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Relationship between Analytical Thinking Skill and Scientific Argumentation Using PBL with Interactive CK 12 Simulation

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Abstract: This study was conducted in order to analyze the relation between analytical thinking skill and scientific argumentation in physics learning. The study was conducted with the interactive CK 12 simulation about optics. The sample of the study consists of 28 randomly selected students in Yogyakarta, Indonesia. The data was collected using pre and post-test after learning in the class. Data was analyzed with descriptive statistic instruments along with t-test, MANOVA test and Correlation Analysis. Research findings show that analytical thinking skill and scientific argumentation of the students are rather low. Problem based learning with web based simulation can enhance student's scientific argumentation and analytical thinking skill. Also, the correlation analysis conducted to determine the relationship between analyses analytical thinking skill and scientific argumentation. The results indicate that there is a statistical significant relationship between the analytical thinking skill and scientific argumentation.

Keywords: Analytical thinking, Scientific argumentation

Introduction

The thinking ability of students in Indonesia is still in the low category. Based on the results of the 2012 PISA survey Indonesian students were only in 64 positions from 65 countries in terms of mathematical and scientific abilities (OECD, 2012). Results that were not much different in 2015, Indonesian students were in 60th position from 74 countries (OECD, 2015). These results indicate that the ability of Indonesian students in the field of mathematics and science is currently lacking.

There are several factors that cause student achievements are still low. Haiti conducted a meta-analysis to find out the biggest causes that affect student achievement. From the findings, it can be concluded that the biggest factor that influences student achievement is the teacher's ability with effect size 1.62 (Haiti, 2017). But at this time many found that the ability of teachers in Indonesia to manage classes was not good. Even, Perdana, Sutrisno and Mahmuda (2016) found that all teachers who were participants experienced misconceptions and were didaktogenic in understanding physics. Based on interviews with several physics teachers, it was found that the application of technology in learning is still rarely applied.

Using technology in learning has given positive impact for the students and teachers.. The students' conceptual understanding as well as interest was increased, the college mentors earned valuable teaching and mentoring experience and the teacher enjoyed more one-on-one time as well as assistance with students when study using online physics lab (Gryczka, Klementowicz, Sharrock, & Montclare, 2016). Using technology such videos is very useful for establishing concepts, understanding course content and increasing general knowledge in physics learning (Chen, Wei, & Li2016). Beside that, learning with game environment can increase student's motivation and willingness to learn (Borrego, Fernández, Blanes, & Robles, 2017). Technology in learning can be effective in supporting student inquiry learning (Williams, Nguyen, & Mangan, 2017). So, using technology in this era must be done by all the school.

Learning with technology can increase student achievement in 21st century skills. Qian and Clark (2016) found that a game-based learning approach might be effective in facilitating students' 21st century skill development. A strong body of evidence suggests that online learning are spaces in which a variety of 21st

Century Skills can be fostered (Sourmelis, Ioannou, & Zaphiris, 2017). But, although teachers see the impact of technology for teaching and learning, they require more guidance on what constitutes 21st-century skills and how to effectively integrate technology (O'Neal, Gibson, & Cotten, 2017). In this paper, we only discussed about two 21st-century skills, there are scientific argumentation and analytical thinking skill student after study using physics on line learning.

To support applying technology in 21st century learning, there are several learning model that can be used effectively such as PjBl, PBL, and Inquiry Learning Model. Project-Based Learning (PjBL) is an innovative approach to learning that teaches a multitude of strategies critical for success in the twenty-first century (Bell, 2010). Learning in the online PBL had a significant effect on increasing the critical thinking skills whereas this is one of the 21st-century skills. Inquiry-based learning activities using social network and cloud computing is appropriate for application to real practice and helps student to develop the knowledge and skills that they will require to achieve success in the information age (Thaiposri & Wannapiroon, 2015). In this paper, we use problem based learning using online simulation to increase student ability in scientific argumentation and analytical thinking skill. The relationship between these skills was discussed.

Literature Review

Analytical Thinking Skill

Analytical thinking skill was very necessary to be used in working as well as daily life in the 21st century by students (Paziotopoulos & Kroll, 2004). Analytical thinking involves a further element of inquiry and situations with less well-defined parameters and outcomes and its necessary when an ambiguous situation requires the learner to identify or create a problem to solve (Robbins, 2011). It is a part of the problem solving process, considered essential for providing the skills required to prepare children for a more complex life and work environment in 21st century (Thaneerananon, Triampo, & Nokkaew, 2016). Analytical thinking involves abilities to (1) take apart a problem and understand its parts, (2) explain the functioning of a system, the reasons why something happens, or the procedures of solving a problem, (3) compare and contrast two or more things, or (4) evaluate and critique the characteristics of something (Sternberg, 2006).

