. The more money required and time-consuming to carry out practicum in the laboratory can be a reason for students to be more interested in digital practicum, consistent with previous studies that reveal that practicum activities are expensive and time-consuming (Chakraborty, 2021). Furthermore, as time goes by, students also need to be introduced to technological developments because AR does not use technology passively but requires users to be able to carry out practical activities as usual on their mobile phones. Especially in the current post-covid era, there is a push towards online learning (Teräs et al., 2020). Thus, we cannot avoid digital learning activities, but students still need to get the same learning experience as real activities, one of which is AR (Billinghurst, 2002). On this basis, the development of AR-assisted worksheets, in this case SWAR, can be an alternative to support digital practicum activities.

Based on the expert's consideration and evaluation, the SWAR is valid based on predetermined criteria. The research results show that experts agree that SWAR has good quality and can be implemented in science practicum activities, but it needs to be optimized in several criteria. After analyzing the research results, the experts stated that to make SWAR more feasible, there are several things that are recommended to be improved, including the level of suitability of teaching materials with the topics discussed in SWAR (content feasibility), and adjusting sentences according to students' ability (language), background color and object layout (graphics), suitability of questions with critical thinking indicators (critical thinking content), type of writing, suitability of image illustrations, shape and quality of button transitions (AR media). However, the results of the analysis show that SWAR is in the almost perfect category based on the K value (valid) interpretation (Viera & Garrett, 2005). This means that experts agree that SWAR can be used or applied in science practicum activities because has fulfilled the criteria for various predetermined criteria. However, improving SWAR is highly recommended as an effort to ensure that the media developed is of better quality.

The research results also show that students' perceptions of SWAR are in the excellent range. Respondents thought that SWAR had usage guidelines, so it was easy to use. In addition, SWAR can increase students' interest and motivation to learn. The application of SWAR as a form of learning tools is believed to have advantages in helping improve student learning outcomes (Barus & Simanjuntak, 2020). Students think that student learning time by using SWAR becomes more efficient, and students can adjust the level of learning speed according to their wishes because the media used can be used repeatedly and is portable (easily carried or moved because it can be installed on your device, such as mobile phone), so it is easy to use anywhere and anytime. In other words, users of instructional media can overcome learning constraints in terms of time (Istyadji et al., 2022). These findings indicate that SWAR products can be said to be very good as an effort to increase students' interest in science education. Prior study shows that augmented reality (AR) media can increase student interest, as indicated by students' courage to learn science after AR is implemented (Istyadji et al., 2022). In addition, AR media can also increase student learning motivation because students are given the opportunity to interact with a medium or tool that they usually learn in class (Kaur et al., 2020). The findings in this research have revealed that students' perceptions of SWAR are in an excellent range, so it can be implemented directly in digital-based science practicum activities because of its advantages.

In terms of the relationship between variables from students' perceptions of SWAR, it is known that there is a negative relationship between the features contained in the media and students' interest's category. This finding is interesting, in line with the statement of (Kirkwood & Price, 2014), which revealed that although technology has a positive impact, investigations are still needed about the effectiveness of technology in education. Continuous exposure to multimedia in learning will reduce student motivation (Kavanagh et al., 2017). In addition, excessive information acquisition can have a negative impact on students (Conrad et al., 2022). These findings provide information that digital learning media can have advantages, but at the same time, they can also have negative impacts. The use of learning media that is reasonable and as needed is assumed to be the key to success in implementing learning media.

The main aim of developing SWAR is to produce a science practicum activity worksheet for prospective science teachers so that it can be done anywhere and at any time without limitations of space, time and without reducing the student's learning experience. AR visualization assistance combined with worksheets gives students the opportunity to gain direct experience in using practical tools and materials when carrying out digital science practical procedures that are made as similar as possible to real conditions. Students' perceptions of worksheets combined with AR make a very significant contribution to the refinement of SWAR so that it can then be tested further to determine its level of effectiveness when used by students, in this case for prospective science teachers. The combination of worksheets and AR media is the right composition because worksheets can guide students in practicum activities as well as convey learning material in order to achieve learning goals (Kirkwood & Price, 2014) while AR can increase student engagement (Huda et al., 2021; Samala et al., 2023), and improve student outcomes (Novaliendry et al., 2022) .

Students' perceptions about the ease of operation of SWAR and the appropriateness of the material content to achieve their learning goals make SWAR have advantages compared to existing worksheets. SWAR, which is equipped with critical thinking questions, aims to improve students' thinking abilities during science practicum activities as well as facilitate them to explore various features of SWAR through the process of searching for answers to the critical thinking

questions provided. Thus, at the same time, through the use of SWAR, students are expected to be able to increase their literacy in using technology as well as train their critical thinking skills. Apart from that, by using SWAR, students will have flexibility in carrying out practicums because all the practicum tools and materials have been visualized. This is an advantage because AR has dynamic 3D simulations, so users will be more interested in using it (Radu, 2012). With the widespread use of AR, there is potential for the development of AR technology that is more integrated with non-academic life (Yuen et al., 2011) so that it can be used to support or assist humans in everyday life.

