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The impact of hybrid model science practicum based on IoT and VR on prospective science teacher students' creative thinking skills

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Abstract

This study aims to determine the impact of the IoT and VR-based hybrid model science practicum on prospective science teacher students' creative thinking skills. In addition, the study introduces how to implement IoT and VR-based hybrid models in science learning. The approach used in this research is quantitative, with an experimental method of one-group pretest-posttest design. The sample consists of 43 prospective science teachers at Universitas Negeri Yogyakarta who were determined by purposive sampling technique. The instruments used include creative thinking tests and observation sheets to implement hybrid model science practicum learning. The quality of the instrument was analyzed with Content Validity Ratio, Fleiss Kappa, Confirmatory Factor Analysis, and Rasch Model. Data analysis included descriptive statistics, paired sample t-tests, and effect size. The result showed that descriptive statistic is a general distribution, paired sample t-test p<0,001, and an effect size of 4.15. The finding showed that there was a significant positive effect on creative thinking skills. The implementation of this science practicum provides a meaningful academic experience for students. The practical implications of this research are that the IoT and VR-based hybrid model science practicum could be used by a prospective science teacher on other topics. Besides that, prospective science teachers' students' creative thinking skills could be increased.

Keywords: Creative thinking skills, Hybrid model, Internet of things, Science practicum, Virtual reality, Prospective science teachers.

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1. Introduction

The COVID-19 pandemic outbreak that has hit the world for more than two years has had a positive impact on the development of various modes of science learning, including in universities [1-3]. Even though at that time the distance learning mode had been implemented, in fact, students spent less time studying. Innovations in various learning processes to date have been carried out to improve the quality of learning outcomes, whether in learning media, learning models, learning curricula, or other aspects of learning. One learning mode that is currently continuing and is able to optimize the use of digital technology is blended learning-based learning. Apart from that, looking at the reality of the very rapid development of digital technology that is currently happening, the application of digital and online technology-based learning is still very limited, so many educators are faced with the challenge of less than optimal learning processes for students [4]. Furthermore, several current levels of education are a continuation of the educational process that occurred during the COVID-19 pandemic outbreak, so it has an impact on learning loss, namely the loss of knowledge and skills in academic development that occurs due to the cessation of learning in the world of education.

The findings of international research show that the results of research on reducing learning loss in schools have significantly decreased [5, 6]. Using the results of the inventory scale assessment in reading and mathematics (n> 80,000 each), competency scores were slightly lower at the end of the pandemic compared to the previous three years (–0.07 standard deviation for reading comprehension, –0.09 for operations, and – 0.03 for numbers) [7]. According to the Education and Development Forum, learning loss is a condition where students lose general or specific knowledge and skills, or academic setbacks occur due to certain conditions, such as prolonged gaps or learning processes that are not optimal [8, 9]. Learning loss occurs due to limited direct interaction between students and educators, limited communication between students, less conducive learning situations during online learning, difficulty focusing, and limited space for direct discussion during online learning [10]. As a result, students have difficulty understanding learning, feel anxiety, stress, and even have symptoms of depression [11]. Some prospective teacher students also feel their enthusiasm for learning has decreased, so they are more often absent from class and experience a decline in their grades.

Reducing learning loss is very important to resolve immediately. This results in a decline in various students' abilities, including the ability to think creatively [12]. Furthermore, creative thinking skills are needed for the continuity of students' lives in the future [13]. If students have very low creative thinking abilities, then this will have a direct impact on their difficulty surviving. Apart from that, the ability to think creatively is one of the benchmarks for achieving educational goals. Therefore, this is very important to be addressed immediately, one of which is by introducing a hybrid science practicum model based on IoT and VR. However, much research has been conducted on creative thinking, but it is still limited to cognitive aspects. There have been few activities during the pandemic until now that have focused on science practicum activities for prospective science teacher students. As a prospective teacher educator in the digital era, it is deemed necessary to develop a practicum model to prepare for what steps can be taken to close the knowledge gap of prospective science teacher students, especially those related to hybrid model science practicum activities based on IoT and VR.

The implementation of the hybrid model of science practicum is seen as more important than just academic remediation for students. Students who have emotional burdens will find it more difficult to learn effectively [14]. In this case, students who need to go through the process of re-adapting to face-to-face learning, coupled with the various anxieties and stress they feel related to this situation, tend to feel emotional turmoil, which can hinder their learning. Although stress can increase learning capacity to a certain degree, excessive stress will actually reduce cognitive abilities, such as attention, problem solving, critical thinking abilities, and so on [15]. On the other hand, happiness was found to improve cognitive abilities and social-emotional connections [14]. A practicum-based learning system that can accommodate the accelerating development of technology over time is necessary to support science learning that is based on technological literacy to improve creative thinking in science learning. For this reason, the author developed and tested the effectiveness of implementing a hybrid science practicum model based on the IoT (Internet of Things) with the MQTT (Message Queue Telemetry Transport) protocol and virtual reality to improve students' creative thinking. This system has two parts, namely wireless sensor nodes and IoT [16].

2. Literature Review

2.1. Hybrid Model Science Practicum

Hybrid model science practicum is a new term designed by researchers to explain the concept of integrated science practicum learning between realistic practicum activities as synchronous activities and virtual practicum activities using virtual reality as asynchronous activities [17-19]. A term that is already well-known and pertinent to this research, hybrid learning, served as the inspiration for this hybrid model practicum [20]. This model is very important to develop as part of efforts to contribute to the digitalization and globalization of the education sector. The development of this hybrid science practicum uses IoT (Internet of Things) technology with the Message Queue Telemetry Transport (MQTT) protocol as a network system that connects the science practicum with the internet network and sensor systems to obtain information about data relevant to science learning in real time [21]. The data is then used as material for practical and experimental activities both realistically and virtually using virtual reality (VR), so that it can be used as best practice for developing technology literacy-based learning to improve creative problem solving for science education students.

