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PAPER

Construction of Immersive Experiences: Development of Virtual Reality Technology to Facilitate Physical Geography Learning

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ABSTRACT

The rapid development of technology encourages using the latest learning media, virtual reality technology. Virtual reality technology can facilitate the study of physical geography by exploring virtual environments and being an innovation in conventional teacher-oriented learning, classrooms, printed books, and lecture methods. The research objective was to produce Geosite Interactive Virtual Technology (GeoVirtex) using the ASSURE development model and to test the practicality and effectiveness of the product in the learning process. The study results are GeoVirtex media which have been declared valid and suitable for use based on expert validators. GeoVirtex can provide immersive experiences based on constructivist ideas by providing active and independent learning to positively impact understanding and learning outcomes. Based on product trials on 85 students, the media is classified as very practical (90.87%), and the effectiveness of the media is moderate (0.38).

KEYWORDS

virtual reality technology, physical geography learning, geo-visualization, immersive experience

1 INTRODUCTION

Virtual reality technology, three-dimensional (3D) photography, spherical images, or simulated real-world [1], [2] are computer-generated media that are real scenes and have a coverage of 360° [3], [4]. Interactivity, immersion, and imagery are the main features of virtual reality that differentiate it from other technologies [5]. Virtual reality has been used since the 1960s in the US military field [6], and education began in the 1990s [7] when its use was limited to research projects and educational experiments [8].

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Virtual reality can be used in learning by providing virtual space for students [5], [9]. This virtual space can be linked to other media, such as infographics, podcasts, video footage, 360° media, 3D models, Uniform Resource Locator (URL) Websites, and so on [10]. A realistic visualization supported by material can make it easier for students to carry out field exploration, thereby increasing student involvement and understanding as a form of immersive experience in learning [11], [12]. Immersive experiences based on the idea of constructivism are active learning [13], situational learning [14], and experiential learning [15] to facilitate learning activities [16], [17].

The study of physical geography on the dynamics of the geosphere is closely related to Geopark as a Geoheritage, which has a Geological Heritage Site (Geosite). One of the goals of geopark development is the field of education [18], [19] through the Ijen Geopark local content curriculum, field visits (geo-education), and so on [19], [20]. Adjusting the local content curriculum and including it in geography lessons can provide motivation, shape character, and make it easier to understand the material according to the competencies to be achieved [19], [21].

Based on the initial analysis results, students struggled with lithospheric material because it has many terms and broad coverage. Most of it is abstract, requires real visual examples, and field practice [22]. The learning technology is limited to PowerPoint texts or learning videos, which are less helpful in facilitating students in understanding the material, and do not involve the surrounding environment as a learning resource [23]. The geo-education program cannot run all the time due to distance, time, cost, number of participants, physic of participants, and weather [24], [25].

The use of virtual reality technology can facilitate field exploration activities regarding the physical study of geography and support active and independent learning by displaying a realistic environment to provide an immersive and meaningful experience [26], [27]. In previous research, the use of virtual reality technology in the learning process increased understanding [13], [28], motivation, participation, and student involvement in virtual field exploration activities [17], [27], and rendered 3D learning realistic, immersive, engaging, compelling, interactive, and enjoyable [29]–[31]. The research objective was to produce and test the practicality and effectiveness of Geosite Interactive Virtual Technology (GeoVirtex) media on the Ijen Geosite Geopark as a learning medium.

2 METHODS

This research includes Research and Development (R&D) with the ASSURE development model, which has six stages, as shown in Figure 1 [32]. The research objects are the five Ijen Geopark Geosites, including the Kalipait Acid Flow Geosite, Wurung Crater Geosite, Blawan Hot Spring Complex Geosite, Plalangan Lava Flow Geosite, and So'on Solor Stone Park Geosite. The product trial phase will occur in Bondowoso 2 Senior High School Bondowoso, Banyuwangi 1 Senior High School, and Banyuwangi 1 Islamic Senior High School. The practicality test is based on the results of the average student response questionnaire, and the effectiveness test uses of the N-Gain Score test [33].

