Virtual Lab Geometry Development as Online Learning Media Alternatives at Universitas PGRI Semarang and Universiti Teknologi Malaysia

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Abstract **– In this contemporary epidemic era, learning media that is easily accessible and engaging to learners is genuinely required. So far, students at PGRI Semarang University and University Teknologi Malaysia have previously been required to apply a compass and ruler to construct flat shapes and spaces, to establish active learning strategies that can encourage students in virtually sketching flat shapes. The ADDIE model was employed in the research, the outcome of this research is a virtual geometry lab. According to student responses, as much as 96 percent agree that the use of virtual media the geometry lab can enhance students' cognitive and spatial abilities.**

Keywords **– Development, Virtual Lab, Geometry, Cognitive ability, spatial ability.**

1. Introduction

Various challenges appear in the educational field during this contemporary epidemic era, such as online learning, which makes it difficult for learners to comprehend mathematics lessons [1], [2]. The educator then struggles in presenting content that requires student to practice and creative [3]. Then, when it comes to understanding mathematics at college, one of which is the geometry course, students struggle to understand the content that is arranged without practice. When the Covid-19 disaster has not yet occurred, students are required to sketch flat shapes and build spaces using a compass and ruler. Nonetheless, students should sketch with correctness, precision, and effort. Finally, based on interviews with various students from Universitas PGRI Semarang and Universiti Teknologi Malaysia revealed that virtual learning is essential to assist students comprehend geometry subject in theory and practice. The next issue is that mathematics education students at PGRI Semarang University and Universiti Teknologi Malaysia struggle to comprehend geometry content. The findings of the 2019-2020 academic year's Final Semester Examinations revealed that 60% of PGRI Semarang and Universiti Teknologi Malaysia students haven't yet grasped the theory and practice of geometry effectively and appropriately. This tends to make it our concern as educators to deliver the best intention so that they can comprehend geometry material properly and adequately, one alternative being to provide learning equipment that can enhance their cognitive and spatial abilities in studying geometry material, the device in question being a well-packaged and up-to-date virtual geometry lab media.

Because mathematics laboratories associated to geometry are still packed conventionally, there are few individuals in Indonesia who apply virtual labs in the design of geometry learning. [4] Those who employ virtual labs are commonly in healthcare and science, whereas no one has established a virtual

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geometry lab using virtual reality for studying mathematics, especially geometry, notwithstanding the fact that many campuses around the world have formed and utilize virtual labs for learning mathematics and science. Because it is essential to attempt to develop a virtual reality application that can demonstrate the placement of flat wakes and real space based on virtual reality, this needs to be attempted in Indonesia so that learning geometry, which has been a scourge in various universities and the private sector in Indonesia, becomes a possibility. Especially the in light of Covid-19 epidemic. As educators, we are responsible to compress material that students may access anywhere, both online and offline, and one of them is to develop a virtual geometry lab application using the TPACK framework that successfully and correctly blends technology, pedagogy, and material content. The urgency in this research is to design an application which can be performed with a VR camera, stick, smartphone, or computer connected to the Virtual lab application on geometry material, notably congruence and parallelism materials, that can be understood both online and offline.

In domestic, there are currently virtual laboratories for scientific or health education run by[5] indicates that using mobile virtual reality to acquire physics curriculum may help students improve their analytical abilities enhanced by [6]. It illustrates how virtual reality packaged as a game may increase students' engagement and learning outcomes in biology, and [7] demonstrated how using a virtual reality-based virtual lab might improve kindergarten children's cognition in learning a variety of fish. On the other hand, [8], [9] stated that they were enabled to increase their proficiency by learning mobile-based augmented reality-based geometry materials. In addition, [10]demonstrate that Mobile augmented reality is really helpful in learning geometry at the college level. The TPACK framework, which has been used effectively in numerous schools or institutions, is used to integrate technology, pedagogy, and material in a helpful and interesting way. According to[11], The TPACK methodology, which integrates technology, pedagogy, art, and material content, makes it easier for students to understand the knowledge since it is well-packed with sustainable technology and the content is appropriately conveyed.. [12] mentioned that TPACK makes it easier for instructors to link course content with renewable technology, making studying more pleasurable for students. In this example, research was undertaken at PGRI University Semarang and Universiti Teknologi Malaysia on establishing a virtual geometry lab for online learning.

2. Related Works

This section discusses the relevant works that fall within the scope of this research.

