JPPIPA 9(10) (2023)

Jurnal Penelitian Pendidikan IPA

*Journal of Research in Science Education*

http://jppipa.unram.ac.id/index.php/jppipa/index

# Using Virtual Outcrop Models as a Geological Learning Media

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Received: March 10, 2023
Revised: July 3, 2023
Accepted: October 25, 2023
Published: October 31, 2023

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DOI: 10.29303/jppipa.v9i10.3398



**Abstract:** The Covid-19 pandemic has impacted various sectors due to a new wave of technology rising shortly, specifically geological learning models. Using research and development methods, the research aims to develop more scientific observations as a provision for pre-field work activities at Geophysical Engineering Department Institut Teknologi Sepuluh Nopember. Furthermore, we need a media that can provide learning that can emphasize process skills and students' abilities to determine and understand the objective concepts of material. Virtual outcrop models integrated with video learning platform can fulfil the learning process by providing experience in observations outcrops directly in the class. A three-dimensional (3D) Virtual Outcrop Model (VOMs) was created using the photogrammetry software Agisoft PhotoScan based on photos taken in the field using smartphones and drones. The existence of this media is expected to add direct experience to visualize how geological phenomena occur in nature. The learning activities are divided into four sequential stages: observation, data collection, interpretation, and hypothesis giving. 87% of respondents stated that learning models using VOMs and videos can boost their knowledge of scientific observation. This learning method can help improve academic achievement because it applies technology implementation in theory and practice, providing geological information to us.

**Keywords:** Geological education; Research and development; Virtual outcrop model

## Introduction

The recent Covid-19 pandemic has had quite a significant impact on various sectors of life. One of the positive impacts is creating a wave of new technology that presents all kinds of innovations in facilitating human life to continue carrying out their activities amid tight human mobility (Renu, 2021). This impact also affects education which gives innovation, especially in supporting geology learning in class by using learning media that can accurately visualize geological structures. From an educational perspective, learning media provides a separate dimension to students, making it a benchmark in deciding the success of the education and learning process (Harahap & Siregar, 2018).

The selection of learning media from the geological learning model activities is necessary to convey conceptual understanding and visualize geological events that occur on earth. For example, geology students must figure out objects or features that appear on a spatial scale, even too large or small, to be observed directly (Gagnier et al., 2017). Likewise, Students need help with observing scientifically and connecting observations to scientific theory. On the other hand, there are limitations that humans have in their ability to capture and respond to things that are imaginary or that have never been recorded in their memory, making students experience difficulties when visualizing geological phenomena when studying (Harahap & Siregar, 2018). To fit this, teaching that is still teacher-centered and learning that tends to memorize material becomes irrelevant. Over time, a learning model like this will have a negative impact because it will form students who are passive in understanding geological material, even though students need to study the relevance of the

**How to Cite:**
Fajar, M.H.M., Widodo, A., Puswanto, E., Alfany, M.K., Wirayudhatama, M., & Abdullah, F. (2023). Using Virtual Outcrop Models as a Geological Learning Media. *Jurnal Penelitian Pendidikan IPA*, *9*(10), 8287–8294. https://doi.org/10.29303/jppipa.v9i10.3398

material they are studying with its appearance in (Rahman, 2017). With direct circumstances in the field, the material only exists in wishful thinking without being able to be applied when conducting geological fieldwork. Therefore, to connect the process of internalizing teaching and learning in the classroom, which can support activities in the area to run optimally, it is necessary to have media that can clarify and influence students in capturing educational messages (Darling-Hammond et al., 2020).

The learning media that is expected here is an object that can provide space for students to observe the reality of the phenomenon of an outcrop in the field during class learning. The selection of learning media is the most critical process in learning because it is through this media that information between lecturers and students can convey effectively (Rahmatullah et al., 2020). According to (Rohani, 2019), learning media can be divided into three parts, namely: Visual media conveys messages that can only see through the eyes of viewers/media. For example, media models are three-dimensional models in the form of imitations of several natural objects, such as objects that are too big or small, too far or expensive, and those that are rarely found or too complicated to bring to class. Audio media is media that contains messages in auditive form (only can be heard, which can stimulate thoughts, feelings, attention, and willingness to understand/learn the contents of the theme, such as voice tapes or radio). Audiovisual media or referred to as listening media, by using this media the presentation of the contents of the theme to students will be complete and optimal, and the teacher's role will shift to being a learning facilitator only; examples of this media can be in the form of educational videos and so on.