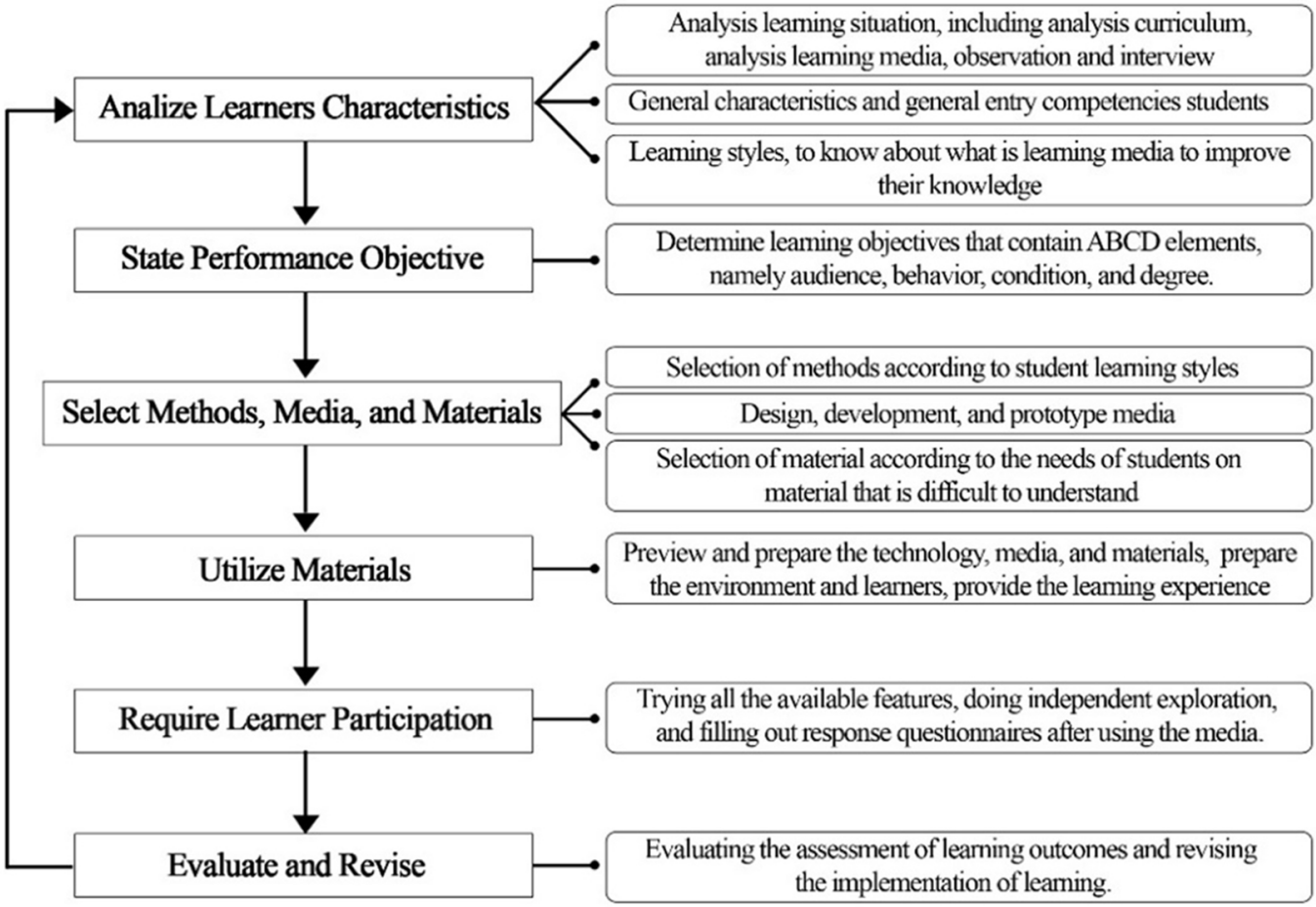

Fig. 1. Flowchart of the ASSURE development model

Step 1: Analyze Learner's Characteristics

The initial stage is to analyze student characteristics, curriculum analysis, material analysis, and media analysis that has been developed and the media used. For the analysis of student needs, an online questionnaire was used and the geography teacher interviewed.

Step 2: State Performance Objective

The next stage is to determine competencies or learning outcomes that contain ABDC elements, namely audience, behavior, condition, and degree.

Step 3: Select Methods, Media, and Materials

The selection of methods is adjusted to the material, media, and student learning styles. Determination of teaching materials adapted to material that is difficult to understand. In this research, Geosite Interactive Virtual Technology (GeoVirtex) was developed at the Ijen Geopark Geosite as a learning medium. Design application of GeoVirtex as a learning medium shown in Figure 2. GeoVirtex leverages virtual reality and the 3D Vista Virtual Tour Pro application to construct virtual spaces. Virtual space is integrated with other media using hotspot features such as infographics to provide material, video footage as visualization reinforcement, and Modeling Maps to show locations and improve spatial understanding. Giving menus to various user interfaces can positively affect the user experience [34].

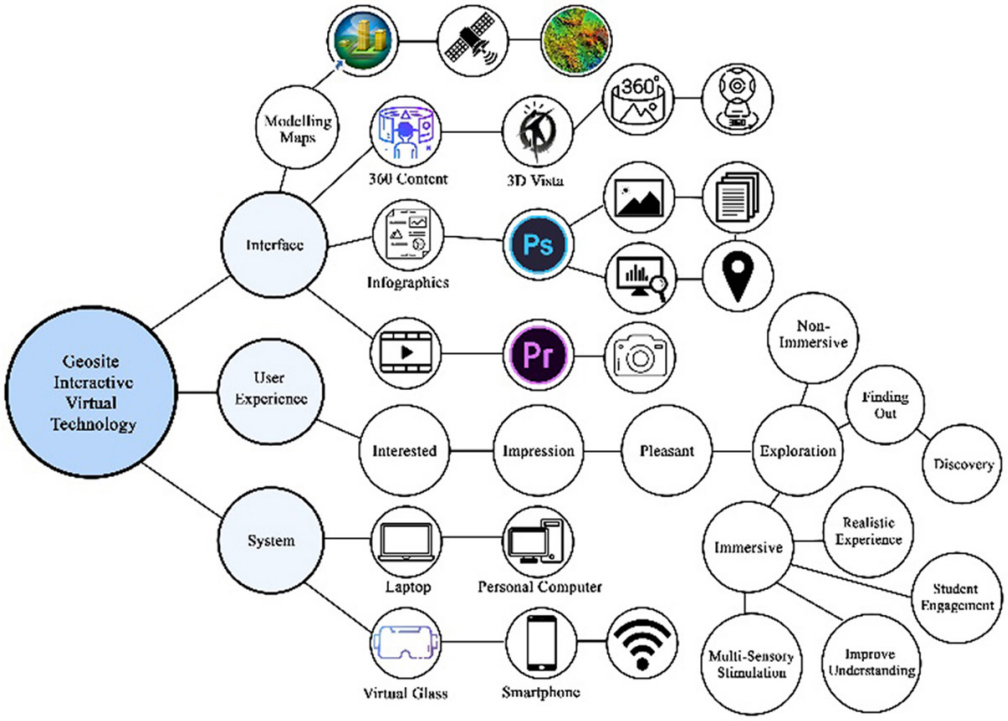

Fig. 2. Design application of GeoVirtex

The results of the GeoVirtex prototype can be tested to determine the suitability of user interface menus and hotspots in virtual space. The GeoVirtex prototype can only be accessed offline using a laptop or computer. The GeoVirtex prototype is uploaded to the website database via cPanel hosting to be accessed online. A validation process was carried out to find out the feasibility by a justification expert based on validity criteria [34], and the revision process was carried out based on professional adjustments to improve the quality of GeoVirtex. GeoVirtex, declared valid, can be used in the learning process. This process is shown by Figure 3.

