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THE EFFECTIVENESS OF INTRODUCTION TO ASTRONOMY TEACHING MATERIALS TO IMPROVE PROBLEM-SOLVING AND GENERIC SCIENCE SKILLS

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ABSTRACT

This study aims to analyze the effectiveness of introductory astronomy teaching materials with inquiry settings on students' problem-solving and generic science skills. This study used a quasi-experimental design with the one-group pretest-posttest design. The research subjects were one class of 23 fourth-semester science education students. Data on problem-solving skills were collected using a test method with ten essay questions, and generic science skills data were collected using 30 multiple-choice questions. Data analysis was carried out descriptively, and a t-test with a significance level of 0.05. The analysis results showed that the use of inquiry-based introductory astronomy teaching materials in astronomy learning was effective in improving the problem-solving skills ($p<0.05$, <g> = 0.67 medium categories) and generic science skills ($p<0$ .05, <g> = 0.53 moderate type). So, it can be concluded that introductory astronomy teaching materials with inquiry settings effectively improve students' problem-solving and generic science skills.

Keywords: generic science skills; introduction to astronomy; problem-solving; teaching materials

INTRODUCTION

Astronomy studies celestial bodies such as planets, asteroids, stars, galaxies, and large-scale universes that can help develop careers in the future. Mastery of astronomical concepts also affects the recognition of the land and sea of a country. However, awareness of studying astronomy and ease of access to astronomy still needs to be improved (Chubko et al., 2020; Usuda-Sato & Canas, 2021). One of the fundamental problems in learning astronomy in the Department of Physics and Science Teaching is the low quality of learning at various levels of education. The low quality of the astronomy process and learning outcomes are influenced by many factors, including teachers, learning infrastructure, and curriculum. Astronomy as a science field is part of Earth and Space Science.

The scope of material in the high school curriculum (physics) has decreased significantly from the competency-based curriculum (KBK) in 2004 to the 2006 KTSP and K-13. In K-2013, the reduction in the quantity of Astronomy material in the junior and senior high school physics curriculum was due to the integration of some of these materials into the social sciences and geography curriculum. On the other hand, junior and senior high school students often compete for Astronomy and Earth materials nationally and internationally. This phenomenon demands that prospective science teacher students have mastery of astronomy, both declarative and procedural knowledge so that future teachers can understand

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the urgency of the importance of this material and its implications for students' daily lives (Bernhardt, 2021).

Changes in astronomy material in the curriculum impact the lack of Astronomy learning tools in junior and senior high schools (Simon et al., 2021). The same condition was also found in Undiksha. The results of observations on Astronomy learning at the Science Education Study Program, FMIPA Undiksha, found no adequate astronomy learning tools. The learning tools used by the teacher are still partial. The teaching materials, student worksheets, syllabus, lesson plans, and evaluation tools stand alone without any connection. Even practicum has never been given with astronomy lectures. In this situation, prospective teacher students are more waiting for the lecturer's instruction in learning so that learning is still teacher-centered. The evaluation tools presented in the student worksheet and teaching materials tend to deviate from the indicators and learning objectives. Therefore, it is necessary to develop teaching material based on the learning objectives listed in the applicable curriculum to improve science teachers' competence in astronomy (Usuda-Sato & Canas, 2021).

Teacher competence in science becomes very important because science is a part of human life since humans know themselves and their natural surroundings. Humans and the environment are sources, objects, and science subjects (Parmiti et al., 2021). Science education is one part of education with tremendous and strategic potential in preparing quality human resources. Through science, learning can be formed by curiosity, open thinking, critical thinking, and the desire to solve problems, build a sensitive attitude to the environment, and respond to an action (Maison et al., 2020). Through integrated science learning, in dealing with the problems of everyday life, students are expected to have complete knowledge of science to solve the problems they face contextually (Wang et al., 2018).