Based on this media can give students an understanding of how to observe an outcrop, starting from identifying to analysing geological objects that can be observed in class. Furthermore, the main problem for students when conducting a geological fieldwork for the first time is the need for more preparation, literacy studies, and field skills in conducting outcrop observations. Therefore, we need a media that can improve skills before carrying out field observation activities because field activities are an important activity that helps geoscientists explore and understand processes that occur on earth.

This virtual outcrop model (VOM) can help the learning process as a medium that can provide a visual description of outcrops in the field without losing geological information. The existence of VOM as a learning medium that does not replace the existence of the fieldwork itself because the existence of VOM is expected to be a medium that can provide experiments in observing an outcrop in a class by showing the original geological phenomenon in the field through VOM. This choice is based on the desire to build an effective learning atmosphere; real and concrete experience is needed as a basis for learning to record permanently in memory. For this reason, the use of learning media in the form of VOM can be a means that brings success to lecturers and students in teaching geology visually in class. Because by using VOM, students can carry out two activities at once. The first activity includes observing rock lithology, measuring outcrop stratigraphy and geomorphology, and then the last activity is analyzing the data obtained.

Then, in addition to using the learning media, this learning method also uses audio-visual learning methods. This audio-visual method is because audio-visual media in the form of video can provide a more realistic picture of something that is abstract and is very good for explaining processes and skills (Kwegyiriba et al., 2022). This audio-visual role is presented starting a video that has been recorded by the teacher together when carrying out data acquisition in making VOM. The choice of video learning media is used because, through video, the teacher can provide information about theory and features that can tell the geological processes in the outcrop (Puspitarini & Hanif, 2019). This learning media is also expected to be more interactive and allow for two-way traffic during the learning process (Sahronih et al., 2019). Even with this video, this learning method can run efficiently against time because students can study a geological outcrop flexibly anytime and anywhere (Widahyu, 2021).

The various problems and expectations challenge teachers to take advantage of technological developments in developing a learning model, especially geospatial technology (Oktavianto, 2020). The advantages of using this learning method include; (1) it can display the original appearance without losing the geological formation (2) Visualization on a virtual display has the potential to support more complex classroom learning experiences, especially on phenomena that are impossible to do without virtual assistance (Kamińska et al., 2019) (3) assist students in observing and analysing data (4) VOM has an interactive 3D view which is crucial in helping students visualize connections between patterns and existing geological information (Teplá et al., 2022). The effectiveness of using instructional media is not determined by how sophisticated and modern the tools used by the teacher are in the learning process but rather by the suitability of the media with the subject matter being taught (Resti & Rachmijati, 2020). Thus, each student's learning process will be significantly facilitated by the presence of learning media that can visualize geological structures in real terms. Where the selection of the type of instructional media in this study is based on the cone of experience proposed by Edgar Dale, as shown.

