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# The steps of the Engineering Design Process (EDP) in science education: A systematic literature review

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**Abstract**

Engineering is one of the crucial parts of STEM Education. The Engineering Design Process (EDP) is a new trend within science education reform. Most science teachers lack information regarding the usage of EDP in learning science. This study aims to review 40 articles from reputable international journals such as indexed by Scopus and Web of Science (WoS), which explains the steps of the EDP used in science education. The articles selected for review were the ones published in the last ten years, from 2011 to 2020. Some previous literature review studies focused on the EDP through project-oriented capstone courses, the EDP in middle school settings, and how to implement the EDP in science learning. However, this study focuses on the steps of the EDP used in science education (Science, Physics, Biology, Chemistry, and a combination of science with other disciplines). In addition, this research also explains the strengths and weaknesses of EDP in science education. The research approach used was a systematic literature review. This study analyzed the representation of research according to their general characteristics consists of type of publication, year of publication, country, research approach, educational level, and science content. This study found that research on the EDP that is implemented at the university level is still limited, especially on subjects related to interdisciplinary knowledge. Furthermore, the steps of the EDP used in science education differ from one research to another. The most commonly used steps of the EDP are defining the problem, building, testing, evaluating, and redesigning. There are also several obstacles to the implementation of the EDP in science education. Regardless, the implementation has a positive influence on students, undergraduate students, teachers, or others. The results of this study provide an overview of how to implement the EDP in science education. Thus, it can be used as a reference for stakeholders in the field of science education when implementing EDP in their learning.

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## Introduction

STEM Education is a learning approach that combines four different disciplines; Science, Technology, Engineering, and Mathematics (Ercan, Altan, Taştan, & Dağ, 2016). Tsai, Chung, and Lou (2018) state that STEM education is one of the most widely implemented learning approaches in various countries today. In addition, the implementation of the STEM approach has pervaded various fields and disciplines, especially science education (Wong, Dillon, & King, 2016). STEM Education is expected to be an alternative solution to improve students' test results, which are still considered low on PISA and TIMMS (Pimthong & Williams, 2018). The aforementioned expectation arises due to several research findings that show that the STEM approach can increase students' understanding (Huri & Karpudewan, 2019; Boyle, 2019; Chen & Chang, 2018), students' scientific experience (Kang, 2019), students'

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motivation (Awad & Barak, 2018; Dyrberg & Holmegaard, 2018), students' creativity (Susilowati, Miriam, Suyidno, Sholahuddin, & Winarno, 2020; Hanif, Wijaya, & Winarno, 2019) and students' attitudes towards science (Toma & Greca, 2018; Gudiño, 2018; Wild, 2015). These studies assert that the STEM approach can conclusively result in positive outcomes pertaining to students' cognitive, skills, and attitudes.

Several studies on STEM education typically integrate the STEM approach with other approaches or learning models. Some examples of such integration include STEM-Project Based Learning (Samsudin, Jamali, Zain, & Ebrahim, 2020; Hanif, Wijaya, Winarno, & Salsabila, 2019), STEM through Problem Based Learning (Tawfik, Trueman, & Lorz, 2014), and STEM through Engineering Design Process (Nurtanto, Pardjono, Widarto, & Ramdani, 2020; English, King, & Smeed, 2016). Lin, Hsiao, Chang, Chien, and Wu (2018) stated that one important part of STEM Education is engineering. Hertel, Cunningham, and Kelly (2007) explained that learning science should be integrated with engineering design because students can learn two aspects at once, which are science and engineering. Educators are expected to emphasize STEM education through the EDP in learning (Yu, Wu, & Fan, 2019). However, most teachers still have no idea on how to implement engineering design in science learning (Schnittka, 2011). This statement is supported by other research, which stated that an EDP is a learning approach that has just been implemented in teaching science (Guzey, Harwell, Moreno, Peralta, & Moore, 2016).