Internationally, the current condition of Indonesian education is of low quality. The results of PISA in 2018 in science lessons showed that the average score obtained by Indonesia is 396 and ranks 70 out of 78 countries (Bellová et al., 2018; Odell et al., 2021). Based on the results of a survey from Trends in International Mathematics and Science Study (TIMSS) in 2015 reporting on the average value of science in the content domain and cognitive domain, which is an important aspect of problem-solving ability, Indonesia is ranked 45th out of 48 participating countries with the acquisition of 397 points (Mullis et al., 2016). This data shows that students' problem-solving and other thinking skills are still low.

The low problem-solving ability, among others, is caused by the availability of teaching materials that facilitate the development of thinking skills. Learning science emphasizes students' thinking patterns, not just understanding concepts. It is done so that students can master and solve problems logically, carefully, critically, and thoroughly (Yearworth et al., 2013; Han et al., 2016). In the basic competencies of science learning, which states to solve problems in students' lives, students are expected to understand the concepts, principles of science, and their relationship and application. This results in important problem-solving skills in the 2013 curriculum. In everyday life, everyone needs problem-solving skills to face various problems that must be solved and require creativity to solve their problems (Sung, 2017; Pucangan et al., 2018).

In addition to problem-solving skills, some higher-order thinking skills also need to be developed in science learning, such as critical thinking, creativity, decision-making, and generic science skills (Canelas et al., 2017; Aristeidou & Herodotou, 2020). The generic ability of science is the skill of thinking and acting based on the knowledge obtained after students learn science (Azalia et al., 2020; Halim et al., 2020). Generic science skills can be used to learn various concepts and solve problems in science (Nurdini et al., 2021; Sakliressy et al., 2021). Therefore, the generic ability of science is an ability that is used in general in various scientific works. Many generic skills can be developed through a practicum with inquiry, such as decision making, problem-solving, communication, group work, and high-level reasoning. Generic science skills that need to be developed in planning and carrying out inquiry activities are (1) the ability to make direct observations, (2) indirect observations, (3) symbolic language, (4) awareness of large scales, (5) logical inference, (6) causal relationships, (7) modeling, (8) principle-compliant logic frameworks, and (9) constructing concepts.

Generic skills are fundamental for students to face the world of work. Through a problem-based and inquiry-based approach, learning will promote the skills employers need from science graduates (Sarkar et al., 2020). When compared with the indicators of science process skills, such as (1) observing, (2) formulating hypotheses, (3) predicting, (4) investigating/researching, (5) interpreting findings and drawing conclusions, and (6) communicating, it appears that the Generic science Skills indicators intersect with the science process skills indicators. This similarity allows the development of generic science skills and students' problem-solving skills through inquiry science learning (Halim et al., 2020).

Based on the problems above, it is necessary to develop a teaching material with a learning model that can accommodate problem-solving skills and students' generic science skills (Väisänen & Hirsto, 2020). One of the learning models that can be used in a learning setting is the inquiry learning model. The inquiry learning model is a learning model that can encourage students to become intelligent, critical, and broad-minded people (Kaeophanuek et al., 2019; Pursitasari et al., 2020). The inquiry learning model aims to train students to conduct research, explain phenomena, find the essence and meaning of a problem, and solve problems through scientific procedures independently (Budiarti et al., 2016). The main purpose of inquiry learning is to help students develop higher-order thinking skills by asking motivating questions, getting answers based on curiosity, and concluding and giving meaning to their findings (Dewi & Mashami, 2019). This study aimed to develop introductory teaching material for inquiry-based astronomy to improve the problem-solving skills and generic science skills of prospective teachers in astronomy.

METHODS

This study uses a quasi-experimental design with a one-group pretest-posttest design. Experimental research was carried out in only one group randomly selected, and there was no stability and clarity test of the group's condition before being given treatment (Sugiyono, 2014; Arsal, 2019). The treatment is in the form of learning by using introductory astronomy teaching materials with inquiry settings. A pretest was given to determine the initial conditions before treatment, and posttest was given to determine differences in problem-solving and generic science skills after the treatment. The data needed in this study consisted of (1) problem-solving skills before the treatment, (2) generic science skills before the treatment, (3) problem-solving skills after the treatment, and (4) generic science skills after the treatment.

