The Development of STEM-Discovery Learning Module in Differential Equations: A Need Analysis

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Abstract
The Differential Equations (DE) is an important subject for solving the problems in various fields. However, the teaching and learning of DE in Indonesia are still textbooks-oriented, focusing on delivery knowledge and not considering learning psychology principles. The module is one of the teaching materials that can be used to promote students’ activities. Hence, this study aimed to analyze the students’ responses to the need for a Science, Technology, Engineering, and Mathematics (STEM)-Discovery Learning Module in teaching and learning of DE. The respondents were 124 students, 96 females and 28 males in mathematics and mathematics education in fifteen public and private universities in Indonesia. The data were collected by questionnaires and analyzed descriptively. The results revealed that about 60% of respondents stated that the teaching and learning of DE are teacher-centered and without the module. Almost 7% of respondents confirmed the use of the STEM approach in learning, and more than 95% of students believe the importance of developing the STEM-Discovery Learning Module to improve the quality of learning. In conclusion, the STEM-Discovery Learning Module development is in high demand for T&L of DE.

Keywords
Differential Equations, STEM, Discovery Learning, Module Development, Need Analysis
Introduction

Differential Equations (DE) is one of applied mathematics that can be used to solve the problems in many various fields, not only in mathematics, but also other fields such as biology, physics, chemistry, engineering, economic, and social. Aisha, Zamri, Abedalaziz, and Ahmad (2017) stated that the concepts of DE can be used to formulate a mathematical model from the daily life problems. In Indonesian universities, DE becomes a compulsory course in mathematics or mathematics education and engineering majors. One of the important goals in Teaching and Learning (T&L) mathematics is to improve students understanding of the subject-matter which is demonstrated by their learning outcome. Similarly, the objective of T&L of DE is to promote the students understanding about topics in DE such as first order DE, first order linear DE, and higher order linear DE. The learning outcome which is presented by their achievement on the test is one of instrument to measure the students’ performance. However, based on the experience in teaching DE, the students are still difficult to understand the topics in DE which is presented in their low-achieving performance in test.

Many studies reported that teacher (lecturer) plays an important role to improve the students’ achievement, not except in higher education. Schneider and Preckel (2017) stated that the lecturer can improve the effect of T&L in higher education. The lecturers should be creative by modifying or developing teaching materials into various forms such as a learning module. Module is a T&L unit which discusses a specific topic systematically and sequentially that can enables students to learn by themselves to easily master a unit of learning (Mohd Noah & Ahmad, 2017). Science, Technology, Engineering, and Mathematics (STEM) education is a T&L approach which integrates the four disciplines of science, technology, engineering, and mathematics in class, unit, or lesson based on the relation between the real-life problems with these disciplines (Moore & Smith, 2014). One of instructional practices referring to the use of inquiry in integrated STEM is discovery learning. Thibaut et al. (2018) explained that in the discovery learning, the learners construct the new knowledge developed from prior knowledge and active experience. However, there was a limited study on STEM based discovery learning in T&L of DE. Moreover, there was no learning module to support the STEM based discovery learning in DE. This study aims to analysis the need for STEM-Discovery Learning Module in the T&L of DE.

Literature Review

Differential Equations

Differential Equations (DE) is a branch of mathematics that is commonly used in many areas, not only in mathematics but also in other areas such as chemistry, engineering, physics, biology, psychology, economy and social. Vajravelu (2018) stated that the DE course introduce science, engineering, and mathematics can be. Besides, it can develop the students’ communication skills, critical thinking skills, reasoning, and knowledge integration. There are many real life problems that cannot be solved directly. Aisha, Zamri, Abedalaziz and Ahmad (2017) argued that the concept of differential equations can be used to make a mathematical model from daily life problems. The three main learning objectives in DE course are: to formulate the problems into differential equations model, to solve the model of differential equations analytically or approximately, and to interpret the solution which is found (Edwards & Penney, 2015). The differential equations is an important subject in various majors. However there is a few research done in this area (Rasmussen, 2016). Spindler (2019) found that project-based learning in differential equations course deeply impact students in motivation, persistence, mathematical learning, and communication skills. A computer algebra system and active learning pedagogical approaches have been implemented in DE course. The finding revealed that the students’ mathematical thinking can be improved by using these strategies (Zeynivandnezhad & Bates, 2018).

Science, Technology, Engineering, and Mathematics (STEM)

STEM is an acronym for Science, Technology, Engineering, and Mathematics. Science represents the knowledge and concepts. Technology is a skill or a system used for managing society, organization, and knowledge, designing and using an artificial tool that can facilitate work.
Engineering includes the knowledge to operate or design a procedure to solve a problem. Mathematics is a science which connects quantities, numbers, and spaces that only require logical arguments with or without empirical evidence (Torlakson, 2014).