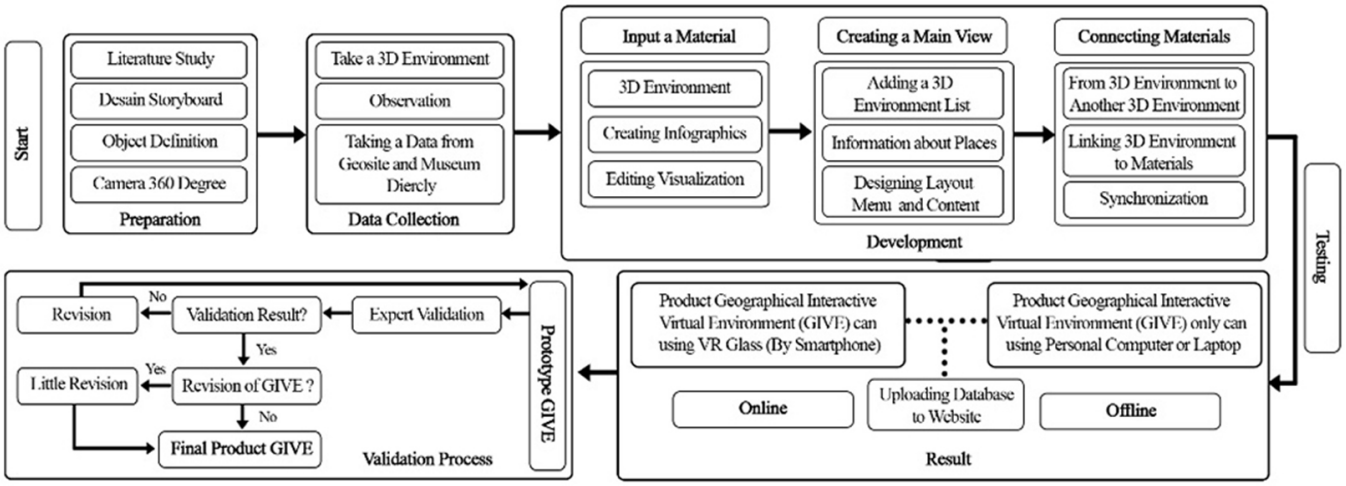

Fig. 3. Framework development GeoVirtex

Step 4: Utilize Materials

The next stage is product implementation, consisting of small-scale trials, preparing learning needs, managing the learning environment, informing the goals and benefits of learning, and providing student-oriented learning experiences.

Step 5: Require Learner Participation

The next stage involved student participation [35], including trying out all the available features, doing independent exploration, and filling out useful questionnaires after using the media. The practicality questionnaire is used to determine the effectiveness of the media in the learning process.

Step 6: Evaluate and Revise

The last stage is the assessment of learning outcomes using a written test with a before-after model and revising the implementation of learning. The results of the written test are used to determine the effectiveness of the media using the N-Gain Score test.

3 RESULT

This research produces Geosite Interactive Virtual Technology (GeoVirtex) based on student needs analysis, curriculum analysis, material analysis, and media analysis used and media that has been developed. GeoVirtex has gone through the validation stage and is declared valid and feasible based on the material expert validator (0.88) and the expert media validator (0.84). Home view of GeoVirtex shown in Figure 4.

Fig. 4. GeoVirtex home view

GeoVirtex is equipped with various menus, including Goals (learning achievements), Information (information about the regional geology of the Ijen Geopark, as shown in Figure 5 and the process of forming the Ijen Ancient Caldera), Geosite (available Geosite information and can go to other Geosites), Map of Geosite (3D map of Geosite location in GeoVirtex), Exercise (quiz linked to Google form), Help (explanation of each menu and setting), References (reference or source material used), Copyright (copyright information), and Tumblist (collection of virtual spaces within

the Geosite area). In addition, GeoVirtex is also equipped with various settings to support immersive experiences [36], such as VR Button, Gyroscope Button, Media Audio, and Fullscreen Button.

Fig. 5. Ijen geopark regional geological information menu

GeoVirtex can be accessed offline by downloading the GeoVirtex app (https://bit.ly/GeoVirtexOffline) and can only run on a laptop or computer with a minimum specification of Windows 8, Intel Celeron N3350 Processor or AMD A-Series 1.1 Ghz, 4GB RAM Hard Disk Storage Drive (HDD) 6 Gb, and a screen resolution of 1280 × 800. The GeoVirtex app can run without installing any other assistive applications [37].

In addition, GeoVirtex can be accessed online (https://bit.ly/Geovirtexonline) through a device browser with a minimum internet speed of 1 Mbps. In addition to easy access, GeoVirtex can also use virtual reality features to provide students with an immersive experience, as shown in Figure 6. However, virtual reality mode can work well if the device has a gyroscope sensor feature to see 3D objects accurately and responsively [38].

a)

Fig. 6. *(Continued)*

b)

Fig. 6. View of the hotspot (a) and video footage (b) in virtual reality mode

The menu display does not appear in virtual reality mode, so the material is connected to the hotspot feature. Hotspots are linked with infographics containing material in the Geosite area and video footage to provide a more in-depth visualization. While in virtual reality mode, the user can use the pointer (the white dot in the middle of the display) as a controller.