This study's procedure for learning astronomy is as follows: (1) Before learning begins, students are given a pretest of problem-solving skills and content-based generic science skills. Then proceed by dividing students into study groups whose members consist of 3-4 people; (2) Carry out astronomy learning activities in an inquiry setting with stages: Learning begins with making a summary after they read the material in the teaching materials. Make a paper according to the topic whose material is developed from teaching materials. Conduct in-depth presentations and discussions related to topics to understand better the material being studied. To get a complete understanding, conduct relevant practicums; (3) At the end of the lesson, students are given a posttest of problem-solving skills and content-based generic science skills.

The research subjects were fourth-semester students of the Science Education Study Program at an Educational Personnel Education Institute in Bali, as many as one class (23 people). In this class, they were given learning using introductory astronomy teaching materials with inquiry settings. The following are nine subjects in the developed teaching materials: the earth's position in the celestial sphere, Solar System, Sun, Earth and Moon System, Movement of Planets and Satellites, Star Physics, Evolution of Stars, Galaxies, Structure of the Universe. This teaching material is equipped with practical instructions to facilitate students' inquiry. Topics in the practicum consist of six topics Astronomy practicum: Sundial, Earth's Rotation & Revolution, Moon's Rotation & Revolution, Coordinates of Observation, Recognition of Constellations, and Observation of Night Sky Objects.

Data collection used the test method to measure students' problem-solving and generic science skills. The test to measure students' problem-solving skills was developed according to the introductory astronomy material in 10 essay questions. In this study, the steps for solving the problem, according to Polya, consisted of understanding the problem, making a solution plan, implementing a solution plan, and rechecking. The test to measure students' generic science skills is a multiple choice test. The test was also developed according to the introductory astronomy material and consisted of 45 multiple choice questions. The dimensions and indicators of generic science skills measured in this study are presented in Table 1.

Table 1. The Dimensions and Indicators of Generic Science Skills

No.	Generic science Skills	Indicators
1	Direct Observation	Using all of one's senses to fully keep an eye on astronomical and natural events
		Gathering information from astronomical and natural events
		Seeking for similarities and dissimilarities
2	Indirect Observation	Monitoring astronomical experiments or natural events with the use of measurement tools as a sensory aid
		Gathering information from astronomical and natural events
		Seeking for similarities and dissimilarities
3	Awareness of scale	Identifying the size of natural items and having strong sensitivity to numerical scales, whether they are microscopic or macroscopic
4	Symbolic Language	Recognizing astronomical terminology and symbols
		Recognizing the numerical significance in an equation of the units and quantities.
		Applying mathematical rules to describe astronomical issues
		Applying mathematical rules to figure out astronomical issues
		Understanding astronomical graphs/diagrams, tables, and mathematical symbols
5	Principle-abiding logic framework	Seeking a connection between two rules that makes sense
6	Logical inference	Knowing the laws
		Debating in terms of laws
		Describing the issue using laws
		Concluding an astronomical phenomenon/event based on previous rules/laws
7	Causality	Describing the connections of variables in a particular natural event
		Assessing the causality of astronomical and natural events
8	Mathematical modeling	Putting events or issues in a graphs or sketches
		Putting events in a formula
		Offering different approaches to issues
9	Develop concept	Offering new concepts

