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Structural Equation Modeling Multi-group of Science Process Skills and Cognitive in PjBL Integrated STEAM Learning

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Abstract. In Science, students tend to use the ability, which is dominantly controlled by their left-hemisphere brain. This study explores how science process skills (SPS) affect cognitive learning achievement (CLA) of dominantly right-brained and left-brained students. By applying project-based learning on the topic that integrates STEAM elements, this research examines the differences of the effects among those groups. The respondents were 32 8th-grade students from two randomly selected intact classes. This study employed a test to measure exogenous (SPS) and endogenous (CLA) latent variables. The partial least square - structural equation modeling (PLS-SEM) and multi-group PLS-SEM were employed to analyze the results. The evaluation of the outer model shows that both latent variables were valid and reliable. The factor loading value for all indicators of each latent variable was over 0.7. The cross-loading value indicates a higher correlation between the latent variable and its indicators compared to the other variables' indicators. The composite reliability and Cronbach's alpha values were over 0.7. The significance test shows that all indicators of each latent variable were valid. The evaluation of the inner model through the significance test (α=5%) suggests that the science process skill influenced CLA with a coefficient of 0.907. Meanwhile, the 0.822 R-square value demonstrates the variability of the SPS can explain the variability of CLA of 82.2%. The multi-group-SEM test reveals a difference in the effect of SPS toward CLA among dominantly right-brained and left-brained students. While the path coefficient for the former was 0.94, the latter was 0.881.
Keywords: STEAM, PjBL, SEM, Multi-Group

Introduction

Numerous studies over the past decade have persistently state that students must master relevant skill sets to address 21st century challenges successfully (OECD, 2018; Scott, 2015). The skills include not only the ability to collaborate and work in teams, but also to think creatively and critically and to solve problems. The 2013 Curriculum is an educational effort introduced by the Indonesian government (Ditjen Dikdasmen, 2017) to help students acquire those critical skills for successful participation in the global economy.

This curriculum suggests that project-based learning can support such learning skills to flourish (Direktorat PSMP, 2018).

Project-based learning (PjBL) is a constructivist-learning strategy where learners actively participate in problem solving activities; the assumption is that students learn best when they are given the opportunity to solve real problems (Bell, 2010; Kokotsaki et al., 2016). Knowledge construction takes place through the questions asked, investigations carried out, analysis of data and decision making done with others (Blumenfeld et al., 2000).

Project-based learning empower students to pursue their own knowledge and to demonstrate new understanding through various presentation models (Stripling et al., 2009). Students are involved in various stages of task completion activities. They run in-depth investigations through interviews, observation, laboratory, and literature research by assembling the required information. As a result, learners can improve their cognitive functioning after experiencing several in-depth learning activities from PjBL, especially through observation, data analysis, problem solving, and result presentation.

In solving a scientific problem, students or some groups of students conduct experiments, observe, collect, and interpret data, and then record the results. Next, each group writes a report and presents their studies in the class. They offer suggestions called "project plans" to solve the problems. These projects are then presented, discussed, and evaluated by all students and teachers (Frank & Barzilai, 2004). The project links between circumstances in the classroom and real-life experiences (Blumenfeld et al., 1991), which then create independent thinkers and learners (Bell, 2010).

In encouraging the ability to design and work on projects, students should master an integrated skill, which includes Science, Technology, Engineering and Mathematics (STEM) simultaneously (Erdogan et al., 2016). Hence, they can be trained through STEM learning. Several studies, the application of the discovery learning model- based STEM (Fadlina et al., 2021), and the application of the problem-based learning model integrated by STEM (Hasanah and Artika, 2021) increased critical thinking skills effectively. Tsupros et al. (2009) state that STEM education is an interdisciplinary learning approach which enables students using those lesson concepts in a real context. This approach connects schools, communities, working world, and global companies developing students' STEM literacy to compete in the new economic era (Tsupros, Kohler and Hallinen, 2009).