2.2. Internet of Things

The Internet of Things (IoT) is a system that includes connected devices that collect data, are connected to the Internet or a local network, generate analytics, and (in some cases) adapt behavior and responses based on data generated over the network [22]. IoT is a scientific development that is very promising for optimizing the quality of life (including education) based on smart sensors and smart equipment that work together via the internet network [23, 24]. With the large number of things, objects, and actuators connected to the internet, massive and, in some cases, real-time data streams will be automatically generated by the connected things and sensors. Of all the activities involved in IoT, one is to collect the right raw data in an efficient manner; but what is more important is to analyze and process raw data into more valuable information [25]. In general, the Internet of Things (IoT) can be interpreted as connecting various objects around you with an internet network. To implement it, IoT requires a communication path that suits the system requirements. One protocol that is suitable for implementing the IoT concept is the Message Queue Telemetry Transport (MQTT) protocol [26]. By using IoT, realistic practical learning in the field of science can be carried out in a more meaningful and data -rich manner, making it more informative and useful. Internet of things (IoT) is a concept that aims to expand the benefits of continuously connected internet connectivity.

The IoT concept is actually quite simple, with the way it works referring to three main elements in the IoT architecture, namely: physical goods equipped with IoT modules, Internet connection devices such as Modems and Speedy Wireless Routers like in your home, and a Cloud Data Center where you can store applications. along with the database [21]. The basic working principle of IoT devices is that objects in the real world are given a unique identity and can be reproduced in a computer system, and can be represented in the form of data in a computer system [27]. One protocol that is suitable for implementing the Internet of Things concept is the Message Queue Telemetry Transport (MQTT) protocol. The Message Queue Telemetry Protocol (MQTT) protocol is a protocol that is often used in implementing the IoT concept. The MQTT protocol is a lightweight protocol, because it sends messages with a small header, namely 2 bytes [28]. The MQTT protocol works using the publish/subscribe concept [29]. The initial implementation of the IoT idea so that it can be identified and read by computers is by using Barcodes, QR Codes and Radio Frequency Identification (RFID) [30, 31]. In its development, an object can be given an identifier in the form of an IP address and use the internet network to be able to communicate with other objects that have an IP address identifier. The way the Internet of Things works is by utilizing a programming argument, where each argument command produces an interaction between machines that are connected automatically without human intervention and at any distance. The internet is the link between the two machine interactions, while humans only serve as regulators and supervisors of the working of these tools directly [31, 32]. The author introduces the design of an IoT-based science practical tool with the MQTT protocol, as shown in Figure 1. Furthermore, prospective science teachers got new experience with this system, which could increase their creative thinking skills.

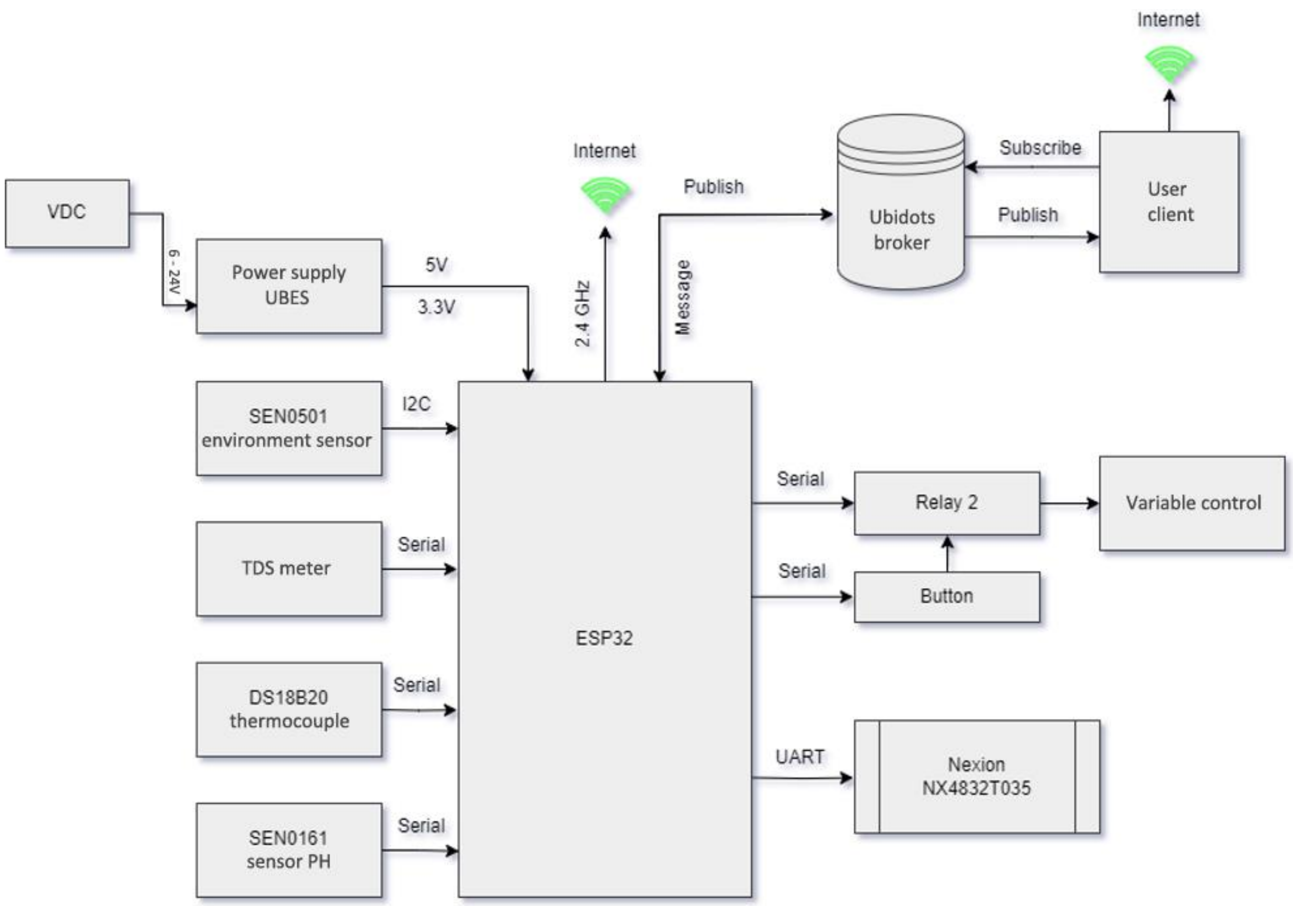

Figure 1.
Design of IoT-based science practical tools with the message queue telemetry protocol (MQTT) protocol.

