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Visual-Digital Literacy in Open-ended Inquiry based Astronomy Observati on Labs and Heaven View

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Abstract

The study investigates students' ability to analyze visual literacy and digital literacy through open-ended inquiry activities with astronomical observations and Heaven View application. The investigation consists of assignments for students to carry out six different variations of observational activities. Supervision is given in introductory astronomy lectures before and after using open-ended inquiry as direct observation and indirect observation activities. We discuss the implicits for open-ended inquiry learning that encourage students to participate in observational activities. Students are expected to develop several 21st century skills through an open-ended inquiry process, including visual-digital literacy. A pretest-posttest control group design with an open-ended inquiry model was applied to the experimental group and a direct instruction model to the control group. This study uses inferential statistical parametric methods, using ANCOVA. Students' visual-digital literacy data were obtained using the pretest and posttest. The results showed that a statistically significant difference between open-ended inquiry through astronomical laboratory observations assisted by Heaven View application compared to direct model recognition. Students' visual-digital literacy has increased due to the application of this learning model. The implications of this research can encourage students' visual-digital science literacy. Other educators can adopt open-ended learning experiences through the Heaven View app-assisted astronomical observation labs to promote visual-digital literacy in science.

Keywords: Visual-digital literacy, open-ended inquiry, astronomy observation, Heaven View.

Introduction

The research visual-digital literacy addresses several challenges and opportunities in enhancing visual-digital literacy in science education, particularly in astronomy observation labs and observation software activities. Some of the significant issues that this research aims to explore lack of integration of visual and digital media in traditional astronomy observation labs and observation software. The traditional methods of astronomy observation labs and Heaven View activities often rely on manual tools such as telescopes, binoculars, and star charts. While these methods are essential for students to observe and interpret astronomical phenomena, they often lack the integration of visual and digital media, which can limit students' understanding and engagement in the subject (Stowell, 2022; Wu et al., 2018). This research aims to investigate the role of visual and digital media in enhancing students' understanding and engagement in astronomy and explore the opportunities and challenges in integrating these media into astronomy observation labs and Heaven View activities.

The learning process and support for learning facilities are still limited in visual-digital literacy skills that combine visual and digital media in astronomy learning, requiring teachers to provide a good understanding of the skills and knowledge needed to utilize digital media more effectively. However, most teachers still lack proper training opportunities and learning process support in developing visual and digital skills. This research seeks to resolve challenges and meet opportunities in providing teacher training and support to develop visual-digital literacy skills, for example optimizing technology and digital media devices in teaching astronomy. Student access to technology tools and digital media is still limited in utilizing visual and digital media for astronomy learning. This requires students to have adequate access to equipment and digital media. However, students from

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schools that lack skilled resources are still limited in accessing technology tools and digital media (DeLisi et al., 2021; Tang et al., 2020). Exploration of challenges and opportunities for equitable access to technological equipment and digital media devices in astronomy learning, including techniques to address digital media centers.

Weaknesses in visual-digital literacy research in directing student activity and mastery of concepts in astronomy learning. While the combination of visual media and digital media in science learning was found to be successful in increasing student interaction, interest, and understanding of natural phenomena and science concepts. Limited-scale research has been conducted on the effectiveness of visual-digital literacy which aims to fill opportunities by investigating the impact of visual and digital media. Digital on the enthusiasm and motivation of students in the laboratory to carry out astronomical observations and activities using the sky map application (Daramola & Etim, 2022; Tabak & Dubovi, 2022; Vasalou et al., 2021).

Challenging learning needs include limited visual media and digital equipment in direct observation laboratories in traditional astronomy learning and no sky map activities. Learning for prospective teachers is limited and support in visual-digital literacy skills is inadequate, students have limited access to using learning technology equipment and digital media tools, and students lack involvement and mastery of content on astronomical knowledge. By addressing these challenges, this research is expected to provide the development of a new pedagogical approach that integrates visual and digital media in science learning and contributes to improving students' visual-digital literacy skills, promoting students' interest and active involvement in learning science (Burnett et al., 2022; Detlor et al., 2022; Hattan & Lupo, 2020).

Visual-digital literacy as an important skill for individuals to collaborate, communicate and interact effectively in the cognitive and psychomotor domains, including science learning in the digital era (Morgan et al., 2022). Visual-digital literacy leads to the ability and skills to access, create and communicate scientific ideas creatively using visual and digital media, including photos, drawings, videos, animations and simulations. The combination of visual and digital media in science learning has been shown to increase active engagement, learning motivation, and mastery of student content on scientific concepts.

