Impact of SE

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IMPACT OF INTEGRATING SCIENCE AND ENGINEERING TEACHING APPROACH TOWARDS STUDENTS ACHIEVEMENT: A META ANALYSIS

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The STEM teaching approach has gained interest among science educators as a panacea in addressing the declining interest in STEM learning among the students. However, the impact of STEM teaching approach on students' achievement is less discussed. One of the critics of STEM teaching approach is to what extent students can learn the concepts of the disciplines during the STEM activities. Thus, this study aims to explore the teaching approach in improving students' achievement in STEM discipline through Science and Engineering (SE) integration. Relevant articles were retrieved from seven databases published between 2000 until January 2020. Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) were applied to ensure a rigorous selection of the desired research articles. The data were then assessed using two online statistical effect size calculators. A total of 14 size effects was calculated. Meanwhile, the overall mean effect sizes obtained were of high effect (es=2.21). The findings postulated that the Design Based Learning (es=3.73, high effect) was the most effective teaching approach to enhance students' understanding and increase their interest in science subjects. Furthermore, to determine the effective teaching approach future studies can be conducted in a way to address students with diverse abilities.

Keywords: integrated STEM; teaching approach; meta analysis

INTRODUCTION

A curriculum consisting of science, technology, engineering, and mathematics, or generally referred to as STEM, was first conceptualized by educators in the United States almost three decades ago. This due to the scarcity of college graduates in relevant technical occupations following the rapid growth of scientific advances in the late 1990s (Chesky et al. 2015; Martin Paez et al. 2019; National Science Foundation, 1998; Vasquez et al., 2013). Afterwards, academicians globally have also realized the importance of improving STEM education in fulfilling students with STEM skill and knowledge for future jobs.

Originally, STEM education can be defined as an education initiative crafted by the National Science Foundation (NSF) that dealing with four disciplines- science, technology, engineering and mathematics (White 2014). However, current research suggests that the concept of STEM education can be branched off into another perspective such as integrated STEM education (Martin Paez et al. 2019). While the classic STEM education focused on the silo approach of four STEM components mentioned previously (Kelly & Knowles, 2016), integrated STEM education emphasizes on the different levels of integration, interconnections between the subject areas and the rich contextualization of content through real-world applications (National Research Council (NRC), 2014).

In general, integrated STEM education may exist in a different classes or teachers and does not necessarily involve all four STEM disciplines. Previous literature suggested that it can be described as (i) an approach that integrates more than two STEM subjects; (ii) integration of engineering design; and (iii) an attempt to incorporate all four STEM components into a real-world problem where teaching is performed in an authentic context (Sander, 2009; Moore et al., 2014; Kelly & Knowles, 2016).

As indicated in previous studies, integrated STEM education carries various definitions without any consensus among scholar. However, Vasque et al. (2012) pinpointed the three important points about integration. Firstly, integration does not mean abandoning standards but skills and concepts are described within disciplinary areas. Secondly, STEM's power lies when students realize that concepts and skills from different disciplines can be put together to help solve problems. Thirdly, the integrated STEM curriculum enables students to learn to apply STEM concepts and skills in their daily lives.

When looking closer, an 'Integration Continuum' featured in Vasquez et al.'s work (2013) defined STEM integration as a continuum consisting increasing levels of integration in which progression across the boundary involves extensive interconnectedness and interdependence between the disciplines. To summarize, the progression starts with a disciplinary approach which emphasises on learning concepts and skills in each discipline separately before learning them within a common theme at a multidisciplinary stage. Afterwards, in order to deepen knowledge and skills, interdisciplinary learning is organized across disciplines. Finally, during transdisciplinary approaches, students get to apply their skills and knowledge through projects or problem-based learning (PBL) on real-world applications. In this study integration of Science and Engineering (SE) located in the third level (interdisciplinary). Once the disciplines are interconnected and interdependent, it allows the mastery of concepts and skill to be accomplished without neglecting the fundamentals knowledge of STEM disciplines. In addition, it also helps one to understand, particularly students, that different disciplines can be combined for problem-solving and application in everyday life.