2.1. Virtual Reality

Virtual reality (VR) is a technology that enables users to communicate with an environment that has been generated by a computer, an actual world that has been copied, or a totally imaginary one. Contemporary virtual reality environments mostly present a visual experience, which is exhibited on a computer screen or through a stereoscopic viewer, but some simulations also contain extra sensory information, such as sound through speakers or headphones [13]. Virtual Device Reality Sensory-immersion VR interface technologies that directly engage sensory feelings, such as headmounted displays (VR helmets), data gloves (gloves), and bodysuits (VR vests). A blindfolded helmet (headmounted display) gives a new viewpoint on the item being viewed. Once moved, the visuals will change so quickly that we will feel as though we are causing these changes with the movement of our heads. Humans are the source of the effect, not the result. Projection Interaction with an item projected on a large screen that portrays an artificial virtual world, such as CAVE (Cave Automatic Virtual Environment) or Responsive Work, is included in VR. A physical environment is included in the VR Simulator in order to bring the environment closer to the user.[14] In the automotive industry, a mockup of the passenger cabin is typically built, complete with a monitor that serves as a windshield and a VR device, so that the mock up can dynamically provide natural sensations such as vibration or shock. Desktop VR refers to the device that displays the VR modeling process on a computer screen. Virtual reality applications in everyday life include 1) education and training, The purpose of using virtual reality (VR) in training is to assist professionals in conducting training in a true artificial environment where they may enhance their talents without possibility of injury[15].

2.2. Technological Pedagocal Content Knowledge

Technological Pedagocal Content Knowledge (TPACK) (formerly TPCK) is the knowledge required to incorporate technology into learning. This knowledge framework is based on Shulman's (1986) Pedagogical Content Knowledge construct (PCK). [16] argues that separately equipping instructors or potential teachers with broad pedagogical skills and subject matter expertise, such as mathematics and physics, is insufficient. Instead, a teaching foundation that is at the confluence of subject matter material and pedagogy is required. A good PCK is demanded of a MIPA instructor in order to carry out an effective scientific learning process. Furthermore, teachers' development of TPACK from PCK is critical in order for technology-integrated teaching to be effective. Teacher candidates and instructors, like PCK developers, are actively analyzing various techniques for training teachers to teach using various technologies [17].

2.3. Geometry

According to [18].states that: "The study of the relationships between points, lines, angles, surfaces, and solids is known as geometry." Geometry is the study of the connection between points, lines, angles, planes, and spatial forms. Geometry is a discipline of mathematics that investigates the intricacies of flat forms and shapes. The comprehension of geometry is organized in stages, beginning with the simplest things and is called the basic notion, leading to elements that require boundaries/ definitions by using the basic comprehension, then axioms/postulates have been compiled, namely the basic assumptions that are approved upon are true and do not need to be proven, based on the existing axioms/postulates and derivations. [18].

2.4. Spatial Thinking

Considering that many earlier research revealed that children struggled to comprehend geometric objects or figures, the topic of spatial thinking is highly intriguing to examine. Spatial thinking is a combination of cognitive skills comprised of three components: spatial conceptions, representational tools, and reasoning processes [19]. Spatial learning outcomes are a concept in spatial thinking. It is capable of categorizing spatial learning results into three groups: (1) spatial perception, (2) mental rotation, and (3) spatial visualization. According to the findings of the following research, spatial student achievement are very essential to enhance in the context of mathematics, particularly geometry, so that every student should attempt to develop learning outcomes and spatial sensing that are very useful in understanding relations and properties in geometry to solve mathematical problems and problems in everyday life [21], [20].

3. Research Methodology

This research involves the use of research and development (R&D). Development research is a research approach used to generate particular items and evaluate their effectiveness. The ADDIE technique is used in this development research, which comprises five stages: Analysis, Design, Development, Implementation, and Evaluation.

3.1. Research Design

The ADDIE model was employed as the research design in this research, which was separated into five phases: analysis, design, development, implementation, and evaluation. These five stages are followed in a consistent and systematic way.

3.2. Population and Sample/ Study Group/Participants

Students from the Mathematics Education study program at the University of PGRI Semarang and students from Mathematics Education at the Universiti Teknologi Malaysia involved in this research, with each taking two experimental classes and one control class.

3.3. Data Collection Tools

The research data was gathered through a Questionnaire response validation of material experts, learning media experts, and user responses was followed by pretest and posttest tests to evaluate students' cognitive and spatial abilities, and then a N Gain test to evaluate the improvement of process skills and cognitive learning consequences between before and after studying at PGRI University Semarang and a student at Universiti Teknologi Malaysia.

3.4. Data Collection

The data was collected using Google form with validation from material professionals and learning media professionals, followed by the student response questionnaire, which was also accomplished using Google form, while the pretest and posttest were completed in writing and scanned results were sent via email to be evaluated in detail.

3.5. Data Analysis

The average score and N Gain test were used to examine the advancement of process skills and cognitive learning consequences of students for the evaluation of the outcomes of the acquisition of research data done using a Likert scale connected to user responses and expert validation.

4. Findings

In this study, the ADDIE paradigm was employed to construct a Geometry Virtual Lab product. A full summary of the product development results based on the ADDIE development approach is provided below:

4.1. Analysis

An analysis of the problems of learning geometry at PGRI University Semarang and Universiti Teknologi Malaysia in the Mathematics Education study program has discovered that 60% of students are still inadequate in acknowledging geometry material, especially flat and spatial shapes, cognitive and spatial abilities, at this stage in the analysis. Based on the preliminary pretest results, they were still below 70, and the students stated that during the 2020-2021 pandemic, 90% of the students at PGRI Semarang University and Universiti Teknologi Malaysia desperately need learning media that can improve their understanding and spatial abilities related to geometry material, specifically congruence and parallelism.