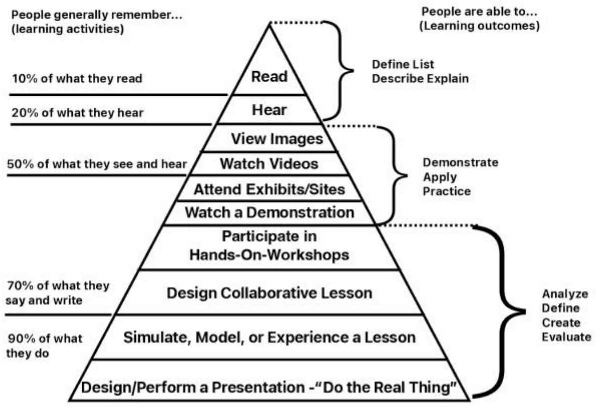


**Figure 1**. Attached Figure in Article (Pietroni, 2019)

A teacher can use various tools to convey educational messages to students through sight and hearing to avoid verbalism, which is still possible if only visual aids are used (Sapriyah, 2019). For this reason, the American educator Edgar Dale in understanding the role of the media in obtaining learning experiences for students, modelled a hierarchy of learning experiences based on the concreteness and abstractness of a cone called Edgar Dale's cone of experience (Figure 1). Based on the picture above shows that the more concrete the learning media students use in the learning process, for example, through direct experience, the more experience they get. Meanwhile, the more abstract students gain experience, for example, only relying on verbal language, the fewer experience students gain. His experiments showed that multi-sensory experiences, active participation, and interaction favour longer memories (Pietroni, 2019). For this reason, learning methods like this are expected to increase students' understanding and experience in observing an outcrop.

## Method

This study uses the Research and Development (R&D) method. As the name implies, Research & Development is used as a research activity that starts with research and continues with development. Research activities are carried out to obtain information about user needs (needs assessment), while development activities are taken out to produce learning tools (Huda, 2022). The expected products of this research are the Virtual Outcrop Model and learning videos as learning media that assist in the geology learning process. Making VOM and learning videos with the Plomp model was chosen because this model is considered more flexible and flexible than other models (Subhi et al., 2020). The Plomp model consists of: (1) preliminary investigation; (2) designs; (3) realization/construction; (4) test, evaluation, and revision, and (5) implementation (Oktaviani et al., 2021). Research design and method should be clearly defined.

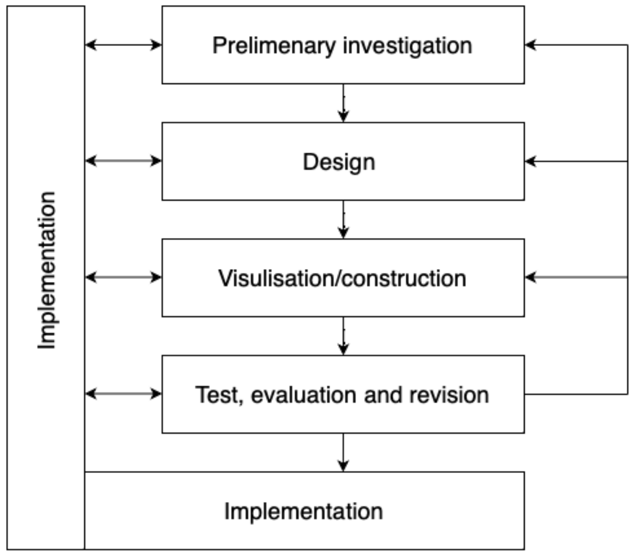


**Figure 2**. Plomp development model flowchart for virtual outcrop models research and development in Geological Learning Media (Putri & Dewi, 2020)

*Preliminary Investigation*

The initial investigative phase was carried out to determine the fundamental problems needed for the development of learning media, in this case, geology learning. Consequently, information is collected related to learning problems and formulating rational thoughts on the importance of developing media to overcome students' learning difficulties. In this study, the data needed to find out the problem was by interviewing 60 Geophysical Engineering students taking the Structural Geology course and the questions related to the problems encountered during the learning process on geology material. In addition, the author also conducts literature studies related to data and problems encountered.

*Design*

In this phase, the activities are to design a solution to the problem resulting from the previous process investigation. The characteristics of activities in this phase are the generalization of a solution, comparing and evaluating various alternatives, and selecting the best design to be the solution. The results of problem-solving in the initial investigation phase concluded that it is essential to develop interactive learning media and prioritize observation activities in the classroom using virtual outcrop models and learning videos that are made as interesting and informative as possible. Based on the learning media that has been proposed, this media can bridge students' visualized concepts and models from reality in the field.