Astronomy as an interesting field of science arouses the curiosity of the public and scientists. The use of astronomical observation laboratories and observation activities includes innovative learning methods applied in science learning to introduce and add scientific insight to students about the amazing universe. This activity involves being able to observe and interpret astronomical phenomena, such as constellations, planets and stars, using a telescope and other observational equipment. However, traditional methods in the astronomy observation laboratory and the use of observational applications are less integrated between visual and digital media, which can limit content mastery and students' active involvement in learning astronomy (Kim et al., 2021; Plummer et al., 2022; Yegorina et al., 2021). Therefore, this research provides an opportunity to optimize the urgency of increasing visual-digital literacy in the astronomy observation laboratory and activities using the Heaven View application. This research is aimed at exploring and developing astronomical observation laboratory practices, analyzing the role of visual and digital media in increasing content mastery and student engagement, and analyzing challenges and opportunities in integrating visual and digital media in science learning.

The implications of this research are directed to be able to make a significant contribution to science teachers, curriculum developers, and policy makers as data findings and information for developing strategies for innovative pedagogical approaches that combine visual and digital media in learning astronomy. This research is directed at contributing to the development of science curriculum standards that integrate visual-digital literacy as an important skill in science learning (Churchill, 2020). In addition, this research can also be useful for students and prospective teachers in training and improving visual-digital literacy skills, increasing their interest and active involvement in learning science. Visual-digital literacy skills are not only important to be trained in science education but are also important to be trained for career development and students' personal lives in the future. The ability to communicate and collaborate as skills that effectively apply visual and digital media is a necessity in various professions, including science, engineering, and communication technology.

Exploration of Visual-Digital literacy in the Astronomical Observation Laboratory can be carried out through the application of investigative activities and scientific methods of learning science which are supported by the use of sky map observation applications. A new pedagogical approach to learning that includes direct observation activities and the application of sky maps. Visual and digital media are more effectively combined to interpret image observations and direct viewing so that they can be clearer, objective, accurate and thorough in data collection. The development of science curriculum standards is aimed at enhancing visual-digital literacy skills, promoting their interest in and involvement in science (Lechner, 2021).

The application of open inquiry is based on existing scientific studies on the use of visual and digital media in science learning, especially astronomy. In recent years, it is very important to develop visual-digital literacy skills in science learning as a basis for the need for content mastery and observation skills. Therefore, student engagement and technical mastery of observations are aimed at interpreting complex scientific phenomena (Khan et al., 2022; Riggs, 2022).

Relevant research has investigated the application of visual media in teaching astronomy. Rodríguez, et al (2022) explored observations using a digital planetarium to increase students' understanding of the celestial sphere. Lalti, et al. (2022) analyzed the use of augmented reality (AR) in studying astronomy. These studies have shown that visual and digital media can optimize student engagement and conceptual understanding of astronomical observations, especially when combined with inquiry-based learning and problem solving approaches.

Another study exploring the development of visual-digital literacy skills among science teachers. Wusqo, *et al*. (2021) analyzed the use of teacher professional development programs that use technology in developing teachers' visual literacy skills, while Eutsler (2021) investigated the impact of teacher training on the use of digital media in science classes. These studies have highlighted the importance of providing teachers with adequate training and use of laboratories in developing visual literacy and digital technology skills. This is because the teacher has an important role in interaction, active involvement and mastery of student content while studying science.

The important functions and roles of visual media and digital media are indispensable in science education, specifically focusing on observational activities in the astronomical observation laboratory and the use of the Heaven View application. This activity offers opportunities and creativity for students to interact and be directly involved in studying astronomical phenomena. In addition, there are potentials and challenges in terms of effectively and efficiently combining visual and digital media (Korona & Hathaway, 2021). Research on visual-digital literacy in learning astronomy through open inquiry aims to fill this gap by exploring the challenges of using visual and digital media for scientific activities learning about astronomy.

Method

Research Design

Mixed methods were used in this study which characterized qualitative methods and quantitative methods (Creswell & Clark, 2018). This study uses data collection techniques that begin with observing class activities, surveying student responses, and developing a digital media device in the form of Heaven View. This study also examines the influence of visual media and digital media on active student involvement, learning motivation, and mastery of content related to astronomical phenomena.