4.2. Design

The product design is focused on the requirements and achievement of learning objectives, particularly constructing a Geometry Virtual Lab application that concentrates on the material Congruence of triangles with virtual reality technology, interpretations referring to Alignment become understandable, and it is hoped that students' geometric spatial competence will be preferable when compared to other traditional media. This virtual geometry lab is designed in Corel Draw, with animations generated in Unity 3D, Blender software, and Vuforia Development. Following the implementation of the application design product, a focus group discussion is planned that takes into account the design presentation and the depth of the material exhibited, namely congruence and parallelism. The outcomes of the focus group discussion indicate that students require practice selecting the placement of congruence and alignment of flat forms in order to understand the mathematics conceptually adequately.

4.3. Development

During this stage of development, the suggested framework is completed in order to produce a deliverable item. The Geometry Virtual Lab media is built in accordance with the congruence and alignment material; after the android-based media is completed, it is validated by media experts and material experts by the validator to obtain feedback and appraise based on the validator's feedback. As a result, the Virtual Reality-based material is modified in response to validator comments in order to develop the product.

A virtual geometry lab was developed during this stage of development that was modified to the outcomes of a focus group discussion between lecturers and students, which covered the design of virtual geometry lb media and the scope of the geometry material obtained, and then the product was expert validated before being tested in the field, which included experts in geometry materials and virtual reality-based learning media experts. The following graphic depicts the Visually Developed Geometry Virtual Lab products:

Figure 1. Virtual Lab product Geometry congruence triangle material front view

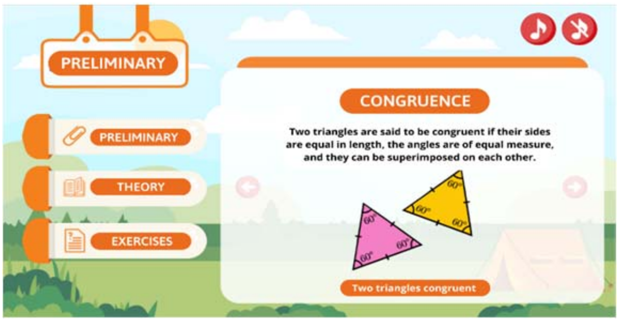

Figure 2. Display of materials Virtual Laboratory Material congruence and parallelism in geometry

The Geometry Virtual Lab product was validated by media experts, obtaining the following results: (1) The appearance of this virtual geometry lab product is suitable as a virtual supplement to geometry course content. (2) Color gradations associated with geometric alignment material can be visualized digitally and attractively, (3) The virtual geometry lab application is enjoyable for lectures because the quizzes are illustrated with fascinating animations; (4) the menu options in the virtual geometry lab application can be used in a pleasurable, convenient, and interesting way; and (5) the product can correlate this congruence and parallel material to students' spatial skills with 3D objects. (6) Established questions must be related to the perspective of the most recent triangular congruence problems, (7) virtual geometry lab applications can be used appropriately and in accordance with the IQF material, and (8) students can overcome geometric congruence and parallelism questions in a chronological and captivating circumstance., and (9) This virtual geometry lab application product has no complication for consumers. ((10) In terms of the practicality of the geometry virtual lab product design, the validation findings show that the average outcome of the learning media expert evaluation is 93, suggesting that the virtual geometry lab item is extremely appropriate to be used in learning.

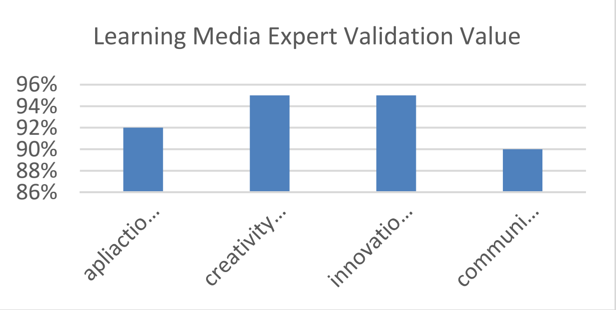

Figure 3. The findings of the virtual geometry lab product evaluation by learning media specialists

Moreover, based on material expert evaluation, the following conclusions were reached: (1) This virtual geometry lab product is ideal as a virtual adjunct to geometry course content; (2) principles linked to congruence and geometrical alignment material may be understood virtually; and (3) The virtual geometry lab program is fascinating to use in other courses, and (4) the virtual geometry lab application's menu options may be used in an exciting and pleasant manner. (5) This geometry congruence and parallelism content might be related to students' spatial cognition; (6) Recent issues must be linked to the framework of the most recent congruence and alignment challenges; and (7) This virtual geometry lab application can be utilized appropriately and in accordance with KKNI content; and (8) Students can address congruence and parallelism problems sequentially, and (9) This virtual geometry lab program is simple to use. (10) According to an expert evaluation of geometry educational materials, the data provided in the virtual geometry lab media is very conceivable to be implemented in learning geometry courses with an average value of 95, revealing that the geometry material used is arranged in a manner that is very adequate to be utilized in learning.