To this extend, researchers discovered that the PBL approach to be a dominant teaching approach for integrated STEM implementation (Kang, 2019; Mustafa et al., 2016). However, PBL in science education is different between PBL of integrated STEM education (Puente et al. 2013; Wij 2000). In science education, PBL typically involves scientific practices. Meanwhile, PBL in integrated STEM education includes an additional feature from an engineering design (ED). ED is a teaching approach that constitutes a learning process by applying knowledge of sciences, mathematics, and engineering to meet the desired engineering outcome (ABET, 2008; Sanders, 2009). In addition, Shahali et al. (2016) noted that benefits of ED are not only limited to solving engineering problems but is also used in the development of new technologies and products.

Furthermore, for the last decade, studies have also shown that the ED process in learning science or mathematics can generate a meaningful outcome through the implementation of scientific and mathematical principles to solve complex, open-ended problems in the real world (Sheppard et al., 2009; Moore, 2013; Bryan, 2016).On another note, ED enables students to enhance their cognitive abilities such as problem solving, creative thinking, formulating solutions, decisions making, and communication skills. As a results student's will be able to learn mathematical or science concepts in a more authentic process by relating them with real-life situations (NRC, 2009; Lewis, 2006; Roth, 2001; Thornburg, 2009; Cantrell et al., 2006; Samsudin et al., 2007; Wang et al., 2011; Yasin et al., 2012).

ED can be divided into three main perspectives such as pedagogy, disciplinary practice or core idea. Purzer (2017) even mixed these three perspectives. These variations are influenced by three different research movements in the United State over the past 30 years. In the late 1990s (first research movement), learning design was perceived as a pedagogical approach focusing on the disciplinary core ideas in physical, life and earth sciences. These pedagogical approaches were also called as; (i) learning by design, (ii) design-based learning, and (iii) design-based science. Meanwhile, the second research movement was led by educators in the engineering field using two influential publications namely (i) "Engineering in K-12 Education: Understanding the Status and Improving the Prospects" and (ii) a report on the status of engineering education in the US (NRC, 2009). Therefore, engineering was then framed as a core content while the design was promoted as a disciplinary practice. Now, integrated STEM emphasizes this effort as a pedagogical approach and design as a practice. The current research movement focuses on ED as a mixture of the three perspectives consists of pedagogy, disciplinary practice and core idea.

ED as a pedagogy can be further divided into three approaches such as Learning by Design (LBD), Design-Based Learning (DBL) and Design-Based Science (DBS). The three approaches vary in terms of the learning process, knowledge acquisition and learning outcomes. LBD focuses more on problem-based and case-based learning, making it easier for students to experience meaningful learning of science and design practice. On the contrary, DBL accentuates comprehension of abstract concepts by integrating ED and science inquiry (Apedoe et al., 2008). As for DBS, it is more an inquiry-based approach and focuses on engaging student metacognition, enabling them to present ideas in multiple ways and improving their problem-solving skills, resulting in learning outcomes in the form of engineering products (Fortus et al., 2005).

ED as a pedagogy does not represent the epistemological underpinnings of each field. Therefore, another framework was used to overcome these dilemmas namely ED as a Disciplinary Practice. In this practice, design-based learning was implemented. For instance, the novel engineering approach was implemented during the elementary level (Purzer, 2017). This innovative approach integrated characters from books and novels for students understanding and to engage them with the engineering design processes (EDP). STEM unit's integration is another approach which engaged students in authentic disciplinary practices (Mathis et al., 2016). According to Goldstein et al. (2017), to implement STEM unit's integration the collaboration between educators and stakeholders is considered as the best approaches during the secondary level because it enhances students' interest in establishing a career in STEM.

Meanwhile, ED as a core disciplinary idea is defined as a framework which outlines two disciplinary core ideas that associate engineering and technology, like the implementation of Engineering, Technology and Application of Science (ETS) framework for K-12 Science Education. ETS1 focuses on "How do engineers solve a problem?", while ETS 2 is about "How are engineering, technology, science and society interconnected?". This approach is introduced in primary education and is implemented throughout high school (NGSS, 2013).

Previous literature also indicated two factors affecting the implementation of integrated STEM teaching approach namely teacher's beliefs and student's belief. Teacher's belief in their students' learning ability is important for effective SE integration teaching style and also influenced student achievement in school (Caprara et al., 2006; Margot & Kettler, 2019; Tran & Nathan, 2010). According to Wang et al. (2011), teaching requires pedagogical content knowledge, besides emphasizing on educational problems, curriculum and techniques to bring the topic alive for students. Each teacher also possesses a specific skill set in forming the material and pedagogical methods which he or she plans to implement in a classroom.