Scientific Argumentation

One important practice that helps shape the nature of scientific knowledge, is argumentation (Sampson, & Blanchard, 2012). Students' poor argumentation has become a concern in science education (Acar, Turkmen, & Roychoudhury, 2010). So as a learning goal, argumentation is viewed as an essential scientific practice (Mc Neill, & Knight, 2013). Research on students' scientific argumentation has thus shifted in focus from identifying and teaching decontextualized skills of argument that students ''lack,'' to exploring the contexts in which students do and do not engage in argumentation (Berland, & Hammer, 2012). The quality of scientific argumentation is given in Table 1.

Table 1. Quality of Scientific Argumentation (Erduran, Simon, & Osborne, 2004)

Quality	Characteristic of argumentation
Level 1	Argumentation consists of arguments that are a simple claim versus a counter-claim or a claim versus a claim
Level 2	Argumentation has arguments consisting of a claim versus a claim with either data, warrants or backings but do not contain any rebuttals
Level 3	Argumentation has arguments with a series of claims or counter-claims with either data, warrants or backings with the occasional weak rebuttal
Level 4	Argumentation shows arguments with a claim with a clearly identifiable rebuttal. Such an argument may have several claims and counter-claims
Level 5	Argumentation displays an extended argument with more than one rebuttal

Toulmin (1958) specify the components in scientific argumentation from data to a conclusion or knowledge claim. The main components identified are:

- *Data:* these are the facts that those involved in the argument appeal to in support of their claim.
- *Claim:* this is the conclusion whose merits are to be established.
- *Warrants:* these are the reasons (rules, principles, etc.) that are proposed to justify the connections between the data and the knowledge claim, or conclusion.

- *Backing:* these are basic assumptions, usually taken to be commonly agreed that provide the justification for particular warrants.
- *Qualifiers:* these specify the conditions under which the claim can be taken as true; they represent limitations on the claim.
- *Rebuttals:* these specify the conditions when the claim will not be true.

Problem Based Learning

Problem based learning is an instructional (and curricular) learner-centered approach that empowers learners to conduct research, integrate theory and practice and apply knowledge and skills to develop a viable solution to define problem (Savery, 2015). PBL is a pedagogical approach that enables students to learn while engaging actively with meaningful problems (Yew & Goh, 2016). It is a student-centered approach in which problems are the stimulus for learning and it is characterized by: (1) learning through problems, (2) small group sessions, (3) group learning facilitated by a teacher, and (4) learning through self-study (Hmelo-Silver, 2004). PBL has several common characteristic such as real world situations, collaborative work, co-constructed solutions, multiple outcomes, and digital tools vary (Barber, King, & Buchanan, 2015).

Web Based Simulations and CK 12 Simulations

A web based simulation system make the educational process more interactive, which in turn will make the student gain knowledge and experience (Gunawan, Fiarni, & Lawalata, 2015). Web-based simulation is highly acceptable to students and appears to provide learning benefits that align with other simulation approaches (Cant & Cooper, 2017). In this study, the web site used is at https://interactives.ck12.org/simulations/physics.html. The web site provides many simulations about physics and in this research we choose about optics.

Methodology

Sample of Research

This study was conducted with a senior high school students studying in Yogyakarta City, Indonesia. Of the participants, 28 students were all aged from 14-16. The class grade is XI MIA 4. For this study, which was designed with simple random sampling was preferred in determining the samples in order to increase generalizability and to ensure an equal chance of being selected (Buyukozturk, Cakmak, Kilic, Ozcan, Karadeniz, & Demirel, 2010).

Instrument and Procedure

The process of collecting data began with a pretest to the students. The question is about concept eyes and glasses base on the aspects of scientific argumentation and analytical thinking skill. After give the pretest, then students were studying using PBL with web simulation in two times, each time was 90 minutes. After studying, they were given posttest. The question of pre and posttest are same, so it can be seen the difference in results after being given the learning by PBL with web simulation. Data was analyzed with descriptive statistic instruments along with t-test, MANOVA test and Correlation Analysis.