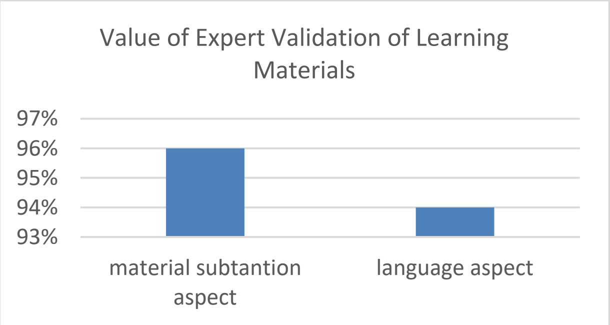

Figure 4. The findings of the learning material experts' certification of the depth of the geometry lab virtual product material

4.4. Implementation

At this stage, students from PGRI Semarang University and Universiti Teknologi Malaysia use the Virtual Lab Geometry product to study and understand Geometry classes on congruence and parallelism materials by first installing the virtual application geometry lab for congruence material, followed by a pretest before studying geometry and a post-test. Following participating in the Virtual Lab Geometry study, this activity is completed online using Zoom meetings.

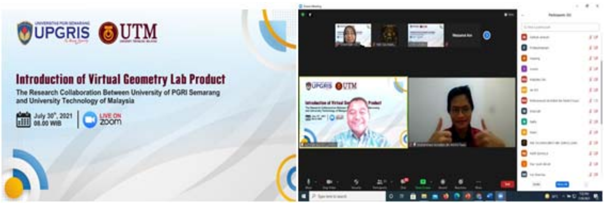

Figure 5. UPGRIS-UTM Geometry Virtual Lab Product Implementation

4.5. Evaluation

This research and development involves assessing the quality of virtual geometry lab instructional media products as well as the influence of using virtual geometry laboratories at PGRI Semarang University and Universiti Teknologi Malaysia, particularly:

a. **Evaluation of the quality of teaching media** is depending on the outcomes of a questionnaire evaluation of teaching material given to learning media experts, learning material experts, and trial participants This evaluation can be used to improve the virtual geometry lab application. The virtual geometry lab product is valid and beneficial according to the outcomes collected from material experts and media development experts, by meeting the material and media indicator criteria with an average score of 94, demonstrating that the virtual geometry lab product is generally useful.
b. **Assessment of the impact of employing a virtual geometry lab application** to measure students' cognitive and spatial abilities while focusing on posttest questions. This assessment is used as a consideration in the use of android-based instructional material with Virtual Reality in online or offline classrooms. The post test results of 86.25, which is deemed good, are one of the benefits of using this Geometry Virtual Lab Application. The following is one of the outputs of the alignment material pretest and posttest:

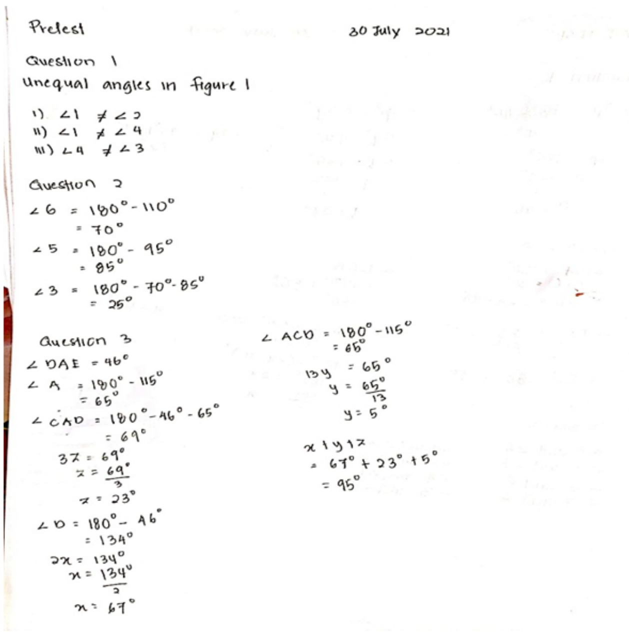

Figure 6. Students' pretest result

According to the pretest results, the research sample created an error in estimating the angle referred to in the question. One of the sources of the mistake is inaccuracy in determining the matching angle in the preceding stage. As a result, the magnitude of the angle at angle 3 was estimated inaccurately.