Moreover, the expertise of integrating STEM into instructions is related to the teachers' ability, teaching backgrounds, content knowledge, time, curricular aims, assessment and classroom management skills (Stohlmann et al., 2012; Gresnigt et al., 2014). Apart from that, the factors that may pose a challenge to the implementation of integrated STEM education include the teachers' beliefs and views about teaching and learning, alongside their resistance or lack of motivation to change their beliefs and practice (Ashgar et al., 2012). Hence, in this study, we conceptualize teachers' beliefs as their capabilities in integrating SE to produce the desired effect on student learning. However, the inclusion of engineering knowledge in science classes has led to problems such as a lack of confidence amongst teachers as they are not equipped with the requisite engineering knowledge to teach students (Kim et al., 2019).

While the second factor is students' beliefs. Currently, there is lack of educational research on the student's belief on the learning process appears in general (Halim et al., 2014). While every teacher or student has their own perspectives regarding the definition of integrated STEM education, majority of students believe that teaching and learning experiences have an effect on their affective variables (e.g., motivation) and behaviors (e.g., learning strategies) to varying degrees, whether consciously or unconsciously and positively or negatively (Klieme & Vieluf, 2009; Stohlmann et al., 2012; Sakiz, 2017). In relation with this study, we conceptualized student's belief as their attitude towards challenging learning strategies, especially on PBL. In general, there are two patterns of student self-perceptions and behaviors in project-based instructions such as 'challenge seekers' and 'challenge avoiders' (Meyer et al.,1997). For challenge seekers, they have high tolerance for failure and a learning goal orientation. Meanwhile, challenge avoiders have a higher negative effect after failure, a performance-focused goal orientation and extensive command of surface strategies (i.e., strategies requiring minimal processing of information).

Moving onto the implementation of integrated STEM, there were arguments regarding when and how integrated STEM should be taught to students. Some scholars debated whether the student need to master the concepts of the disciplines before integrated STEM education can be implemented or they can learn them through integrated STEM teaching and learning (English 2016; NAP 2014, Stohlmann 2012, Thibaut et al 2018). While others questioned on how the mastery of different disciplines are being done since STEM is a combination of multiple disciplines (NAP 2014). Apart from these issues, it is also imperative to know the effectiveness of integrated STEM towards student achievement as emphasized by English (2016) in his study. Therefore, this meta-analysis study was conducted to examine student's achievement in science subject through SE integration.

However, Becker & Park, (2011) and Mustafa et al., (2016) investigated the impact of integrated STEM on student achievement. Becker and Park (2011) examined the effects of an integrative approach based on subject's integration, where their preliminary meta-analysis data revealed that the 28 studies from 1989 to 2009 involving elementary, high school and college students indicated high effect (es=0.63). In other words, integrative approaches between STEM subjects have positive effects on the achievement of the students. Whereby, the integration of four STEM subjects (science, technology, engineering and mathematics) exhibited the highest effect size (es=1.76). Meanwhile, a study by Mustafa et al. (2016) which focused on effective strategies for integrated STEM education revealed that the project-based learning (PBL) approach was deemed as a dominant strategy in STEM education implementation. Even though they claimed to have performed a meta-analysis study on STEM integration and its impact on achievement, there is a need to further perform the review based on two reasons: 1) Previous meta-analysis only covered studies from 2000 to 2009, and 2) Effect size was not calculated. Thus, readers were unable to understand the magnitude of differences because the impact of the study outcome was not determined. However, to our knowledge, no meta-analysis study has ever focused on the impact of integrating science and engineering teaching approach towards students' achievement.

In this meta-analysis study, we conceptualized students' achievement as an understanding of a science subject. Tran and Nathan (2010) revealed that the limited integration of science into engineering courses has resulted in reduced achievement gains in science. To better focus on meta-analysis study, the integration between SE based on the four (4) objectives will be highlighted in this study. Firstly, embedding engineering practice into science subjects that influence student's achievement to understand the science concepts and enhancing scientific process skills. Secondly, understanding the most effective science subject in the SE integration. Thirdly, investigate the appropriate teaching strategies to enhance teachers' skills. Finally, identifying appropriate educational level to implement SE integration.

