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Stellarium Assisted Celestial Coordinate Learning to Encourage Students' Concept Comprehension and Digital Literacy

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Abstract. The aim of this work is to determine the understanding of concepts and digital literacy of students using the Stellarium application in learning astronomy, specifically the celestial body coordinates. The study used pre-experimental one-group pretest-posttest design. The sample consists of physics students at UNNES who were taking the Astronomy course. Data was collected through testing using a concept comprehension test and a digital literacy questionnaire. Due to the non-normal distribution of the data, hypothesis testing was conducted using the Wilcoxon test, which showed that the increase in students' concept comprehension was not significant (z-score = -1.43, p-value = 0.076). This result was confirmed by the N-gain of 8.71% (low). However, there were three indicators of the seven concept comprehension indicators tested, that showed a significant improvement, i.e. interpreting, exemplifying, and inferring. Rasch model analysis of the digital literacy questionnaire showed that students' digital literacy skills were very good and consistent with the model's prediction. Thus, the use of Stellarium in learning celestial coordinates can partially improve students' concept comprehension and digital literacy skills.

Keywords: Stellarium, Celestial Body coordinates, concept comprehension, Digital Literacy.

1. Introduction

Indonesia is a country that must continue to catch up in the field of science education to compete and stand alongside other countries properly and fairly. From the evaluation carried out by The Programme for International Student Assessment (PISA) in 2018, Indonesia ranked 74th in reading ability, 73rd in mathematics, and 73rd in science, out of 79 participating countries [1]. These rankings indicate that the quality of education in Indonesia is not up to par with global standards. This may be due to several factors, such as the large number of teachers who are not qualified for their field of work, or in other words, the need for an improvement in astronomy knowledge among teachers [2]. The impact of this situation is the difficulty in changing students' concepts related to how nature works [3]. Concepts are essential to understanding a subject, as the concepts of one subject relate to those of another. Therefore, without mastering them, the goal of learning, which is understanding, cannot be achieved [4].

One topic in astronomy that has a high level of difficulty is the celestial coordinate system. Students often face difficulties with this topic, as it requires certain tools, such as mathematics and spatial thinking skills. This is consistent with the findings of Plummer [5] and Hans et al. [6], who found that the difficulty of learning the coordinate system is common among students, partly due to the abundance of abstract concepts, such as the coordinate system, rotation and revolution movements, and others, which require spatial thinking skills. These abstract concepts are difficult for some students to understand, especially those who are not skilled in mathematics or physics. Additionally, some students may have never observed celestial bodies with the naked eye, making it difficult for them to imagine what happens in the sky. Similar findings were found by several researchers that students have difficulty learning the coordinate system due to a lack of understanding of the mathematical tools used, a lack of understanding of the movements or orbits of celestial bodies, and a lack of direct experience in observing these celestial bodies [7], [8].

To overcome the learning difficulties mentioned above, a process of astronomy learning, particularly the celestial coordinate system, is needed that involves the use of astronomy application media. The purpose of using this media is to facilitate and guide students in understanding the movement and coordinates of celestial bodies as a function of time and place, so that students can explore the observation of celestial bodies anytime and from anywhere on the surface of the earth. On the other hand, the use of this media is also expected to improve students' digital literacy. Digital literacy is an individual's interest, attitude, and ability to use digital technology and communication tools to access, manage, integrate, analyze, and evaluate information, build new knowledge, and communicate with others effectively to participate in society [9]. Digital literacy is becoming increasingly important for everyone, given the massive development of digital technology that accompanies almost all activities in life.

One astronomy application that has the capacity as mentioned above is Stellarium. Stellarium is an applicable and relevant learning tool in teaching the basics of astronomy. With this application, one can observe celestial objects in real-time, either at a specific time and location or by advancing or reversing time, zooming in on objects, changing observation locations, setting star boundaries, and so on [10]. This application also provides complete astronomical data of celestial objects, such as the case of changes in solar intensity due to a solar eclipse through the information of the solar apparent magnitude per second during the eclipse [11]. While the several astronomy applications can be used in online mode, Stellarium can be used both online and offline, and the user can set the time and location for observing the celestial object, although by default, both of these will be automatically set based on the user's location and the time of observation.