Several previous studies on the EDP in science education have been published in various international journals. The research methods used vary, ranging from quantitative, mixed methods to qualitative. Some quantitative studies are found to have investigated the influence of the EDP on students' scientific structures and transfer situation (Chase, Malkiewich, & Kumar, 2019); students' participation, interest, and self-concept (Capobianco, Yu, & French, 2014); and students' knowledge (Chao et al. 2017). Furthermore, Crotty et al. (2017) in their study tested the difference in students' achievement, comparing the class that received engineering lessons at the beginning with the one given at the end. In addition, some researches using mixed methods is also found. Dohn (2013) implemented the EDP by challenging the students to design a catapult. The development of the project was expected to improve students' situational interest. Berland et al. (2013) examined the influence of the EDP on students' ability to connect a discussed topic with the project they were developing. In the aforementioned study, the students were given the task of creating a wind turbine. In addition, one other study intended to delve into students' ability to handle the complexity of a task by giving an earthquake-resistant building project (English, King, & Smeed, 2016). Pertaining to students' perceptions of technology and engineering, Hammack, Ivey, Utley, and High (2015) analyzed the influence of the EDP on it by assigning the students to design a model of an airplane. Last but not least, the qualitative method is found to have also been used as the research approach when it comes to the EDP. The aforementioned studies aimed to investigate conceptual understanding (Schnittka, 2011; Park, Park, & Bates, 2016; Mesutoglu & Baran, 2020), conceptual understanding and pedagogical content knowledge (Hynes, 2012); and the use of engineering talk on middle science teacher (Johnston, Akarsu, Moore, & Guzey, 2019). In addition, King and English (2016) scrutinized the influence of the engineering design model on primary school students. In their research, teachers taught the topic of mirror and lens by assigning the students to design an optical instrument. The implementation of an engineering design model by designing an optical instrument can be useful for structuring stages of design, construction and redesign in primary school students.

Studies of systematic literature review (meta-analysis) relating to the EDP have also been published by several researchers previously. Dutson, Todd, Magleby, and Sorensen (1997), in their literature review research, aimed to provide information related to EDP through project-oriented capstone courses. Furthermore, Lammi, Denson, and Asunda (2018) also aimed to investigate the EDP in middle school settings. Mesutoglu and Baran (2020) conducted a meta-analysis of articles relating to the integration of engineering into teacher professional development programs. Similarly, Arık and Topçu (2020) aimed to review the article EDP in science learning. The research explained that most research related to the EDP in science learning uses open-ended questions and problem scenarios. Although there has been a literature review study in science education, however, researchers have not found a literature review study investigating the steps of the EDP used in Science, Physics, Biology, Chemistry, and Science combined with other disciplines. On top of that, this research also explains the strengths and weaknesses of the EDP in science education.

Additionally, the results of several studies suggest that EDP implementation can increase students' content knowledge (Chao et al. 2017; Aydin-Gunbatar, Tarkin-Celikkiran, Kutucu, & Ekiz-Kiran, 2018; Guzey, 2017), students' problem-solving skills (English, Hudson, & Dawes, 2013; Syukri, Halim, Mohtar, & Soewarno, 2018), as well as teachers' views on the implementation of the engineering design process in their teachings (Pleasants, Olson,

& De La Cruz, 2020). Furthermore, Shahali, Halim, Rasul, Osman, and Zulkifeli (2016) explain that EDP implementation can also generate interest in STEM subjects and careers. Based on these results it shows that the implementation of EDP is not only beneficial for students, but also for teachers. Therefore, systematic review research pertaining to steps of EDP is important to be carried out. The results of this study can be used as a reference for stakeholders in the field of science education when implementing EDP in their learning.

### Problem of Study

Currently, the implementation of learning science still experiences several obstacles, such as students' assumption that implies science subjects are difficult, uninteresting, and abstract (Winarno, Rusdiana, Riandi, Susilowati, & Afifah, 2020). Guzey, Harwell, Moreno, Peralta, and Moore (2016) also explained that most science teachers lack information regarding the usage of EDP in learning science. Based on this, the literature review research relating to the EDP is needed by stakeholders relating to science education. The results of this study can illustrate the steps of the EDP used in science education. Steps of the EDP can also be adapted to be implemented in learning in other fields. In this study, the authors aim to review 40 articles from international journals relating to the steps of the EDP in science education. The reviewed article was published from 2011 to 2020. The research questions determined in this study is the following:

- How is the representation of research according to their general characteristics?
- What are the steps of the engineering design process (EDP) in science education?

## Method

### Research Design

The research approach used was a systematic literature review. A systematic literature review is a review of the research literature using systematic and explicit accountable methods. A systematic review aims to obtain explicit, rigorous, and accountable methods. The systematic literature review conducted focuses on answering specific research questions (Gough, Oliver, & Thomas, 2017).

### Data Collection

In this study, the authors chose 40 reputable international journals from 2011 to 2020. A summary of the journals chosen for review can be seen in Table 1.