Fan & Yu (2016) proposed the characteristics of STEM as follows: (1) stating issues in STEM as daily life problems, (2) designing curriculum based on project, problem, or inquiry, (3) focusing on the objective of course, content domains, and indicators of learning formulated explicitly, (4) allowing student-centered learning, (5) emphasizing the integrated STEM, (6) Stressing the high order thinking involving logical thinking, problem solving, and critical thinking, and (7) stressing on the intercourse of curriculum and the markets of job. The advantages of STEM education are 1) integrated training in "topics", not subjects, 2) using the scientific and technical knowledge in real life, 3) enhancing the critical thinking skills and problem solving, 4) improving self-confidence, 5) developing an active communication, and teamwork, 6) developing an interest in technical disciplines, 7) making creative and innovative approaches to projects, 8) the bridge between education and careers, and 9) prepare the children for technological innovation in their lives (Morze, Smyrnova-Trybulska, & Gladun, 2018). In the T&L process, STEM gave a positive impact on the students’ achievement and attitude in low education (Acar, Tertemiz, & Taşdemir, 2018; Ayaz, Şekerci, & Orall, 2016; Uğraş, 2018). However, the result of a meta-analysis study confirmed that STEM education is more effective in improving students' academic achievement in low and higher education levels (Saraç, 2018).

### Discovery Learning

Discovery learning is one of instructional practices referring to the use of inquiry in integrated STEM. (Thibaut et al., 2018). In Indonesia, discovery learning is highly recommended learning model to strengthen the scientific, thematic, and holistic learning process (Permendikbud, 2016). The Ministry of Education and Culture described the syntaxes of discovery learning such as stimulation, problem-oriented, data collecting, data processing, verification, and generalization (Ariyana, Bestary, Zamroni, & Pudjiastuti, 2018). The main characteristics of discovery learning are: (1) exploring and solving problems to create, combine and generalize the knowledge; (2) learner-centered; (3) combining new knowledge and existing knowledge. The advantages of the discovery learning are serving the students opportunities to be a problem solver, a scientist, or mathematicians (Kemdikbud, 2017). Many previous studies revealed the positive impacts of discovery learning model in the T&L. Discovery learning model effectively promoted the students’ mathematics achievement (Amiyan & Widjajanti, 2019; Hong, Thuy An, & Triet, 2017). The discovery learning model can also foster the student critical thinking skills (Julita, Putra, Perrianty, & Yenti, 2019; Robi, Hobri, & Dafik, 2018).

### Module

Module is a teaching and learning unit that discusses a specific topic systematically and sequentially. The module can facilitate the students to learn individually and easily (Sidek & Jamaludin, 2017). Prastowo (2015) argued that module will helps the students to learn independently according to their level of knowledge and age. With the module, the role of teacher or lecture will change to be a facilitator rather than instructor. The module can also encourage the students to teach themselves and does not depend on the media used (Hamdani, 2011). Basri (2015) stated that the module can provide the opportunity of the students to verify theirs’ own abilities by doing the exercises served in the module, develop the student ability to interact directly with the environment and other learning resources. The use of modules in the teaching and learning process has a positive impact on various abilities. Julita, Putra, Perrianty, and Yenti (2019) have developed the discovery learning module with probing prompting technique to increase the students’ critical thinking skill in salt solution. Ellizar, Hardeli, Beltris, and Suharni (2018) also have developed the module to facilitate the students in understanding the learning concept in chemistry. In their research, they designed the module based on discovery learning and scientific approach. The development the module based on STEM have also been conducted by some researchers. Hasanah, Aisyafahmi, and Fauziana (2019) integrated STEM Biotechnology Modules (Science, Technology, Engineering, and Mathematics) to enhance the creative thinking skills students in high school. However, none of the researchers have developed STEM Discovery Learning in T&L of DE course.
Methods/Methodology

Research Design

The research employed descriptive survey design which is conducted within three months in January until March 2020. The respondents are 124 college students, 28 males and 96 females from Mathematics and Mathematics Education Program in fifteen public and private universities in Indonesia. All selected respondents have passed or being studying the DE course. Therefore, they have experienced with the teaching and learning model carried out by their lecturer in DE course. Hopefully, the information from such respondents is accurate to answer the research problems of this study.