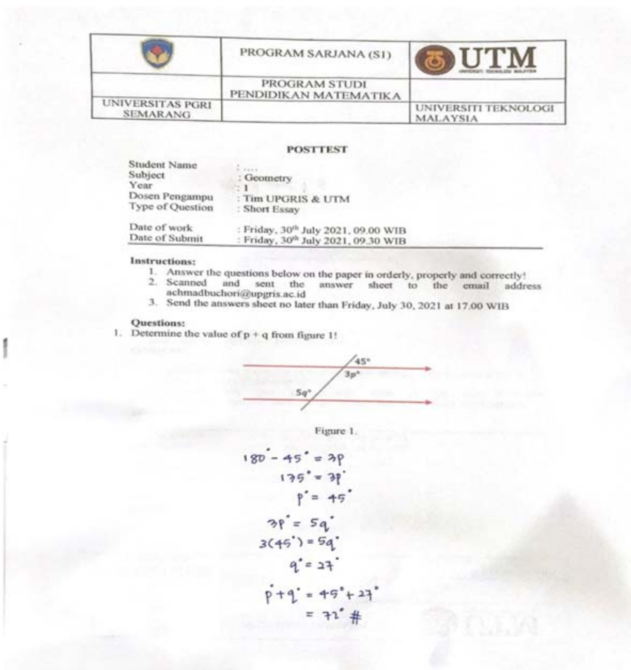

Figure 7. Students' posttest result

According to Figure 7, students can calculate the angle. By constructing parallel auxiliary lines and connecting them with the angle generated by two more parallel lines, researchers may find the value of x. To establish the efficacy of the final product, the data from the pre-test and post-test findings will be examined for N-Gain. The [22] criteria are utilized in the categorization of N-Gain interpretations.

Table 1. Criteria N-Gain score[22]

Index N-Gain	Criteria
$g < 0{,}03$	Low
$0{,}03 < g < 0{,}70$	Medium
$0{,}07 < g < 1{,}00$	High

Meanwhile, it relates to [23] in the following table when interpreting the success of attaining N-Gain as a percentage:

Table 2. Product Effectiveness Interpretation through N-Gain Score[23]

Presentation	Effectiveness
< 40	Ineffective
40-55	Less effective
56-75	Effective enough
> 76	effective

The pre-test average is 98.33, whereas the post-test average is 88. This outcome could be used to gauge the improvement in students' spatial geometry ability using the N-Gain score test.

The following N-Gain formula was used:

$$\text{N-Gain} = \frac{skor\ postest - skor\ pretest}{skor\ maksimal - skor\ pretest}$$

$$= \frac{88-98{,}33}{100-98.33} = \frac{-10.33}{1.67} = -6.18$$

The g value obtained is in the low and ineffective range, according to the N-Gain Score data. This is demonstrated by a decrease in the post-test value. This decrease in value was caused by the sample's numerous errors in post-test question number two. This question is more difficult than question number 2 on the pre-test.

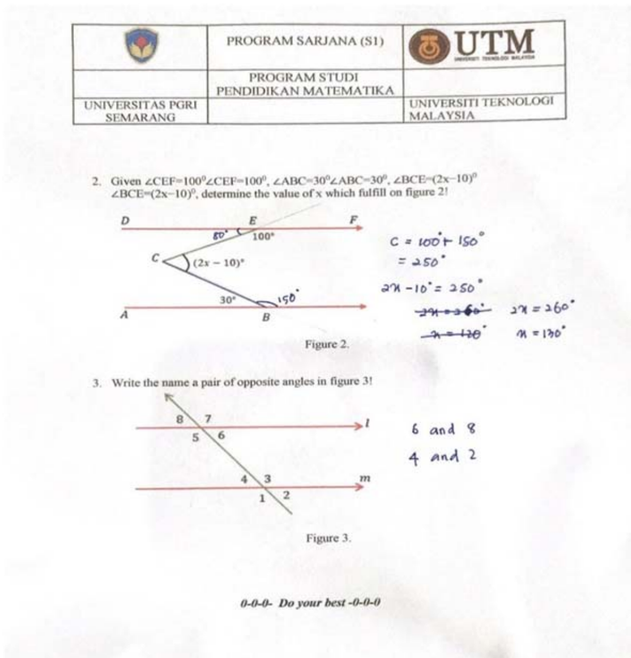

Figure 8. The comparison of question number 2 on Pretest as in figure 6 and Post test

It is also based on a response questionnaire that contains the following achievement indicators:

Table 3. Students' responses to the use of virtual lab geometry

The responses of using virtual lab geometry	strongly agree	agree	disagree	strongly disagree
I can virtually rephrase a geometric notion to address an issue.	34%	66%	0%	0%
Virtually, I comprehend an idea connected to material geometry.	36%	64%	0%	0%
I am interested in using the Geometry lab application	48%	52%	0%	0%
I can view and utilize the virtual geometry lab application's menus in a fascinating and entertaining manner.	52%	48%	0%	0%
I can connect the geometry content in the virtual lab medium to the spatial abilities of the learners.	34%	62%	4%	0%
I try to solve problems related to geometry properly and correctly	48%	52%	0%	0%
I can apply geometric formulas well and according to the application	28%	72%	0%	0%
I can solve questions about geometry in order	32%	66%	2%	0%
I'm sure this virtual geometry lab application product is simple to use.	36%	60%	4%	0%
This application is able to improve the cognitive abilities of students	52%	48%	0%	0%

The virtual geometry lab greatly enhances students' cognitive and spatial abilities in learning geometry, based on student response data from PGRI Semarang University and Universiti Teknologi Malaysia.