**Table 1.**

*Summary of Selected Journals for Review*

| No | Name of journal | f | Indexed By | H-Index (SJR 2019) |
|---|---|---|---|---|
| 1 | Journal of Research in Science Teaching | 2 | Scopus (Q1) & WoS | 121 |
| 2 | Science Education | 3 | Scopus (Q1) & WoS | 108 |
| 3 | International Journal of Science Education | 4 | Scopus (Q1) & WoS | 102 |
| 4 | Journal of Engineering Education | 3 | Scopus (Q1) & WoS | 101 |
| 5 | The Journal of Educational Research | 1 | Scopus (Q1) & WoS | 71 |
| 6 | Journal of Science Education and Technology | 4 | Scopus (Q1) & WoS | 56 |
| 7 | Research Science Education | 2 | Scopus (Q1) & WoS | 50 |
| 8 | Chemistry Education Research and Practice | 1 | Scopus (Q1) & WoS | 40 |
| 9 | International Journal of Technology and Design Education | 3 | Scopus (Q1) & WoS | 37 |
| 10 | International Journal of Science and Mathematics Education | 5 | Scopus (Q1) & WoS | 35 |
| 11 | European Journal of Engineering Education | 1 | Scopus (Q1) & WoS | 41 |
| 12 | Journal of Baltic Science Education | 1 | Scopus (Q2) & WoS | 14 |
| 13 | Journal of Pre-College Engineering Education Research | 6 | Scopus (Q1) | 8 |
| 14 | Eurasia Journal of Mathematics Science and Technology Education | 1 | Scopus (Q2) | 31 |
| 15 | Jurnal Pendidikan IPA Indonesia | 1 | Scopus (Q2) | 8 |
| 16 | Australasian Journal of Engineering Education | 1 | Scopus (Q2) | 5 |
| 17 | Journal for the Education of Gifted Young Scientists | 1 | Scopus (Q3) | 7 |
| | **Total** | **40** | | |

Based on table 1, it is explained that the articles chosen for review consisted of 17 reputable international journals indexed by Scopus and Web of Science (WoS). All of these articles, on average, have a high H-index. Therefore, the authors concluded that the articles chosen for review are of good quality and can be accounted for.

**Data Analysis**

This study analyzes the representation of research according to their general characteristics and the steps of the EDP in science education. Data were collected and interpreted in tables and figures, then analyzed descriptively. The results of the data analysis are in the form of numbers or percentages. In the discussion section, the authors explained the relationship between the results of this study with the results of previous studies. Furthermore, the results of the discussion will explain the strengths and weaknesses of the implementation related to the steps of EDP in science education.

**Research Procedure**

The authors adapted the research procedure from the Martín-Páez, Aguilera, Perales-Palacios, and Vílchez-González (2019) studies, which explained that there are several stages used in the literature review research. The stages of the review process can be seen in Figure 1.


**Figure 1.**
*Stages of the Review Process*

In the clarification and approach stages, the authors investigated the reasons for reviewing articles related to the steps of the EDP in science education, then determined research questions, article criteria, and formed the research framework. In the searching, screening, and selecting stages, the authors searched for articles explaining the steps of the EDP in science education. The authors searched for articles on the publisher's website or directly to the journal's website. The authors then screened and validated other researchers to ensure that the selected articles fit the criteria. To guarantee the quality of the articles reviewed, the authors only chose articles from Scopus indexed journals by Elsevier with categories Q1, Q2, and Q3 in SJR 2019. The authors searched for articles in several publishers, such as John Wiley and Sons Inc., Wiley-Liss Inc., Taylor and Francis Ltd., Wiley-Blackwell, Routledge, Springer Netherlands, Ioannina University School of Medicine, Scientific Methodical Center, Purdue University Press, Modestum Ltd., and others. Researchers use keywords like "engineering design," "engineering design in science education," "steps of the EDP," or other keywords. As a result, the authors found two hundred of articles related to EDP. However, the authors decided that only 40 articles were selected for review. The selection of 40 journals is based on the validity and reliability of other researchers. Researchers stated that the article was following specified criteria. We selected 10 articles indexed by Scopus. In addition, 30 other articles are indexed both Scopus and Web of Science (WoS). In the analyzing and interpreting phase, the authors analyzed the representation of the characteristics of the study. The results of the data analysis were then described using tables and figures. Also, we discuss and interpret the results obtained. The results of the data analysis were made to be a draft article. Thereafter, the authors adjusted the article draft with the intended journal template. In the final stage, the article was sent to international journals for publication.

## Results

### Theme 1. Representation of Research According to Their General Characteristics

In this study, the representation of research according to their general characteristics consists of type of publication, year of publication, country, research approach, educational level, and science content.

### Representation of Research based on Types of Publications

The results of this study were published either in journals, proceedings, books, theses, or others. The representation of research based on the type of publications can be seen in table 2.

**Table 2.**

*Representation of Research According to The Type of Publications*

| No | Type of Publications | Number of articles (f) | % |
|---|---|---|---|
| 1 | Journal | 40 | 100 |
| 2 | Proceeding, book, thesis, or others | 0 | 0 |
| | **Total** | **40** | **100** |

Table 2 explained that the type of publication chosen for review was taken from 40 articles. Researchers did not take publications from proceedings, books, theses, or others so that the articles selected for review are of good quality. It can also be concluded that based on the data, articles selected for review are 100% from international journals.