Several studies related to the use of this sky ball application have been conducted, such as Marina and Prima [12] who found that the use of Stellarium greatly supports astronomy learning. The same was done by Acut and Latonio [13], who also found the effectiveness of Stellarium as an astronomy learning tool related to the implementation of technology aspects of STEM and student performance improvement. Research conducted by Susilawati and Rusdiana [14] regarding a case study of learning celestial object coordinates in the Physics Education Program at a university in Semarang city also showed the need for an astronomy application tool to support student concept mastery. Therefore, this study implemented celestial object coordinate lectures using Stellarium to improve students' concept comprehension and digital literacy.

2. Methods

This research was conducted in the Astronomy course of Physics Department at Universitas Negeri Semarang, with the population of all students taking the course that semester, and the sample is 35 students in the course. The research sample was taken using saturation sampling techniques, and the research type was a pre-experimental design with a one-group pretest-posttest design.

This study used two data collection methods, namely a test method that includes a pretest and posttest, and a Likert-scale questionnaire method. The first stage was to conduct a pretest before the celestial object coordinate material was presented, followed by the implementation of learning assisted by Stellarium. The final stage was to conduct a posttest and questionnaire to obtain data on students' digital literacy skills. The design used in this study can be shown in Table 1.

Table 1. *Design of one group pretest-posttest research.*

Pretest	Treatment	Posttest
O_1	X	O_2

O_1 = pre-experimented class
O_2 = post-experimented class
X = Stellarium utilization in the learning.

Concept comprehension data collection was done through tests, while digital literacy measurement was done through a questionnaire prepared using a Likert scale. Teaching materials along with lesson plans and instruments for testing the comprehension of celestial object coordinate concepts and digital literacy questionnaires were tested by two experts. The expert review was conducted to ensure that the teaching materials and instruments were adequate in content and construct. Some input from the experts was followed up for improvement. Particularly, item testing was conducted for the concept comprehension test instrument to obtain relationships and consistency between item questions, resulting in a valid and reliable test instrument. Teaching materials that had been validated by experts were then implemented in lectures. Test instruments that met validity and reliability standards were used to measure students' concept comprehension through pretest and posttest, while digital literacy questionnaires were used to measure students' digital literacy.

The Rasch model was used for expert validation analysis, item validation, and digital literacy questionnaire data analysis [15]. The improvement of celestial object coordinate concept comprehension was analyzed using inferential statistics (normality, N-gain test to determine the increase due to treatment, and hypothesis testing to determine if the given treatment significantly improves students' concept comprehension) and the Rasch model to provide further confirmation [16].

3. Results and Discussion

In the initial stage, the lesson plan was created, as well as concept comprehension test instruments and digital literacy measurement instruments. The lesson plan and their instruments underwent content validation to ensure their suitability for use. Then, a specific validation test was performed on the test instrument to assess the consistency between test items, resulting in valid and reliable questions [17]. The results of the Rasch model analysis of the lesson plan, test instruments, and digital literacy questionnaire instruments are presented in Table 2. According to the experts, the prepared lesson plan, concept comprehension test instrument, and digital literacy questionnaire instrument have excellent suitability with the model, as shown by values of 0.5 < Outfit MNSQ < 1.5, and -2.0 < Outfit ZSTD < 2.0 for both experts and their average [15], [18]. The level of difficulty of the concept comprehension test instrument and lesson plan for implementation is relatively high, with a logit (measure) value above the range of 0.00 - 1.00 [19]. This indicates that the lesson plan must be implemented carefully and by teachers/instructors who have mastered the material, as the same applies to the concept comprehension test instrument, which requires students' proper understanding to complete the test correctly. For the digital literacy instrument, all critical components have been met in the excellent category. The difficulty level of all three sets of instruments is also excellent, with a value of 0.4 < Pt Measure Corr < 0.85 [16], [20]. Overall, it can be shown that according to experts, the lesson plan, test instrument, and digital literacy instrument are suitable for research or further validation tests (especially the concept comprehension test instrument).