A small-scale trial was conducted at 11 Social Science Banyuwangi 1 Senior High School with 12 students to find out the practicality of GeoVirtex. The trial phase includes (1) an Explanation of virtual reality technology and introduction to GeoVirtex, (2) Accessing media, explaining and trying all menus and settings, especially the VR Button and how to use it, (3) an Explanation of material on the information menu using GeoVirtex, (4) Doing independent exploration using VR Glasses to get an immersive experience, and (5) Filling out a helpful questionnaire. Based on the results of a practicality questionnaire on small-scale trials, the media is classified as very practical (92.45%).

In addition, GeoVirtex also conducts large-scale trials to determine its practicality and effectiveness in the learning process [39]. The large-scale trial was conducted in 11 Social Sciences at Bondowoso 2 Senior High School, Banyuwangi 1 Senior High School, and Banyuwangi 1 Islamic Senior High School, with 85 students. Based on the pretest-posttest results using the Wilcoxon test, all subjects experienced positive ranks and asymp values. Sig. (2-tailed) which shows that there is a significant average difference of 31.84. The questionnaire results show that the media is classified as very practical (90.87%), and the effectiveness of the media is moderate (N-Gain Score of 0.38).

4 DISCUSSION

Based on curriculum analysis, learning achievement indicators in GeoVirtex include (1) Types and characteristics of the earth's crust, (2) The process of forming volcanic areas in the Banyuwangi-Bondowoso region, (3) The development of Ancient Ijen Volcano, (4) Endogenous processes and exogenous on the Ijen Geopark Geosite, (5) Types, types, and materials resulting from the eruption of the Ancient Ijen Volcano and the Ijen Intra-Caldera Volcano, (6) Types of rock on the Geosite, and (7) Impacts on human life and other living things. Geovirtex is composed of various media, such as maps and 3D modeling maps as shown in Figure 6 and various topics. The composition and topic of each geosite in Geovirtex can be seen in Table 1.

Table 1. Geosite composition and topics in Geovirtex

Geosite	Location	Composition	Topic
Kalipait Acid Flow Geosite	8°03′44.5″S 114°12′59.2″E	Three equirectangular images, six Infographics, one Footage Video	Rocks, water conditions, vegetation, living things, and their utilization.
Wurung Crater Geosite	8°03′53.4″S 114°09′40.9″E	Five equirectangular images, five Infographics, one Footage Video	The process of formation, mountain types, and ecosystems, and their utilization
Blawan Hot Spring Complex Geosite	7°59′11.7″S 114°10′28.3″E	Seven equirectangular images, five infographics, one footage video	Distribution, geothermal manifestations, and their utilization
Plalangan Lava Flow Geosite	8°00′34.0″S 114°09′25.0″E	Four equirectangular images, six infographics, two footage videos	Composition and structure of black lava, ecosystems, residual landforms
So'on Solor Stone Park Geosite	7°51′30.0″S 114°04′37.8″E	Eight equirectangular images, five Infographics	Ijen Purba volcanic eruption results, ignimbrite distribution, endogenous and exogenous controls

Source: Research Data.

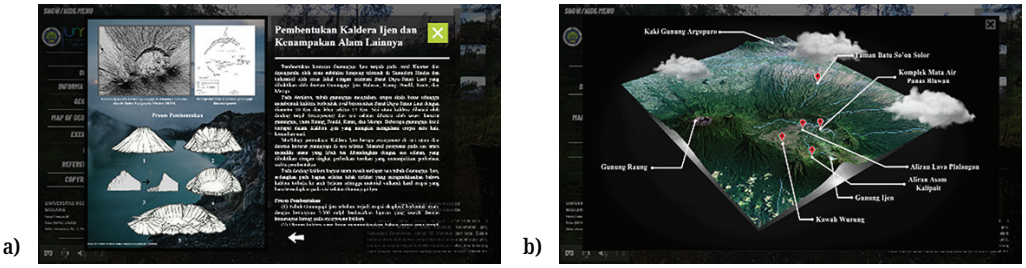

Fig. 7. GeoVirtex equipped with 2D (a) and 3D (b) modelling maps

The user experience element is the user's experience or feelings after using GeoVirtex. After using GeoVirtex, it is hoped that students will have positive feelings such as interest, impressment, and fun. To support exploring and discovering, GeoVirtex is equipped with a support system that supports using VR Glasses [40]. These VR Glasses are not mandatory but essential to provide an immersive experience.

GeoVirtex can facilitate physical geography studies and field practice virtually [41]. In geography learning, physical studies are found in geosphere phenomena and can utilize the geopark environment as a learning resource [25], [42]. The Ijen Geopark has various Geological Sites (Geosites) related to geological processes [19], [43]. The Ijen Geopark Geosite includes physical features, weather and climate, soil, water, vegetation, and living things [27]. Geosite objects in GeoVirtex are shown in the Table 2 below.

Table 2. Geosite characteristics in the Ijen Geopark

Geosite	Characteristics
Kalipait Acid Flow Geosite	Rivers with high H_2SO_4 content. A natural chemical reaction containing H_2SO_4 with $CaCO_3$ produces gypsum crystals $CaSO_4 \cdot {}_2H_2O$ and CO_2.
Wurung Crater Geosite	It is an inner caldera volcano formed from volcanism and has geothermal potential.
Blawan Hot Spring Complex Geosite	Hot springs whose distribution follows the existence of a fault in the northern area of Wurung Crater.
Plalangan Lava Flow Geosite	Representation of black lava flow with basaltic basalt-andesite composition along 9.9 km with an area of 10.51 km^2 from Mount Anyar to the Blawan area.
So'on Solor Stone Park Geosite	It is an Old Ijen Volcanic Rock Unit, consisting of volcanic breccia, pumice breccia, tuff, and basalt lava.