### Representation of Research based on the Year of Publication

The year of publication was determined by seeing the year of the published article in a journal. Representation of research based on the year of publication can be seen in Figure 2.

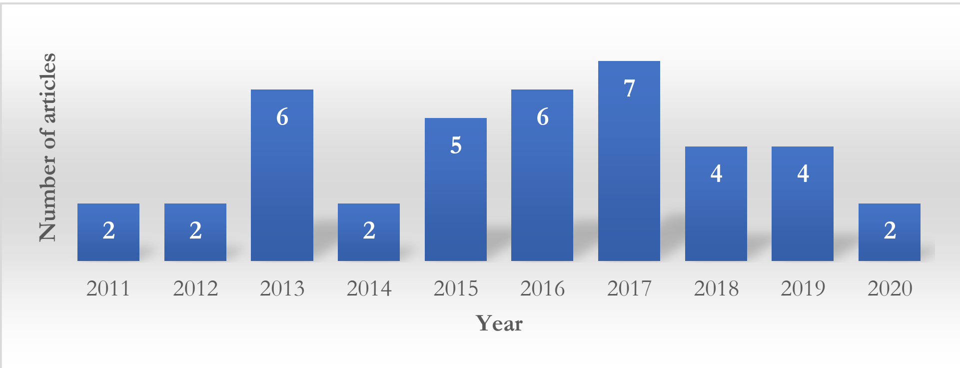


**Figure 2.**

*Representation of Research-Based on the Year of Publication*

Figure 2 explains the selected articles relating to the steps of engineering design in science education were from 2011 to 2020. The 40 articles selected for review consist of 2 articles (2011), 2 articles (2012), 6 articles (2013), 2 articles (2014), 5 articles (2015), 6 articles (2016), 7 articles (2017), 4 articles (2018), 4 articles (2019), and 2 articles (2020). The most reviewed articles are seven articles published in 2017. The least reviewed articles were published in 2011, 2012, 2014, and 2020, each with two articles. Based on these data, it is concluded that the articles selected for review are the ones published in the last ten years. It shows that the articles reviewed are up to date, so the results of this study can be used by stakeholders related to science education or further researchers.

### Representation of Research Based on the Country Implementing It

The authors determined the country that implements the steps of the EDP in science education by looking at the location of research or affiliation of the first author (corresponding author) in the article. Representation of research based on the country implementing it can be seen in Figure 3.

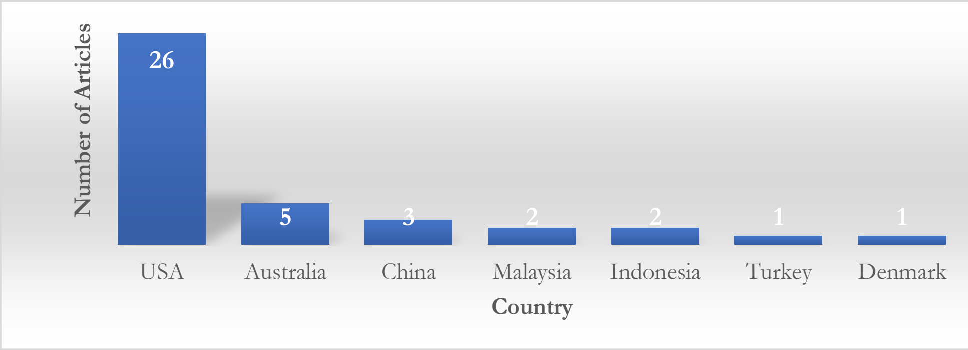


**Figure 3.**
*Representation of Research Based on the Country Implementing It*

Figure 3 shows that the country with the most published articles related to the steps of the EDP is the United States of America (USA) with 26 articles, while the country with the least published articles related to the steps of the EDP is Denmark and Turkey, each of which was 1 article. Currently, most research that uses the EDP in science education has been implemented in the United States of America (USA) compared to other countries such as Australia, China, Malaysia, Indonesia, Turkey, and Denmark. This is because the United States of America (USA) is one of the pioneer countries implementing the EDP in science education. Meanwhile, other countries rarely implement the engineering design process in science learning. Based on these data, it is concluded that the research explaining the steps of the EDP is still dominated by a few countries. So, the results of this study can show the mapping of countries that have implemented the engineering design process in science education.