Table 2. *Results of instrument analysis based on expert validation*

Category	Expert	Instrument item output value: Lesson plan	Decision	Concept comprehension	Decision	Digital literacy	Decision
Outfit MNSQ	#1	0.83	Good	0.71	Good	1,00	Good
	#2	0.81	Good	0.69	Good	1,00	Good
	Mean	0.82	Good	0.70	Good	1.00	Good
Outfit ZSTD	#1	-0.34	Moderate	-0.26	Moderate	0,00	Good
	#2	-0.41	Moderate	-0.29	Moderate	0,00	Good
	Mean	-0.37	Moderate	-0.27	Moderate	0,00	Good
Pt Measure Corr	#1	0.74	Fit	0.88	Fit	0,53	Fit
	#2	0.84	Fit	0.78	Fit	0,53	Fit
	Mean	0.79	Fit	0.83	Fit	0.53	Fit
Measure	#1	3.47	Difficult	3.55	Difficult	0,00	Good
	#2	3.80	Difficult	3.55	Difficult	0,00	Good
	Mean	3.63	Difficult	3.55	Difficult	0.00	Good

The item validity testing using Rasch also obtained excellent results (Table 3). The difficulty level of the concept comprehension test instrument on celestial coordinate is relatively good, with an average measure logit value of 0.06, which means the questions are generally moderately difficult [19]. The compatibility between data variation and the model is also excellent, with an Outfit MNSQ value of 1.02, which means the data variation in the test items only exceeds the model by 2% [16], [18]. This is confirmed by the very small Outfit ZSTD value, which is 0.08 (around 0), meaning the data is slightly more varied than the model [19]. This instrument also has good discriminant power (0.30 < Pt Measure Correlation < 0.40), so it can effectively distinguish respondents with high, medium, and low abilities [20].

Table 3. *Results of item analysis using Rasch model*

Category	Item output value			
	Concept comprehension	Decision	Digital literacy	Decision
Measure/logit	-0,60	Moderate	0,00	Difficult
Outfit MNSQ	1,02	Good	1,06	Good
Outfit ZSTD	0,08	Good	-0,20	Moderate
Pt Measure Corr	0,31	Low	0,47	Fit
Reliability	0,76	Moderate	0,89	Good

Table 4. *Results of normality test using Shapiro-Wilk test*

Group	p-value	Decision
Pretest	0.037	Not normally distributed
Posttest	0.004	Not normally distributed

The normality tests were conducted using Shapiro-Wilk and obtained p-values of 0.037 (pretest) and 0.004 (posttest) respectively, where both of which are less than 0.05, hence, it was concluded that the data was not normally distributed (Table 4). Therefore, for hypothesis testing, with H_0 = there is no increase in concept comprehension after treatment, and H_a = there is an increase in concept comprehension after treatment, using non-parametric difference tests, in this case the Wilcoxon signed-rank test was used, and the results obtained as in Table 3 [21]. According to the z-score table (Table 5), with a value of $z = -1.435$, the p-value was obtained as 0.076, which is greater than 0.05, then Ha was rejected, meaning there was no significant increase in understanding of the concepts due to the use of Stellarium media in learning astronomy of celestial coordinate material. This result is further confirmed by the low student value improvement, namely N-gain of 8.71% (Table 6).