STEM learning is an effort to prepare the generation independently by educating positive attitudes in the workplace (Jehopio & Wesonga, 2017). Teaching such attitudes should be done as early as possible. A study by Parmin and Sajidan (2019) suggests that STEM learning is aimed for junior high schools in industrial areas in Indonesia to improve students' life skills so that they are well equipped to compete in the work field (English, 2016). Enhancing student competence in STEM has been considered the most effective approach to help alumni become more competitive in the world job market in the United States (Colegrove, 2017). Beier et al. (2019) found the involvement of at least one PjBL during four semesters influenced students' perceptions of STEM skills, perceptions of utility value of participating in STEM learning, and career aspirations involving STEM for their future.

Some basic competencies of science learning in the 2013 curriculum for the junior secondary school level could be integrated with STEM. Rahmania (2021) recommended the PjBL integrated STEM because it could shape students of the capability of creative and critical thinking, systematic, and logic. Students had the science process skills in the good category on optical concepts after getting PjBL integrated STEM learning (Bhakti et al., 2020). The active engagement of the students in scientific practices and interactions with experts were essential conditions for career-based scenarios to successfully enhance students' interest and STEM career understanding (Drymiotou et al., 2021). However, creation and innovation are needed to win industrial competitions in the future (Guyotte et al., 2015). Art education stimulates creativity which underlies innovation, which is essential to produce a modern industry in the future. Eventually, this innovation provides a fundamental element for economic prosperity. Therefore, art education is often considered an important factor in the entire competitiveness of the country's economy (Bequette & Bequette, 2015). Creativity and innovation skills can be achieved by integrating artistic elements (Connor et al., 2015). Art and Science are two incomparable and irreplaceable parts of education that complement each other; some skills such as drawing well, observing precisely, understanding an object from several dimensions, thinking spatially, and working efficiently with others which are considered as scientific tools are also the core of the arts (Akturk & Demircan, 2017). The integration between art and science education could engage students in creative projects and encourage them to express science in multitude of ways (Turkka et al., 2017).

Hence, learning is insufficient if it only applies STEM learning. It means that STEM learning needs to be combined with art, called STEAM (Watthananon, 2018). STEAM-based learning aims to prepare children to sort out problems through innovation, creative and critical thinking, cooperation, and effective communication through new information (Quigley & Herro, 2016). Research related to the integration of art elements in STEM (STEAM), definitely can improve student learning achievement as a whole (Barry, 2010), increase student learning motivation (Henriksen, 2017), improve student cognitive learning outcomes (Posner & Patoine, 2009), and enhance student literacy in the STEM field (Wynn & Harris, 2012).

In Science, students tend to use the ability, which is dominantly controlled by their left-hemisphere brain. The reason is that the required skills relate to analyzing, calculating, and concluding abilities (Jensen, 2011). By implementing art-integrated STEM or STEAM in science, students are expected to balance their two-side brain, so that it can work properly. A study of STEAM education in South Korea found that students' experiences in STEAM were effective in cognitive and affective learning. The affective was more effective than the cognitive domain (Kang, 2019).

Many studies have examined STEM, PjBL, and STEAM learning, but little interest has been put into the integration of those concepts. For example, Beier et al. (2019) explore how PjBl was integrated with STEM. The study found that student involvement in at least one project- based program during four semesters influenced students' perceptions regarding skills, participating value and career aspiration in STEM. A study conducted by Aprianty et al. (2020) found that PjBL through the STEM approach has improved students' science process skills and learning outcomes. However, there is limited research on STEAM integrated with PjBL learning. Besides, fewer studies are conducted on modeling science process skills and cognitive success for the implementation of STEAM integrated with PjBL using structural equation modeling (SEM). SEM as a statistical analysis technique, which combines several aspects in path analysis and confirmatory factor analysis to estimate several equations simultaneously is rarely used in this field. Therefore, this study aims to address this research gap by employing SEM analysis to understand the effects of science process skills and cognitive learning achievement, particularly for dominantly right-brained and left-brained students.