Data Collection

The data were collected by the questionnaire which contains two parts, A and B. Part A involves the questions about the respondent’s demographic: gender, student status, and type of university. Part B consists of three main questions on the questionnaire: learning approach in DE course (one item), characteristic of T&L process in DE course (three items), and the need for STEM-Discovery Learning module development (three items). The purpose of the questions in Part B is to reveal the need of the development of STEM-Discovery Learning module in DE course. In case of the pandemic Covid-19 situation, the data collection was employed by online using Google Form. The sample questions in Google Form are presented as Figure 1 follows:

![Sample of Questions](attachment:figure1.png)

**Figure 1.** Sample of Questions

Data Analysis

The data from the questionnaire were processed in the form of percentage. Therefore, the data of the percentage would be analyzed descriptively to reveal the meaning of the information presented.
Result and Discussion

Part A of Questionnaire

There are three questions in part A: gender, student status and university. This study involves 124 students, 28 males and 96 females in Mathematics and Mathematics Education Program in fifteen public and private universities in Indonesia. Most of the respondents are the student who have enrolled the DE course in the private university in Central Java. The data of the demographic of research respondents are presented in Table 1.

Table 1. Demographics of Respondents

<table>
<thead>
<tr>
<th>Respondents Identity</th>
<th>Frequency</th>
<th>Percentage (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gender: Male</td>
<td>28</td>
<td>22.58</td>
</tr>
<tr>
<td>Female</td>
<td>96</td>
<td>77.42</td>
</tr>
<tr>
<td>Status: Have enrolled DE Course</td>
<td>97</td>
<td>78.23</td>
</tr>
<tr>
<td>Enroll DE Course</td>
<td>27</td>
<td>21.77</td>
</tr>
<tr>
<td>Region: East Java</td>
<td>8</td>
<td>6.45</td>
</tr>
<tr>
<td>Central Java</td>
<td>103</td>
<td>83.06</td>
</tr>
<tr>
<td>West Java</td>
<td>6</td>
<td>4.84</td>
</tr>
<tr>
<td>DIY</td>
<td>6</td>
<td>4.84</td>
</tr>
<tr>
<td>Outside Java</td>
<td>1</td>
<td>0.81</td>
</tr>
<tr>
<td>Type of University: Public</td>
<td>50</td>
<td>40.32</td>
</tr>
<tr>
<td>Private</td>
<td>74</td>
<td>59.68</td>
</tr>
</tbody>
</table>

Part B of Questionnaire

In part B, there are three main questions on the questionnaire: learning approach in DE course, characteristic of T&L process in DE course, and the need for STEM-Discovery Learning module development

Learning Approach in DE Course

The result study indicates that there are various learning approaches used in the T&L of DE such as STEM, Project based learning, Problem based learning, inquiry, contextual, adventure, game, and mastery-based learning. Table 2 present the percentage of the respondent response on each learning approach in DE course.

Table 2. Learning Approach

<table>
<thead>
<tr>
<th>Learning Approach</th>
<th>Frequency</th>
<th>Percentage (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>STEM based learning</td>
<td>16</td>
<td>6.48</td>
</tr>
<tr>
<td>Project based learning</td>
<td>15</td>
<td>6.07</td>
</tr>
<tr>
<td>Problem based learning</td>
<td>69</td>
<td>27.91</td>
</tr>
<tr>
<td>Inquiry based learning</td>
<td>27</td>
<td>10.94</td>
</tr>
<tr>
<td>Contextual based learning</td>
<td>61</td>
<td>24.70</td>
</tr>
<tr>
<td>Adventure based learning</td>
<td>5</td>
<td>2.01</td>
</tr>
<tr>
<td>Game based learning</td>
<td>4</td>
<td>1.61</td>
</tr>
<tr>
<td>Mastery based learning</td>
<td>50</td>
<td>20.23</td>
</tr>
</tbody>
</table>

More than twenty percent of the respondent stated that the lecturer used problem based,
contextual based, or mastery-based learning in T&L DE course. In contrast, adventure based and game-based learning are less carried out in T&L DE course. Furthermore, STEM based, project based, and inquiry-based learning are three learning approaches that has not been widely implemented in T&L DE course. Vajravelu (2018) argued that the DE course introduces students to science, engineering, and mathematics. There are many topics in DE that are very closely with Science, Technology, Engineering, and Mathematics (STEM). For example, science in DE can be in the form of radioactive decay problem, technology is the use of computer/laptop/smartphone to solve the problem, engineering is the use of Matlab/Maple software to describe the problem solution, and mathematics is the topic on first order linear DE (Zill, 2018). However, based on the survey result, there are only about 7% of participants stated that the learning approach used in the DE course is STEM based learning. It means that it is very prospective to develop T&L based on STEM in DE course.

**T&L Process in DE Course**

Figure 2 present the characteristics of the T&L process in the DE course.

![Percentage (%)](image)

**Figure 2. T&L Process in DE Course**

Almost 60% of respondents argued that the T&L process in DE course is a teacher-centered. This is in line with the study of Muganga and Ssenkusku (2013) which stated that the most of students assured that the teacher-centered approaches were used by their instructors. Ganyaujpfu (2013) confirmed that the least effective teaching method was the teacher-centered approach. Al-qahtani (2015) stated that the weak performance of students probably was because of the teacher-centered approach that is widely practiced by teachers. Wright (2011) reported in their pedagogical literature review, teachers in higher education believe that a student-centered classroom provides a more effective learning environment. The students provide positive response on the new learning environment. Furthermore, teachers believe they can achieve learning objectives through student-centered learning. It means that it is very prospective to develop T&L based on student-centered in DE course.

