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# Meta-Analysis of the Influence of the STEM-Based Project Based Learning (PjBL) Model on Science Learning

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***Abstract***

*In science learning, the STEM approach has been combined with project-based learning. This is an easy way to introduce the STEM approach to science learning. STEM (Science, Technology, Engineering, and Mathematics)-based learning can train students in applying their knowledge to create designs as a form of solving environmental-related problems by utilizing technology. This study will analyze how much influence STEM education with the PjBL model has on student learning outcomes. This study uses a meta-analysis method by calculating the effect size. Research data was obtained from 50 national and international journals. That the results of the analysis of the influence of the STEM education integration PjBL meta model on learning outcomes based on class level found that the STEM education integration PjBL model gave the highest influence at the Junior High School level, namely with an effect size of 2.07, then Senior High School, namely with an effect size 1.42, and Elementary School with an effect size of 1.39. Meanwhile, the appearance of Higher Education is in the smallest height category, namely 0.86. This shows that the STEM education integration PjBL model is effective when used at all levels of education. Based on the subjects, it was found that mathematics was in the highest category with an effect value of 3.03, while chemistry was in the medium category with an effect size of 0.60. So it can be concluded that the effect size of the STEM education integrated PjBL model on learning outcomes in terms of subjects has a high effect.*

***Keywords: Science Learning, STEM, PjBL, Meta Analysis***

## INTRODUCTION

Education in the 21st Century is an education that integrates knowledge, skills, attitudes and mastery of ICT. Teachers are expected to be able to develop the skills needed in the 21st century. By developing activity-based learning models that are in accordance with the characteristics of competencies and learning materials.

Science is a science that trains individuals who study it to develop thinking skills, investigate a problem, gather knowledge and relate it to technology (Chiappetta and Koballa, 2010). Science does not only produce conceptual knowledge. IPA also produces IPA products and processes which are named after the scientific method (Maghfirah & Herowati, 2017). the products resulting from studying natural science are facts, principles, laws, and theories (Sund & Carin, 1989). Science learning aims to develop thinking skills, investigate a problem, gather knowledge and relate it to technology. Science learning does not only produce conceptual knowledge. But also science products and processes through discovery process activities. Science learning does not only produce conceptual knowledge. But also the products and processes of science through the discovery process activities of science learning should be appropriate and play a role in facing the demands of 21st century skills.

Organizing the science curriculum is included in the Broad Field. Knowledge that is presented in a partial and narrow form makes it less useful in preparing students to be able to deal with a complicated life (Taba: 1962). The strength of the field board is positioning high-level reasoning abilities in learning with in-depth analytical studies (Ediger & Rao: 2011).

21st century skills are skills that must be internalized by everyone who will be involved in global competition. We know that nowadays we have to compete not only at the national and regional level, but also in the global world. People who don't have this skill find it very difficult to compete for their lives. So this is the reason, why we, science teachers, must ensure that our students have these skills during science learning, in addition to the science content itself. 21st century skills represent at least 4 aspects of skills, such as critical thinking, collaborative, communicative and creative. One of the current learning approaches that strongly supports the creation of 21st century competencies is STEM-based learning.

In science learning, the STEM approach has been combined with project-based learning. This is an easy way to introduce the STEM approach to science learning. STEM (Science, Technology, Engineering, and Mathematics)-based learning can train students in applying their knowledge to create designs as a form of solving environmental-related problems by utilizing technology. STEM education emphasizes the integrated study of science across the boundaries of traditionally labeled disciplines while demonstrating its application in real life (Hazwan, et al. 2019). STEM is an integration between the four disciplines of science (science), technology, engineering, and mathematics in an interdisciplinary approach and is applied based on real-world contexts and problem-based learning.

The educational process today has shifted from teacher-centered learning to student-centered learning. This shows that the learning strategy must emphasize the learning process that prioritizes the needs of students. The teacher as a facilitator must be more creative and innovative in creating situations in the learning process in the classroom so that it is more attractive to students. At this time we know a learning method with the name STEM which stands for Science, Technology, Engineering and Mathematics (Rahayu, R., Iskandar, S., & Abidin, Y. 2022)

STEM is a method in which science, technology, engineering, mathematics are integrated in an educational process that focuses on solving problems in everyday life as well as in professional life. STEM is basically an integration of several disciplines which are also still open for other disciplines to be integrated, therefore there are those who add one of the disciplines namely art as part of this learning model so that it is no longer STEM but what about the integration of science, technology, engineering , art and mathematics (STEAM).