The quantitative approach uses a quasi-experimental design involving two groups of students. The experimental group that received open-ended inquiry learning interventions assisted by direct observation and Heaven View media and the control group that received astronomy learning through discussion. The experimental group received digital media devices consisting of visual media and digital media in the form of images, videos and interactive simulations. The experimental group studied in the context of an astronomical observation laboratory through open inquiry and the use of the Heaven View application. Learning in the experimental group and control group involved mastery of student content regarding astronomical phenomena.

The learning control group received interactive discussions, did not use digital media devices, did not make observations in the astronomy laboratory and did not use Heaven View. This design compares the effectiveness of digital media devices in improving students' visual literacy and digital literacy skills. The intervention was carried out in two stages. In the first phase, both groups took part in and completed a pre-test which measured visual-digital literacy skills and astronomy mastery prior to learning. The purpose of the pretest is to show that the two groups have comparable abilities before learning. In the second phase, the experimental group received digital media devices.

The post-test measures visual literacy skills, digital literacy and students' mastery of astronomical phenomena after completing observation activities and using the Heaven View application. Mixed methods were used to analyze the data including descriptive statistics, inferential statistics, and qualitative analysis based on class observations and student responses. The strengths of the quasi-experimental design of this study are comparing digital media devices for students' visual literacy and digital literacy skills, analyzing students' active involvement and mastery of content related to astronomical phenomena. Some limitations of this design are that it cannot completely eliminate the impact of extra variables, especially those that are difficult to control, such as differences in learning styles and individual characteristics between students. Another limitation is that the design cannot establish a causal relationship between the open ended inquiry intervention and the results of the intervention because there are other factors that contribute (Magana et al., 2022).

Participants

All students taking astronomy courses in Semarang, Central Java, come from private universities and state universities. All these students as the study population, the research sample was selected from the population so that two groups of students were obtained. The first group was the experimental group of five semester students (N=37). The second group is the control group of sixth semester students (N=32). Selection of both groups using convenience sampling, in which researchers select groups based on availability.

The selection of the sample is based on the accessibility of students based on certain considerations. One consideration includes students completing the prerequisite courses to take an astronomy course. Another consideration, the minimal potential impact of extra variables that could affect research results. The selection of two groups of students at the same educational stage can control the academic level and content knowledge of each meeting. The research sample was used to be more representative of the entire Physics Education student population. The research sample is suitable for answering the problem formulation and research questions relevant to the research objectives focusing on the effectiveness of certain interventions on students' visual-digital literacy skills.

Data Collection Tools

The main instruments as collection tools are visual-digital literacy observation sheets, visual-digital literacy tests, and student response questionnaires. Assessment of observational activity in the astronomy laboratory using observation sheets. Assessment of visual-digital literacy skills uses a visual-digital literacy test designed to evaluate students' abilities in interpreting data, creating visual media and using digital media. The visual-digital literacy test includes a series of questions identifying visual elements, analyzing images, creating visual presentations and optimizing digital media. Tests were given to students before and after the open ended inquiry intervention to evaluate the increase in students' visual-digital literacy skills that took place during the astronomy learning process.

Data Collection

Data collection was carried out through observing students' scientific activities during astronomy learning activities, namely observing and using the Heaven View application. Data collection focuses on how students are actively involved in using visual and digital media in real-world settings and conducting open inquiry activities. Observations were made by observers during the intervention and recorded student activities during astronomy learning. The questionnaire as an instrument captures student responses to open inquiry learning which is used to collect data. The questionnaire was designed to evaluate students' attitudes towards the use of visual and digital media in their learning process. The questionnaire was administered to students after the intervention, to gather their feedback on the usefulness and effectiveness of the intervention. The data collection tools used in this research are designed to gather both quantitative and qualitative data on students' visual-digital literacy skills, and attitudes towards the use of visual and digital media in learning. The combination of these tools enables the researchers to evaluate the effectiveness of the intervention and to gain insights into how students engage with visual and digital media in their learning process.

Data Analysis

The data analysis in this research includes both quantitative and qualitative methods. The quantitative analysis utilizes parametric tests, specifically the t-test to compare the means of the pre-test and post-test scores on visual-digital literacy tests. The effect size is also calculated to determine the magnitude of the intervention's impact on students' skills. The t-test is a parametric statistical test used to determine whether there is a significant difference between two means. In this research, the t-test is used to compare the mean scores of the pre-test and post-test on the visual-digital literacy tests. A significant difference in the mean scores between the pre-test and post-test indicates the effectiveness of the intervention (Hahs-Vaughn, 2017).