4.6. Discussion

Throughout the ADDIE model's research development stage, the following components were particularly developed:

During the analysis stage, it was encountered that up to 60% of students in the Mathematics Education study program at PGRI University Semarang and students at Malaysia University of Technology were still weak in mastering geometry material, particularly congruence and parallelism material, due to the majority's inability to practice virtually during the pandemic. The appropriate solution analysis is to construct media that can optimize students' practical skills in geometry material, with students being able to practice virtually during a pandemic, one of which is by using interesting virtual reality-based media that can improve students' cognitive and spatial abilities. [24] Proved that using a virtual lab to teach biology boosted students' interest and learning experience. then D.[14]. Explaining that studying through virtual labs By combining e-learning, students become more interested about studying, which is backed by [25], who indicates that virtual reality-based online learning makes it easier for students to acquire learning information.

A virtual geometry lab learning media design that can be installed on all Android devices was created throughout the design process. Geometry course content is offered in virtual media design, which includes flat and space-building materials that are cleanly and aesthetically packed with color gradations and animations capable of captivating students' cognitive and spatial abilities through exercise. [13] stated that Implementing a virtual physics laboratory enabled students to be more critical when researching a problem, but [26]found that virtual reality-based chemistry teaching increased abilities. Students who are creative in combining substances that have been tested in the laboratory, Then [27] the difference in efficiency in comprehending learners of a learning material between virtual-based learning and conventional learning is relatively obvious.

During the **development** stage, a virtual geometry lab product was developed and assessed by learning media and learning material specialists, who concluded that the virtual geometry lab product is well-suited for use in the geometry learning process. The virtual geometry lab product was integrated in the Mathematics Education study program at PGRI University Semarang and Universiti Teknologi Malaysia after expert evaluation. [28] demonstrated that the use of augmented reality, the Android-based Hijaiyyah Letter Recognition application built with Unity 3D was able to make it easier for students to absorb the Koran study material. [29] subsequently determined that educational games based on virtual augmented reality can boost students' motivation and spatial abilities by delivering entertaining activities. Then, [15] show how The virtual lab in physics learning assists students in better understanding the material's structure. According to [30], virtual reality is a renewable creation that makes school and college learning more interesting and engaging. It will be fascinating for the students.

During the implementation phase, students at PGRI University Semarang and Universiti Teknologi Malaysia were very enthusiastic about using virtual geometry lab products because the virtual geometry lab application displayed enjoyable objects and pushed students to master measuring angles, congruences, and parallels in geometry lab virtual app.

As stated by [31] Students in the vocational education study program at UTM acquired internships based on their abilities in mastering technology; one of the media taught is virtual reality, which is particularly useful in studying geometry and design-based computer science. Then, [32]emphasized Campuses must provide students with mastery of virtual reality tools so that they may package learning in an engaging and meaningful manner., In addition, L. [33] stated that the novelty of studying with virtual reality media pushes students to learn and try to produce interesting media supplements to their learning [34] clarified that in today's pandemic era, the world of education cannot be distinguished from augmented reality and virtual reality, both of which are very encouraging of the learning process, with students encouraged to adventure in the virtual world and the existence of an entertaining augmented reality.

In the **evaluation** phase, Students from PGRI University Semarang and Universiti Teknologi Malaysia completed the pretest and posttest, and the results show that using a virtual geometry lab product improved students' cognitive and spatial ability. The N Gain test also demonstrates a considerable gain in cognitive abilities and student spatial; however, one student's score is lower than the maximum since the pretest and posttest were administered at separate sites.[35] revealed that the training approach that combines virtual reality in its education astounds and encourage participants [36] indicated that virtual reality for education is incredibly intriguing to listen to since virtual reality makes studying more exciting and entertaining at all educational levels. [37] explained that vocational education in Malaysia has learnt a lot about utilizing virtual reality in mathematics instruction since learners are believed to be comfortable with using sustainable media and in accordance with the times.

5. Conclusion

According to the findings and discussions, the virtual geometry lab product development is a virtual geometry lab application based on the TPACK framework that is valid and feasible for use as one of the online learning media alternatives at PGRI Semarang University and Universiti Teknologi Malaysia. Although the N-Gain acquired is negative, this is due to the fact that the posttest questions are more harder than the pre-test questions. However, based on student response, the Virtual Lab Geometry product was well appreciated. Consequently, more emphasis should be placed on the development of test instruments for the degree of difficulty in the pretest and posttest equivalent for future research.

