DEVELOPMENT AND EFFECTIVENESS OF STEM DISCOVERY LEARNING (STEMDISLEARN) MODULE ON CRITICAL THINKING SKILLS, COLLABORATION SKILLS, AND ACHIEVEMENT IN DIFFERENTIAL EQUATIONS COURSE

RITA PRAMUJIYANTI KHOTIMAH

SULTAN IDRIS EDUCATION UNIVERSITY

2024

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RECOGNITION

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ABSTRACT

This study aims to develop a STEMDISLEARN module; to test the module's effectiveness on the critical thinking (CT) skills, collaboration skills, and achievement in the Differential Equations (DE) Course; and to test the relationships between CT and collaboration skills, the relationship between CT and achievement, and the relationship between achievement and collaboration. The research employs design development research to develop the module. A quasi-experimental design was used to test the module's effectiveness. The research sample involved 123 students who enrolled in the DE course in the Mathematics Education Program at a university in Surakarta; 64 students of the experimental group, and 59 students of the control group. A t-test was conducted to determine the module's effectiveness on the critical thinking (CT) skills, collaboration skills, and achievement. A Pearson correlation analysis was conducted to test the relationship between CT and collaboration, the relationship between CT and achievement, and the relationship between achievement and collaboration. The findings showed that the STEMDISLEARN module was effective in enhancing students' achievement and CT but ineffective in enhancing collaboration; the relationships between CT and collaboration, between achievement and collaboration were not found in both groups; the relationship between achievement and CT was found only in the experimental group. In conclusion, the STEMDISLEARN module was valid, practical, and effective in enhancing CT skills and achievement in the DE course. The study implies that the teaching and learning of DE should integrate STEM-based discovery learning to improve the learning outcomes.

PEMBANGUNAN DAN KEBERKESANAN MODUL STEM DISCOVERY LEARNING (STEMDISLEARN) TERHADAP KEMAHIRAN PEMIKIRAN KRITIKAL, KEMAHIRAN KOLABORASI DAN PENCAPAIAN DALAM KURSUS PERSAMAAN DIFERENSIAL

ABSTRAK

Kajian ini bertujuan untuk membangunkan modul STEMDISLEARN; menguji keberkesanan modul terhadap kemahiran pemikiran kritikal (CT), kemahiran kolaborasi, dan pencapaian dalam kursus Persamaan Diferensial (PD); dan menguji hubungan antara CT dan kolaborasi, hubungan antara CT dan pencapaian, serta hubungan antara pencapaian dan kolaborasi. Kajian ini menggunakan reka bentuk penyelidikan pembangunan untuk membangunkan modul. Reka bentuk kuasi eksperimen digunakan untuk menguji keberkesanan modul. Sampel kajian melibatkan 123 pelajar kolej yang mendaftar dalam kursus PD di sebuah universiti di Surakarta; 64 pelajar kumpulan rawatan dan 59 pelajar kumpulan kawalan. Kajian-t dijalankan untuk menentukan keberkesanan modul terhadap kemahiran pemikiran kritikal (CT), kemahiran kolaborasi, dan pencapaian. Analisis korelasi Pearson dijalankan untuk menguji hubungan antara CT dan kolaborasi, hubungan antara CT dan pencapaian, serta hubungan antara pencapaian dan kolaborasi. Dapatan kajian menunjukkan bahawa modul STEMDISLEARN berkesan dalam meningkatkan pencapaian pelajar dan CT, tetapi tidak berkesan dalam meningkatkan kolaborasi; hubungan antara CT dan kolaborasi, antara pencapaian dan kolaborasi tidak ditemui dalam kedua-dua kumpulan; hubungan antara pencapaian dan CT hanya didapati dalam kumpulan rawatan. Kesimpulannya, modul STEMDISLEARN adalah sah, praktikal, dan berkesan dalam meningkatkan CT dan pencapaian pelajar. Implikasinya, pengajaran dan pembelajaran PD perlu mengintegrasikan STEM-*Discovery Learning* untuk meningkatkan hasil pembelajaran.