*Construction and Visualisation*

In creating a virtual outcrop model as a geological learning medium, photogrammetric data acquisition is carried out in an outcrop by requiring tools such as drones and smartphone photos equipped with GNSS chipsets, which enable the positioning of photos. In this example, a scaly clay virtual outcrop was created using a drone with a 12 Megapixel camera. This acquisition resulted in 162 precision GPS images acquired with an orientation of the camera that was mainly orthogonal to the outcrop surface with a camera to a preserved distance of roughly 2 - 3 meters to consider the details of the geological structure to be used. Based on the number of photos, in improving the data collection process, we must select the photos to be filtered based on contrast, brightness, colour balance, and saturation to improve the photograph quality, homogenize the pictures and speed up the process (Uzkeda et al., 2022).

The following process in modelling the outcrop to form a mosaic and 3D was selected using Agisoft PhotoScan Professional software. The selection of this software is based on its advantages, which can automatically construct 3D models throughout the system without setting initial values and control points, making completing it very convenient for users (X. Li et al., 2016). The photo can be taken at any position and angle with only one pre-condition: connected points exist between two adjacent target pictures (X. Li et al., 2016). Before processing, the pictures of the study area should be sufficient to minimize blind areas. The overlap of the images is better than 80%, covering the total surface. For this reason, in making the structure from motion (SfM), the camera position and orientation are determined by identifying and matching standard features in multiple overlapping images (Inama et al., 2020).

The process in Agisoft PhotoScan Professional starts with adding photos, aligning photos, building a dense cloud, building mesh, and building texture. The technique of aligning photos aims to improve the camera position in each photo with the output of the process in the form of a point cloud and identify the camera's location. The alignment process takes a long time if there are numerous photographs. The next step is to let PhotoScan generalize and visualize dense point clouds by calculating their height data. After alignment, excluded images are manually removed, which ultimately improves the reconstruction quality of the 3D settings. These images are recognized through the manual preference of points associated with unrealistic or blurry geometries within the sparse cloud. Usually, it is a frame characterized by excessive overlap. In dense cloud builds, the selection of the surface type is arbitrary, with a medium face count. Building texture is the last stage before finally getting a digital surface model. The preference for blending mode in the form of a mosaic is because aerial photos are generated from overlapping between photos. The parameters used during the processing are indicated in Table 1. The results of this processing are in the form of .kmz files which will later be processed on the GeoVis3D application to obtain geological structure data that can be further interpreted.

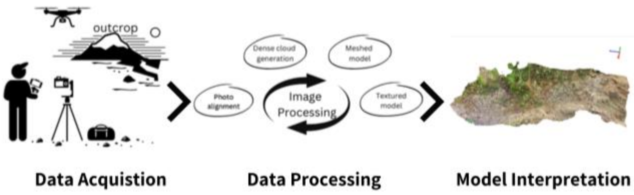


**Figure 3.** Schematic photogrammetic acquisition

**Tabel 1.** Processing parameters used in Photoscan software**.**

| Process | | Processing parameters | |
|---|---|---|---|
| Image alignment and sparse point cloud generation | Accuracy Medium | Tie Point 4.000 | Key Point 40.000 |
| Dense point cloud generation | Quality Medium | Depth filtering Mild | |
| Mesh generation | Source data Depth maps | Surface type Arbitrary | Face count Medium |
| Texture generation | Mapping mode Generic | Blending mode Mosaic | |

*Test, Evaluation and Revision*

After designing and manufacturing products with the Agisoft PhotoScan and GeoVis3D applications, tests were then carried out on several experts to ensure that the learning media that had been created were well-created and informative in conveying educational messages. In the learning media test in the form of a virtual outcrop model, the standard that this media has made properly is the skill of VOM with good resolution without losing its geological information. Then for the learning videos, a test is carried out regarding the content in the learning videos that follows the essential competencies. The trial was carried out to find out how the learning media used could achieve the goals of geology learning properly and could improve students' abilities to increase their sense of geology in the field.

*Implementation*

After evaluating and obtaining a suitable product, the learning media created can be tested on the product.

Then, based on the trial results, the author can interpret the results by analyzing them simply using the results of interviews and direct observation of students.