Source: [27].

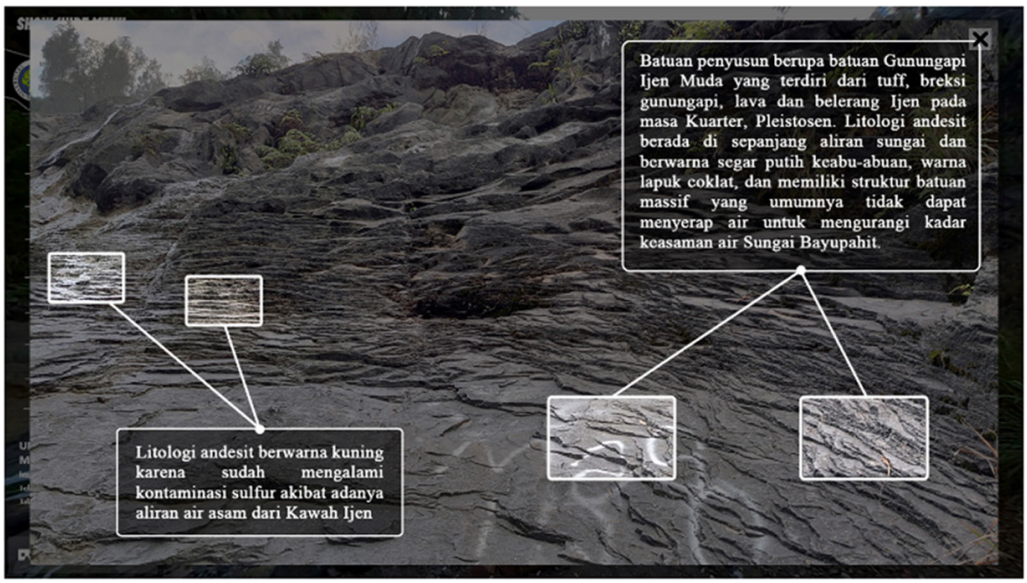

Fig. 8. Study of rocks in the Kalipait Acid Flow Geosite

Apart from contributing to learning geography, GeoVirtex also supports the Geoeducation program, which aligns with the Ijen Geopark's objectives: conservation, education, and sustainable development. GeoVirtex also supports the P5 program (Project for Strengthening Pancasila Student Profile) Independent Curriculum on the theme "Local Wisdom" by adopting Geopark Ijen as the central theme by Bondowoso 2 senior high school.

The strengths of GeoVirtex in the learning process are (1) Facilitating field exploration activities in studying geosphere phenomena without being hindered by physical body conditions, weather, time, costs, or other obstacles. [44], (2) Improving students' spatial abilities because they describe conditions that are natural and equipped with maps and 3D modelling [45], (3) Arousing curiosity and encouraging students to find answers [46], (4) Easy use so that it can support active and independent learning processes [47], and (5) Having a virtual reality mode so that students get an immersive experience [48].

The disadvantages of GeoVirtex include (1) Only available on some Ijen Geopark Geosites, (2) It does not cover all learning outcomes in the material, (3) It requires fast and stable internet, (4) The VR Button must be equipped with a gyroscope feature on a smartphone, and (5) Use of VR Glasses can cause dizziness in users with visual impairments.

To find out the practicality and effectiveness of GeoVirtex, a product trial stage was carried out in the learning process. The trial stages are shown in the Figure 9 below.

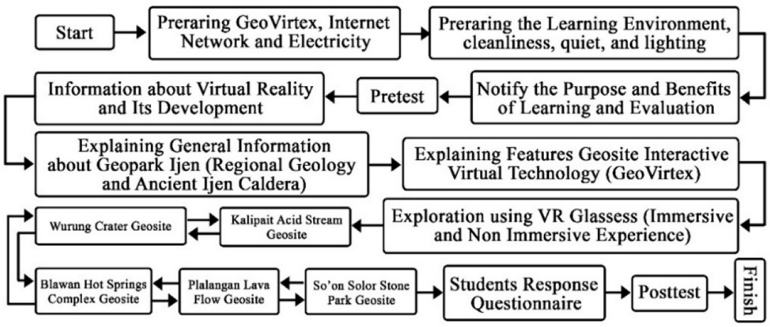

Fig. 9. Flowchart of testing GeoVirtex products in the learning process

To measure understanding and learning outcomes, students who had gone through the instrument trial stage answered pretest and posttest questions. The instrument used is a descriptive test of five questions according to the learning achievement indicators, namely (1) The process of forming a volcanic area in the Banyuwangi-Bondowoso area, (2) the development of the Ijen Geopark area, (3) Endogenous processes in the Geosite Geopark Ijen in the form of material resulting from intra-caldera volcanic eruptions, (4) Endogenous processes at the Ijen Geopark Geosite in the form of geothermal distribution, and (5) Impacts caused by the Banyupahit River.

The trial results show that the enthusiasm and motivation shown by students are very high because they use virtual reality technology [49]. GeoVirtex is a trigger to attract interest in learning and increase student engagement, so learning is more interactive than PowerPoint Text or learning videos. GeoVirtex encourages student curiosity and supports the process of discovery as a form of meaningful learning. GeoVirtex is an ideal learning media regarding the physical study of geography by providing a realistic picture of the environment and is accompanied by learning materials.