This research, henceforth, investigates the effect of science process skills on cognitive learning outcomes in learning using the STEAM integrated PjBL model by comparing an experimental group and a control group. Students in the experimental class underwent project-based learning integrating Art in STEM/Science subject, while those in the control group learned Science using the traditional teacher-centered approach. Moreover, this study compares the impacts among the groups of students with right-brain and left-brain dominance in the experimental class.

Methods

This research employed a quasi-experimental research design where two intact classrooms of 8th graders in SMP Plus Miftahul Ulum, Sumenep, East Java, Indonesia were chosen randomly as sample. This study compares the experimental group taught by using an integrated STEAM project-based learning and the control group by using the traditional teacher-centred approach. The selected STEM subject for the PjBL was Science, specifically on the topic of Sound Wave. The infusion of art in PjBL involved music- and design-related aspects to perhaps indicate what were 'measured', where students were asked to make simple guitar from scrap materials and then engage in activities allowing analysis of vibrations, waves, sounds, and so forth.

Before applying the integrated STEAM-PjBL, students did a test aiming for classifying students' brain dominance. The test was adopted from Jensen (2011) and Purwaningsih et al. (2015) consisted of 20 multiple-choice questions interpreting the characteristics of each brain dominance. This classification was used to decide the appropriate treatment for students during break time. Students with left-brain dominance were given some treatments, including listening to music, doing brain gym movements, and drinking water. The other group was asked to do crossword puzzles and brain gym movements as well as to drink water.

After the implementation of the learning model, students' cognitive learning outcomes and science process skills were measured. The test consisted of six questions for measuring students' cognitive outcomes. The indicators of the test were learners' basic competence to analyse the relationship between frequency, tone, amplitude, string length, cross-sectional area, string tension, and string density. On the other hand, the test for science process skills consisted of five questions. The indicators included the abilities to read, write, observe, understand tables, analyse, understand images, imagine, observe, communicate, interpret, apply concepts, and conclude.

The research variables were exogenous latent variables (scientific process skills) and endogenous latent variables (cognitive learning outcomes). Those variables were used. The analysis stages were based on the study objectives. The analysis included:

a. Constructing a model based on theoretical studies, shown by Figure 1

Cognitive learning achievement has six indicators, namely: analysing the relationship between string length and frequency (kog1), analysing the relationship between cross-sectional area and frequency (kog2), analysing the relationship between frequency and tone (kog3), analysing the relationship between density and frequency (kog4), analysing the relationship between amplitude and pitch strength (kog5), and analysing the relationship between string tension and frequency (kog6). The indicators of science process skills are observing (sp1), applying concepts (sp2), interpreting (sp3), concluding (sp4), and communicating (sp5).

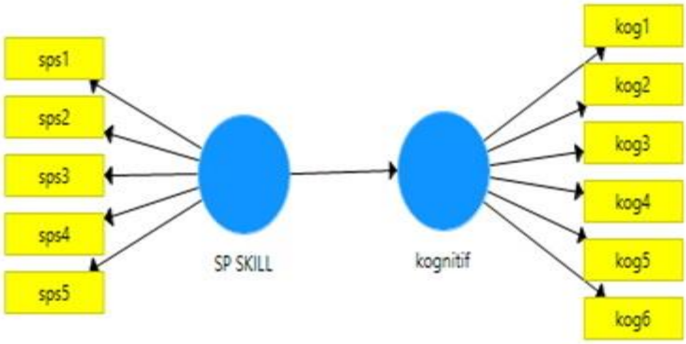

Figure 1. Full Model

b. Evaluating the outer model

Evaluating the outer models include; (i) Convergent validity is measured by the loading factor. If the loading factor is more than 0.5, it means that the indicators are valid (Hair et al., 2009); (ii) Discriminant validity is measured by the correlation between the latent variable and its indicators; (iii) Variance extracted (AVE) is measured by the comparing between the square of AVE and the correlation between the two latent variables; (iv) Reliability is measured by the composite reliability and Cronbach's alpha. In general, a composite reliability value greater than 0.6 is acceptable (Sujit & Rajesh, 2016); (v) Significance test used the resampling bootstrapping method. If P-value is less than 0.05, it means that all constructs significantly affect the latent variables.