2.3. Virtual Reality

Virtual reality, also known as Mixed Reality (MR) is a branch of technology that concerns Virtual Reality (VR) and involves combining the real world and the virtual world [33, 34]. The use of 3D can be implemented using Virtual technology which is a combination of the real world and the virtual world. The use of VR can produce precise perceptions by combining real-world rooms and virtual objects so that the user's experience feels more real. This VR technology is used to provide direction or guidance to students in the form of an integrated science practicum (Biology, Physics and Chemistry). This research tries to create innovation so that the virtual 3D objects displayed can not only be seen but can also be physically held. Users can use a smartphone to track a 3D IPA object [35, 36]. Unity 3D can also be used to create other interactive content, such as architectural visuals and real-time 3D animation. Apart from being a game engine, Unity 3D can also be used as an editor for existing games [37].

2.4. Creative Thinking Skills

Creative thinking skills are a thought process that goes beyond memorizing and retelling information that is already known [38]. Creative thinking is one of the skills that are needed to support the success of 21st-century learning. Furthermore, creative thinking is thinking about how to get new knowledge, new approaches, new perspectives, or new ways of understanding things [39]. Creative thinking skills also provide opportunities for students to develop their potential, such as hidden interests and talents [40]. By using creative thinking skills, students become accustomed to generating new ideas that can later make them successful. Creative thinking skills include several aspects, namely fluency, flexibility, originality, and elaboration [41]. Creativity from a psychological perspective is the ability to produce essentially new, previously unknown, and original compositions, products, or ideas [42]. Creativity is a unique mental process-something that is solely to produce something new, different from the original, which includes specific thinking that is freely divergent ideas and thoughts. This thinking follows a convergence path where the idea uses available information to reach a conclusion and leads to the correct answer. In our study, aspects of creative thinking skills that were developed and used in measuring the creative thinking skills of prospective teacher students include aspects of fluency, flexibility, originality, and elaboration.

2.5. Research Question

How does the implementation of IoT and VR-based hybrid science practicum models on the creative thinking skills of prospective science teachers?

2.6. Research Objectives

This article explains how the implementation of IoT and VR-based hybrid science practicum models affects the creative thinking skills of prospective science teachers. In addition, this article also introduces how to implement IoT and VR-based hybrid models in science learning.

3. Research Method

3.1. Study Approach and Design

The approach used in this research is quantitative, with an experimental method of one group pretest-posttest design [43-45]. This design can be used to determine the increase and effectiveness of treatment before and after implementing the IoT and VR-based hybrid science practicum on the creative abilities of prospective science teacher students. This research design includes a pretest before being given the application of a hybrid science practicum model based on IoT and VR in a discovery learning model setting and a posttest after being given treatment, as shown in Figure 2.

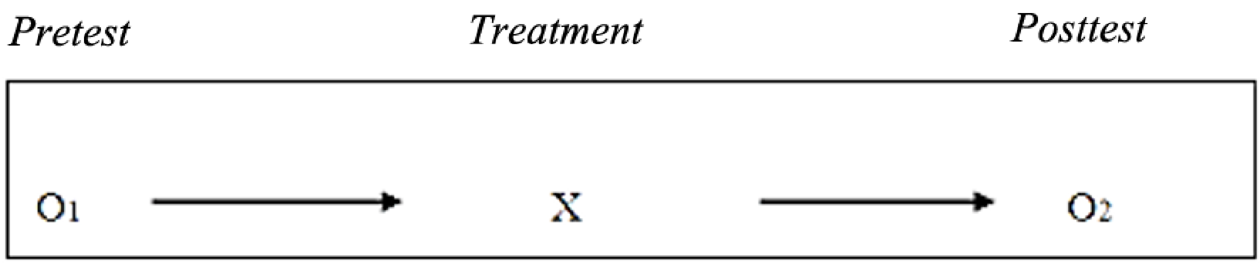

Figure 2.
Research design.

3.2. Study Group

The sample used in the research consisted of one class with 43 prospective science teacher students in Universitas Negeri Yogyakarta. The sampling technique uses a purposive sampling technique, namely a technique for determining samples based on certain considerations [43-45]. These considerations include prospective science teacher students who take the course "Measuring Instruments and Science Measurement Methods" and pre and posttest scores meet the normal distribution.

3.3. Research Instrument

The research instruments used to collect data consisted of observation sheets for the implementation of science practicum learning for IoT and VR-based hybrid models and pre-posttest questions. Science practicum learning is implemented using a discovery learning model that includes six phases: stimulation, problem statement, data collection, data processing, verification, and generalization. Pre and post test questions to measure students' creative thinking skills before and after the application of the IoT and VR-based hybrid model science practicum consist of five description questions as shown in Table 1.

Table 1.
Dimensions of creative thinking.