In addition, GeoVirtex also supports independent learning because it can be accessed via each student's smartphone. GeoVirtex is open-access, so it can be used outside of learning hours and is not tied to the classroom [50]. GeoVirtex guarantees students' security in studying physical phenomena of geography with exploration activities and conservation of Geosites without causing pollution footprints [28], [34].

GeoVirtex provides an immersive learning experience because (1) It provides a realistic picture of the environment [34], (2) It involves student participation and involvement [27], (3) It provides information in the form of material so that students do not only see a virtual environment [51], (4) Improving understanding and student learning outcomes [50], and (5) Using multi-sensory stimulation in the form of sight and hearing [29]. An immersive experience can use VR Glasses so that students feel they are in a virtual environment [36].

Fig. 10. Use of VR Glasses to provide an immersive experience in small-scale product trials (a) and large-scale trials for students of banyuwangi 1 senior high school (b) students of banyuwangi 1 islamic senior high school (c) and students of bondowoso 2 senior high school (d)

5 CONCLUSION

Ijen Geopark is an earth heritage (Geoheritage) that has Geological Diversity (Geodiversity) and is indicated by the existence of Geological Sites (Geosite). Geosite can be a source of student learning in studying physical phenomena through field exploration activities. However, as there can be many obstacles, media that can facilitate exploratory activities in the learning process is required. For this reason, GeoVirtex media was developed, which utilizes virtual reality technology to bring students to explore virtual space without the need to go directly to the location. GeoVirtex was developed based on student needs, curriculum, material, and media analysis developed and the media used. GeoVirtex has gone through the validation stage and was declared valid and suitable for use in learning processes by the material expert validator (0.88) and the media expert validator (0.84). GeoVirtex can facilitate field exploration activities in assessing the physical environment, creating active and independent learning, and fostering students' positive attitudes and activities. GeoVirtex is evidenced by increased student learning outcomes through the N-Gain Score of 0.38, and the media is classified as very practical (90.87%).

6 REFERENCES

[1] Y. Zhou, L. Tian, C. Zhu, X. Jin, and Y. Sun, "Video coding optimization for virtual reality 360-degree source," *IEEE J. Sel. Top. Signal Process*, vol. 14, no. 1, 2020. https://doi.org/10.1109/JSTSP.2019.2957952

[2] R. Chen and A. Sharma, "Retracted article: Construction of complex environmental art design system based on 3D virtual simulation technology," *Int. J. Syst. Assur. Eng. Manag*, p. 50091, 2021. https://doi.org/10.1007/s13198-021-01104-z

[3] J. Li and T. Hou, "Application of virtual reality technology in analysis of the three-dimensional evaluation system of rural landscape planning," *Math. Probl. Eng*, vol. 2021, 2021. https://doi.org/10.1155/2021/6693143

[4] Y. Qiu and J. Tao, "The development and realization of digital panorama media technology based on VR technology," *Comput. Intell. Neurosci*, vol. 2022, 2022. https://doi.org/10.1155/2022/1023865

[5] F. Wang, "Computer distance virtual experiment teaching application based on virtual reality technology," *Int. J. Emerg. Technol. Learn*, vol. 13, no. 4, pp. 83–94, 2018. https://doi.org/10.3991/ijet.v13i04.8472

[6] X. Liu, J. Zhang, G. Hou, and Z. Wang, "Virtual reality and its application in military," *IOP Conf. Ser. Earth Environ. Sci*, vol. 170, no. 3, 2018. https://doi.org/10.1088/1755-1315/170/3/032155

[7] P. A. Rospigliosi, "Metaverse or Simulacra? Roblox, Minecraft, Meta and the turn to virtual reality for education, socialisation and work," *Interact. Learn. Environ*, vol. 30, no. 1, pp. 1–3, 2022. https://doi.org/10.1080/10494820.2022.2022899

[8] S. N. Kader, W. B. Ng, S. W. L. Tan, and F. M. Fung, "Building an interactive immersive virtual reality crime scene for future chemists to learn forensic science chemistry," *J. Chem. Educ*, vol. 97, no. 9, pp. 2651–2656, 2020. https://doi.org/10.1021/acs.jchemed.0c00817

[9] T. Y. Volodymyrovych, K. Tetiana, T. B. Yaroslavovych, A. Agrawal, and D. Ghosh, "Evaluation of virtual reality technology and online teaching system for medical students in Ukraine during COVID-19 pandemic," *Int. J. Emerg. Technol. Learn*, vol. 16, no. 23, pp. 127–139, 2021. https://doi.org/10.3991/ijet.v16i23.26099

[10] J. Cheng, "Evaluation of physical education teaching based on web embedded system and virtual reality," *Microprocess. Microsyst*, vol. 83, p. 103980, 2021. https://doi.org/10.1016/j.micpro.2021.103980

[11] L. N. Lee, M. J. Kim, and W. J. Hwang, "Potential of augmented reality and virtual reality technologies to promote wellbeing in older adults," *Appl. Sci*, vol. 9, no. 17, 2019. https://doi.org/10.3390/app9173556

[12] A. A. Malik, T. Masood, and A. Bilberg, "Virtual reality in manufacturing: Immersive and collaborative artificial-reality in design of human-robot workspace," *Int. J. Comput. Integr. Manuf*, vol. 33, no. 1, pp. 22–37, 2020. https://doi.org/10.1080/0951192X.2019.1690685

[13] Z. Jin, "A constructivism-based 3D scene display teaching system for wushu teaching," *Int. J. Emerg. Technol. Learn*, vol. 12, no. 1, pp. 84–94, 2017. https://doi.org/10.3991/ijet.v12i01.6485