## Result and Discussion

Research can set off by the existence of problems or potentials that exist around. Based on these problems and potentials, they can be used as a reference for developing research products. In this case, it was made aware of a potential problem that needed more preparation before conducting geological fieldwork activities at the Geophysical Engineering Department Institut Teknologi Sepuluh Nopember. Although field activities are one of the essential activities for a geoscientist to observe phenomena that occur in nature, due to time and cost constraints, field activities can only be carried out some of the time. So it is necessary to develop a geological learning media that can upskill students to observe an outcrop in class to boost understanding so that field activities can run optimally. Because with the ads for complex learning activities, more experience will be gained, and the learning process will become more straightforward and attractive.

As we know, learning media are needed to encourage students to understand fully in improving the geology learning process, which is influenced by many factors, both conceptual material and the reality of phenomena in the field. It is hoped that the learning media will be able to convey learning material to students in a flexible and easy-to-understand. When these points are fulfilled, it will create student interaction with the material, students with lecturers, and fellow students. Then the most important thing in selecting learning media to understand the concept of geology is a medium that can assist students in carrying out observation activities as a form of practice before fieldwork.

One medium that can fulfil the learning is using virtual outcrops to provide experience in characterizing outcrops directly in class. The VOM was presented using Structure from Motion – Multi-view Stereo (SfM-MVS) photogrammetry. Photogrammetry techniques using Structure from Motion are needed to create an object or feature with a three-dimensional set of points corresponding to the surface of the feature (each with an X-Y-Z coordinate) called a point cloud (L. Li et al., 2019). The creation of this learning media focuses on the importance of analysing geological structures in three dimensions to support students' understanding of identifying an outcrop with geological information. However, there are areas for improvement in learning media in the form of information gaps in VOM, which makes students ask to investigate outcrops through more traditional methods, such as photos (Figure 5) and learning videos (Figure 4).

Using these two learning media aims to arouse curiosity and assist students in observing phenomena that occur on earth that can be observed directly in the classroom. The learning video (Figure 4) will act as a complement in conveying geological concepts. The selection of audio-visual media is because the more concrete the students learn the teaching material, the more experience they will get. When these two media are used in applying this learning method, it is hoped that it will increase students' understanding of the concepts of geology that occur in the outcrop itself.


**Figure 4**. Audio visual as leaning media photographs of scaly clay in Karangsambung geological nature reserve, Kebumen, Central Java

**Tabel 2.** The results of the expert validation of the geology lecturer

| VOM | Video |
|---|---|
| Increases the image resolution of the VOM. | Add subtitles to video. |
| Minimize blind areas. | Eliminate noise in videos. |
| Improve the photograph quality. | Adding an animated description of supporting material to the video. |

After creating VOM using Agisoft PhotoScan software, it exported to GeoVis3D software to serve as learning media to be an object of observation. Then, for creating learning videos as a companion to the VOM itself, it is used as a medium that can explain theoretically. The two learning media were tested for validation by one of the lecturers who was involved in subjects in the field of Geology at the Sepuluh Nopember Institute of Technology. The results of validation by experts can be seen in Table 2. Input from the results of validation by experts, then carried out several revisions before the product was tested on students.

**Figure 5.** Field photographs of scaly clay in Karangsambung geological nature reserve, Kebumen, Central Java

This research ended at the product trial stage for 60 students of Geophysical Engineering at the Sepuluh Nopember Institute of Technology who were taking a structural geology course. This learning process is expected to provide more knowledge to help students develop a more scientific understanding of geology and rock structures. This learning activity is divided into four sequential stages: observation, data collection, interpretation, and provision of hypotheses. Observation activities are preserved on learning media in virtual outcrop models and learning videos. This method is needed because studying outcrops is the key to analysing the earth's crust materials. After carrying out observation activities, it will produce data in the form of lithology, geological structure, geomorphology, and stratigraphic measurements. Based on the data that has been obtained, students can interpret the data using analytical methods. If exemplified by one of the virtual outcrops in Figure 6, from VOM using GeoVis3D software, strike and dip values will be obtained, which can later be made utilizing stereo nets to show deformation through tectonic. Finally, from the data processing and analysis that has been carried out, we will obtain geological processes describing the 23.