c. Evaluating the outer model

The test of the outer model was conducted based on the results of the significance test and the R-square value as the goodness-fit model test. The significance test used resampling bootstrapping method because, in PLS SEM, the data distribution is unknown. According to Chin (2000), the R-square values of 0.67, 0.33 and 0.19 indicate a strong, moderate and weak model, respectively. Meanwhile, Hair et al. (2009) suggest that the R-square values of 0.75, 0.50 and 0.25 indicate the strong, moderate and weak model, respectively.

d. Multi-group analysis

Multi-group analysis aims to compare data analysis based on the characteristics of 2 different samples. This analytical approach used a permutation test procedure which was distribution-free. According to Chin (2000), if there is a sample group which is not normally distributed and the variance of the two groups are different, the Smith-Satterthwait test is used with the following formula:

$$t = \frac{\text{path}_{\text{sample1}} - \text{path}_{\text{sample2}}}{\sqrt{\text{SE}^2_{\text{sample1}} - \text{SE}^2_{\text{sample1}}}} \qquad (1)$$

e. Difference test

A difference test was carried out to examine whether there were differences between the groups of students with dominant left- and right-hemisphere brain regarding science process skills and cognitive learning outcomes. The difference test uses the t-test when the data is normally distributed, otherwise the Mann-Whitney test is used instead.

Results and Discussion

The science process skills model relates to many dimensions, and a conceptual model is formed based on the dimensions, as shown in Figure 1. The following presentation is the result of data processing using Smart-PLS and SPSS software for model evaluation, both the outer and inner models.

a. The evaluation of the outer model

1. Convergent validity

Table 1 shows the loading score from each indicator. Several studies state that a factor loading of 0.50 reflects a sufficiently strong validation to explain latent constructs (Hair et al., 2009). All indicators both the latent variable science process skills and cognitive abilities show a loading factor score which was more than 0.5. It means that all indicators can be employed to allow the constructs of these two latent variables.

Table 1. The factor loading score

Science Process Skill		Cognitive	
Indicator	Factor loading	Indicator	Factor loading
sps1	0.788	kog1	0.716
sps2	0.972	kog2	0.874
sps3	0.753	kog3	0.875
sps4	0.734	kog4	0.900
sps5	0.761	kog5	0.874
-	-	kog6	0.921

2. Discriminant validity

Table 2 shows cross-loading score from each indicator.

Table 2. The score of cross loading

Indicator	Science Process Skill	Cognitive Learning Achievement
kog1	0.530	0.716
kog2	0.823	0.874
kog3	0.826	0.875
kog4	0.787	0.900
kog5	0.829	0.874
kog6	0.839	0.921
sps1	0.788	0.666
sps2	0.972	0.959
sps3	0.753	0.706
sps4	0.734	0.644
sps5	0.761	0.617

This table reveals that the correlation of the latent science process skill variable with its indicators was more significant than the indicators of other variables (cognitive learning achievement). It shows that the latent variables of science process skill predicted indicators in their group better than indicators from other groups. Likewise, the correlation of the latent variable cognitive learning achievement with its indicators was more significant than the indicators of other variables (science process skills). It shows that the latent variable cognitive learning achievement predicted indicators in this group better than indicators from other groups. It means that the two latent variables had good discriminant validity.

However, the $\sqrt{\text{AVE}}$ score of the two latent variables was less than the correlation score between the two latent variables (Table 3). This result shows that the two latent variables had low discriminant validity.