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References

[1]. Kusumaningrum, B., & Wijayanto, Z. (2020). Apakah pembelajaran matematika secara daring efektif?(studi kasus pada pembelajaran selama masa pandemi covid-19). *Kreano, Jurnal Matematika Kreatif-Inovatif*, *11*(2), 136-142. doi:10.15294/kreano.v11i2.25029

[2]. Syafar, F., Gao, J., & Du, J. T. (2015). Mobile Collaboration Technology to Support Maintenance Enterprise System in Large Industry. *AMCIS 2015 Proceedings*, 4.

[3]. Annur, M. F., & Hermansyah, H. (2020). Analisis kesulitan mahasiswa pendidikan matematika dalam pembelajaran daring pada masa pandemi covid-19. *Paedagoria: Jurnal Kajian, Penelitian Dan Pengembangan Kependidikan*, *11*(2), 195-201.

[4]. Noviartati, K., & Ernawati, A. (2017). Respon Mahasiswa terhadap Desain Perkuliahan Geometri yang Mengembangkan Kemampuan Komunikasi Matematika. In *Prosiding Seminar Nasional Matematika dan Pendidikan Matematika FMIPA UNY 2017* (pp. 403-409).

[5]. Triatmaja, A. K., & Khairudin, M. (2018, December). Study on skill improvement of digital electronics using virtual laboratory with mobile virtual reality. In *Journal of Physics: Conference Series, 1140*(1), 1-10. IOP Publishing. doi:10.1088/1742-6596/1140/1/012021

[6]. Zhang, M., Zhang, Z., Chang, Y., Aziz, E. S., Esche, S., & Chassapis, C. (2018). Recent developments in game-based virtual reality educational laboratories using the microsoft kinect. *International Journal of Emerging Technologies in Learning (iJET)*, *13*(1), 138-159. doi:10.3991/ijet.v13i01.7773

[7]. Kusuma, G. T. A., Wirawan, I. M. A., & Arthana, I. K. R. (2018). Virtual Reality for Learning Fish Types in Kindergarten. *iJIM*, *12*(8), 41-50. doi:10.3991/ijim.v12i8.9246

[8]. Buchori, A., Setyosari, P., Dasna, I. W., & Ulfa, S. (2017). Mobile augmented reality media design with waterfall model for learning geometry in college. *International Journal of Applied Engineering Research*, *12*(13), 3773-3780.

[9]. Syafar, F., Gao, J., & Du, J. T. (2014). Mobile-enabled collaborative maintenance. *Pacific Asia Conference on Information Systems, PACIS 2014.*

[10]. Buchori, A., Setyosari, P., Dasna, I. W., Ulfa, S., Degeng, I. N. S. & Sa'dijah, C.(2017). Effectiveness of direct instruction learning strategy assisted by mobile augmented reality and achievement motivation on students cognitive learning results. *Asian Social Science*, *13*(9), 137-144. doi:10.5539/ass.v13n9p137

[11]. Ronau, R. N., Rakes, C. R., & Niess, M. L. (Eds.). (2011). *Educational Technology, Teacher Knowledge, and Classroom Impact: A Research Handbook on Frameworks and Approaches: A Research Handbook on Frameworks and Approaches*. IGI Global. doi:10.4018/978-1-60960-750-0

[12]. Graham, C. R. (2011). Theoretical considerations for understanding technological pedagogical content knowledge (TPACK). *Computers & Education*, *57*(3), 1953-1960. doi:10.1016/j.compedu.2011.04.010

[13]. Aşıksoy, G., & Islek, D. (2017). The Impact of the Virtual Laboratory on Students' Attitudes in a General Physics Laboratory. *International Journal of Online Engineering*, *13*(4), 20-28. doi:10.3991/ijoe.v13i04.6811

[14]. Liu, D., Valdiviezo-Díaz, P., Riofrio, G., Sun, Y. M., & Barba, R. (2015). Integration of virtual labs into science e-learning. *Procedia Computer Science*, *75*, 95-102. doi:10.1016/j.procs.2015.12.224

[15]. Potkonjak, V., Gardner, M., Callaghan, V., Mattila, P., Guetl, C., Petrović, V. M., & Jovanović, K. (2016). Virtual laboratories for education in science, technology, and engineering: A review. *Computers & Education*, *95*, 309-327. doi:10.1016/j.compedu.2016.02.002

[16]. Shulman, L. (1987). Knowledge and teaching: Foundations of the new reform. *Harvard educational review*, *57*(1), 1-23.

[17]. Rafi, I., & Sabrina, N. (2019). Pengintegrasian TPACK dalam Pembelajaran Transformasi Geometri SMA untuk Mengembangkan Profesionalitas Guru Matematika. *SJME (Supremum Journal of Mathematics Education)*, *3*(1), 47-56. doi:10.35706/sjme.v3i1.1430

[18]. Craps, B., Roose, F., Troost, W., & Van Proeyen, A. (1996). The definitions of special geometry. *arXiv preprint hep-th/9606073*.