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LIST OF ABBREVIATIONS

ADDIE	Analysis, Design, Development, Implementation, and Evaluation
CT	Critical Thinking Skill
CLO	Course Learning Outcome
CDP	Calculus Differential Point
CIP	Calculus Integral Point
CVI	Content Validity Index
COVID-19	*Coronavirus* Disease 2019
DE	Differential Equations
DIY	*Daerah Istimewa Yogyakarta*
ELIPSS	Enhancing Learning by Improving Process Skills In STEM
FRISCO	Focus, Reason, Inference, Situation, Clarity, and Overview
GPA	Grade Point Academic
HOTS	Higher Order Thinking Skills
I-CVI	Item - Content Validity Index
IP-21CSS	Indonesian Partnership for 21 Century Skill Standards
KU	*Keterampilan Umum*
KK	*Keterampilan Khusus*
Kemristekdikti	*Kementerian Riset dan Teknologi Pendidikan Tinggi*

NETS	National Educational Technology Standards
PLO	Program Learning Outcome
Pc	Probability of Chance
PP	*Penguasaan pengetahuan*
STEM	Science, Technology, Engineering, and Mathematics
STEMDISLEARN	STEM Discovery Learning
S	*Sikap*
SAS	Students' Activity Sheets
S-CVI	Scale - Content Validity Index
SPSS	Statistical Packages For The Social Science
TL	Teaching and Learning
UMS	*Universitas Muhammadiyah Surakarta*
UNICEF	United Nations International Children Emergency Fund

APPENDIX

CHAPTER 1

INTRODUCTION

1.1 Preface

The Industrial Revolution 4.0 (IR4.0) era in the 21st century caused many things to happen without limits. This era can make disruption in many fields, including science, technology, and higher education. Schwab (2019) stated that in addition to new opportunities, globalization and the Fourth Industrial Revolution have also caused disruption and polarization within and between economies and communities. Thus, various skills are needed to face the challenges of the 21st century to have global competitiveness. To face the 21st century successfully, Barry (2012) have formulated the top ten skills: critical thinking, communication, leadership, collaboration, adaptability, productivity and accountability, innovation, global citizenship, the ability and spirit of entrepreneurship, as well as the ability to access, analyze, and synthesize

information. ŽivkoviĿ (2016) mentioned that with the advent of global competition, the emphasis is on the necessity of preparing students to be communicative, cooperative, innovative, and creative, to think logically and critically, and to be able to successfully handle real-world problems.

The Assessment and Teaching of 21st Century Skills (ATC21S) developed the framework of 21st-century skills in the four categories: 1) the ways of thinking, consisting of creativity and innovations, critical thinking, problem solving, decision making, learning to learn and metacognition, 2) the ways of working, involving communication and collaboration (teamwork), 3) tools for working, consisting of information literacy which includes research on sources, evidence, biases, etc. and ICT literacy, and 4) living in the world that consists of citizenship, life and carrier, and personal & social responsibility (Griffin & Care, 2015).

The education in the disruption era must be able to equip students with the necessary of the 21st-century skills. The World Economic Forum (WEF) has formulated 16 important skills for lifelong learning in the 21st century. The three main skills are foundational literacies, competencies, and character qualities. Foundational literacies concern how students employ essence skills to an everyday task. These literacies include literacy, numeracy, ICT literacy, scientific literacy, financial literacy, cultural, and civic literacy. Competencies concern how students face complex challenges so that they need to develop four skills, including critical thinking or problem solving, creativity, communication, and collaboration. Character qualities to how students approach their changing environment by using six skills: curiosity, persistence/ grit, adaptability, leadership, social and cultural awareness (WEF, 2016).