The learning model that refers to STEM-based learning is learning that is oriented towards the stages of how to think (way of thinking), how to work (way of working), the use of tools for working (tools for working) and skills for living or (skills for living). in the world). In a learning process like this students can directly develop their abilities in one problem solving, the second is creativity, the third is the ability to analyze critically, the fourth is cooperation, the fifth is independence in thinking, the sixth is self-initiative, the seventh is communication, and the last is ability in the real world.

STEM is an interdisciplinary approach to learning in which students use science, technology, engineering and mathematics in real contexts. (Tsupros, 2009). STEM is an approach to teaching 2 or more STEM fields to enhance student learning (Kelly, et al. 2016).

STEM can be integrated into a variety of teaching methodologies. Model is a tool that is used to create curricula, gather materials for instruction, and promote learning in schools (Nurdyansyah and Fahyuni, 2016). STEM education can be complemented by a variety of teaching methods, but one of the most popular is project-based learning (PjBL) (Esthi, 2020).
The educational paradigm that was recommended for use in the 2013 curriculum is one that is student-focused (student center). In this regard, the 2013 curriculum includes several teaching models, the most notable of which is the Project-Based Learning (PjBL) model (Hariyanto, S., Sukarmin, Saputro, & L., 2019). According to the 2013 module for curriculum implementation, project-based learning is a method of instruction that uses projects or initiatives as the primary means of instruction. To successfully complete a variety of learning formats, educate learners to engage in exploration, assessment, interpretation, synthesis, and information gathering.

Although the Project Based Learning approach has some very important and beneficial features for students, it is rarely used by teachers since in practice it requires extensive planning and long-term commitment. According to Mulyasa (2014), project-based learning, also known as PJBL, is a type of education that focuses students' attention on complex problems that must be solved through research and investigation. This model also aims to engage students in collaborative projects that incorporate a variety of subject areas into the curriculum, give students the opportunity to analyze content (material) using a variety of methods that are personally appropriate, and conduct collaborative experiments.

The current problem is that the instruction isn't engaging the students' active participation in the classroom (Ramadan, Jumadi, & Astuti, 2020). Learning must always be conducted with students, but in practice, this has not been done effectively in line with the 2013 curriculum. The absence of two-way communication will lead to teacher-centered learning and of course result in students not being active and not understanding the lesson. This will result in the student learning outcomes being reduced. The single best solution to the problem at hand is PjBL-STEM implementation.

To the left of the aforementioned assertion, the researchers conducted a meta-analysis of the effects of integrating STEM education into the PjBL paradigm on student learning outcomes. This empirical meta-analysis offers a suitable solution for readers to choose from. There may be a reason why the researcher chose to conduct this meta-analysis, but there are a few. First, look at the results of the research. Next, see the more extensive research that is being used. Third, view the more extensive reflective writing.

Meta analysis has some flaws in its execution. There are eight key findings in the research meta analysis. To start, the meta analysis procedure highlights disciplines that are useful in the process of analyzing qualitative research. Additionally, this study was conducted in a manner that was more creative than the conventional review procedure's constant interference with the qualitative summary principle. Finally, this study's findings can be used to identify any problematic connections or relationships.

Is there a problem with the way that STEM integration in the PjBL model of education affects test results that are drawn from the disciplines of education, instruction, and assessment of test results? This study was conducted with certain goals in mind. The first step is to see some of the biggest rewards that are the PjBL model of integrating STEM education into lessons that are designed according to the learning objectives that are given forth. The second is to see the most significant guidance that the PjBL model of STEM integration into subject-specific learning programs offers. The third is to examine the significant benefits that the PjBL model's integration of STEM education into instruction has on student achievement.

## RESEARCH METHODS

The type of data analysis that is used is data analysis based on a quantitative approach, or "meta data analysis." Meta analysis has a strong quantitative component since it employs numerical calculations and statistics for practical purposes, ie, to extract and organize information from a sizable amount of data. The data in this research are second-order data because they were derived from the previous research's results.

The current study includes 50 articles from international and national journals. The articles that were chosen highlight the benefits of integrating STEM education within the PjBL approach to improve student learning outcomes. The current research instrument uses a coding category sheet. To make data analysis easier, coding during meta-analysis is a crucial principle. The goal of this is for the variables used for the grant code dash to include the required information.