Indicators of creative thinking	No. item	Max score
Fluent thinking	1	5
Flexible thinking	2	5
Original thinking	3 and 4	5
Elaboration thinking	5	5

The pre- and post-test instruments used were tested on students who had studied the topic of measurement and analyzed in terms of validity and reliability. Content Validity Ratio (CVR) is used to ensure content validity is met, and Fleiss Kappa statistic is used for interater reliability so that agreement between two or more raters on categorical variables is known. Content Validity Ratio (CVR) according to Lawshe with the following mathematical equation [46].

$$CVR = \frac{\left(n_e - \frac{N}{2}\right)}{\frac{N}{2}}$$

Description:

Ne: Number of validators who agree and strongly agree or give a score of 3 or 4.

N: Number of validators or expert team members.

After calculating the CVR value for each criterion, the CVI (Content Validity Index) value or average value is calculated. The question set instrument used is declared valid if the CVI value is 0.99. In addition, interater reliability which shows agreement between two or more raters on categorical variables was analyzed using the Fleiss Kappa statistic. The results of the Kappa statistic provide information about the level of agreement beyond the possible [47, 48]. The mathematical equation for calculating the Fleiss Kappa Statistics coefficient is as follows.

$$K = \frac{Pr(a) - Pr(e)}{1 - Pr(e)}$$

Cohen suggested that the kappa result should be interpreted as follows: values ≤ 0 as indicating no agreement, and 0.01-0.20 as none too weak agreement, 0.21-0.40 as fair agreement, 0.41-0.60 as moderate agreement, 0.61-0.80 as substantial agreement, and 0.81-1.00 as almost perfect agreement [47].

Analysis of the construct validity of the instrument of the creative thinking skill using the Confirmatory Factor Analysis (CFA) test. CFA analysis was carried out using the Jamovi application. The conditions used to determine the analysis results are as shown in Table 2 [49].

Table 2.
Reading of CFA analysis results.

Criteria	Recommendation value
Chi-square (X^2)	Expectedly small
X^2- significance probability	≥ 0.05
Tucker-Lewis index (TLI)	≥ 0.90
Comparative fit index (CFI)	≥ 0.90
Root mean square error of approximation (RMSEA)	≤ 0.08

Furthermore, the items used as questions were also analysed with the Rasch model. Determination of the item fit model using (Winstep 5.3.6) computer application. Item fit with Rasch-Rating Scale Model with several criteria: 1) Outfit Mean Square (MNSQ) value with a range of 0.5 < Outfit MNSQ < 1.5, 2) Outfit Z-Standard with range -2.0 < ZSTD < +2.0, and 3) Point Measure Correlation value with range 0.4 < Pt Mean Corr < 0.85 [49-52].

3.4. Data Analysis

The data that have been obtained in the study are quantitative, including the implementation of science practicum learning of IoT and VR-based hybrid models implemented with the discovery learning model, pre-test, and post-test, so that the data are analysed quantitatively. Details of data analysis in this study are as follows:

a. Analysis of the total pretest and posttest scores from the creative ability aspect using the differential weighting scoring method because the questions are in the form of descriptions [53-55].
b. Descriptive statistical analysis to get a general picture of research data without generalizing [43, 45, 56]. This analysis was carried out using the Jamovi application so as to get a general overview of the results of implementing

IoT and VR-based hybrid model science practicum learning from the perspective of creative thinking abilities.

c. Prerequisite test analysis is used to determine the type of inferential statistics used [43, 45, 57]. Analysis prerequisite tests include normality tests carried out using the Jamovi application. The purpose of this analysis is to see the distribution of data so that it is known whether the next statistical test will use parametric or non-parametric statistics.
d. Analysis of the effectiveness of implementing hybrid model science practicum learning based on IoT and VR from the aspect of creative thinking abilities using effect size [58]. Interpretation of the Cohen's D coefficient to determine the relative size between pretest and posttest as in Table 3 [59, 60].

Table 3.
Interpretation of effect size.

Relative size	Effect size (Cohen's D)
Ignored	0.00
Small	0.20
Currently	0.50
Big	0.80
Very large	1.40 >

4. Results and Discussion

This article presents the results and discussion to answer the purpose of writing this article, which is divided into three parts. This section includes the quality of the research instruments used, the application of hybrid model science practicum learning based on IoT and VR, and the creative thinking abilities of prospective science teacher students.

4.1. Research Instrument Quality

All instruments used in the research were analyzed using expert judgment quantitatively and involving empirical tests in class. Valid and reliable research instruments will produce accurate measurement results so as to produce accurate conclusions. The first instrument used was a discovery learning device to teach hybrid science practicum models based on IoT and VR, analyzed from the aspect of content validity with the Content Validity Ratio (CVR) involving five lecturers in the fields of science and physics education, with the results as shown in Table 4.

Table 4.
Results of CVR analysis of the hybrid model science practicum guide.

Aspects	Validator					CVR
	Rater 1	Rater 2	Rater 3	Rater 4	Rater 5	
Content	3	4	4	3	3	0.99
Language	4	4	3	3	4	0.99
Presentation	4	4	4	4	4	0.99
Graphics	3	4	4	3	3	0.99
CVI	0.99					

The instrument used is determined to be valid based on Lawshe's criteria if the CVI value is 0.99 [46]. Table 4 shows that all aspects of the IoT and VR-based hybrid model science practicum device are valid in terms of content, language, presentation, and graphics. The content of this learning tool covers the topic of measuring physical quantities that affect plant growth and development. Learners measure physical quantities in the classroom by combining IoT and VR-based practicum tools that are connected to the internet network so that they can get real-time data continuously. The integration of classroom learning with learning that utilises the internet directly in the classroom forms a new learning pattern known as the hybrid model. Furthermore, the assessment results from the experts were also analysed with interater reliability with Fleiss Kappa Statistic, as shown in Table 5.

Table 5.
Results of Fleiss Kappa analysis of practical guide.