[19]. Uttal, D. H., Amaya, M., del Rosario Maita, M., Hand, L. L., Cohen, C. A., O'Doherty, K., & DeLoache, J. S. (2013). It works both ways: Transfer difficulties between manipulatives and written subtraction solutions. *Child Development Research*, *2013*, 1-13. doi:10.1155/2013/216367

[20]. Zhang, C., Chen, M., Xu, X., Zhang, L., Zhang, L., Xia, F., ... & Gao, J. (2014). An extraordinary stable modified reduced graphene oxide suspension and its catalysis. *Science of Advanced Materials*, *6*(4), 760-770. doi:10.1166/sam.2014.1766

[21]. Burte, H., Gardony, A. L., Hutton, A., & Taylor, H. A. (2020). Elementary teachers' attitudes and beliefs about spatial thinking and mathematics. *Cognitive Research: Principles and Implications*, *5*(1), 1-18. doi:10.1186/s41235-020-00221-w

[22]. Meltzer, D. E. (2002). The relationship between mathematics preparation and conceptual learning gains in physics: A possible "hidden variable" in diagnostic pretest scores. *American journal of physics*, *70*(12), 1259-1268. doi:10.1119/1.1514215

[23]. Hake, R. (2002). Lessons from the physics education reform effort. *Conservation Ecology*, *5*(2), 28.

[24]. Kapilan, N., Vidhya, P., & Gao, X. Z. (2021). Virtual laboratory: A boon to the mechanical engineering education during covid-19 pandemic. *Higher Education for the Future*, *8*(1), 31-46. doi:10.1177/2347631120970757

[25]. Srinivasa, A. R., Jha, R., Ozkan, T., & Wang, Z. (2021). Virtual reality and its role in improving student knowledge, self-efficacy, and attitude in the materials testing laboratory. *International Journal of Mechanical Engineering Education*, *49*(4), 382-409. doi:10.1177/0306419019898824

[26]. Gorghiu, L. M., Gorghiu, G., Alexandrescu, T., & Borcea, L. (2009). Exploring chemistry using virtual instrumentation-challenges and successes. *Research, Reflections and Innovations in Integrating ICT in Education*, *1*(1), 371-375.

[27]. Osuna, J. B., Gutiérrez-Castillo, J., Llorente-Cejudo, M., & Ortiz, R. V. (2019). Difficulties in the incorporation of augmented reality in university education: Visions from the experts. *Journal of New Approaches in Educational Research (NAER Journal)*, *8*(2), 126-141. doi:10.7821/naer.2019.7.409

[28]. Nisa, K. F., Khoiri, N., & Wijayanto, W. (2020). Aplikasi Pengenalan Huruf Hijaiyyah Berbasis Android Menggunakan Unity 3D. *JIPETIK: Jurnal Ilmiah Penelitian Teknologi Informasi & Komputer*, *1*(1), 21-27.

[29]. Sunandar, N. D., Rahmawati, A. W., & Buchori, A. (2020). Development of game education basic virtual augmented reality in geometry learning. *Test Eng. Manag*.

[30]. Zheng, R., Zhang, D., & Yang, G. (2015, March). Seam the real with the virtual: a review of augmented reality. In *2015 Information Technology and Mechatronics Engineering Conference* (pp. 77-80). Atlantis Press. doi:10.2991/ITOEC-15.2015.17

[31]. Amin, N. F., Latif, A. A., Arsat, M., Suhairom, N., Jumaat, N. F., & Ismail, M. E. (2020). The implementation of the internship as a coursework in teaching and learning vocational education. *Journal of Technical Education and Training*, *12*(1), 82-90. doi:10.30880/jtet.2020.12.01.009

[32]. Kavanagh, S., Luxton-Reilly, A., Wuensche, B., & Plimmer, B. (2017). A systematic review of virtual reality in education. *Themes in Science and Technology Education*, *10*(2), 85-119.

[33]. Freina, L., & Ott, M. (2015, April). A literature review on immersive virtual reality in education: state of the art and perspectives. In *The international scientific conference elearning and software for education, 1*(133), 10-1007.

[34]. Elmqaddem, N. (2019). Augmented Reality and Virtual Reality in Education. Myth or Reality?. *International Journal of Emerging Technologies in Learning (iJET)*, *14*(3), 234-242. doi:10.3991/ijet.v14i03.9289

[35]. Pantelidis, V. S. (2010). Reasons to use virtual reality in education and training courses and a model to determine when to use virtual reality. *Themes in Science and Technology Education*, *2*(1-2), 59-70.

[36]. Alnagrat, A. J. A., Ismail, R. C., & Idrus, S. Z. S. (2021, May). Extended reality (XR) in virtual laboratories: a review of challenges and future training directions. In *Journal of Physics: Conference Series* (Vol. 1874, No. 1, p. 012031). IOP Publishing. doi:10.1088/1742-6596/1874/1/012031

[37]. Amin, N. F., Jwasshaka, S. K., & Latif, A. A. (2021). Validation of Employers Views on Soft and Hard Job Skills of Nigeria Polytechnic Construction Graduates. *International Journal of Research in Education*, *1*(1), 16-32. doi:10.26877/ijre.v1i1.6257