[14] L. Ni, "Learning process through virtual reality: A theory-based application," *Proc. 2022 2nd Int. Conf. Mod. Educ. Technol. Soc. Sci. (ICMETSS 2022)*, pp. 698–705, 2023. https://doi.org/10.2991/978-2-494069-45-9

[15] O. B. Tarnopolsky and S. P. Kozhushko, "Principled pragmatism and experiential learning: Two facets of constructivism in ESP," *J. Teach. English Specif. Acad. Purp*, vol. 8, no. 2, pp. 123–133, 2020. https://doi.org/10.22190/JTESAP2002123T

[16] A. Dengel and J. Magdefrau, "Immersive learning predicted: Presence, prior knowledge, and school performance influence learning outcomes in immersive educational virtual environments," *Proc. 6th Int. Conf. Immersive Learn. Res. Network, iLRN 2020*, no. iLRN, pp. 163–170, 2020. https://doi.org/10.23919/iLRN47897.2020.9155084

[17] N. Songkram, N. Songkram, S. Chootongchai, and T. Samanakupt, "Developing students' learning and innovation skills using the virtual smart classroom," *Int. J. Emerg. Technol. Learn*, vol. 16, no. 4, pp. 34–51, 2021. https://doi.org/10.3991/ijet.v16i04.15221

[18] C. Ansori, N. I. Setiawan, I. W. Warmada, and H. Yogaswara, "Identification of geodiversity and evaluation of geosites to determine Geopark themes of the Karangsambung-Karangbolong National Geopark, Kebumen, Indonesia," *Int. J. Geoheritage Park*, vol. 10, no. 1, pp. 1–15, 2022. https://doi.org/10.1016/j.ijgeop.2022.01.001

[19] I. K. Mastika, S. Sisbudi, W. Khristianto, P. Oktawirani, and P. Satriya, "Creative strategies of local resources in managing geotourism in the Ijen Geopark Bondowoso, East Java, Indonesia," *Int. J. Geoheritage Park*, vol. 11, no. 1, pp. 149–168, 2023. https://doi.org/10.1016/j.ijgeop.2023.01.002

[20] H. Reizal, A. Sujana, and W. Sopandi, "Analysis of elementary teachers understanding on Ijen Geopark," *Int. Conf. Elem. Educ*, vol. 4, no. 1, pp. 263–276, 2022.

[21] A. A. K. Budiastra, S. Puspitasari, I. Wicaksono, and N. Erlina, "Study of the local wisdom curriculum of Geopark Belitung to support local cultural values in context of natural science learning for elementary school," *Adv. Soc. Sci. Res. J*, vol. 8, no. 5, pp. 692–706, 2021. https://doi.org/10.14738/assrj.85.10280

[22] N. Shaherani, A. K. Putra, D. Soelistijo, and B. Yembuu, "The development of mobile geography virtual laboratory for rock and soil practicum studies," *Int. J. Interact. Mob. Technol*, vol. 16, no. 22, pp. 142–156, 2022. https://doi.org/10.3991/ijim.v16i22.36163

[23] E. Sulistianingsih and M. Mukminan, "The development of web-based learning multimedia on lithosphere material and its effectivity in improving students' learning motivation and outcomes," *J. Geosfera Indonesia*, vol. 4, no. 1, pp. 11–24, 2019. [Online]. Available: https://jurnal.unej.ac.id/index.php/GEOSI; https://doi.org/10.19184/geosi.v4i1.9882

[24] M. Wolf, F. Wehking, M. Montag, and H. Söbke, "360°-based virtual field trips to waterworks in higher education," *Computers*, vol. 10, no. 9, 2021. https://doi.org/10.3390/computers10090118

[25] K. A. Ritter and T. L. Chambers, "Three-dimensional modeled environments versus 360 degree panoramas for mobile virtual reality training," *Virtual Real*, vol. 26, no. 2, pp. 571–581, 2022. https://doi.org/10.1007/s10055-021-00502-9

[26] Y. Choi, B. Hickerson, and J. Lee, "Investigation of the technology effects of online travel media on virtual travel experience and behavioral intention," *J. Travel Tour. Mark*, vol. 35, no. 3, pp. 320–335, 2018. https://doi.org/10.1080/10548408.2017.1340224

[27] A. K. Putra, Purwanto, M. N. Islam, W. N. Hidayat, and M. R. Fahmi, "Development of mobile virtual field trips in ijen crater geosites based on 3600 auto stereoscopic and geospatial technology as geography learning media," *Geoj. Tour. Geosites*, vol. 41, no. 2, pp. 456–463, 2022. https://doi.org/10.30892/gtg.41216-850

[28] N.-N. Dao *et al.*, "Virtual field trip for mobile construction safety education using 360-degree panoramic virtual reality," *Int. J. Eng. Educ*, vol. 34, no. 4, pp. 1174–1191, 2018.

[29] S. J. Yu, Y. L. Hsueh, J. C. Y. Sun, and H. Z. Liu, "Developing an intelligent virtual reality interactive system based on the ADDIE model for learning pour-over coffee brewing," *Comput. Educ. Artif. Intell*, vol. 2, p. 100030, 2021. https://doi.org/10.1016/j.caeai.2021.100030

[30] A. A. Eldokhny and A. M. Drwish, "Effectiveness of augmented reality in online distance learning at the time of the COVID-19 pandemic," *Int. J. Emerg. Technol. Learn*, vol. 16, no. 9, pp. 198–218, 2021. https://doi.org/10.3991/ijet.v16i09.17895

[31] Y. Jia and R. Qi, "Influence of an immersive virtual environment on learning effect and learning experience," *Int. J. Emerg. Technol. Learn*, vol. 18, no. 06, pp. 83–95, 2023. https://doi.org/10.3991/ijet.v18i06.37815

[32] B. A. Pribadi, *Model ASSURE untuk Mendesain Pembelajaran Sukses*, I. Jakarta: PT. Dian Rakyat, 2011.