The US-based Partnership for 21st Century Skills (P21-CS) formulate various kinds of competencies and skills for learning and innovation skills to face up the 21st century, known as "The 4Cs", which consist of communication, collaboration, critical thinking, and creativity (Battelle for Kids, 2019). Indonesia has also formulated the 21st-century conceptual framework in accordance with the demands of education in Indonesia, known as the Indonesian Partnership for 21st Century Skill Standard (IP-21CSS). It consists of 1) 4CS: creativity thinking and innovation, critical thinking and problem solving, communication and collaboration; 2) ICTs: information, media, and technology skills; and 3) character building and spiritual values: life and career skills (Ariyana et al., 2018).

In the organization of education in the Industrial Revolution (IR) 4.0., the Indonesian government has currently implemented a road map Making Indonesia 4.0. It is one of the visions to make Indonesia in 2030 rank in the top ten countries with the strongest economy in the world. There are ten priority programs in Making Indonesia 4.0. One of the programs is improving Human Resources quality. In improving the quality, Indonesia plans to adapt the education curriculum to the interests of the industry in the future (Hartanto, 2018).

The higher education curriculum in Indonesia is formulated by referring to Presidential Regulation Number 8/2012 concerning the Indonesian National Qualification Framework (KKNI). Article 1 explained that KKNI is a competency qualification framework that can juxtapose, equalize, and integrate education, job training, and working experience to recognize work competence through an operational structure in various sectors (Presiden RI, 2012a). Besides that, it refers to the Higher

Education National Standard for each Study Program that includes the development of intellectual intelligence, noble character, and skills (Presiden RI, 2012b).

1.2 Research Background

In the previous section, Indonesia has formulated the Indonesian Partnership for 21st Century Skill Standard as the 21st-century conceptual framework appropriate to the demands of education. Science, technology, engineering, and mathematics (STEM) education is one of teaching and learning approach that has been currently regarded to be very suitable for developing the 21st-century learning skills (Peters-burton & Stehle, 2019; Sen et al., 2018). The use of STEM in education has a number of benefits, including fostering teamwork and active communication, incorporating knowledge into real-world contexts, enhancing critical thinking and problem-solving abilities, boosting self-confidence as a link between learning and career planning, and empowering students to create technological innovations in the real world (Morze et al., 2018). In the context of Indonesia, the implementation of STEM in Indonesia was carried out in teaching and learning process, and there was very limited STEM implementation in higher education level (Khotimah et al., 2021a).

Torlakson (2014) revealed that Science, Technology, Engineering, and Mathematics (STEM) includes four disciplines: a) science, representing knowledge and concepts, b) technology, a skill or a system used for managing society, organization, knowledge or designing, and using artificial tools for facilitating work, c) engineering, the knowledge to operate or design a procedure to solve a problem, and d) mathematics,

a science that connects quantities, numbers, and spaces that only require logical arguments accompanied by empirical evidence or not. All of these aspects can make knowledge more meaningful if they are integrated into a learning process.

Kemristekdikti (2019) stated that the learning material in higher education can be presented in various forms such as textbooks, modules, practical instructions, reference books, monographs, and other forms of equivalent learning resources. Teacher or lecturers must be creative by developing and modifying teaching or instructional materials into various forms such as a learning module. In a learning module, the teaching materials were arranged systematically so that they can learn on their own (independently) with minimal help or guidance from teacher or lecture (Prastowo, 2015). Sidek and Jamaludin (2017) explained that by using a learning module, the student can master the learning unit easily and accurately by themselves.

The learning module materials can be presented in many various learning models, one of them is discovery learning (Julita et al., 2019; Wahyudi et al., 2019; Yuliani & Saragih, 2015). Thibaut et al. (2018) revealed that discovery learning is one of instructional practices referring to the use of inquiry in integrated STEM. Bruner (1960) stated that in the discovery learning, the learners construct the new knowledge developed from prior knowledge and active experience. By using a discovery learning, the students can construct their knowledge and become more active in class (Siregar, Rosli, & Maat, 2019). Discovery learning is one of learning model that highly recommended in a learning process to strengthen the scientific, thematic, and holistic learning (Permendikbud, 2016). In discovery learning model, the learning materials were not presented in the final form, students are encouraged to organize their own

material in the learning process through activities given during the discovery learning (Kemendikbud, 2013).