The effect size is a measure magnitude of the difference between two means. In this research, the effect size is calculated using Cohen's d, which indicates the standardized difference between the pre-test and post-test scores. The effect size is used to determine the practical significance of the intervention. In addition to the parametric tests, quantitative analysis is also conducted to examine the relationships between variables. Specifically, the Pearson correlation coefficient is used to examine the relationships between the students' visual-digital literacy skills and their response to the intervention. The qualitative analysis involves the analysis of the observation data and questionnaire responses. The observation data is analyzed using thematic analysis to identify themes and patterns in the students' engagement with visual and digital media during the astronomy observation labs. The questionnaire responses are analyzed using content analysis to identify common themes and patterns in students' feedback on the usefulness and effectiveness of the intervention.

The data analysis in this research employs both quantitative and qualitative methods to evaluate the effectiveness of the intervention on students' visual-digital literacy skills and reasoning abilities. The use of parametric

tests, effect size, and quantitative analysis allows for the evaluation of the intervention's impact on students' skills. The use of qualitative analysis allows for a deeper understanding of students' engagement with visual and digital media during the astronomy observation labs and their feedback on the intervention.

Findings

The initial part of the results of students' digital visual literacy was analyzed on the differences in pre and posttest in the experimental group through an independent sample t test analysis, the result in Table 1.

Table 1 shows a comparison between the pretest and posttest results for each visual-digital literacy. According to the results analysis of the average pretest and posttest visual digital literacy abilities, a significant difference was obtained between before learning compared to after open-ended inquiry learning based on the astronomical observation lab and Heaven View. Further, ANCOVA results for visual-digital literacy on open-ended inquiry in Table 2.

The difference in mean scores in visual literacy, digital literacy and the two groups showed significant differences. The difference between the experimental-control group indicates a high score. Therefore, the results of the analysis

Table 1: Visual Digital Literacy Results

Visual-Digital Literacy	*Measure*	*Mean*	*SL*	*t*	*p*
Visual Literacy					
information and data literacy	Pretest	36.82	2.78	5.321	0.000
	Posttestw	85.86	17.32		
communication and collaboration	Pretest	31.56	2.59	4.565	0.000
	Posttest	75.62	16.27		
Digital content	Pretest	27.43	1.76	7.142	0.000
	Posttest	53.49	2.26		
Safety	Pretest	34.35	2.81	5.879	0.000
	Posttest	79.72	16.83		
Solving technical problems	Pretest	29.68	1.94	4.670	0.000
	Posttest	69.85	16.72		
Digital Literacy					
identification and narrative	Pretest	52.97	4.85	5.643	0.000
	Posttest	87.41	17.32		
conceptualization	Pretest	43.18	2.54	4.372	0.000
	Posttest	72.53	16.18		
interpretation and analysis	Pretest	31.34	2.31	5.318	0.000
	Posttest	83.36	16.57		
recognition and representation	Pretest	32.08	1.95	4.372	0.000
	Posttest	76.84	17.03		
object manipulation	Pretest	31.54	1.83	4.476	0.000
	Posttest	77.39	17.43		

Table 2: ANCOVA Results on Visual-Digital Scores

Variance source	df	Sum of squares	Mean of squares	F	p
Visual literacy	37	198.652	4.75		
Digital literacy	32	187.982	7.98		
Between the groups	2	176.951	0.49	184.256	0.000
Error	69	32.065			
Total	69	397.166			

show that there are differences between students who receive open-ended inquiry learning through astronomical observations assisted by Heaven View media and students who receive discussions. The analysis shows whether the open-ended learning of astronomical observation with the help of Heaven View is a significant predictor, so a regression analysis is carried out. The results of a simple regression analysis are shown in Table 3.

Table 3: Analysis of Regression for Visual-Digital Literacy

Aspect	*B*	*Standard Error*	*β*	*t*	*p*
RU-BRICS ANALY-SIS	98.645	18.002	0.646	5.782	0.000
	6.751	1.365		5.331	
R=0.674		F=28.457			

Table 3 states the visual-digital literacy score based on the stud1ent's posttest. The results of the regression analysis show high visual-digital literacy variability. The results of the visual-digital literacy test based on the magnitude of the learning influence obtained by the experimental group using open-ended inquiry through astronomical observations assisted by Heaven View are shown in Table 4.