**Representation of Research Based on the Research Approach**

The research approach used in the studies consists of qualitative, quantitative, mixed methods, or other approaches. A summary of the research approach to the 40 articles selected for review can be seen in Table 3.

**Table 3.**
*Representations of Research Based on the Research Approach*

| No | Research Approach | f | (%) |
|---|---|---|---|
| 1 | Qualitative | 17 | 42.50 |
| 2 | Quantitative | 12 | 30.00 |
| 3 | Mixed Methods | 11 | 27.50 |
| | **Total** | **40** | **100** |

Based on Table 3, the most used research approach is qualitative with 17 articles (42.50%), while the least used research approach is mixed methods with 11 articles (27.50). Based on these data, it is concluded that the research approach used for research related to the EDP consists of qualitative, quantitative, mixed methods.

**Representation of Research Based on Educational Level**

The determination of the educational level in this study can be seen from research participants. Representation of research based on the educational level can be seen in table 4.

**Table 4.**
*Representations of Research Based on the Educational Level*

| No | Participants | Educational Level | f | (%) |
|---|---|---|---|---|
| 1 | Student | Elementary school | 7 | 17,50 |
| | | Secondary school | 13 | 32,50 |
| | | High school | 6 | 15.00 |
| | | University | 1 | 02,50 |
| | | Elementary & middle school | 2 | 05.00 |
| | | Secondary & high school | 1 | 02.50 |
| 2 | Teacher | Elementary | 6 | 15.00 |
| | | Secondary School | 3 | 70.50 |
| 3 | Others | Undergraduate & graduate students | 1 | 02.50 |
| | | **Total** | **40** | **100** |

Table 4 shows the participants in the study that is related to the steps of the EDP. They consist of students, teachers, and others. Most research used participants from secondary school students with 13 articles (32.50%), while very little research used participants from university students and a combination of undergraduate and graduate students with 1 article each (02.50%). Based on these data, it is concluded that the implementation of research using the EDP approach is still very limited at the university level.

**Representation of Research Based on the Science Content**

The determination of science content in this study can be seen from the participants, subjects, or topics chosen in their research. The participants, subjects, or topics are all related to science. The representation of research based on science content can be seen in Table 5.

**Table 5.**
*Representations of Research-based on Science Content*

| No | Science content | f | (%) |
|---|---|---|---|
| 1. | Science | 16 | 40.00 |
| 2. | Physics | 13 | 32.50 |
| 3. | Biology | 3 | 07.50 |
| 4. | Chemistry | 3 | 07.50 |
| 5. | The combination of science with other disciplines | | |
| | • Science & mathematics | 3 | 07.50 |
| | • Science, mathematics, science & mathematics, general, computer | 1 | 02.50 |
| | • Physics & Biology | 1 | 02.50 |
| | **Total** | **40** | **100** |

Table 5 shows that the science content in research related to the steps of the EDP consists of Science, Physics, Biology, Chemistry, and the combination of science with other disciplines. Based on these data, it is concluded that research related to the steps of the EDP is rarely implemented in interdisciplinary knowledge or integrated science. Most of the engineering design process research published is related to physics content. Physics topics are more easily implemented using the engineering design process than in other fields.

**Theme 2. Steps of the Engineering Design Process (EDP) in Science Education**

In this study, the steps of the EDP are divided based on their science content, such as Science, Physics, Biology, Chemistry, and a combination of science with other disciplines. The steps of the EDP used in science can be seen in table 6.

**Table 6.**
*Steps of EDP Used in Science Education*

| No | Steps of Design | E.g., (only first author cited) |
|---|---|---|
| 1. | Define the problem, plan possible solutions, choose the possible solution, design, test, redesign, and communicate | Mesutoglu (2020) |
| 2. | Learn, plan, teach, reflect | Wendell (2019) |
| 3. | Analysis, problem-solving, learning, evolution, the creation of solutions to problems, integrating into a coherent whole and a fundamental human activity | Lie (2019) |
| 4. | Defining the problem, identifying criteria, generating ideas, evaluating | Yu (2019) |
| 5. | Design, construct, test, redesign, review the EDP | McFadden (2018) |
| 6. | Define the problems, investigate possible solutions, create, test, analyze, and optimize | Watkins (2018) |
| 7. | Designing, building, test, redesign, rebuild, and retest | Guzey (2017) |
| 8. | Identify of the problem, design, create and improve models, communicate | Maeng (2017) |
| 9. | Identify the problem, develop a plan, create, test, communicate result, improve and retest | Capobianco (2018) |
| 10. | Articulate multiple solutions, evaluate, select solutions, retell the performance of the solution, analyze solutions, improvements | Wendell (2017) |