Result

Reliability of the scales were examined; Cronbach Alpha Coefficient of the test was $\alpha = 0.742$. These results show that the scale can be accepted as being reliable assessment instruments. The level of scientific argumentation students is shown in Table 2.

Table 2. Scientific Argumentation Skill

Level	***Percentage of Level***

	Nearsightedness	*Farsightedness*	*Power of Lens (Farsightedness)*	*Power of Lens Nearsightedness*	*Eye Accommodation*
Level 1	28	44	16	28	60
Level 2	44	32	64	40	24
Level 3	28	24	8	8	16
Level 4	0	0	0	0	0
Level 5	0	0	0	0	0

According to Table 2, most participant scientific argumentation skill is in optics. This shows that the students had low level or quality about this scientific argumentation skill. Data indicates that there are no students in level 4 and 5, so all the students only in level 1, 2 and 3 about scientific argumentation in topics eyes and glasses. Data on the average score of pretest and posttest scientific argumentation and analytical thinking skill are shown in Figure 1.

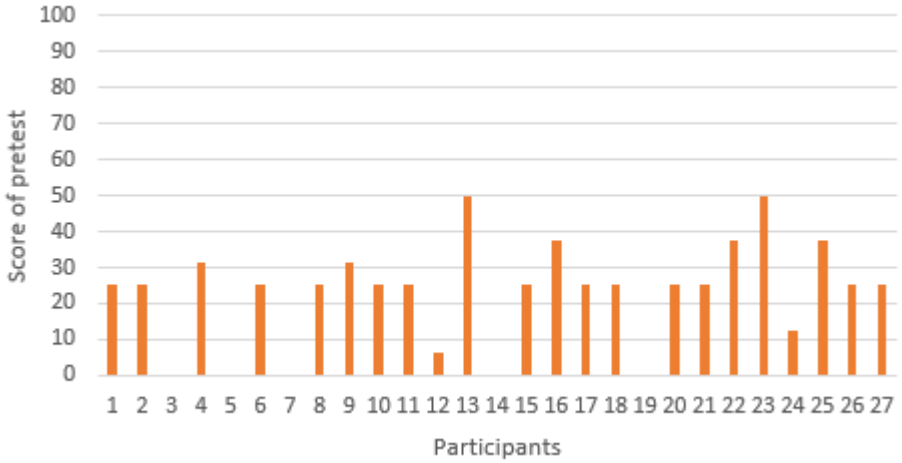

Figure 1. Analytical Thinking Skill

When these data are examined, it is evident that the most of participants (100%) have score below 60.These findings suggest that student achievement was also not good. T-test was conducted in order to determine whether or not using PBL with web based simulations addiction score posttest of analytical thinking skill in Table 3.

Table 3. t-test Analytical Thinking Skill

Model	Mean	t	df	Sig (2-tailed)
Pretest-posttest	-23.148	-7.089	26	<.001

According to Table 3, there is statistically significant difference pretest and posttest score with PBL using web based simulation (p=0.000<0.05). The score of posttest are higher than pretest. Similarly, the test result, which was conducted to determine whether or not PBL with web based simulations addiction score posttest of scientific argumentation skill were statistically significant (p=0.000<0.05) are shown in Table 4. The descriptive statistics of the average score the participants from scientific argumentation skills are show in Table 5.

Table 4. t-test Scientific Argumentation Skill

Model	Mean	t	df	Sig (2-tailed)
Pretest-posttest	-33.519	-11.985	26	<.001

Table 5. Average Score Gained from the Scientific Argumentation Variable

Model	Mean	N	Std Deviation	Std. Error Mean
Pretest	12.96	27	6.830	1.314
Posttest	46.48	27	13.288	2.557

According to Table 5, the average score of the participants are all below 50. According to the scale, in order to claim using PBL with web based simulation was effective (medium significantly) to increase scientific argumentation skills students. Similarly, the descriptive statistics of the average score the participants from analytical thinking skills are show in Table 6.

Table 6. Average Score Gained from the Analytical Thinking Skill Variable

Model	Mean	N	Std Deviation	Std. Error Mean
Pretest	22.92	27	14.294	2.751
Posttest	46.06	27	19.775	3.806

According to Table 6, the average score of the participants are all below 50. According to the scale, in order to claim using PBL with web based simulation was effective (medium significantly) to increase analytical thinking skills students. A Multivariate Analysis of Variance was conducted in order to determine whether or not there is a significant difference between scientific argumentations level and analytical thinking skill, the results of which are shown in Table 7, Table 8 and Table 9.