Table 3. AVE score from each latent variable

Latent Variable	AVE	$\sqrt{\text{AVE}}$	Correlation
Science Process Skill	0.650	0.806	0.907
Cognitive Learning Achievement	0.744	0.863	0.907

3. Reliability

Reliability test is to examine the consistency and accuracy of the instrument in measuring constructs or latent variables. In this study, the reliability test used composite reliability and Cronbach's alpha. In general, the composite reliability score of more than 0.6 is acceptable (Sujit & Rajesh, 2016). The composite score is reliable, and Cronbach's alpha for confirmatory studies is more than 0.7, while explanatory studies more than 0.6 is still acceptable (Chin, 1998; Hair et al., 2009; Vinzi et al., 2010). Table 4 is a summary of the reliable composite values and Cronbach's alpha of the two latent variables.

The table demonstrates that the composite value of reliable and Cronbach's alpha for latent variables were more than 0.7. These results mean that all latent variables were reliable, or indicators of these variables were consistent in measuring science process skill and cognitive learning achievement.

Table 4. The score of composite reliability

Latent variable	Composite reliability	Cronbach's Alpha
Science process skill	0.902	0.862
Cognitive learning achievement	0.946	0.930

b. The evaluation of inner model

The inner model was evaluated through the R-Square value, which is the model's goodness-fit test. The R-Square value can be used to explain the effect of certain exogenous latent variables on endogenous latent variables, whether they have a substantive effect. Chin (1998) interpreted the R-Square score of 0.67, 0.33 and 0.19 to show strong, moderate and weak models. Meanwhile, according to Hair et al. (2009), the R-square values of 0.75, 0.50 and 0.25 indicated that the model was strong, moderate and weak, respectively. Table 5 shows the R-square value.

Table 5. The score of R-square

Correlation latent variable	R-square	Interpretation
Cognitive ←SP Skill	0.822	Strong category

The R-square score was 0.822 with a model in the strong category (Hair et al., 2009) and showed that the variability of the cognitive learning achievement latent variable can be explained by the variability of science process skill of 82.2%. The remaining 17.8% were explained by other variables beyond those studied.

c. Significance test

The significance test of the model cannot be done in this PLS SEM method because the data distribution was unknown. Therefore, the significance test used the resampling bootstrapping method. Table 6 provides a summary of the significance test results for both the outer model using α = 5%. All indicators of each latent variable are valid. It is reasonable to argue that all indicators are representative enough to be used to construct latent variables.

Table 6. The result of the significance test of the outer model

Correlation among indicator with other latent variables	T-stat	P-value	Interpretation
sps1←SP Skill	8.737	0.001***	Valid
sps2←SP Skill	6.422	0.001***	Valid
sps3←SP Skill	9.133	0.001***	Valid
sps4←SP Skill	7.516	0.001***	Valid
sps5←SP Skill	7.526	0.001***	Valid
kog1← Cognitive	7.919	0.001***	Valid
kog2← Cognitive	19.421	0.001***	Valid
kog3← Cognitive	17.270	0.001***	Valid
kog4← Cognitive	20.671	0.001***	Valid
kog5← Cognitive	12.927	0.001***	Valid
kog6← Cognitive	19.368	0.001***	Valid

*** Significant difference at $p < 0.001$

Table 7. The result of the significance test of inner model

Relationship	T-stat	P-value	coefficient	Interpretation
Cognitive ← SP Skill	24.996	0.001***	0.907	Affected

*** Significant difference at $p < 0.001$

The results of the significance test show that there was an effect of science process skill on cognitive learning achievement with a coefficient of 0.907. It means that each point increase in science process skill will increase cognitive learning achievement by one point. Figure 2 shows the result of the significance test and the evaluation of the entire model.