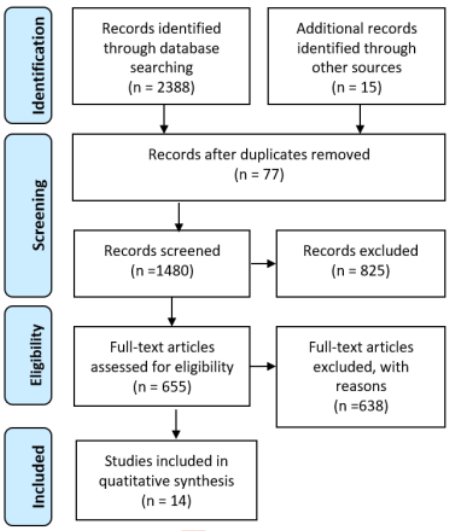
METHODS

This study follows a Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guideline by Moher et al., (2009). This guideline provides a series of stages as outlined in Figure 1, which starts with the process of identification, screening, eligibility, and inclusion.

For the process of identification, electronic databases were used to search relevant articles (including unpublished work) for this study include EBSCOhost, Emerald, ERIC, Scopus, Web of Science and Wiley. Therefore, during the identification process, we practiced several steps such as: (i) used Boolean search "+, -, AND, NOT", (ii) used specific keyword terms and their variants include: integrated STEM, STEM education, student achievement, student outcomes, engineering design, learning by Design, Design Based Science, Design Based Learning, problem-based learning, project-based learning, project-oriented problem-based learning, inquiry and problem solving, school, (iii) used alternatives keywords for achievement such as ''performance'' ''success'' and "outcomes'', (iii) combined keywords achievement with science disciplines, such as "biology" "chemistry" "physics" "science" and (iv) used references to track other suitable articles.

After the initial identification process, the result yielded a total of 671 from Web of Science, 173 from Scopus, 266 from Emerald, 712 from

EBSCOhost and 566 from ERIC. In the meantime, an additional 15 studies have been identified following manual searches using the reference lists of the recovered articles to locate other related articles that might have been omitted during the database search. Hence, a total of 2403 articles were retrieved. However, after careful identification process, we removed 77 duplicate studies.



Source: Moher et al. (2009)

Figure 1. PRISMA flow diagram

Then the process continued with the screening, eligibility, and inclusion. For screening process 2263 studies were excluded and only 63 studies were eligible. After that the 63 studies that went through screening process were then filtered using a set of criteria. At this stage, we prioritized the article that were (1) quantitative research studies, (2) completed after year 2000, (3) published in English or Malay language, and (4) comprised of school samples. Besides that, we also excluded studies which (i) do not measure the relationship between integrated STEM (science and engineering) and student's achievement, and (ii) do not have enough data or basic statistics to calculate the effect size. The main rationale of these inclusion criteria was made based on the previous coverage of integrated STEM meta-analysis and due to other substantive reasons. Therefore, the number of qualified studies were only 14.

Based on the framework of this study, the related articles were coded to define the final analytic sample. However, there are inherent challenges in categorizing the range of measurement approaches across studies. Therefore, several steps were taken to maximize coding accuracy. First, before moving onto the included articles, a calibration exercise was conducted on the previous excluded articles which include reconciling differences and refining the current codebook. The codebook included all relevant information by adopting the MUTOS framework (Cronbach, 1982): U (grade level), T (teaching approach, teaching strategy, types of subject integration) and O (student achievement). After that the effects of integrated STEM between the combination of SE focusing on student achievement in all 4 science subjects (S-science, P-physics, C-chemistry, B-biology) were measured. The effect size in this study was calculated using statistical tools from credible online sources (www.psychometrica.de/effect_size.html and www.campbellcollaboration.org/escalc/html/EffectSizeCalculator-SMD1.php).

Hattie's Continuum Effect (2009) was used to evaluate and explain the calculation of effect size (Cohen's d). This interpretation was chosen because it applies to specific educational contexts. Based on Hattie (2009), d=0.2 is considered a small effect, while d=0.4 is a medium effect and d=0.6 a large effect. Hence, d=0.4 is considered as a hinge point which is interpreted as a 'greater than average influence' on achievement. Hattie et al. (2013) also mentioned that the factors on the left of this scale are those with decreased achievement, while the scale on the right refers to increased achievement. Effect size below zero will not affect the results of the test.