Ratings	Fleiss' kappa	SE	95% CI	
			Lower	Upper
Overall	0.763	0.158	0.647	0.872
3	0.762	0.158	0.648	0.872
4	0.763	0.158	0.647	0.873

Table 5 shows the Fleiss Kappa coefficient with a value of 0.763. The coefficient is in the range of 0.61-0.80, so it is in the moderate-to-substantial category and is suitable for use in research [47, 48]. The coefficient value shows that the tools used in the study have been agreed upon by the science education experts.

The second instrument used was question items used to measure the creative thinking abilities of prospective science teacher students. There are five items in the questions that were developed from the dimensions of creative thinking ability and analyzed from the aspect of content validity using the Content Validity Ratio (CVR), with results as shown in Table 6.

Table 6.
Content validity ratio analysis of creative thinking skill questions.

Item	Aspect	Validator					CVR
		Rater 1	Rater 2	Rater 3	Rater 4	Rater 5	
1	Construction	4	4	4	4	3	0.99
	Content	4	4	4	3	3	0.99
	Language	3	3	4	4	4	0.99
2	Construction	3	4	4	4	3	0.99
	Content	4	3	4	3	3	0.99
	Language	3	3	4	4	4	0.99
3	Construction	4	4	3	4	3	0.99
	Content	4	4	4	3	3	0.99
	Language	3	3	4	4	4	0.99
4	Construction	4	3	4	4	3	0.99
	Content	4	4	4	4	3	0.99
	Language	3	4	4	4	3	0.99
5	Construction	4	4	4	4	3	0.99
	Content	4	4	4	3	3	0.99
	Language	3	4	4	4	4	0.99
	CVI	0.99					

The question items used are stated to be valid based on Lawshe's criteria if the CVI value is 0.99 [46]. Table 6 shows that all aspects of the questions are valid because they fulfil these criteria. Furthermore, the assessment results from the experts were analysed with interater reliability using the Fleiss Kappa Statistic, with the results as shown in Table 7.

Table 7.
Results of Fleiss Kappa analysis of creative thinking items.

Ratings	Fleiss' kappa	SE	95% CI	
			Lower	Upper
Overall	0.786	0.082	0.646	0.826
3	0.786	0.082	0.646	0.826
4	0.786	0.082	0.646	0.826

Table 7 shows that the Fleiss Kappa coefficient has a value of 0.763. The coefficient is in the range of 0.61-0.80, making it moderate, substantial, and suitable for use in research. Furthermore, the items were also analysed empirically using confirmatory factor analysis (CFA) and the Rasch model. The results of the analysis using CFA are shown in Table 8.

Table 8.
Results of CFA factor loadings analysis.

Factor	Indicator	Estimate	SE	Z	p	Stand. estimate
Factor1	S1	1.112	0.1186	9.38	< 0.001	1.000
Factor2	S2	1.203	0.1283	9.38	< 0.001	1.000
Factor3	S3	0.848	0.1309	6.48	< 0.001	0.831
	S4	0.947	0.1152	8.23	< 0.001	0.975
Factor4	S5	0.734	0.0783	9.38	< 0.001	1.000

Table 8 shows the results of the factor loading analysis of CFA, including indicators of fluent thinking ability (S1), flexible thinking ability (S2), original thinking ability (S3) and (S4), and detailed thinking ability (S5). All standard estimates are greater than 0.5. The standard value of the estimate on factor loading if it is greater than or equal to 0.5, then the indicator in question is valid and significant in measuring a construct, in this case, the creative thinking ability of prospective science teachers on the topic of measuring physical quantities that affect plant growth and development. After determining what the items meet the validity of the construct, the next analysis looks at the fit model with the analysis results as shown in Table 9.

Table 9.
Results of model fit analysis of CFA.

Chi-square			CFI	TLI	RMSEA	RMSEA 90% CI	
χ^2	Df.	P				Lower	Upper
4.25	2	0.120	0.980	0.901	0.160	0.00	0.375

Table 9 shows the results of the fit model analysis of CFA, including Chi-Square worth 4.25 (small) and p value = 0.120 > 0.05, indicating there is a fit between the indicators and the measured variable, namely creative thinking ability. In addition, the CFI value = 0.980 ≥ 0.9, TLI = 0.901 ≥ 0.9 and RMSEA = 0.160 > 0.08. Four of the five criteria set by the fit model analysis in CFA were met, which means that the items created met the criteria for construct validity. This can be seen in Figure 3's path diagram.

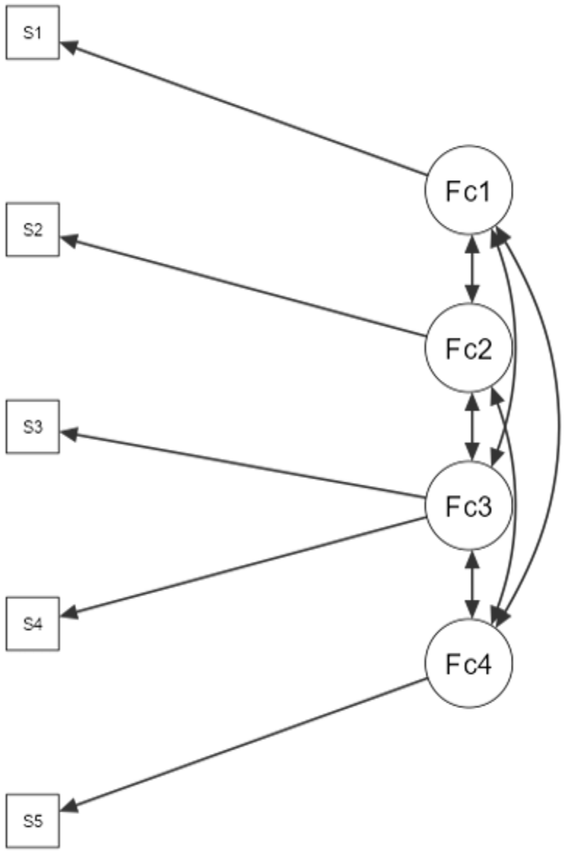

Figure 3.
Model fit CFA of creative thinking skills.