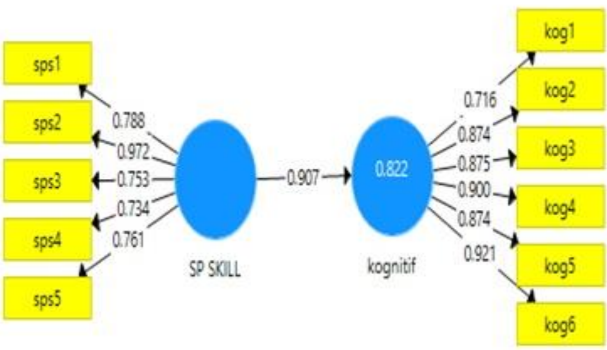

Figure 2. The score of loading and coefficient, and R-Square model

d. Multi-group and Mann-Whitney test

This multi-group analysis aims to compare data analysis based on the characteristics of two different samples. This analytical approach used a permutation test procedure which is distribution-free. According to Chin (2000) if the customary sample group used is not normally distributed and the variance of the two groups was different, the Smith-Satterhwaitv test is used, and the results were shown in Table 8.

Table 8. The result of the multigroup test

Group	Relationship	T-stat	P-value	Coefficient	SE
Dominant right brain	Cognitive ← SP Skill	52.472	0.001***	0.941	0.018
Dominant left brain	Cognitive ← SP Skill	8.897	0.001***	0.881	0.099

*** Significant difference at $p < 0.001$

Based on the results of the t calculation, the t value was obtained through this following formula : $t = \frac{0.941-0.881}{\sqrt{0.018^2-0.099^2}} = 2.158$. By using α=5% the value was more than 1.96 (t-table). Therefore, the result means that there was an influence of science process skill on cognitive learning achievement and a difference among the two groups of students with right- and left-brain dominance. Then, the difference test was carried out to examine whether there were differences within the groups of students who were dominated by their right- and left- hemisphere brain regarding science process skill and cognitive learning achievement. Previously, the normal distribution test was employed. The results of the normality test were summarised in Table 9, while the difference test by using the Mann-Whitney test is shown in Table 10.

Table 9. The result of the normality test

Latent variable	P-value Kolmogorov-Smirnov	Interpretation
Science Process Skill	0.001***	Data is not distributed normally
Cognitive Learning Achievement	0.007*	Data is not distributed normally

*** Significant difference at $p < 0.001$
* Significant difference at $p < 0.05$

There were differences in cognitive learning achievement among students who were dominated by their left- and right side of the brain, where students with left-hemisphere brain dominance had better achievement than the other group. There was no difference in the achievement of the science process skill within the two groups.

Table 10. The result of the difference test by using Mann-Whitney

Latent variable	P-value	Interpretation
Science Process Skill	0.071	There is no difference
Cognitive Learning Achievement	0.001***	There is a difference

*** Significant difference at $p < 0.001$

Cognitive learning achievement consists of 6 indicators. Based on the loading score in Table 1, the Kog6 indicator provided the most outstanding contribution to cognitive learning achievement. The kog6 indicator in question was to analyse the relationship between string tension and frequency. PjBL integrated STEAM learning by involving making a simple guitar has helped students to understand the relationship between string tension and frequency well. Learning PjBL involving making a simple guitar and discussing the results has helped students understand the concept of the relationship between string tension and frequency well.

Before the learning process, students were classified based on the right-left hemisphere and upper-lower academic ability, which consisted of six study groups. Preliminary observation data show that students who dominantly used the left hemisphere of the brain are students who have high academic abilities. Meanwhile, students with right-hemisphere brain dominance tend to have poor academic abilities. The student hemisphere data show that 70% of the samples were students with right-hemisphere dominance, while 30% of the students were the left-hemisphere dominance. Therefore, each group consisted of three students with right-hemisphere brain dominance and a student with left-hemisphere dominance, except the group 6. This exceptional group consisted of two members of the left-hemisphere dominance, and a couple of the right-hemisphere dominance.