The results of the analysis of the difficulty of the open-ended inquiry activity obtained the difference between the distribution of variance and the average achievement scores for each project activity. The level of task solution with an average score of 45% to 73%. The results of the analysis show that some of the tasks are quite long and the phase of assessment are in direct observation. The solution finding rate in inquiry activities ranges from 42% to 64% on average. The results of the open-ended inquiry are shown in Table 5.

Performance gaps using open-ended inquiry affect performance in learning which can be directed at the distribution of observation assignments and the use of Heaven View. The effect size of the visual-digital literacy achievement from the implementation of open-ended inquiry based on astronomical observations and Heaven View media is in the medium and high categories. The magnitude of this influence is due to the inquiry activities that are trained in observation activities starting with observing the azimuth of the stars, determination of star height, star hour angle determination, determination of hour angle starts at certain hours, determination of the rising time of the star and determination of the hour of sunset. The percentage of direct observation activity and use of Heaven View media is shown in Figure 1.

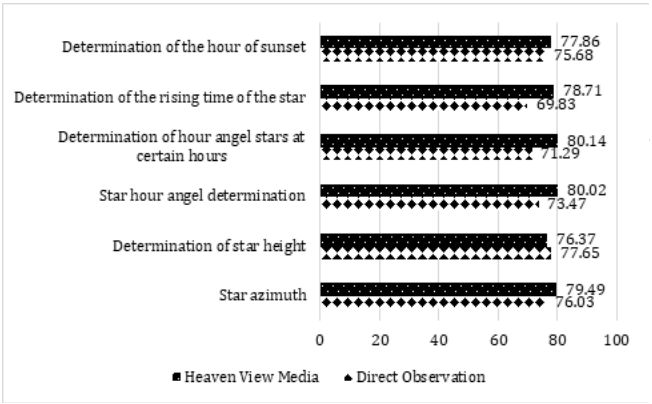

Fig. 1: Direct observation activities and the Heaven View application

Table 4: Effect Size of Visual-Digital Literacy Results

		Ability Aspect		*Effect Size*		
Parameter (%)	*Group*	*Visual Literacy*	*Digital Literacy*	*Z*	*p*	*Cohen's d*
Average	Experiment	72.31	79.62	-0.52	0.86	0.8 (High)
	Control	52.53	41.35			
Std Dev	Experiment	19.62	16.75			
	Control	20.16	17.96			

Table 5: Analysis of the Implementation of Open-ended Inquiry

Activity	*Mean (%)*	*Std.dev (%)*	*Cronbach's Alpha*
Star Azimuth	67.53	17.52	0.51
Determination of star height	73.54	17.65	0.63
Star hour angle determination	75.21	18.02	0.65
Determination of hour angle starts at certain hours	75.63	18.15	0.69
Determination of the rising time of the star	76.39	19.47	0.71
Determination of the hour of sunset	76.16	18.35	0.70

and simple tools reach the high category. Students have high interest and curiosity to actively use observational equipment and analyze the results of direct observations. The use of the Heaven View application by students reaches a high category. Students are interested in using the application because virtual observations are not determined by weather factors and can be repeated. Heaven View can also be applied by setting the stars according to the observation date, estimated date, star name and observation location.

Discussion

Open ended inquiry learning in the astronomy laboratory triggers students to improve their visual-digital literacy skills and investigative skills including formulating questions, collecting data, and making scientific observations. Astronomy learning explores students' curiosity and develops critical thinking skills that are contextual in the surrounding environment. Involvement in open inquiry-based activities, students can master astronomical knowledge and be skilled at making observations in new situations. Heaven View as a digital application that directs students to explore the universe using media. Digital media is used effectively by people who have the opportunity to explore the universe using digital media and to develop visual-digital literacy skills. The use of digital media in astronomy learning can help traditional classroom learning (Sui et al., 2023; Weng et al., 2022).