Table 10 explains the construction of the set of questions used in the research to measure the creative thinking abilities of prospective science teacher students with five questions: S1, S2, S3, S4, and S5. Question items were developed based on indicators of creative skills from several theories about creativity. Indicators of prospective science teachers' creative thinking abilities are seen in four dimensions, including fluent, flexible, original, and detailed thinking skills. In addition, the path diagram shows the interrelationship between four dimensions of abilities that represent the ability to think creatively. The quality of instruments regarding creative thinking abilities was also analyzed using the Rasch model. The summary results of the Rasch model analysis of person and item aspects are as shown in Table 10.

Table 10.
The summary results of the Rasch model analysis.

Person	**44 Input**		**44 Measured**		**Infit**		**Outfit**	
	Total	**Count**	**Measure**	**Realse**	**MNSQ**	**ZSTD**	**MNSQ**	**ZSTD**
Mean	20.9	5.0	2.87	1.00	0.98	0.0	0.87	0.0
S.D.	4.2	0.0	2.03	0.40	0.62	0.9	0.53	0.8
Real RMSE	1.07	True SD	1.72	Separation 1.61		Person reliability 0.72		
Item	5 Input		5 Measured		Infit		Outfit	
	Total	Count	Measure	Realse	MNSQ	ZSTD	MNSQ	**ZSTD**
Mean	184.2	44.0	0.00	0.30	1.03	0.0	0.87	-0.3
S.D.	11.7	0.0	0.86	0.06	0.31	1.1	0.22	0.8
Real RMSE	0.30	True SD	0.81	Separation 2.69		Item reliability 0.88		

Table 10 shows that the OUTFIT MNSQ value for both the person aspect and the item aspect is 0.87, and the OUTFIT ZSTD value for the person aspect is 0.0 and the item aspect is -0.3. This value is within the range of Rasch model fit criteria, namely 0.5 < OUTFIT MNSQ < 1.5, -2 < OUTFIT Z-STANDARD (ZSTD) < 2 [49-51]. The summary results of the analysis of the five-item instrument to measure the creative thinking abilities of prospective science teachers meet the Rasch model fit criteria. Apart from that, the item reliability value is 0.88 in the very good category [49, 61]. Furthermore, each item is also analyzed for whether it fits or not with the Rasch model, as shown in Table 11.

Table 11.
Analysis results for each item on Rasch model.

Item	Total Score	Model		Infit		Outfit		PT-Measure	
		Measure	S.E.	MNSQ	ZSTD	MNSQ	ZSTD	Corr.	Exp.
S1	201	-1.37	0.33	1.54	1.6	0.71	-0.6	0.76	74.9
S2	166	1.22	0.23	1.21	0.9	1.15	0.7	0.80	54.8
S3	178	0.51	0.25	0.78	-0.9	0.81	-0.7	0.83	56.4
S4	190	-0.34	0.28	0.71	-1.1	0.59	-1.5	0.85	64.9
S5	186	-0.03	0.27	0.90	-0.3	1.10	0.4	0.81	58.8
Mean	184.2	0.00	0.27	1.03	0.0	0.87	-0.3		
S.D.	11.7	0.86	0.03	0.31	1.1	0.22	0.8		

Table 11 shows the results of the analysis of each item against the Rasch model fit with the Outfit MNSQ values of item one 0.71, item two 1.15, item three 0.81, item four 0.59, and item five 1.10. The OUTFIT MNSQ values are all in the range 0.5 < Outfit MNSQ < 1.5, which means that each item is valid and meets the Rasch model fit [49-51]. In addition, -2 < Outfit Z-Standard (ZSTD) < 2 and 0.4 < Pt Mean Corr < 0.85 are also met in the five items.

4.2. Implementation of IoT and VR-based Hybrid Model Science Practicum

Science practicum learning of IoT and VR-based hybrid models in the classroom using a discovery learning model. IoT and VR-based practicum devices are used as data collection tools for physical quantities that affect plant growth and development. Implementation of practicum in the course "Measuring Instruments and Science Measurement Methods" was observed by two observers. Data on the implementation of IoT and VR-based hybrid model science practicum is shown in Table 12.

Table 12.
Observation results of IoT and VR-based hybrid model science practicum in the classroom.

Aspects of the learning process	Description	Results observation	
		Observer 1	Observer 2
Class opening	Class conditioning by educators including group divisions	√	√
Stimulation	Learners answer questions given by educators as a stimulus to enter into learning factors that affect plant growth and development.	√	√
Problem statement	Learners discuss to identify problems obtained from the stimulus to be investigated in science practicum activities based on IoT and VR hybrid models.	√	√
Data collection	Learners in groups collect data related to physical quantities that affect plant growth and development using IoT and VR-based practical tools with guidance from educators. In addition, educators guide and direct learners, especially those who experience problems in data collection.	√	√
Data processing	Learners in groups discuss and analysis the results of data findings from the use of IoT and VR-based practical tools and other information they get from various sources. In addition, educators guide and direct learners, especially those experiencing problems in data processing.	√	√
Verification	Learners conduct a careful examination in proving whether or not it is correct with the existing literature with direction from the educator.	√	√
Generalisation	Learners make conclusions from the data that has been obtained and has been analysed together to get the correct answer. In addition, in this phase the educator directs that students are able to write conclusions correctly.	√	√
Class closing	Educators provide reinforcement related to the concepts obtained from IoT and VR-based hybrid model science practicum activities to measure physical variables that affect plant growth and development.	√	√
The implementation of IoT and VR-based hybrid model science practicum learning activities		100%	

Table 12 shows that the implementation of the IoT and VR-based hybrid model science practicum using the discovery learning model is well implemented, as can be seen from all stages of the opening, core, and closing activities that have described the discovery learning model. The learning stages follow the discovery learning syntax, which consists of stimulation, problem statement, data collection, data processing, verification, and generalization [62, 63]. All students in this learning process use the worksheet guide that has been prepared with the phases of the discovery learning model.