The documentation technique for data collection is the documentation technique for the components of the forthcoming journal. Data tabulation in the research process is necessary for meta analysis. A summary of the table can be seen as follows: Identify the research variables and enter them into the appropriate variable column, identify the average value and standard deviation of the control and experimental classes, 3) if the standard deviation is not known, then the next step is Use cooperation to reduce size effect threshold:

a. Mean and Standard deviation pretest-posttest

$$ES = \frac{\bar{X}post - \bar{X}pre}{SDpre} \text{ ...................... (1)}$$

Information:
ES = Effects sizes
Xpost = Average posttest
Xpre = Average pretest
SD = Standard deviation

b. Mean and standard deviation of two groups posttest only

$$ES = \frac{\bar{X}E - \bar{X}C}{SDc} \text{ ...........................(2)}$$

Information:
SE = Effects sizes
XE= Average of the experimental class
XC= Average control class
SDc= Standard deviation control class

c. Mean and standard deviation of two group pre-post test

$$ES = \frac{(\bar{x}_{post} - \bar{x}_{pre})_E - (\bar{x}_{post} - \bar{x}_{pre})_C}{\frac{SD_{preC} + SD_{preE} + SD_{postC}}{3}} \text{ .................(3)}$$

Information:
SE = Effects sizes
XpostE = Average posttest experimental group
Xpre E = The pretest mean of the experimental group
XpostC = The posttest mean of the control group
Xpre C = Average pretest control group
SDE = Standard deviation of the experimental group
SDC = Control group standard deviation

d. If the standard deviation is not known, it can be done with the t test

$$ES = t\sqrt{\frac{1}{n_E} + \frac{1}{n_C}} \text{ ................(4)}$$

Information:
SE = Effect size
T = Result of t test
nE = Number of experimental groups
nC = Number of control groups

After obtaining the effect size (ES), the results can be interpreted into the Table 1.

**Table 1**. ES Classification (Cohen's, 1988)

| Effect Size (ES) | Standard category |
|---|---|
| 0 < ES < 0.2 | Low |
| 0.2 < ES < 0.8 | Medium |
| ES > 0.8 | High |

## RESULT AND DISCUSSION

### Research result

The selected articles are 50 international and national articles and are coded J1 to J50 sorted by year of publication. The following presents the code, source and effect size that has been analyzed from the 50 journals.

**Table 2: Journal Code, Author, Year of publication and Effect Size**

| No | Journal Code | Writer | Publication Year | Effect Size | Category |
|---|---|---|---|---|---|
| **1** | J1 | Lestari, L. et al | 2021 | 1,13 | High |
| **2** | J2 | Nusa, JG N | 2021 | 0.49 | Medium |
| **3** | J3 | Saefullah et al | 2021 | 0.44 | Medium |
| **4** | J4 | Anggreni, L.D et al | 2020 | 0.83 | High |
| **5** | J5 | Aureola, Septian | 2020 | 0.51 | Medium |
| **6** | J6 | Fitriyani, Toto, Erlin | 2020 | 0.80 | High |
| 7 | J7 | Lukitawanti at al | 2020 | 1.33 | High |
| **8** | J8 | Mawarni, Sani | 2020 | 0.63 | Medium |
| **9** | J9 | Oktavia, Ridlo | 2020 | 1.63 | High |
| **10** | J10 | Parno et al | 2020 | 3,20 | High |
| **11** | J11 | Rosyidah et al | 2020 | 1.05 | High |
| **12** | J12 | Samsudin at al | 2020 | 1,13 | High |
| **13** | J13 | Septi et al | 2020 | 0.55 | Medium |
| **14** | J14 | Susilowaty, N | 2020 | 1.05 | High |
| **15** | J15 | Sylvia et al | 2020 | 0.82 | High |
| **16** | J16 | Yulianti et al | 2020 | 2,42 | High |
| **17** | J17 | Prabaningrum at al | 2019 | 9.79 | High |
| **18** | J18 | Astuti, I.D et al | 2019 | 3.46 | High |
| **19** | J19 | Hariyanto, S. et al | 2019 | 0.81 | High |
| **20** | J20 | Ozcam et al | 2019 | 1.58 | High |
| **21** | J21 | Widyasmah & Herlina | 2019 | 2.25 | High |
| **22** | J22 | Ali, Nurulazam, MJ, & AE | 2018 | 2,19 | High |
| **23** | J23 | Fitriya, F | 2018 | 0.88 | High |
| **24** | J24 | Furi, LM I et al | 2018 | 0.63 | Medium |
| **25** | J25 | Geoff, Kelley et al | 2018 | 0.40 | Medium |
| **26** | J26 | Lutfi, L., Azis, A et al | 2018 | 1.46 | High |
| **27** | J27 | Moi, Ambo | 2018 | 0.54 | Medium |
| **28** | J28 | Murniyati, M | 2018 | 3.72 | High |
| **29** | J29 | Antika, RN | 2017 | 1.19 | High |
| **30** | J30 | Dewi, BM M | 2017 | 3.78 | High |
| **31** | J31 | Fatmala, S.A | 2017 | 0.72 | Medium |
| **32** | J32 | Lou, Chou et al | 2017 | 0.51 | Medium |
| **33** | J33 | Mohamad et al | 2017 | 3.04 | High |
| **34** | J34 | Tati, H., Riandi | 2017 | 0.84 | High |