The combination of visual media and digital media in the astronomical observation laboratory and Heaven View demonstrates a multimedia approach and scientific activities for learning science. The multi-modal learning approach is more effective in enhancing learning and active engagement with traditional methods. The use of a variety of astronomy learning media, for example pictures, videos, and simulations. The use of this media guides students to store data and develop visual-digital literacy skills. Students' creativity is encouraged to complete assignments because of the demands of independent learning and collaboration in teams conducting open ended inquiry (Blown & Bryce, 2022; Jimenez-Liso et al., 2022). Inquiry and exploration is carried out by students openly in discovering concepts and interpreting meanings that lead to increased mastery of concepts. Students are given the opportunity to freely explore and find meaning. Level of mastery of content and active involvement of students. This learning helps to arouse students' interest in learning and increases curiosity for lifelong learning.

The combination of direct observation activities and the use of Heaven View media through open ended inquiry helps analyze and explore the universe. Digital media in learning based on open ended inquiry can develop connectedness with the surrounding environment which can increase learning motivation and active involvement. Direct observation activities have the advantage of improving students' visual literacy and digital literacy skills. Open ended inquiry activities can provide opportunities in digital media learning, multi-modal approaches, creativity and increase curiosity. Observational tools can improve students' reasoning and learning experiences that encourage mastery of concepts that are contextual with the universe (Bose & Humphreys, 2022; Le et al., 2022).

Firstly, the integration of open-ended inquiry-based astronomy observation labs and Heaven View provides a unique opportunity for students to engage with astronomy through digital.

Optimizing the use of digital media in the astronomy laboratory as a vehicle for direct observation and Heaven View media as an indirect observation tool can help improve students' digital-digital literacy skills. People are curious and familiar with Heaven View media to apply it effectively. The environmental context involved in using digital media can develop skills in navigating and utilizing digital media professionally (Susilawati et al., 2020, 2021). Optimizing the use of digital media in the astronomy laboratory as a vehicle for direct observation and Heaven View media as an indirect observation tool can help improve students' digital-digital literacy skills. People are curious and familiar with Heaven View media to apply it effectively. The environmental context involved in using digital media can develop skills in navigating and utilizing digital media professionally (Susilawati et al., 2020, 2021). Stargazing activities and the use of digital media are carried out in open-ended inquiry-based astronomy learning to encourage students to develop their scientific inquiry skills, such as formulating questions, collecting data, making observations and analyzing data. This learning directs students to explore scientific curiosity and develop critical thinking in real-world contexts (Kaliampos et al., 2023; Ong et al., 2023). Under certain conditions and unfavorable weather, observations using digital technology and telescopes are difficult. The use of digital media is easier and more supportive for use in learning. (Bloor & Santini, 2023; Brown et al., 2021). By exploring the universe through digital media and inquiry-based learning, students are more likely to develop a sense of connection with the world around them, which can lead to increased motivation and engagement in learning.

Visual-Digital Literacy in open-ended inquiry learning shows certain advantages in achieving visual literacy skills and digital literacy skills which also influence students'

probabilistic reasoning abilities (Binali et al., 2022; Macias et al., 2022). By encouraging greater student interaction and motivation through the use of a multi-modal approach to learning, encouraging student creativity, enhancing students' visual-digital literacy skills, encouraging scientific investigations, these learning tools are able to develop deep understanding and student learning experiences towards curiosity, interaction, student involvement in astronomy learning.

Conclusion

The application of scientific activities to conduct open inquiry and the use of visual media in the laboratory provides opportunities for students to develop abilities and skills to identify and manipulate visual elements, analyze abstract concepts, interpret and analyze visual data, recognize and represent visual information accurately, and manipulate objects in a literate manner. The results of the analysis of the students' visual-digital literacy test obtained a high average in the experimental group. Student activities in direct observation and use of Heaven View show significant results. This study also found that the integration of astronomical tools and digital media in the laboratory can improve students' visual and digital literacy skills, particularly in the areas of information and data literacy, numeracy literacy, communication skill, collaboration team, digital content creation, online security, and problem solving.

Suggestion

The results suggest that the combination of Open-ended Inquiry based Astronomy Observation Labs and Heaven View with digital tools and resources can provide a rich and engaging learning experience that can enhance students' visual and digital literacy skills. These findings can have implications for science education and instructional design, particularly in the design and implementation of inquiry-based learning activities that incorporate visual and digital media.

Limitation

The sample size was relatively small and restricted to undergraduate physics education students in Semarang, Indonesia, which may limit the generalizability of the findings to other populations and contexts. Furthermore, the study relied solely on self-reported measures to assess students' visual and digital literacy skills, which may have introduced social desirability bias and measurement error. Finally, the study did not explore the long-term effects of the intervention on students' visual and digital literacy development.

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