| No | Steps of Design | E.g., (only first author cited) |
|---|---|---|
| 11. | Identify and investigate the problem, draw/sketch possible ideas, choose the best possible solutions, design, test, evaluate, and communicate | Siew (2016) |
| 12. | Problem, brainstorm, experiment, design, build, redesign/test, solution | English (2016) |
| 13. | Observing, generating questions, conducting investigations, analyzing, and reflecting | Capobianco (2014) |
| 14. | Identifying problems, gathering information, modeling, and analyzing potential solutions, prototyping, testing, and analyzing prototype performance | Wendell (2013) |
| 15. | The designing invention, test design, achieved functionality of the invention, and collaboration | Dohn (2013) |
| 16. | Identity problem, create a design, test design, create and test model, final model | English (2012) |

Table 6 shows that 16 articles explained the steps of EDP in science. Based on these data, it is concluded that each study uses steps of the EDP in science, which differs from one research to another. Furthermore, the steps of the EDP in Physics can be seen in table 7.

**Table 7.**
*Steps of the EDP Used in Physics*

| No | Steps of Design | E.g., (only first author cited) |
|---|---|---|
| 1. | Identify and define a problem, gather information, identify the possible solution, create a prototype/make a model, test the model, reflect and redesign, and communication | Nurtanto (2020) |
| 2. | Design, build contrasting cases, and reading. | Chase (2019) |
| 3. | Asking, imagining, planning, creating, and improving | Syukri (2018) |
| 4. | Representation, analysis, and reflection | Chao (2017) |
| 5. | Make a sketch, prototyping, design aims, predictions about design, generate design ideas, design of the structure, design of system/process, materials, and collaboration | Zhou (2017) |
| 6. | Problem, brainstorm, design, build, test, redesign, solution | King (2016) |
| 7. | Ask, imagine, plan, create, improve | Shahali (2016) |
| 8. | Explain the need, characterize the need, generate concepts, select a concept, embody the concept, test and evaluate, finalize and share the design, reflect on the design process | Valtorta (2015) |
| 9. | Design, predictive analysis, construction, evaluation, and redesign of mechanism models | Fan (2015) |
| 10. | Defining the problem, gathering information, planning, building, testing, evaluating, redesigning, and communicating | Bamberger (2013) |
| 11. | Design, construct, test, and evaluate | English (2013) |
| 12. | Define the problem, investigating possible solutions, selecting the best solution, designing a prototype, testing, repeating any steps needed, improving the design. | Marulcu (2013) |
| 13. | Introduce design challenge, build, test, discuss designs, rebuild/retest, posttest | Schnittka (2011) |

Table 7 shows that 13 articles explained the steps of the EDP in Physics. Based on these data, it is concluded that each study uses steps of the EDP in Physics, which varies from one to another. Furthermore, the steps of the EDP in Biology can be seen in Table 8.

**Table 8.**
*Steps of the EDP Used in Biology*

| No | Steps of Design | E.g., (only first author cited) |
|---|---|---|
| 1. | Problem, plan & implement, test, evaluate | Johnston (2019) |
| 2. | Define the problem, plan, carry out investigations, design, evaluate, and redesign | Lie (2019) |
| 3. | Problem, plan, implement, test, and evaluate | Crotty (2017) |

Table 8 shows that three articles explained the steps of the EDP in Biology. Based on these data, it is concluded that each study uses the steps of the EDP in Biology, which varies from one to another. Furthermore, the steps of the EDP in Chemistry can be seen in table 9.

**Table 9.**
*Steps of the EDP used in Chemistry*

| No | Steps of Design | E.g., (only first author cited) |
|---|---|---|
| 1. | Brainstorming study, design, construction & testing, redesign, and evaluation | Aydin-Gunbatar (2018) |
| 2. | Researching, modeling, implementing, measuring, communicating | Hammack (2015) |
| 3. | Eliciting, adding, distinguishing, and sorting out ideas | Chiu (2011) |

Table 9 shows that three articles explained the steps of the EDP in Chemistry. Based on these data, it is concluded that each study uses steps of EDP in Chemistry, which differ from one another. Steps of the EDP used in the combination of science with other disciplines can be seen in table 10.