Table 5. *Results of the significance test for concept comprehension improvement using Wilcoxon signed-rank test*

Pretest	Posttest	z-score	p-value	Decision
51.33	55.57	-1.435	0.076	Not significant

The non-significance of the increase in concept comprehension obtained by students after this treatment can be explained as follows. Astronomy is a course that is quite difficult for students to understand because of its very broad study object and requires strong imagination to be able to imagine the spatial aspects of the object [7]. Difficulties also arise due to the lack of teaching aids, such as simulation applications and simple teaching aids [22]. Even when there are simulation applications available to support learning, the ease of use may not be felt by students because they also have to learn from scratch how to use them. This learning implementation was carried out online in the pandemic era.

There is a possibility that many obstacles and difficulties arise due to the online learning process above, among others due to the lack of interaction between students and their teachers, and the emergence of anxiety in students who, when in face-to-face conditions, can be easily handled through direct interaction with lecturers and classmates. This is in line with the results of Daher et al. [23] and Sun et al. [24] which found that direct interaction between students and lecturers has a positive influence on student learning outcomes in online learning. Students who feel more involved and active in interactions with lecturers and classmates have better learning outcomes in online learning [25]. Furthermore, direct interaction in class can increase student learning motivation, thus improving their understanding of the learning material [26].

In addition, online learning can also increase student anxiety, as found by Phanphech et al. [27] that students with higher levels of anxiety tend to have difficulty adapting to online learning, due to factors such as lack of support from teachers and classmates, as well as feelings of loneliness and isolation, which can exacerbate student anxiety in online learning. Furthermore, student anxiety in online learning can negatively affect their learning outcomes, while direct interaction with teachers and classmates can help reduce anxiety and improve student learning outcomes [28].

Nevertheless, if we look at the results, there was an improvement in the average, lowest, and highest grades obtained by students (Table 6). For example, in the case of the highest-grade increase, a score of 90.66 was obtained during the pretest, and an increase to 98.90 was found after this treatment. Although the N-gain was only 8.71%, this result shows a very good trend, namely that the student's understanding of the concept is moving towards maximum mastery. However, since astronomy, especially celestial body coordinate material, is relatively difficult, the increase in concept comprehension achieved by students is very small (not significant). This is in accordance with the finding of Jansri & Ketpichainarong [29] on students' understanding of basic astronomy concepts, which revealed that the concept of celestial coordinate is one of the most difficult concepts for students to understand. This occurred since the material not only requires numerical and mathematical understanding but also spatial skills to understand [7]. With this explanation, it can be understood that the use of Stellarium in online learning of celestial body coordinates, although it has been able to increase students' concept comprehension, the increase is not significant.

Table 6. *Achievement score of concept comprehension*

Category	Pretest score	Posttest score	Decision
Highest score	90.66	98.90	Increase
Lowest score	16.48	24.73	Increase
Average score	51.33	55.57	Increase
N-gain (%)	8.71		Low

When analyzed by indicator, three of seven indicators experiencing a significant increase due to the use of Stellarium in the learning, i.e. the aspects of interpreting, exemplifying, and inferring (Table 7). The increase in these three indicators is believed to be because the use of Stellarium, in principle, allows students to visually see how celestial bodies are arranged in astronomical coordinates. This can help students interpret, provide examples, and conclude the concepts they are learning. These partial findings are also in line with the finding of Ziden et al. [30] that the use of augmented reality media in astronomy learning can improve students' understanding of the position of celestial bodies in the sky, specifically the research found an increase in the ability to interpret and exemplify difficult astronomy concepts. In addition, the use of technology such as Stellarium in learning can help students visualize abstract concepts such as celestial body coordinates and increase student interest in astronomy [12], [30], [31].