Based on Figure 1, most of respondents in the study also stated that the T&L process in DE course is without a module. About 40% of respondents mentioned a module, but it was not a STEM based module. Siregar, Rosli, and Maat (2020) confirmed that the usage of the module can give positive impact in the T&L process. Furthermore, STEM based modules can improves the knowledge, attitudes, and skills as students' learning competencies (Selsine, Sari, & Ramli, 2019). Many studies reported that STEM based module plays an important role to improve the students' learning outcomes (Adnan, Puteh, Tajuddin, Maat, & Hoe, 2018; Goovaerts, De Cock, Struyven, & Dehaene, 2018; Van Eck, Guy, Young, Winger, & Brewster, 2015).

**The Need for STEM-Discovery Learning Module Development.**

Figure 3 present the percentage of respondent response on the importance of the developing STEM-Discovery Learning Module. Most of respondent argued that the development of STEM-Discovery Learning Module is needed to improve the quality of the T&L DE course. All topics in DE course need to develop using module. Moreover, most of the respondent stated that the module should involve the learning material and students’ activities. More than a half of respondent suggest that the module should also be designed in digital form. The digital module
will motivate the students learn DE course.

Figure 3. The Need of STEM-Discovery Learning Module

The finding revealed that there are various approaches used in the T&L of DE course. However, only a few respondents mentioned STEM and inquiry/discovery as a learning approach used by their lecturer. Moreover, most of the respondents stated that the T&L process in DE used teacher centered and without a module. Even though some respondents mention the module in T&L DE course, however, none of the module integrate with innovative learning approach. Hence, the development of module that integrate with innovative learning model is indispensible to improve the quality of T&L DE course. The STEM education is a teaching and learning approach which integrates science, technology, engineering and mathematics knowledge and skills. It plays an important role for developing the 21st-century learning skills such as problem solving, collaboration, critical thinking skill and creative thinking skill (Ah-Namand & Osman, 2018; Australia Education Council, 2015). Previous studies showed that STEM has a positive impact on the students’ achievement and attitude, critical thinking skills, and collaboration skills (Han, Rosli, Capraro, & Capraro, 2016; Mutakinati, Anwari, & Yoshisuke, 2018; Saraç, 2018; Toma & Greca, 2018).

Furthermore, discovery learning model will encourage the students to organize their own material in the learning process through activities given during the learning (Kemendikbud, 2013), Siregar et al., 2020) stated that the used of discovery learning in the teaching and learning process can foster mathematical reasoning skills, communication, and self-confidence. The STEM-Discovery Learning Module is a learning module based on STEM education approach and Discovery Learning model. There are three main parts in the module. Firstly, the guideline for student and lecture. Secondly, learning material is integrated with STEM that is real life problem in DE for science, DE topic for mathematics, computer/laptop for technology, and Maple Software for engineering. Thirdly, the student learning activities are developed based on discovery learning phases.

Siregar, Rosli, and Maat (2020) confirmed that the use of the module will provide positive impact in the T&L process. Furthermore, STEM based modules can improves the knowledge, attitudes, and skills as students' learning competencies (Selsne et al., 2019). Many studies reported that STEM based module plays an important role to improve the students’ learning outcomes (Goovaerts, De Cock, Struyven, & Dehaene, 2018; Van Eck, Guy, Young, Winger, & Brewster, 2015). The STEM based module can be integrated with vary learning models. One of them is discovery learning model. Thibaut et al. (2018) confirmed that discovery learning is one of instructional practices referring to the use of inquiry in integrated STEM. The research result is similarly with Nawi, Faiz, Yaakob, Yusof, and Ren (2020) that confirmed the need of module development in environmental education. Dewi, Sunarno, and Supriyanto, 2019) revealed that a module development based on creative problem-solving was needed to foster the problem-solving ability of the students.
Conclusion

The purpose of this study is to analyze the need for STEM-Discovery Learning Module development in T&L of DE. The results revealed that most of respondents believed that the T&L of DE was a teacher centered and without the module. Almost all students assured the importance of developing the STEM-Discovery Learning Module to improve the quality of learning. The findings showed that the STEM-Discovery Learning Module development is in high demand for T&L of DE. The limitations of the study are the researcher could not clarify all the respondents whether they really understood the terms used in the questionnaire or not. This study was carried out as the first stage of the development of STEM-Discovery Learning Module. For further study, the development of STEM-Discovery Learning Module will be carried out.

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References