| | | | | | |
|---|---|---|---|---|---|
| **35** | J35 | Wijanarko, A.G | 2017 | 0.83 | High |
| **36** | J36 | Afriana, J et al | 2016 | 3.80 | High |
| **37** | J37 | Dubriwny at al | 2016 | 0.20 | Medium |
| **38** | J38 | Pratama, H et al | 2016 | 1.46 | High |
| **39** | J39 | Rauziani, R et al | 2016 | 0.34 | Medium |
| **40** | J40 | Tsai, Chan, & Huang | 2016 | 0.29 | Medium |
| **41** | J41 | Uswatun Chasanah, A.R | 2016 | 0.45 | Medium |
| **42** | J42 | Capraro et al | 2016 | 1.09 | High |
| **43** | J43 | Bilgin, I et al | 2015 | 0.81 | High |
| **44** | J44 | Birgili, B | 2015 | 0.83 | High |
| **45** | J45 | Ceylan., Ozdilek | 2015 | 4,40 | High |
| **46** | J46 | Rahmasiwi, A et al | 2015 | 1.67 | High |
| **47** | J47 | Ahlam, ES, & Gaber, H | 2014 | 0.70 | Medium |
| **48** | J48 | Ergül, NR, & Kargın, E.K | 2014 | 1.11 | High |
| **49** | J49 | Khoiriyah, N | 2018 | 0.84 | High |
| **50** | J50 | Samatowa, U et al | 2010 | 1.46 | High |

**The Influence of the STEM Education Integration PjBL Model on Learning Outcomes in terms of Education Level**

The first finding of the meta-analytic study concerned the impact of the PjBL integration of STEM on test scores from the school system. The average effect size value based on educational level was obtained from the average effect from each article. The mean value of the effect size is reviewed from the level of education using 50 articles from national and international journals is shown in the table. 3.

**Table 3. Effect Size Result Data Based on Education Level**

| Educational level | Journal Code | Effect Size | Average effect size | Category |
|---|---|---|---|---|
| **COLLEGE** | J2 | 0.49 | 0.86 | High |
| | J14 | 1.05 | | |
| | J29 | 1.19 | | |
| | J38 | 1.46 | | |
| | J40 | 0.29 | | |
| | J44 | 0.83 | | |
| | J47 | 0.70 | | |
| **SENIOR HIGH SCHOOL** | J7 | 1.33 | 1.42 | High |
| | J8 | 0.63 | | |
| | J11 | 1.05 | | |
| | J12 | 1,13 | | |
| | J15 | 0.82 | | |
| | J18 | 3.46 | | |
| | J21 | 2.25 | | |
| | J22 | 2,19 | | |
| | J23 | 0.88 | | |
| | J25 | 0.40 | | |
| | J26 | 1.46 | | |

| | | | | |
|---|---|---|---|---|
| | J30 | 3.78 | | |
| | J39 | 0.34 | | |
| | J41 | 0.45 | | |
| | J42 | 1.09 | | |
| | J46 | 1.67 | | |
| | J49 | 0.84 | | |
| **JUNIOR HIGH SCHOOL** | J1 | 1,13 | 2.07 | High |
| | J3 | 0.44 | | |
| | J6 | 0.80 | | |
| | J10 | 3,20 | | |
| | J13 | 0.55 | | |
| | J16 | 2,42 | | |
| | J17 | 9.79 | | |
| | J19 | 0.81 | | |
| | J20 | 1.58 | | |
| | J27 | 0.54 | | |
| | J32 | 0.51 | | |
| | J34 | 0.84 | | |
| | J36 | 3.80 | | |
| | J37 | 0.20 | | |
| | J45 | 4,40 | | |
| **PRIMARY SCHOOL** | J4 | 0.83 | 1.39 | High |
| | J5 | 0.51 | | |
| | J9 | 1.63 | | |
| | J24 | 0.63 | | |
| | J28 | 3.72 | | |
| | J31 | 0.72 | | |
| | J33 | 3.04 | | |
| | J35 | 0.83 | | |
| | J43 | 0.81 | | |
| | J48 | 1.11 | | |
| | J50 | 1.46 | | |