The six groups then carried out the investigation in order. The first group conducted the first investigation. The second group also carried out the second investigation, and so on. After doing the investigation, students presented the results of this learning activity by making a group presentation in front of the class. In this case, the teacher allowed students' freedom in conveying concepts during presentations. The concept delivery carried out by the first to fifth groups was merely reading the title, objectives, tools, materials, and the investigation results without re-enacting the investigation. In contrast, the sixth group re-enacted the investigation process that had been carried out in their group. In addition to re-modelling, students in this last group also explained in detail the results and conclusions of the investigation. Through this demonstration process, students' memory was different from the memory when they only listened to the presentation. Students' memory after learning through demonstrations or performances was greater than learning through listening.This result is in accordance with the cone of Edgar Dale's experience, stated by Sani et al. (2015) that students' learning experiences through a demonstration or performance process will produce a memory of 50%. Meanwhile, for listening activity, it only produces 20% memory.

In science process skills, indicators applied the concept (sps2), which made the most contribution. The reason was that these indicators were the compulsory skills for students to achieve learning objectives in the material of vibration, waves, and sound. During the learning process, students were carrying out six types of investigations that the teacher had prepared. Each investigation analysed the relationship between indicators in the science process skills. Investigations were aimed for students to obtain the lesson concepts through the investigating process and results. Then, the concept can be used to compile a simple guitar-making project using scrap materials. Compared to other indicators of science process skills, the sps2 indicator connects directly with students' learning process. Therefore, the sps2 indicator contributed the most to students' science process skills.

This finding is also supported by the results of several studies. PjBL learning helped students to understanding concepts (Sumarni et al., 2016), while STEM helped students to be actively involved in learning and developed an understanding of concepts through contextualized problem-solving activities (Dasgupta et al., 2019). PjBL-STEM could improve conceptual understanding (Afifah et al., 2019; Beier et al., 2019; Saleh et al., 2020) and could improve students' analytical abilities (Tipani et al., 2019).

The data in Table 7 show that students' science process skills affected their learning outcomes with a coefficient of 0.907. The reason was because the science process skills are the abilities to acquire or build knowledge. Hence, students with abilities related to science process skills would find a concept of knowledge. This finding is also supported by Nirwana et al. (2014) who define science process skills as the skill for obtaining a concept of knowledge. Science process skills should also be trained in the learning process. It aims to provide flexibility in using these skills. This study taught science process skills through the implementation of project-based learning, while learning requires students to carry out the skills that exist in science process skills. The PjBL also shapes students' learning environment, which enables the acquisition of knowledge concepts. Thus, students can construct their own knowledge, as suggested by Vygotsky's learning theory. This learning theory carries a concept where students are given opportunities to create an active learning environment. This idea is coherent with Santrock (2017), who argues that Vygotsky's learning theory provides students with opportunities to build their knowledge independently.

Previous data show that students who used the left-side of the brain dominantly tended to have better cognitive learning achievement than students with dominant right-side of their brain. The possible reason is that the indicators used to build cognitive learning achievement use the C4 level of knowledge, namely analysing. The analysis ability is one ofthe abilities possessed by the left-hemisphere brain. Similarly, Zulkaida et al. (2005) also argue that analysing skill is an ability possessed by students with left-hemisphere dominance. Therefore, those students have better cognitive learning achievement than students with right-hemisphere dominance.

Although the indicator of cognitive learning achievement uses C4 (analysing), which tends to be beneficial for left-brain students. However, analysing skill is not the only ability to solve cognitive learning achievement questions. Other abilities include writing, reading, imagining, concluding, reading graphs, tables and pictures. The writing, reading, imagining, and reading pictures are skills typically possessed by right-brain students. Meanwhile, the concluding and reading tables abilities can be found in left-brain students (Zulkaida et al., 2005). Finally, this study can help teachers to understand the implications of the integrated STEAM-PjBL towards students with the left-hemisphere and right-hemisphere of brain dominance.

Conclusion

Based on the purpose of the study and the result of data analysis, this study concludes that: science skill process influenced cognitive learning outcome in the learning process using the PjBL model integrated with STEAM, and there was a different influence between the group of students with right- and left-brain dominance.

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