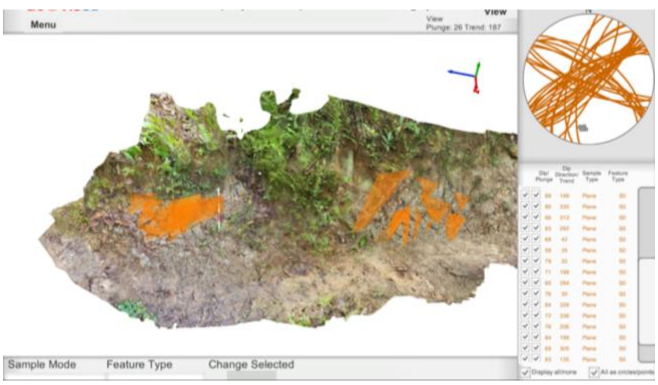


**Figure 6.** The capture of a three-dimensional outcrop model in GeoVis3D Software with lines that show the direction of strike and dip

This trial activity was also followed by filling out a questionnaire at the beginning and end of the activity. The questionnaire carried out was intended to obtain data on how the preparation and difficulties of students in facing field lectures regarding geological fieldwork. Then, the results of this questionnaire will be used to carry out the analysis stage of students' needs to help solve problems related to the geology learning they are facing.

Based on the results of the questionnaire in Figure 7 and Figure 8, students still experience difficulties when observing an outcrop during fieldwork. Even though 40 students out of 60 respondents had already carried out pre-fieldwork activities before. 80% of the respondents stated that the problem they faced was the lack of activities to help students develop more scientific observations in the class. This is because the pre-fieldwork activity only includes activities such as a literature review regarding the geological regional conditions of the location. While, a learning model like that only be seen from the ability of students to memorize facts. Although many students can present a good level of memorization of the material received, they often do not understand the substance of the material studied.

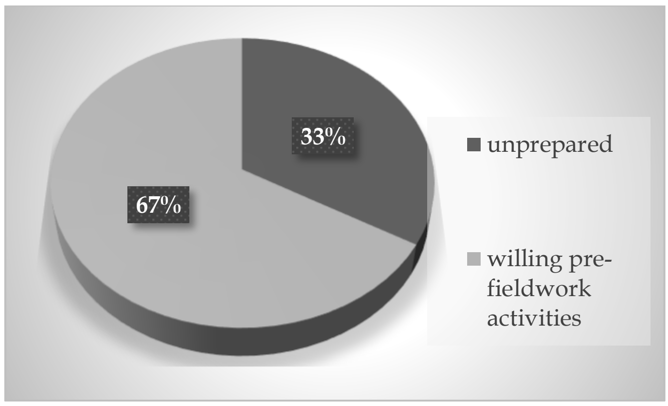


**Figure 7.** Questionnaire results regarding student preparation in carrying out pre-fieldwork activities

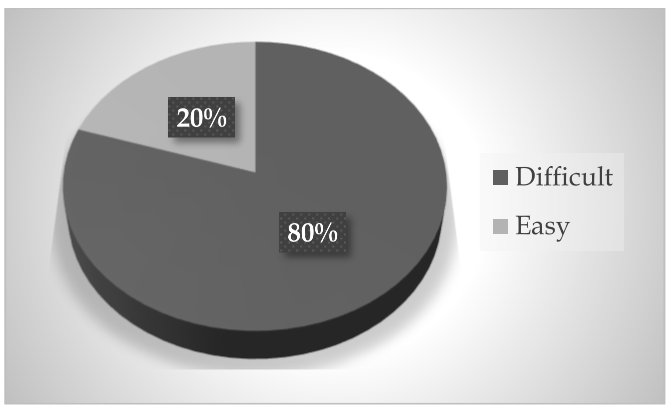


**Figure 8.** Questionnaire results regarding the difficulties of students in making observations in the fieldwork

Based on the data, learning media using VOM and video can be used as an alternative to visualize how geological phenomena occur in nature. By using this learning media class activities become more complex because these activities can be in the form of observation, data collection, and data analysis from VOM. So that it will build students' ability to digest the results of observational data and scientific writings in analyzing geological data. Overall, interactive learning methods through virtual outcrop models like this can improve students' understanding scientific observation which only be observed in the field but can be obtained through classroom learning.