Table 7. Levene's Test of Equality of Error Variances

Model	F	df1	df2	Sig
Pretest	6.963	2	78	.002
Posttest	4.431	2	78	.015

According to Table 7, there is statistically significant difference between pretest and posttest scores of student achievements (scientific argumentation and analytical thinking). For posttest, using PBL with web based simulation $p=0.015<0.05$ and pretest with $p=0.002<0.05$. Table 8 shows the significant difference between pretest and posttest PBL with web based simulation.

Table 8. Multivariate Test

Effect		F	dF	Sig
Intercept	Pillai's Trace	3.366E2[a]	77.000	<.001
	Wilks Lambda	3.366E2[a]	77.000	<.001
	Hotelling's Trace	3.366E2[a]	77.000	<.001
	Roy's largest Root	3.366E2[a]	77.000	<.001
Variable	Pillai's Trace	7.033	156.000	<.001
	Wilks Lambda	7.699[a]	154.000	<.001
	Hotelling's Trace	8.358	152.000	<.001
	Roy's largest Root	17.152[b]	78.000	<.001

According to Table 8, there is statistically significant difference pretest and posttest score with PBL using web based simulation ($p<0.05$) about scientific argumentation, analytical thinking and student achievement. Based on the results, the most significant variable are described it shown in Table 9.

Table 9. The Most Significant Variable

Model	Variable 1	Variable 2	Mean difference
Pretest	Analytical thinking	Scientific argumentation	9.95
Posttest (PBL with web based simulation)	Scientific argumentation	Analytical thinking	0.42

According Table 9, mean difference score of analytical thinking skill to scientific argumentation is 9.95. It shows that pretest of analytical thinking skill is better than scientific argumentation. PBL with web based simulation can effectively to increase student scientific argumentation skill more than analytical thinking skill (Mean difference=0.42). The relationship between scientific argumentation and analytical thinking skills of the participants was examined. Correlation analysis is shown in Table 10. According to Table 10, there is significant relationship between scientific argumentation level and analytical thinking skills ($p=0.029<0.05$).

Table 10. Relationship between Scientific Argumentation Level and Analytical Thinking Skills

Variable	**n**	**r**	**p**
scientific argumentation level	27	0.421	0.029
analytical thinking skills	27		

Discussion and Conclusion

This study, which aimed at determining the relationship between analytical thinking skill and scientific argumentation level of high school students, was conducted with the pretest and posttest score. One of the most important research findings suggest that scientific argumentation levels of participants that are in the sample are rather low. This finding is in line with other research results which analyze scientific argumentation level. Aydeniz and Ozdilek (2015) showed that majority of participants (teachers) lacked an adequate understanding of science and scientific argumentation. Many of participants that did not provide any genuine support for an explanation when give scientific argumentation (Sampson, & Blanchard, 2012). It can be happen because teacher had difficulty applying the reasoning component of argumentation to classroom practice, and found designing argumentation questions to be challenging (Mc Neill, & Knight, 2013).

Findings show that using PBL with web based simulation is effective to enhance student's scientific argumentation and analytical thinking skill. This finding is similar with the study results of Wang (2014) Iordanou and Constantinou (2015), Acar and Patton (2016), Akpinar, Ardac, and Amuce (2015), Spires (2015) indicate that web base learning effective to enhance student's scientific argumentation and analytical thinking skill. The Correlation Analysis conducted to determine relationship between scientific argumentation skill and analytical thinking skill students. Research findings suggest that there is a significant relationship between scientific argumentation skill and analytical thinking skill students. This finding is in line with the study results of Sourmelis, Ioannou, and Zaphiris (2017), Lundström, Hamfelt, and Nilsson (2005) Weng, Lin, and She (2017), Andersson (2016), Van Eemeren, de Glopper, Grootendorst, and Oostdam (2015), Wagemans (2016), Kuhar and Jeznik (2018) indicate that there is a significant relationship between scientific argumentation and analytical thinking skill.

Finally, according to the findings, it can be asserted that the scientific argumentation levels and analytical thinking skill the participants are rather low. To enhance these skills, teachers can use PBL with web based simulations in the classroom. In addition, the relationship between scientific argumentation skill and analytical thinking skill can be found in web based simulation learning environment as 21st century skills.

Recommendations

For the future research, can use others model and web site simulation to enhance 21st century skills and examine the relationship between them.

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