**Table 10.**
*Steps of the EDP Used in the Combination of Science with Other Disciplines*

| No | Steps of Design | Science Content | E.g., (only first author cited) |
|---|---|---|---|
| 1. | Define the problems, design, and optimize | Science & Math | Park (2016) |
| 2. | Teacher preparation, curriculum content, and context, resources, constraints, goals, design processes, representing and constructing, collaborating, evaluating, documenting, and reporting | Physics & Biology | Ward (2016) |
| 3. | Define the problem, generate or select possible solutions, modeling, analysis and iteration | Math & Science | Berland (2014) |
| 4. | Understand the problem, quantify the need, engineer the concept, embody the concept, implement the design, and finalize the design. | Science & Math | Berland (2013) |
| 5. | Identify the problem, investigate the problem, develop and choose the possible solution, design, test, evaluate, communicate, and redesign. | Science; Math; General, Computer, Science and Math | Hynes (2012) |

Table 10 shows that five articles explained the steps of the EDP in the combination of science with other disciplines. Based on these data, it is concluded that each study uses steps of the EDP in Biology, which varies from one research to another. After the authors analyze the steps of the EDP in Science, Physics, Biology, Chemistry, or a combination of science with other disciplines. Based on this analysis, the authors found that the steps of the EDP in science education vary from one study to another. Although each study uses different steps of the engineering design process, the results of the research have a positive impact on students.

## Discussion and Conclusion

The authors reviewed 40 articles from reputable international journals related to the steps of the EDP in science education. This study discusses the representation of research according to their general characteristics. These general characteristics consist of the type of publication, year of publication, country, research approach, educational level, and science content. The authors also investigate the steps of the EDP used in science education. Several previous studies analyzed the representation of research characteristics to explain the general description of the articles reviewed

(Martín-Páez, Aguilera, Perales-Palacios, & Vílchez-González, 2019; Jayarajah, Saat, Rauf, & Amnah, 2014). Furthermore, Deveci and Çepni (2017) explained that the research representation based on the type of publication, year of publication, country, research approach, educational level, and science content is one of the initial stages required to be explained in the literature review research. Based on the data analysis' result, the representation of the characteristics of the study shows that the articles selected for review are those published in the last ten years, from 2011 to 2020. Most of these articles have a high H-index based on the 2019 SJR data. All of these articles originated from international journals indexed by Scopus or Web of Science, so the authors provide a guarantee that the reviewed articles are of good quality. Research explaining the steps of the EDP in science education is still dominated by a few countries. The United States of America (USA) is the country that has implemented the approaches in its learning the most. According to Guzey, Harwell, Moreno, Peralta, and Moore (2016), the EDP is a new learning approach that can be used in teaching science. Based on this statement, other countries -especially developing countries- are expected to try to implement the EDP in learning science, both at the primary educational level as well as at the university level. All of the 40 articles reviewed use varied research approaches such as qualitative, quantitative, and mixed methods. The most used research approach is qualitative, while the least used research approach is a mixed method. Most research approaches using a qualitative method for collecting data use interviews, questionnaires, observation, audio/video recording, and others. Data collection using content tests (cognitive) tends to implement fewer EDP in science education. The representations of research based on the educational level and science content are also analyzed in this study. The results of the analysis stated that the implementation of research using the EDP approach is still very limited at the university level. Also, research implementing steps of the EDP is still rarely found in interdisciplinary knowledge or integrated science. According to Winarno, Widodo, Rusdiana, Rochintaniawati, and Afifah (2019), students' conceptual understanding of integrated science courses is still below expectations. Consequently, the STEM approach through the EDP can be one alternative approach to implementing integrated science.

This study analyzes the steps of the EDP that is commonly used in science education. Research explaining the steps of the EDP is divided based on its science content, such as Science, Physics, Biology, Chemistry, and a combination of science with other disciplines. The results show that the articles explaining the steps of the EDP in science totaled 16 articles, 13 physics articles, 3 biology articles, 3 chemistry articles, and 5 articles in a combination of science and other disciplines. The results show that research in Science, Physics, Biology, Chemistry, and a combination of science with other disciplines used steps of the EDP that differ from one research to another. Although the steps of the EDP used in each study are different, the authors conclude that the steps of the EDP have several stages in common. The difference between each study is that there are additional or reduced stages in the EDP cycle. Bamberger and Cahill (2013) used the steps of the EDP by starting from defining the problem, gathering information, planning, building, testing, evaluating, redesigning, and communicating, while Shahali, Halim, Rasul, Osman, and Zulkifeli (2016) used the steps of the EDP by starting from asking, imagining, planning, creating, improving. Besides, Schnittka (2011) used the steps of engineering design from introducing design challenges, building, testing, discussing designs, rebuilding and retesting, and post-testing. Based on the analysis of 40 articles, the authors conclude that most stages of the EDP include defining problems, building, testing, evaluating, and redesigning. The results of the study are consistent with previous research, explaining that most researchers use four stages - drawing, making, testing, and redesigning (Arık & Topçu, 2020). However, the difference between this research and previous research locates at the scope of the research. Previous literature review research only investigated the steps of engineering in K-12 science classrooms, while the authors in this study analyze with a broader scope, including students (K-12 classrooms), undergraduate or graduate students, and teachers. Even though this study has a broader scope compared to previous studies, the results of this study are consistent with previous research, which states that the steps of the EDP for students (K-12 classroom), undergraduate students, graduate students, or teachers are similar in several stages.