Learners, in this case prospective science teacher students, work together in groups to develop problem statements related to factors that affect the growth and development of plant participants. With the guidance of educators, learners design and collect data using IoT and VR-based measuring instruments. The author uses a science practicum tool on this topic called Universitas Negeri Yogyakarta (UNY) IoT Agrotech that has been developed. The data collection activity is associated with the process of photosynthesis and the frequency of audiosonic bloom, so students will be able to find physical quantities that affect plant growth and development.

Figure 4 (Left) Science practicum design using IoT and VR; (Right) Plant stomatal aperture when it opens and closes.

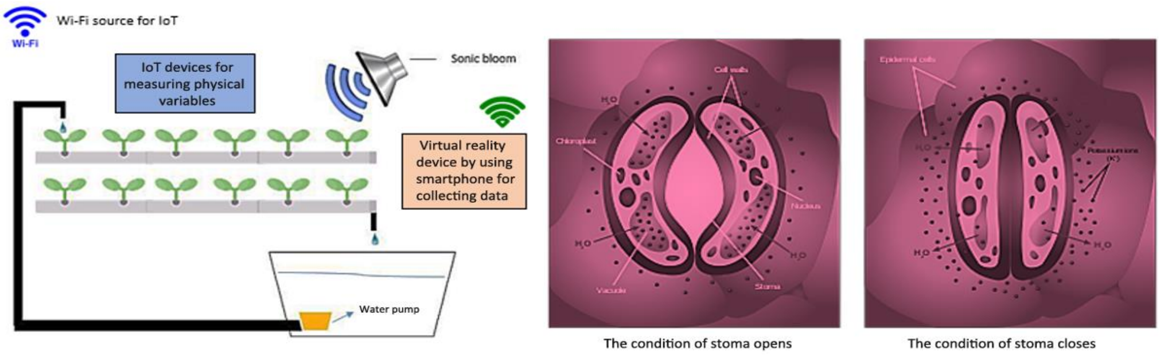

Figure 4.
Science practicum design (Left) and data processing associated with plant stomatal aperture (Right).

The next phase of learning is data processing where students will analyse the data obtained from IoT and VR-based science practicum. The data collected from the practical activities are quantitative with details of the physical quantities as follows.

a) Altitude : Instrument altitude from sea level (meter).
b) Soil : Soil moisture (%).
c) Temp : Air temperature (Celcius).
d) Temperature DS : Air/water temperature (Celcius).
e) UV : Ultraviolet radiation (mw/ 〖cm〗 ^2).
f) Hum : Air humidity (%).
g) Lux : Light intensity (Lux).
h) pH : pH (pH).
i) Press : Air pressure (hPa).
j) TDS : TDS (ppm).

Although the data collected is quantitative, students are also directed to use a qualitative approach and relate it to the photosynthesis process as a result of audio-sonic bloom applied to plants related to stomatal openings on the leaves [64-66]. Students are directed to verify the results of the practicum with various literature so that in the generalization phase they are able to find factors that affect plant growth and development using data collected from IoT and VR-based practicum tools. At the end of the lesson, the prospective science teacher students stated that the hybrid learning model was able to facilitate meaningful learning and support the development of competencies as prospective science teachers in the 21st century. In addition, students want hybrid learning to be developed as a student-centered learning method and varied in other topics [67].

4.3. Prospective Science Teacher Students' Creative Thinking Skills

The creative thinking skills of learners on the topic of measuring physical variables that affect plant growth and development are measured using five description test questions that have been quantitatively analysed with CFA and Rasch models. The results of the descriptive statistical analysis of pre-test and post-test data are shown in Table 13.

Table 13.
Descriptive statistics analysis.

Descriptive statistics	Pretests	Posttest
Mean	38.68	83.76
Standard error	1.21	2.60
Median	37.00	88.00
Mode	35.00	88.00
Standard deviation	7.96	17.04
Range	30.00	60.00
Minimum	25.00	40.00
Maximum	55.00	100.00
Count	43.00	43.00

Table 13 shows the results of descriptive statistical analysis of pretests and postests of the creative thinking ability of science teacher candidates, including the mean, median, standard deviation, standard error, and other quantities that describe the general distribution of data. The average value of each item that describes the ability to think creatively is shown in Table 14.

Table 14.
Average score of creative thinking skills.

Indicators of creative thinking	Item	Average		Difference	N-gain
		Pretest	Posttest		
Fluent thinking	1	10.12	18.28	8.16	0.73
Flexible thinking	2	6.6	15.08	8.48	
Original thinking	3	9.64	16.2	6.56	
Original thinking	4	7.36	17.28	9.92	
Elaboration thinking	5	4.96	16.92	11.96	
Total average creative thinking skills score		38.68	83.76	50.92	

Table 14 shows the mean score of the each item of students' creative thinking ability. The mean scores of the pretest and posttest were 38.68 and 83.76, respectively. In addition, the N-Gain from pretests and posttests was 0.73. The N-Gain value is greater than 0.70, so that the pretest-to-posttest increase from the results of the application of IoT and VR-based hybrid model science practicum learning on creative thinking skills is in the high category. The score of creative thinking skills for each item done by students can also be seen in Figure 5.