RESULTS AND DISCUSSION

The impact of integrating of SE teaching approach that focusing on student achievement were measured. A total of 26 calculated effect sizes were obtained from 14 studies based on a sample size of 33,791(Table 1). Positive effect is obtained with the overall mean effect sizes (es=2.21, high effect). According to Hattie et al. (2013), although meta-analysis is powerful due to the placement of all the effect size on a common continuum, the potential multidimensionality of the findings from the moderator variables needs to be considered too. Therefore, two moderator variables namely T (teaching strategy), U (gred level) were also explored (refer Table 1).

Table 1. Summary of Effect Size Value

Researcher	Sample Size (k)	Teaching Approach	Type of subject	Grade Level	Strategy of Integration	Effect Size (ES)
Yaki et al. (2019)	100	Integrated STEM-Based	SE	High School	ISTEMA	C1: 0.53
Ozcan & Koca, (2019)	33	STEM Education-based Curriculum	PE	Middle School	STEM Education-Based Teaching Module	C2: 0.80
Guzey et al. (2016)	4450	Engineering Design Process	SE	Elementary School	Engineering Design-Based STEM Integration Curricula Unit	C3: 6.02 C4: 9.45 C5: 9.63
				Middle School		C6: 5.43 C7: 4.12 C8: 4.52 C9: 7.34
Mehalik et al. (2008)	587	Systems Design	SE	Middle School	Alarm System Module	C10: 0.89
Riskowski et al. (2009)	126	Engineering Design Process	SE	Middle School	Interdisciplinary Water Resources Engineering Module	C11: 0.44
Apedoe et al. (2008)	1,400	Engineering Design Process	CE	High School	Heating/Cooling System Unit	C12: 0.25 C13: 0.18 C14: 0.23
Rethwisch et al. (2012)	26030	Engineering Design Process	SE	High School	Project Lead The Way (PLTW) Engineering Curriculum	C15: 0.44
Francis et al. (2019)	12	Engineering Design Process	PE	High School	Workplace Simulation Project (WSP)	C16: 1.33
Doppelt et al. (2008)	38	Design Based Learning	SE	Middle School	Electrical Alarm System Module	C17: 2.24 C28: 1.49
Standish et al. (2016)	40	Engineering Design Process	SE	Middle School	Engineering Design Module	C19: 1.38 C20: 0.99
Fortus et al. (2004)	92	Design Based Science	SE	Middle School	Design-Based Science Unit	C21:2.10 C22: 1.90 C23:2.70
Alemdar et al. (2018)	543	Engineering Design Process	SE	Middle School	Engineering Curriculum	C24:1.53
Korur et al. (2015)	65	Engineering Design Process	SE	Middle School	Scaffolded Design Based Learning (SDBL)	C25: 2.09
Guzey et al. (2016)	275	Design Based Science	SE	Middle School	Engineering Design Based Science Unit	C26: 0.07

Based on Table 1, six teaching approaches were utilized to implement the integrated STEM lesson including the (i) Integrated STEM-based (1, es=0.53), (ii) STEM Education-based Curriculum (1, es=0.80), (iii) Engineering Design Process (8, es=14.24), (iv) System Design (1, es=0.89), (v) Design-Based Learning (1, es=3.73) and (vi) Design-Based Science (2, es=3.80).

The overall mean effect size results for teaching approaches are shown in Figure 2. Based on the overall mean effect size results in Figure 2, the highest calculated effect size was obtained from the Design-Based Learning (es=3.73, high effect) and the lowest from the Integrated STEM-based (es=0.53, medium effect).

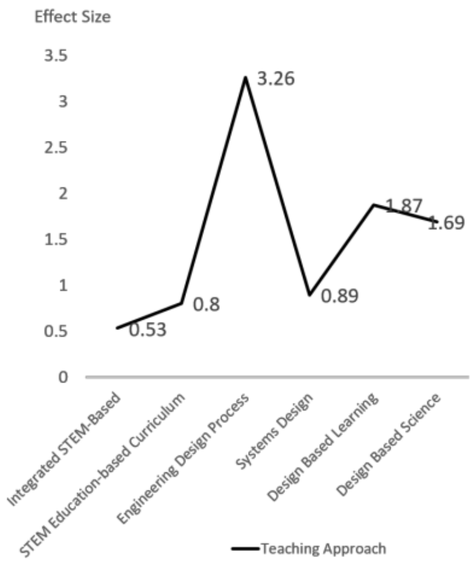


Figure 2. Overall Mean Effect Size for Teaching Approach

Meanwhile Table 1 also revealed that students demonstrated positive respond towards integrating SE lessons. The overall mean effect size results for types of science subject in SE integration are shown in Figure 3.