Table 7. *Results of significance test for each concept comprehension indicator using Wilcoxon signed-rank test.*

Indicator	Z score	p-value	Decision
Interpreting	-1.880	0.0301	Significant
Exemplifying	-2.210	0,0136	Significant
Classifying	-0.258	0.4013	Not significant
Summarizing	-1.291	0.0985	Not significant
Inferring	-2.524	0.0059	Significant
Comparing	-0.333	0.3707	Not significant
Explaining	-0.701	0.3707	Not significant

Furthermore, for students' digital literacy, from the analysis of the questionnaire filled out by students using the Rasch model, the results were obtained as shown in Table 8. From the Outfit MNSQ and Outfit ZSTD data, values of 0.97 and -0.10 were obtained, respectively, which mean that after using the Stellarium application in the celestial coordinate learning, students' digital literacy was very good and in line with the expected model [19]. Students' digital literacy ability was also very good, as indicated by a measure value of 0.00, that is in the range of 0.00-1.00 [20].

The use of Stellarium in astronomy learning can enhance students' digital literacy since the application allows students to interact with digital technology in the context of astronomy. Students will also learn how to use the application to observe celestial bodies, search for information about celestial bodies, and create visualizations [9], [32]. Thus, the use of Stellarium can help improve students' digital literacy skills in the context of astronomy. The use of digital technology such as Stellarium in astronomy education can improve students' digital literacy skills, such as the ability to use digital technology and software in the context of astronomy, understand digital information about celestial bodies, and create visualizations of celestial bodies [33]–[35].

***Table 8**. Digital literacy achievement*

Category	Value	Decision
Outfit MNSQ	0.97	Very Good
Outfit ZSTD	-0.10	Good
Measure	0.00	Fit

Further, with each indicator analysis, it was obtained that students underwent digital literacy for all indicators (Table 9). The ability to find knowledge, the ability to evaluate knowledge, and the awareness of the knowledge impact are the maximum achievement, while the ability to use knowledge and the ability to explore the knowledge are slightly lower achievement that are still in moderate results. This achievement can be understood since the Stellarium utilization encourages students to find the data of several celestial bodies, such as planet and stars [13]. They also used and evaluated to compare the data with their calculation using several celestial coordinates formulas. Even, they done some exploration using the application to obtain several other bodies [12]. With all the process, they experienced and had an awareness of the knowledge impact.

***Table 9.** Digital literacy achievement for each indicator*

Category	Outfit MNSQ	Outfit ZSTD	PT Meas Corr	Measure
Ability to find data/knowledge	0.89 (Fit/Good)	-0.14 (Fit/Good)	0.70 (Good)	0.00 (Very Good)
Ability to use data/knowledge	1.10 (Moderate)	0.32 (Fit/Good)	0.59 (Good)	0.00 (Very Good)
Ability to evaluate knowledge/data	0.90 (Fit/Good)	-0.31 (Fit/Good)	0.70 (Good)	0.00 (Very Good)
Ability to explore knowledge/data	1.02 (Moderate)	0.15 (Fit/Good)	0.69 (Good)	0.00 (Very Good)
Awareness of the impact of data/knowledge on oneself and society	0.93 (Fit/Good)	-0.16 (Fit/Good)	0.65 (Good)	0.00 (Very Good)

In conclusion, the use of Stellarium in astronomy education can help improve students' digital literacy, allowing them to be more skilled in operating digital technology in the context of astronomy. Conversely, the research found no significant improvement in concept comprehension due to this treatment. However, partial improvement in some aspects of concept comprehension (in this case interpretation, exemplifying, and inferring) indicates that this learning still has meaningfulness, feasibility, and prospects for further development.

4. Conclusion

The use of Stellarium in astronomy learning on celestial coordinates has been implemented. Hypothesis testing using the Wilcoxon test showed that the increase in students' concept comprehension in the learning process was not significant (z-score = -1.435, p-value = 0.076), which was confirmed by the low relative improvement (N-gain = 8.71%). However, from the seven tested indicators of concept comprehension, three indicators showed significant improvement: interpretation, exemplification, and summarization. Furthermore, the rate of students' digital literacy since the Stellarium utilization was found to be very good. Thus, the use of Stellarium in astronomy learning on celestial coordinates matter can improve certain aspects of concept comprehension, such as interpretation, exemplification, and inference, as well as promote students' digital literacy.

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