Based on the questionnaire results above Figure 9 & Figure 10, learning media using VOMs and videos can be used as an alternative to learning geology. Eighty seven percent of respondents stated that learning models with VOMs and videos can boost their knowledge of scientific observation. Thereby VOMs play a role in media that provides practical experience, while the video is a medium that theoretically explains the outcrop. A learning model like this can prepare students to do competent fieldwork. Due to the fact that complex learning activities will provide insight and experience of actual learning activities in class, which help students understand the objective of material learning.

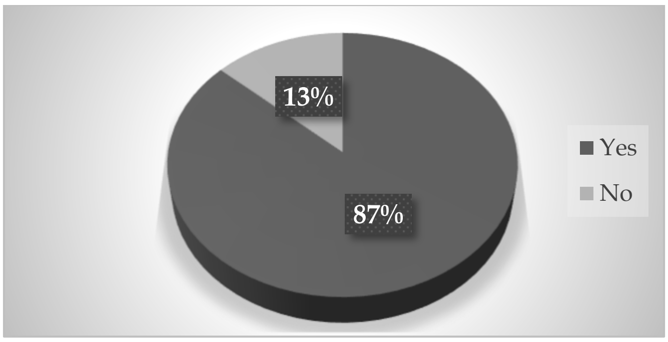


**Figure 9.** Questionnaire Results Regarding Learning Media Voms and Learning Videos Can Be Helpful In Boosting Interpretation During the Observation Process in Class

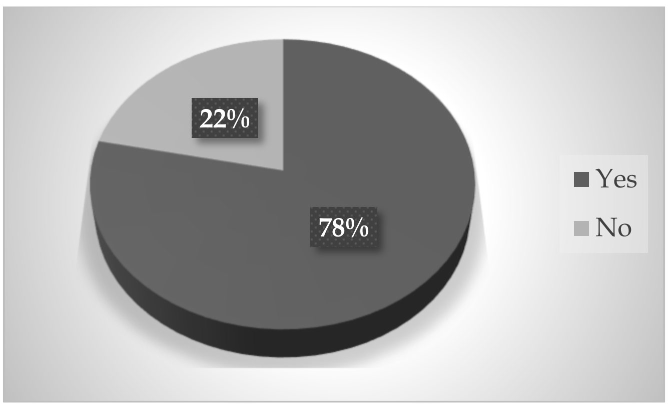


**Figure 10.** The Results of the Questionnaire About the Success of The Learning Method with Voms and Video Learning Media to Build A Scientific Understanding Of Geology

## Conclusion

Applying this kind of learning method using virtual outcrop models (VOMs) can help improve students' observation to support them in developing a more scientific understanding of rock and geological structures. The existence of this learning media is expected to emphasize a learning system based on process skills and the ability of students to determine and understand the objective concept of material that can be applied directly by observing geological phenomena in the field virtually. Understanding this learning model can provide students with experience from providing literature before going into the fieldwork, collecting data, interpreting data, and analysing data from VOM. However, this method cannot be used as a substitute for field activities due to the limitations of computers and technology in describing geological outcrops in detail and accurately.

**Acknowledgments**

The authors would like to thank Institut Teknologi Sepuluh Nopember for facilitating and financing this research through the following research grant number: 941/PKS/ITS/2020.

**Author Contributions**

The writing of this research article is conducted with contributions from several authorss with individual contribution: Conceptualization from M. Haris Miftakhul Fajar, Amien Widodo, and Eko Puswanto; methodology from Marsha Khairia Alfany, Mahendra Wirayudhatama, Fikri Abdullah and M. Haris Miftakhul Fajar; validation from M. Haris Miftakhul Fajar; and writing from Marsha Khairia Alfany. All authors have read and agreed to the published version of the manuscript.

**Funding**

This research was funded by Institut Teknologi Sepuluh Nopember, grant number 941/PKS/ITS/2020.

**Conflicts of Interest**

The authors declare no conflict of interest.

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