Conclusion

This research investigates students' responses to SWAR, the level of validity of SWAR, and students' perceptions of SWAR. The findings from this research are that most respondents stated that SWAR has the potential to be used as an alternative to support learning in the classroom. The worksheet developed in this research had a good response from respondents and had an almost perfect level of validation based on expert assessment. Apart from that, students who tried SWAR had an excellent perception of the worksheet because it had many advantages in facilitating students in carrying out science practicum activities. The various advantages possessed by the AR feature are the main reason researchers combine worksheets in practical activities with the AR feature. However, this research only focuses on students' responses and perceptions of AR-assisted worksheets. The effectiveness of SWAR needs to be tested further so that it can then be considered as a learning tool that can facilitate student learning outcomes. In addition, this research is limited to prospective science teacher students in science education study programs. Therefore, different findings may occur if the research is applied to other programs.

Recommendations

The abundance of advantages possessed by Augmented Reality (AR) makes the integration of AR in a worksheet have enormous potential so that it is worthy of being developed in various learning topics, not only in science subjects but also in other subjects. Students' perceptions of AR media are very positive and are believed to be able to help students understand the material better. The advantage of AR media that can be accessed anywhere and anytime is one of the great benefits that can be obtained, including in terms of digital practicum. Lastly, further research can develop the AR-assisted worksheets for another integrated science topic to support the digital practicum activity.

Limitations

This study is still limited to testing the validity and perceptions of the media being developed. Thus, a more comprehensive and extensive test is needed to determine the effectiveness of the developed AR media in supporting digital science practicum activities, as well as to involve a larger number of research samples. However, the results of this study can be used as a reference for researchers who will develop learning media in the form of worksheets equipped with AR media because they contain a lot of information related to students' perceptions of the media being developed.

Conflict of Interest

The authors have no conflicts of interest to declare.

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Authorship Contribution Statement

Muttaqiin: Conceptualization, design, data analysis/ interpretation, writing, critical revision of manuscript. Oktavia: Critical revision of manuscript, data acquisition. Luthfi: Material support supervision, admin, designing instruments. Yulkifli: Material support supervision.

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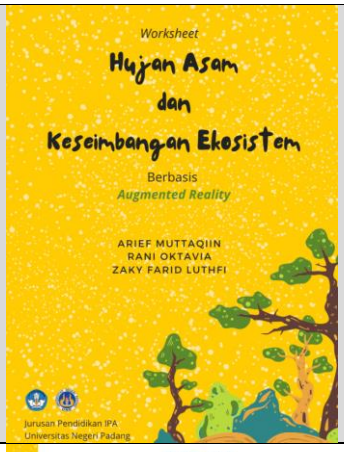
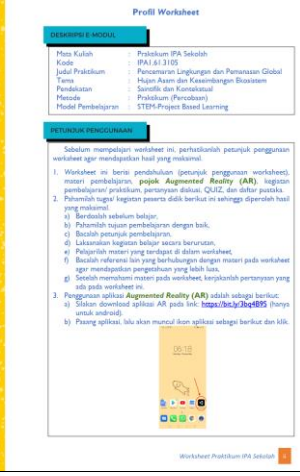
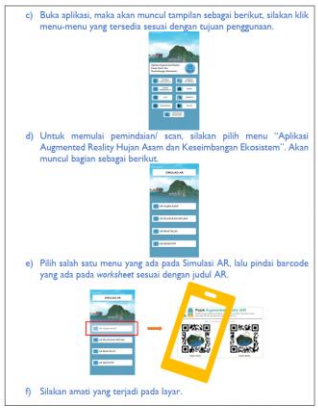
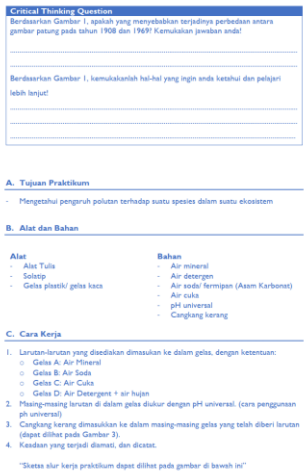
Appendix

Illustration of science worksheet-augmented reality (SWAR)

This worksheet has been registered with the Ministry of Law and Human Rights, Republic of Indonesia and has received a creation registration letter (Intellectual Property), Application Number: EC002022113157 Date: 26 December 2022, Registration Number: 00042891

Component	Screenshoot of Worksheet
Cover	
Identity and Instruction for using the worksheet	 
Learning objectives	

Component	Screenshoot of Worksheet
Sample of Critical thinking questions	
Sample of Augmented Reality marker to be scanned	 Gambar 2. Hujan Asam yang diakibatkan oleh senyawa NOx