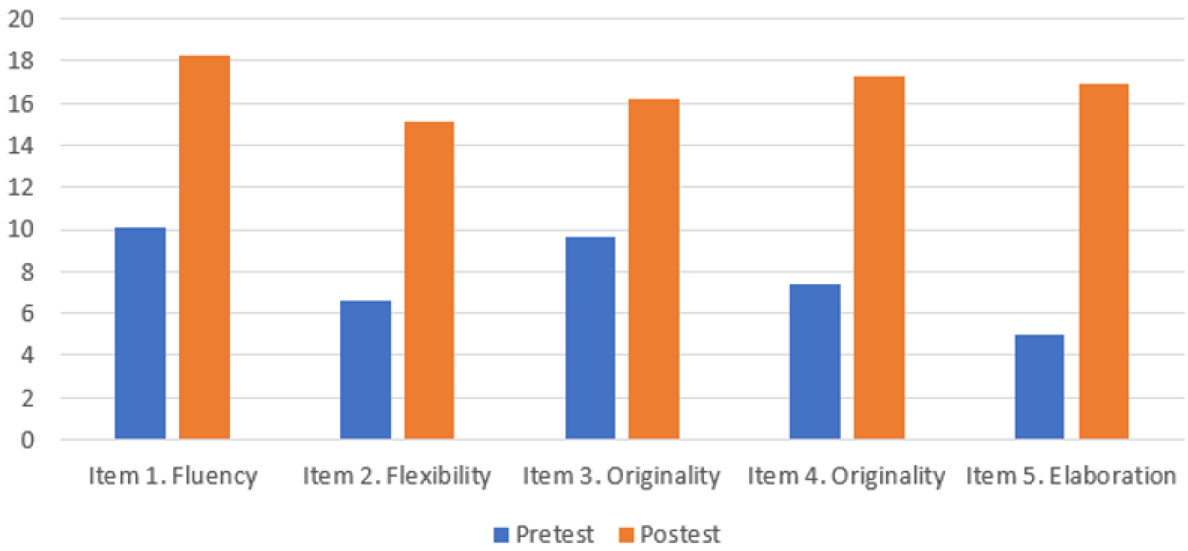

Figure 5.
Comparison of pretest and posttest of creative thinking skills.

Figure 5 shows that all items of the pretest score are higher than the pretest. Fluency thinking ability is in item one with a pretest score of 10.12 and a posttest 18.28. Flexible thinking ability in item two with a pretest score of 6.60 and a posttest of 15.08. Original thinking ability in item three with a pretest score of 9.64 and posttest score of 16.20. Original thinking ability is in item four with a pretest score of 7.36 and posttest of 17.28. Elaboration thinking ability in item five, with a pretest score of 4.96 and a posttest of 16.92. Moreover, the improvement of the four aspects of creative thinking ability from highest to lowest is respectively elaboration thinking, fluent thinking, flexible thinking, and original thinking. The pretest and posttest data were analysed using inferential statistics, namely paired t tests, to further determine whether there is a significant difference between pretests and posttests from the application of the IoT and VR-based hybrid model science practicum on creative thinking skills. This statistical test was preceded by a normality distribution test as a prerequisite test that must be met using Shapiro-Wilk, with the results as shown in Table 15.

Table 15.
Normality test results (Shapiro-Wilk).

Post_test	Pre_test	W	p
83.76	38.68	0.963	0.174

Table 15 shows the probability value of $p = 0.174 > 0.05$, which means that the distribution of data on pretest and posttest scores meets the normal distribution, so the inferential statistical test using a paired sample t test. The results of the analysis of the pretest and posttest data difference tests from the implementation of the IoT and VR-based hybrid model science practicum are shown in Table 16.

Table 16.
Results of analysis of paired T test.

Post_test	Pre_test	Student's t	Statistic	Df.	p	Effect size (Cohen's D)
83.76	38.68	1.68	27.5	43.0	< 0.001	4.15

Table 16 shows the results of the t-test using a paired sample t-test with a significance value of $p < 0.001$. The value of $p < 0.05$ indicates that there is a significant difference between the pretest and posttest of the application of the IoT and VR-based hybrid model science practicum on students' creative thinking skills. In addition, the effect size coefficient is 4.15, with a high category.

The results of this analysis are in line with several other studies that state that the implementation of the Science Practicum Hybrid Model has a positive impact on students' learning achievement [68]. The implementation of blended learning in the hybrid model conducted by Marsiti, et al. [69] stated that the learning can improve student achievement indirectly through increased student creativity [69]. Another study conducted by Kazu and Yalçin [70] stated that learning using Hybrid Learning has a greater effect size than learning without Hybrid Learning [70]. Similarly, the results of this study are also in line with Alhalabi [71] which states that the implementation of VR in learning also contributes positively to students' academic achievement [71]. Moreover, the findings of this study are also in line with research conducted by Elneel, et al. [72] which states that e-learning systems require modern techniques such as IoT to enable interconnection, improve reliability, and increase learners' enjoyment in the education process, which ultimately brings positive changes to learners in science learning [72]. The findings in this study also show that hybrid learning based on the integration of traditional face-to-face and online teaching-learning paradigms is becoming popular along with technological advances in the 21^{st}-century. This popularity creates the need to continuously develop and innovate hybrid models in science learning by integrating IoT and VR to support students' academic achievement.

The results of the analysis show that there is a significant positive effect of the application of IoT and VR-based hybrid model science practicum on students' creative thinking skills. The implementation of this learning provides a more valuable experience for students [33, 67, 73, 74]. Furthermore, this learning is able to improve the performance and activeness of students in learning activities, especially in the digital era, which can support the mastery of skills in the 21^{st} Century [75-77]. The findings of the study indicate that there is a significant positive influence on academic performance, especially the creative thinking skills of prospective science teachers.

5. Conclusion

The conclusion of this study shows that there is a significant positive effect on academic performance, especially in terms of creative thinking skills. The application of IoT and VR-based hybrid model science practicum provides a meaningful academic experience for prospective science teacher students. IoT and VR-based science practicum tools used in teaching science topics in a science learning model will be able to improve students' academic performance.

The limitations of this study are that it was only conducted on a small scale in the form of one class and on one topic. Future research can develop IoT and VR-based practicum designs. In addition, it is carried out on a wider scope and used to improve the various abilities of prospective science teacher students in various regions.

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