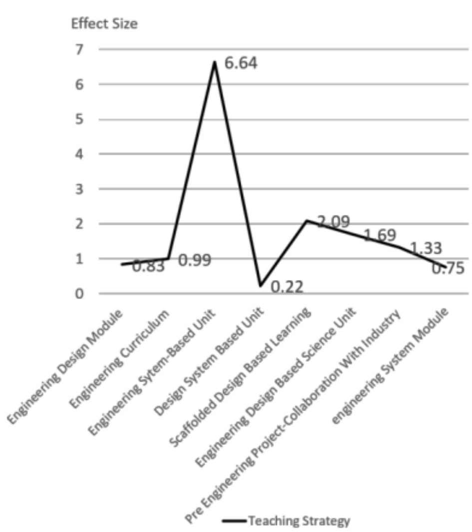


Figure 3. Overall Mean Effect Size for Teaching Strategy

Based on Figure 3 the overall effect size for types of subject integration was estimated at 34.19 with a mean effect size of 11.40 (large effect). Meanwhile, for types of subject integration, all 4 science subjects (S, P, C, B) integrated with engineering (E) were examined. However, none of the articles was suitable to calculate the effect size integrating Biology and Engineering (BE) subjects. Based on the graph in Figure 3, Science and Engineering (SE) indicated highest number of effect size (11, es=31.40) and overall mean effect 2.85 which is high effect, followed by Physics and Engineering (PE) (2, es=2.13) and Chemistry and Engineering (CE) (1, es=0.66).

Furthermore, Table 1 also describe a teaching strategy demonstrated positive effects on student's achievement. The overall mean effect size results for teaching strategies are shown in Figure 4.

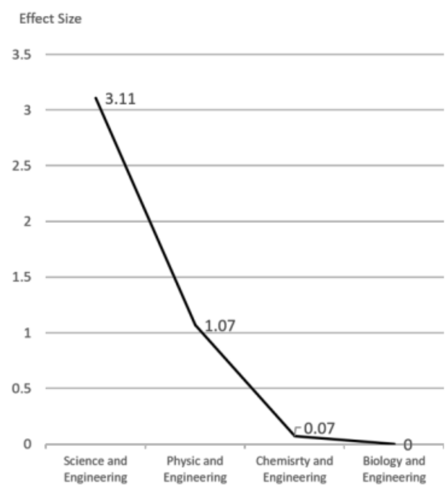


Figure 4. Overall Mean Effect Size for Type of Subjects Integration

The mean overall effect size of teaching strategy towards student achievement estimated a large effect (overall mean es=4.87). There were six types of strategies used to implement the integrated STEM (SE) lesson; (i) Engineering Design Module (4, es=8.23), (ii) Engineering Curriculum (2, es=1.97), (iii) Engineering Design-Based Unit (4, es=12.81), (iv) Design-Based STEM Integration Based Curricula (1, es=1.97), (v) SDBL (1, es=2.09), (v) Instructional Approach (1, es=0.80), and (vi) Pre-Engineering Project-Collaboration With Industry (1, es=1.33). The effect size varies depending on the strategy used. The results indicated that the highest calculated effect size was obtained from the Engineering Design Unit.

Finally, Table 1 summarizes the effect size of student achievement based on the grade level. The overall mean effect size results for types of science subject in SE integration are shown in Figure 5. Based on Figure 5 all grade levels indicated a high effect. The overall mean effect size for all 3 grade levels exhibited a large effect (15, 4.54). However, compared to middle or high schools, elementary schools scored the highest effects size. The mean effect size for middle schools was estimated at 2.35, 8.37 for elementary schools and 0.49 for high schools.