From the data in Table 3 it can be explained that the results of the meta-analysis of the influence of the STEM education integration PjBL model on learning outcomes based on class level found that the STEM education integration PjBL model had the highest influence at the junior high school level, with an effect size of 2.07, then Senior High School, with an effect size of 1.42, and Elementary School with an effect size of 1.39. Meanwhile, for the Higher Education level it is in the smallest height category, namely 0.86. This shows that the STEM education integration PjBL model is effective when used at all levels of education.

**The Effect of the STEM Education Integration PjBL Model on Learning Outcomes Based on Subjects**

The second result of this meta-analysis research is related to the influence of the STEM education integration PjBL model on learning outcomes in terms of subject aspects. The average effect size is obtained from calculating the effect size of each article. The average value of the effect size based on the learning materials used from 50 articles in national and

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international journals is shown in Table 4.

**Table 4. Effect Size Result Data by Subject**

| SUBJECTS | JOURNAL CODE | EFFECT SIZE | AVERAGE EFFECT SIZE | CATEGORY |
|---|---|---|---|---|
| **BIOLOGY** | J18 | 3.46 | 1.68 | High |
| | J24 | 0.63 | | |
| | J26 | 1.46 | | |
| | J29 | 1.19 | | |
| | J46 | 1.67 | | |
| **PHYSICS** | J2 | 0.49 | 1.33 | High |
| | J7 | 1.33 | | |
| | J8 | 0.63 | | |
| | J11 | 1.05 | | |
| | J12 | 1,13 | | |
| | J14 | 1.05 | | |
| | J21 | 2.25 | | |
| | J22 | 2,19 | | |
| | J30 | 3.78 | | |
| | J38 | 1.46 | | |
| | J39 | 0.34 | | |
| | J41 | 0.45 | | |
| | J49 | 0.84 | | |
| **CHEMICAL** | J15 | 0.82 | 0.60 | Medium |
| | J40 | 0.29 | | |
| | J47 | 0.70 | | |
| **MATHEMATICS** | J17 | 9.79 | 3.03 | High |
| | J42 | 1.09 | | |
| | J44 | 0.83 | | |
| | J25 | 0.40 | | |
| **SCIENCE** | J1 | 1,13 | 1.52 | High |
| | J3 | 0.44 | | |
| | J6 | 0.80 | | |
| | J10 | 3,20 | | |
| | J13 | 0.55 | | |
| | J16 | 2,42 | | |
| | J19 | 0.81 | | |
| | J20 | 1.58 | | |
| | J27 | 0.54 | | |
| | J32 | 0.51 | | |
| | J34 | 0.84 | | |
| | J36 | 3.80 | | |
| | J37 | 0.20 | | |
| | J45 | 4,40 | | |
| **ELEMENTARY** | J4 | 0.83 | 1.41 | High |

| | | |
|---|---|---|
| **SCIENCE** | J5 | 0.51 |
| | J9 | 1.63 |
| | J23 | 0.88 |
| | J28 | 3.72 |
| | J31 | 0.72 |
| | J33 | 3.04 |
| | J35 | 0.83 |
| | J43 | 0.81 |
| | J48 | 1.11 |
| | J50 | 1.46 |