The EDP also has strengths and weaknesses in its implementation. The strengths and weaknesses of the EDP usage have not been explained in previous studies. Based on the data analysis, there are several strengths of research using steps of EDP in science education. There have been various advantages for students, undergraduate students, teachers, or others by learning using EDP. This statement is supported by several previous studies that explained the implementation of the EDP could increase participation, student interest, and self-concept in 274 elementary students (Capobianco & French, 2014). Furthermore, Schnittka (2011) stated that the use of EDP could improve 27 middle school students' conceptions on the topic of heat transfer and thermal energy. Moreover, the EDP also had a positive effect on conceptual understanding, higher-order thinking (HOT), and the ability to design a project in 332 high school students (Fan & Yu, 2015). According to Chase, Malkiewich, and Kumar (2019), 41 graduate and undergraduate students could pay attention to learning at a deeper level and improve the transfer situation after implementing the EDP. Currently, the EDP is not only implemented by students, but also by teachers. The results showed that the implementation of the EDP could contribute to higher science teachers' understanding from the study of 30 middle school science teachers (Mesutoglu, & Baran, 2020).

There are some weaknesses to the implementation of the EDP in learning science. The author believes that the implementation of the EDP requires more time compared to using other learning approaches. That is because students, not only develop a project but also evaluate and redesign the project. Furthermore, educators still face difficulty in designing science learning using EDP. Most educators have difficulty in determining the suitable project and the stages for implementing the EDP. Students also still face difficulty understanding the connection between the projects they develop and the topics studied. Most research related to the EDP is dominated to improve students' attitudes and skills compared to students' cognitive. Steps of the EDP -such as defining the problem, gathering information, planning, building, testing, evaluating, and redesigning- are suitable for training students' attitudes or skills. This is because the steps of the EDP implemented toward students tend to focus on activities developing their projects. For courses with learning objectives like mastery of concepts (content), the authors suggest that there should be variations in other stages of learning, so there will be a balance between conceptual grading and attitudes/skills that will be trained on students. The results of the problem analysis are consistent with several previous studies, which stated that there are some weaknesses in the implementation of the EDP in learning science (Capobianco, 2011). According to Berland et al. (2013), the EDP is still not consistent in its implementation. The results of this study are also supported by several other studies that explain students find it difficult to integrate science with the projects they develop (Chao et al. 2017). Moreover, engineering design is a learning approach considered new, so there are still some obstacles in implementing it (Guzey, Harwell, Moreno, Peralta, & Moore, 2016).

Based on these explanations, we conclude that the EDP in science education still experiences several obstacles in its implementation. The EDP is a new learning approach, so the information obtained by science educators has not reached an optimal level. Based on these problems, literature review research explaining the steps of the EDP in science education is needed for stakeholders in science education. The results of these studies can provide comprehensive information about the steps of the EDP for teachers, lecturers, or further researchers. The authors have reviewed 40 articles from reputable international journals related to the steps of the EDP in science education. This research investigates the representation of the general characteristics of the study and the steps of the EDP used in science education. The representation of the general characteristics of the study shows that the articles selected for review are from 2011 to 2020. Furthermore, all articles are taken from Scopus or Web of Science indexed journals, so the authors ensure that the reviewed articles are of good quality. Research explaining the steps of the EDP in science education is still dominated by a few countries. The research approach that is used varies, such as qualitative, quantitative, and mixed methods. Research using the EDP approach still has limitations to be implemented at the university level, particularly in courses related to interdisciplinary knowledge or integrated science. The implementation of the steps of the EDP used in Science, Physics, Biology, Chemistry, and the combination of science with other disciplines is different from one research to another. The advantage of learning using the EDP is in its numerous benefits for science education stakeholders, while the weakness of the EDP is in the obstacles it faces in the implementation.

## Recommendations

The results of this study provide an overview of how to implement the EDP in science education. Thus, it may encourage science educators or educators of other disciplines to implement the EDP in learning. The implementation of the EDP is still very limited at the university level, especially in subjects related to interdisciplinary knowledge. The authors recommend implementing EDP in integrated science courses at the university level. Furthermore, the steps of the EDP are expected to be implemented in science education or other fields.

## Limitations of the Study

This study only analyzed journals explaining the usage of the steps of the EDP in science education. All articles selected for review are from January 2011 to June 2020. All articles are indexed by Scopus (Q1, Q2, and Q3) or Web of Science (WoS)

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