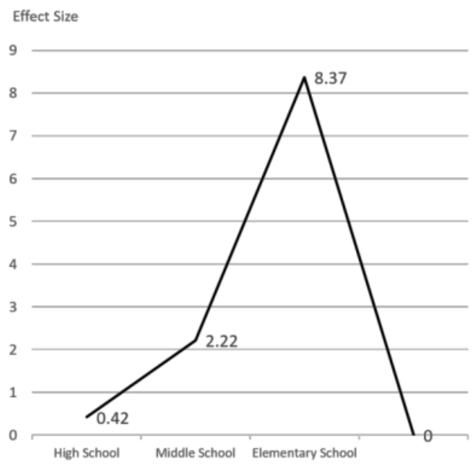


Figure 5. Overall Mean Effect Size for Grade Level

Based on results, SE integration shows a positive effect towards students' achievement. This outcome aligned with the previous studies which stated that the integration of SE enhanced students' achievement in science subjects (Starr et al., 2020; Brown, 2016; Yoon et al., 2014; Foster et al., 2013). SE is required to solve many problems and to deepen students understanding by applying scientific knowledge to solve engineering problems (Cunningham et al., 2019). The integration of SE indirectly results in students mastering math concepts and link scientific concepts with technology (Asghar et al., 2012; Rockland, 2010) and enhances student's metacognition including creativity, critical thinking, problem-solving, and knowledge application (Goodpaster et al., 2012; Rockland, 2010). Furthermore, it is also believed that student's interest towards science can also improve through STEM integration (Bagiati & Evangelou, 2015; Dare et al., 2014; El-Deghaidy et al., 2017; Wang et al., 2011). In addition, integrating engineering concepts into the science curriculum through interesting practical applications increase students' interest in STEM education (Rockland, 2010).

SE based approach in this study can be interpreted as integrating engineering concepts and applications into various content areas in the curriculum (Rockland, 2010). Based on the results, DBL yielded the highest calculated effect size (mean es= 3,73 high effect), indicating that it is the appropriate approach to integrate SE into the curriculum. DBL is a part of ED disciplinary practice. In general, ED is used in multiple means in practice and the framework as a pedagogy, disciplinary practice and a disciplinary core idea (Purzer, 2017). Therefore, ED serves as a structure in SE-based approach since they both have parallel processes and similar problem-solving characteristics while also assisting teachers in teaching scientific inquiry (Rockland, 2010). Moreover, SE based approach allows the implementation of PBL such as hands-on activities (Rockland, 2010) and the application of scientific knowledge during problem-solving, which promotes new development of understanding among students (Mooney and Laubach, 2002). Gates (2014) also stated that dynamic learning approaches need to be tailored to a new curriculum in line with the students' specific capabilities and interests. Therefore, dynamic approach and integration efforts should be intensified to increase students' interest and motivation towards STEM (Bagiati et al., 2015; LaForce et al., 2016).

SE also yielded the highest number of effect size in science subject (S) (11, es=31.40) compared to P and C. The mean effect size of SE was 10.46 indicating a large effect. This finding was parallel with Honey et al. (2014) and Walkington et al. (2014), as they pointed out that engineering-based problems tend to be science-oriented. Moreover, Lachapelle and Cunningham (2014) mentioned that engineering education is science-oriented rather than mathematic. Science is perceived as a real-life explanation, while engineering is accepted as a solution by humans (Rockland, 2005). Therefore, integrating SE through EDP allows teachers to use inquiry learning and scientific reasoning to help bridge discipline boundaries between these two subjects (Lewis, 2006; Rockland, 2005). However, STEM integration will only succeed with qualified science teachers.

CONCLUSION

Educational boards in many nations spend millions of dollars into research on improving science education (Honey et al., 2014; National Research Council, 2014). The high dropout rate of students in science has increased the attention on successful SE integration into the curriculum. Based on our findings, it is implicitly understood that not many studies have demonstrated statistically significant results to be considered in this meta-analysis study. In other words, the studies that investigated the effects of integration of SE on achievement may not exhibit the intended contribution. Thus, this meta-analysis study is timely as this study can identify the forms of integration of SE that could provide significant effects on achievement, thus, such studies could serve as best practices in terms of instructional practices.

Integrating SE into the curriculum indicated a large effect on student achievement (es= 2.21). Hence, integrating SE will (i) effectively improving knowledge in science, (ii) grow students' enrolment in science, and (iii) inspire and interest students to try engineering career paths. Moreover, ED is suitable for all types of students with different learning abilities if the teachers are well prepared for the challenge (Schnittka, 2012). Students need different methodologies to help them become independent and strategic learners. Therefore, more research is necessary to determine how science teachers could incorporate ED to fit students' abilities.

The selection of teaching strategy is crucial where teachers must pay attention to choosing the most suitable approach for the betterment of the students' performance. Hence, future research could look into the most effective strategies in implementing integrated SE approach based on the students' abilities.

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