[33] B. K. Prahani, I. A. Rizki, K. Nisa, N. F. Citra, H. Z. Alhusni, and F. C. Wibowo, "Implementation of online problem-based learning assisted by digital book with 3D animations to improve student's physics problem-solving skills in magnetic field subject," *JOTSE*, vol. 12, no. 2, pp. 379–396, 2022. http://dx.doi.org/10.3926/jotse.1590

[34] M. R. Fahmi, A. K. Putra, and B. Handoyo, "Development of web-based virtual reality as media learning for baluran conservation area with geographical characteristics," in *... International Conference on ...*, pp. 332–346, 2022. https://doi.org/10.2991/978-2-494069-63-3

[35] T. I. Salsabila, A. K. Putra, and T. Matos, "Mobile virtual field trip and geography education: Potential exploration of complex problem solving and spatial intelligence capabilities," *Int. J. Interact. Mob. Technol*, vol. 16, no. 24, pp. 21–31, 2022. https://doi.org/10.3991/ijim.v16i24.36157

[36] A. P. Walmsley and T. P. Kersten, "The imperial cathedral in Königslutter (Germany) as an immersive experience in virtual reality with integrated 360° panoramic photography," *Appl. Sci*, vol. 10, no. 4, 2020. https://doi.org/10.3390/app10041517

[37] M. Zahabi and A. M. Abdul Razak, "Adaptive virtual reality-based training: A systematic literature review and framework," *Virtual Real*, vol. 24, no. 4, pp. 725–752, 2020. https://doi.org/10.1007/s10055-020-00434-w

[38] S. Zucchi, S. K. Fuchter, G. Salazar, and K. Alexander, "Combining immersion and interaction in XR training with 360-degree video and 3D virtual objects," 2020. https://doi.org/10.1109/ISMCR51255.2020.9263732

[39] S. Sumarmi, A. K. Putra, and A. Tanjung, "Developing digital natural laboratory based on edutourism for environmental geography," *TEM J*, vol. 12, no. 1, pp. 224–232, 2023. https://doi.org/10.18421/TEM121-29

[40] E. A. Shudayfat, Y. Sharrab, M. Tarawneh, and F. Alzyoud, "Towards virtual university based on virtual reality and terabits internet speed," *Int. J. Emerg. Technol. Learn*, vol. 17, no. 24, pp. 57–68, 2022. https://doi.org/10.3991/ijet.v17i24.36009

[41] M. Slater *et al.*, "The ethics of realism in virtual and augmented reality," *Front. Virtual Real*, vol. 1, pp. 1–13, 2020. https://doi.org/10.3389/frvir.2020.00001

[42] Y. Zhu and N. Li, "Virtual and augmented reality technologies for emergency management in the built environments: A state-of-putrthe-art review," *J. Saf. Sci. Resil*, vol. 2, no. 1, pp. 1–10, 2021. https://doi.org/10.1016/j.jnlssr.2020.11.004

[43] A. D. Wirakusumah, D. Murdohardono, and D. Rosiani, "Geotourism of Banyuputih catchment area, Mount Ijen, East Java, Indonesia," *J. Phys. Conf. Ser*, vol. 1363, no. 1, 2019. https://doi.org/10.1088/1742-6596/1363/1/012012

[44] R. Al-Azawi, A. Albadi, R. Moghaddas, and J. Westlake, *Exploring the Potential of Using Augmented Reality and Virtual Reality for STEM Education*, vol. 1011. Springer International Publishing, 2019. https://doi.org/10.1007/978-3-030-20798-4_4

[45] R. Sun, Y. J. Wu, and Q. Cai, "The effect of a virtual reality learning environment on learners' spatial ability," *Virtual Real*, vol. 23, no. 4, pp. 385–398, 2019. https://doi.org/10.1007/s10055-018-0355-2

[46] P. Araiza-Alba *et al.*, "The potential of 360-degree virtual reality videos to teach water-safety skills to children," *Comput. Educ*, vol. 163, p. 104096, 2021. https://doi.org/10.1016/j.compedu.2020.104096

[47] A. Scavarelli, A. Arya, and R. J. Teather, "Virtual reality and augmented reality in social learning spaces: A literature review," *Virtual Real*, vol. 25, no. 1, pp. 257–277, 2021. https://doi.org/10.1007/s10055-020-00444-8

[48] H. Lee, T. H. Jung, M. C. Tom Dieck, and N. Chung, "Experiencing immersive virtual reality in museums," *Inf. Manag*, vol. 57, no. 5, p. 103229, 2020. https://doi.org/10.1016/j.im.2019.103229

[49] Y. Wang and A. Mughaid, "Design of a virtual reality-based learning system for spoken English," *Int. J. Emerg. Technol. Learn*, vol. 17, no. 24, pp. 25–41, 2022. https://doi.org/10.3991/ijet.v17i24.35655

[50] P. Yang and Z. Liu, "The influence of immersive virtual reality (IVR) on skill transfer of learners: The moderating effects of learning engagement," *Int. J. Emerg. Technol. Learn*, vol. 17, no. 10, pp. 62–73, 2022. https://doi.org/10.3991/ijet.v17i10.30923

[51] R. LeBrasseur, "Virtual site visits: Student perception and preferences towards technology enabled experiential learning," *Int. J. Emerg. Technol. Learn*, vol. 18, no. 02, pp. 115–140, 2023. https://doi.org/10.3991/ijet.v18i02.32013

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