Several tests were conducted to ensure the validity and reliability of the instrument. Item validity test used the CVR formula with the calculation results of each instrument item is 1. The total CVR of all items of the problem-solving skills test is 10, so it is declared valid based on the provisions of the validity of the instrument item. The total CVR of all items of the generic science skills test is 45, so it is declared valid based on the provisions of the validity of the instrument item. The reliability of the problem-solving skills test with data in polytomies using the Alpha Cronbach formula with the results obtained is 0.92 in very high criteria. The reliability test of the generic science skills test with data in dichotomies using the KR-20 formula with the results obtained is 0.85 in high criteria. The increase in problem-solving skills and generic science skills are classified based on the percentage of normalized gain calculated by the formula from Hake (Haji et al., 2015; Wahyuni et al., 2019). The % g value is then converted to the following normalized gain criteria. The gain level of 71 - 100 criteria is high, 31 - 70 is medium, and 0 - 30 is low. To determine the program's effectiveness in improving students' problem-solving and generic science skills, a different test with paired t-test was conducted. All analyzes were performed using the SPSS version 22.0 application at a significance level of 5%. The null hypothesis (Ho) is rejected if the significant figure is sig. (p-value) is greater than the value of (0.05).

RESULTS AND DISCUSSION

Students' increased problem-solving skills (PSS) are shown by calculating the normalized gain percentage (%g). They scored problem-solving ability, ranging from 0 to 100 with n = 23. The pretest, posttest, and normalized gain percentage (%g) of astronomy problem-solving skills obtained in the study are shown in Table 2.

Table 2. Frequency Distribution of Pretest and Post-Test Scores for Problem-solving Skills

No	Interval	Criteria	Problem-Solving Skills			
			Pretest		Post-test	
			f	%	f	%
1	85.0 – 100.0	Very Good	0	0	3	13.0
2	70.0 – 84.9	Good	0	0	14	60.9
3	55.0 – 69.9	Enough	0	0	6	26.1
4	40.0 – 54.9	Not enough	2	8.7	0	0
5	0 – 39.9	Very less	21	91.3	0	0
	Amount		23	100	23	100
	Average			24.41		74.78
	%(g)	currently		67%		

Based on Table 2, the pretest score of problem-solving ability, ranging from 0 to 100 with n = 23, obtained an average of 24.41 with a very poor category. Meanwhile, the average posttest data was 74.78, with a good category. 8.7% had pretest results in the poor category and 91.3% very poor. The posttest results showed an increase, where 26.1% were in the sufficient category, 60.9% in the good category and 13.0% in the very good category. It means an increase in the average score from pretest to posttest, with <g> 0.67 in the medium category. In other words, the average score of students in the posttest is greater than that of students in the pretest. In line with previous research, this is indicated by the intervention that makes a difference in the pretest and posttest scores (Tabuena, 2021). These findings indicate that inquiry-based learning or setting fosters students' ability to interpret, analyze, conclude, evaluate, explain and self-regulate, which are critical thinking skills (Wale & Bishaw, 2020).

To find out the significance of the increase in the mean score from pretest to posttest, an average difference test was performed with a paired t-test. The results of the different tests are listed in Table 3.

Table 3. T-Test Results of Astronomy PSS

Paired Samples Test								
	Paired Differences					t	df	Sig. (2-tailed)
	Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
				Lower	Upper			
Pretest - Postest	-50.37	3.77	0.79	-51.99	-48.74	-64.13	22	0.00

Based on Table 3, the value of sig (2 tailed) is 0.000 < 0.05, so it can be concluded that there is a difference in student scores before and after learning. Thus, using Introductory Astronomy teaching materials effectively improves students' problem-solving skills. The results of this study are in line with the results of previous studies, which showed that significant differences were found for both the experimental and control groups that supported the posttest after implementing innovative learning. In addition, significant differences were also found in the posttest in favor of the experimental group regarding astronomical achievement and interest in astronomy (Önal & Onal, 2021). In line with previous research, these results can also be used to help understand the best way of learning and, as an alternative, in learning that does not go well (Tabuena, 2021). This implementation can provide innovations by providing problems and solutions, especially in students' understanding of concepts. The increase in generic science ability (SGA) of students with n = 23 is shown by calculating the normalized gain percentage (%g). The values of pretest, posttest, and percentage of normalized gain (%g) of the generic science skills in astronomy obtained in the study are shown in Table 4.