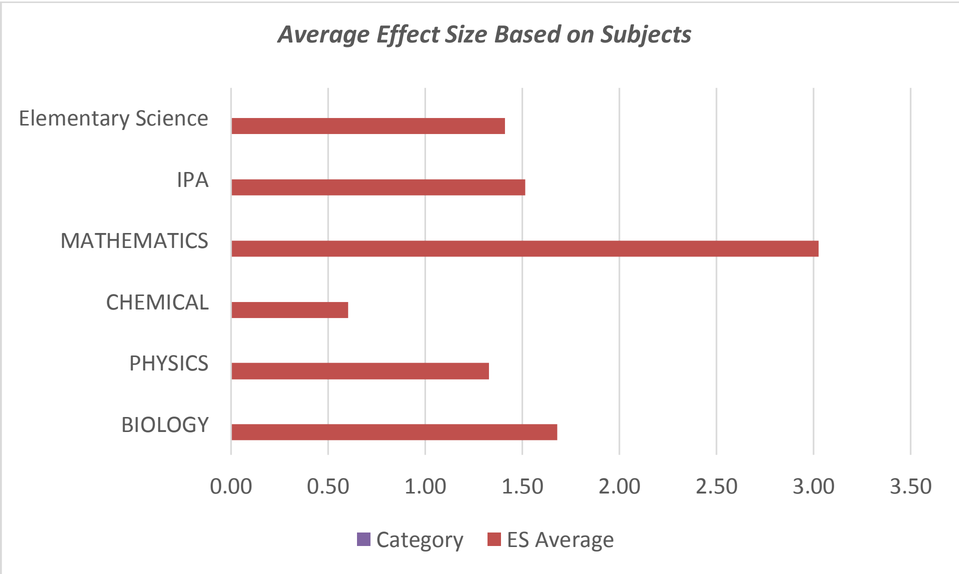


Figure 1. Average Effect Size by Subject

From the data in Table 4 it is described that the results of the meta-analysis of the influence of the PjBL model of STEM education integration based on subjects found that mathematics is in the highest category with an effect value of 3.03, while chemistry is in the medium category with an effect size 0.60. So it can be concluded that the effect size of the STEM education integrated PjBL model on learning outcomes in terms of subjects has a high effect.

**Discussion**

The results of this study were conducted in two categories, namely the effect of the PjBL model of integration of STEM education on learning outcomes based on educational level (PT, SMA, SMP and SD) and the effect of integration of STEM education on learning outcomes based on subjects (Elementary Science, Science, Mathematics, Chemistry, Physics and Biology). The results of this study indicate that the use of the STEM education integrated PjBL model can improve student learning outcomes.

The first result achieved was the PjBL model of integration of STEM education in the aspect of education level which has a high effect on all levels of PT, SMA, SMP and SD education. This is found in the results of a meta-analysis of the effects of the STEM education integration PjBL model on learning outcomes based on class level in Table 3. PjBL is a student-centered learning model for building and applying concepts from projects produced by exploring and solving real-world problems independently . STEM integration in education aims to prepare students to be able to compete and be ready to work according to their fields. To foster creative thinking skills, students must be given the opportunity to develop creativity by working as much as possible in learning.

The second result achieved was the influence of the STEM education integrated PjBL model in terms of subject aspects which consisted of 5 subjects. From the calculation results, the effect of PjBL-STEM integration on the subjects of Elementary Science, Science, Physics, Mathematics and Biology has a high effect. Whereas in chemistry subjects it has a moderate effect. PjBL-STEM learning can provide students with contextual learning through complex activities such as exploring planning learning activities, carrying out projects collaboratively, and ultimately producing a product (Robi'atul, Suwono, & Ibrohim, 2017). Therefore, PjBL-STEM will certainly have a positive impact and provide optimal results in a given subject if implemented properly.

There is advice that can be given to the teacher based on the results of the study that have already been reported. In addition, teachers can use the PjBL STEM integration paradigm when teaching in schools. Because it integrates or connects three academic disciplines, including science, technology, engineering, and mathematics, students are more eager to participate in classroom instruction and project-based learning activities. Project-based learning models have important and beneficial qualities for students, but they are difficult to implement. As a result, they are rarely used in schools. According to (Rustaman N, 2016), there is a significant difference between regular PjBL and PjBL-STEM, especially in terms of performance. PjBL-STEM began with a problem that was vaguely defined and highly contextual in order to develop a solution using other materials in addition to STEM in order to produce a prototype (well-defined outcome). As a result, integration of STEM education within the PjBL paradigm can be considered a priority and integrated into classroom instruction.

## CONCLUSION

Based on the data that has been stated in this study, two research results can be stated. First, the PjBL model of integration of STEM education has a high influence on all levels of SD-PT, for the SMP level it has the highest influence, with an ES size of 2.07. The two models of PjBL integration of STEM education have a high impact on science, physics, biology, and mathematics subjects. while chemistry subjects are in the medium category with an ES size of 0.60. So it can be concluded that the effect size of the STEM education integrated PjBL model on learning outcomes in terms of subjects has a high effect.

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