Table 4. Pretest and Posttest Scores for Generic Science Skills

No	Interval	Criteria	Generic Science Skills			
			Pretest		Post-Test	
			f	%	f	%
1	85.0 – 100.0	Very Good	0	0	0	0.0
2	70.0 – 84.9	Good	0	0	10	43.5
3	55.0 – 69.9	Enough	0	0	9	39.1
4	40.0 – 54.9	Not enough	5	21.7	4	17.4
5	0 – 39.9	Very less	18	78.3	0	0
	Amount		23	100	23	100
	%(g)	currently	0.53			

Based on Table 4, 21.7% of students with general science skills are in the not enough category, and 78.3% are in the very less category. The posttest data showed an increase, where 17.4% of their generic science skills were in the poor category, 39.1% in enough category, and 43.5% in the good category. An increase is in the acquisition of the average score from pretest to posttest, with a %g of 0.53 moderate category. In other words, the results indicate an intervention on the pretest and posttest scores in the generic science skills. These findings indicate that the application of learning can help students master several generic science skills and skills (Khoiri et al., 2021). These indicators can be in the form of skills in developing generic science skills, including direct observation, awareness, indirect observation, a symbolic, logical framework based on natural law, logical inference, causal law, mathematics, and concept building.

Significance of the increase in the mean score pretest to posttest, resulting from the average difference test with paired t-test. The results of the different tests are listed in Table 5. Based on the table above, the sig (2 tailed) value is 0.000 < 0.05, so it can be concluded that there is a difference in student scores before and after learning.

Table 5. Astronomy SGA T-Test Results

Paired Samples Test								
	Paired Differences					t	df	Sig. (2-tailed)
	Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
				Lower	Upper			
Pretest - postest	-37.76	8.83	1.84	-41.58	-33.95	-20.52	22	0.00

Table 5 results in an interpretation that the use of Introduction to Astronomy teaching materials effectively improves the Generic Science Ability of Students. The results of research on the development of astronomy teaching materials can support the generic aspects of science skills, namely direct and indirect observations (Usuda-Sato & Canas, 2021). Through observation skills, students use as many senses as possible to observe natural experiments/phenomena. In line with previous research, the fulfillment and development of these skills, several things need to be considered, namely: providing the broadest possible opportunity or various ways to obtain information and its implementation in learning, selecting goals, objectives, and content in the learning process, and improving and evaluate a series of learning applications (Botiraliyevna, 2021). In addition, students use measuring instruments as sensory aids in observing IPBA/astronomy experiments or natural phenomena.

Based on the results of the different test analyses on problem-solving skills and generic science skills, learning astronomy by applying Introductory Astronomy Teaching Materials in an inquiry setting can significantly improve students' problem-solving skills and generic science skills in the field of astronomy. The increase in PSS by % (g) = 66.98% and an increase in SGA by % (g) = 52.8%, both are classified as moderate. The results of the t-test also showed that this increase was significant at the 5% significance level with p<0.005. Thus, Introductory Astronomy Teaching Materials are stated to improve students' problem-solving and generic science skills.

This increase was due to, among other things, because in this study, learning by giving assignments to make papers, creating reading literacy in students, and assignment of presentations concerning teaching materials made students happier to take astronomy courses. The existence of practicums such as observing the night sky supports the development of generic science skills. Practical activities that are integrated with the media can arouse students' motivation to learn science, develop basic skills in conducting experiments, and become a vehicle for learning scientific approaches (Aththibby & Kuswanto, 2021).

CONCLUSION

Introductory astronomy teaching materials with inquiry settings effectively improve students' problem-solving and generic science skills. It is indicated by the increase in students' problem-solving and generic science skills before and after the treatment. This study recommends implementing an innovative learning model for astronomy to improve students' problem-solving and generic science skills, develop astronomy lectures in theory, and provide inquiry experience to students through practical activities.

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