Differential Equations is an important subject in various majors at most universities (Kwon, 2020). Differential Equations is an essential subject because of its wide application not only in mathematics but also in other fields such as physics, engineering, biology, chemistry, ecology, economics (Agarwal et al., 2021; Boyce et al., 2021; Grimshaw, 2017; Simmons, 2017). Vajravelu (2018) stated that it becomes a central part of bachelor's degree programs in the science and engineering. This course introduces students to science, engineering, and mathematics.

Universitas Muhammadiyah Surakarta (UMS) is a private university in Surakarta, Indonesia which has a large number of students. Like in other universities, at UMS, differential equations becomes a compulsory course in mathematics education and engineering majors. According to Act Number 20, 2003, concerning the National Education System, the curriculum is developed by a university according to the national education standards for each study program. The material depth and breadth, the semester credit unit, and the placement of this course depend on the policies of each university.

Aisha et al.(2017) argued that the differential equations is closely related with science, social science, and technology. This subject is used to create models and find solutions to a range of problems in daily life. In line with Aisha et al.(2017), Zeynivandnezhad et al.(2013) stated that differential equations involves the knowledge of modeling, problem solving, and interpreting the solution to real life problem. To

formulate the model, it needs to analyze the problem that is understanding the information to determine meaning. Furthermore, to solve and interpret the formulated model, it needs to evaluate and synthesize the information that is determining the relevance and reliable information and connecting or integrating the information to support an argument or reach a conclusion. These abilities are a critical thinking dimension as stated by Reynders et al. (2020). This is in line with Vajravelu (2018) who stated that the differential equations is very close to developing critical thinking skills.

Critical thinking skill development could be promoted by the students' collaboration skills (Dinh & Salas, 2017; Loes & Pascarella, 2017). Lai et al. (2017) mentioned that collaboration skill is a common set of skills and knowledge as an important learning outcome. Collaboration skills might contribute to an individual's success in the workplace, teams will perform better if members have more knowledge of collaboration and team-building skills. Rodríguez-Sabiote et al (2022) revealed that the greater the collaboration skills is ascociated with, the better the critical thinking skills will be.

There was a positive and significant relationship between students' critical thinking skills and achievement (Akpur, 2020). Critical thinking skills positively and significantly contributes to academic achievement in higher education (Ghanizadeh, 2017). Students who have better critical thinking skills perform better in solving the problems and achievement better (Pu et al., 2019). The other research result show that students with good learning achievement can demonstrate good reasoning and critical thinking skills in the problem-solving (Ramnarain, 2015).

1.3 Problem Statement

Differential equations are widely used in many other subjects besides mathematics, including physics, engineering, biology, chemistry, ecology, and economics. Hence, differential equations become a crucial subject for most collegiate majors (Agarwal et al., 2021; Boyce et al., 2021; Grimshaw, 2017; Simmons, 2017). A strong critical thinking skills is needed by the students in solving the issues or problems (ŽivkoviĿ, 2016). However, students still encounter challenges when attempting to solve the differential equation problems (Faradiba et al., 2018), most of the students' mathematical thinking in the Differential Equations Course was in the low category (Zeynivandnezhad et al., 2013). Students in the low category could not fulfill all aspects of critical thinking skills in solving the problems (Nurrahmah et al., 2021).

Many research on Science, Technology, Engineering, and Mathematics (STEM) module stated that STEM-based learning modules can promote students' critical thinking skills (Retnowati et al., 2020; Savran Gencer & Dogan, 2020; Yaki, 2022). Furthermore, according to several earlier studies (Julita et al., 2019; Wahyudi et al., 2019; Yuliani & Saragih, 2015), learning modules utilizing the discovery learning model might enhance students' critical thinking abilities. Thibaut et al.(2018) and Ah-Namand and Osman (2018) mentioned that the learning theory underlies STEM education is constructivism. Constructivism was also used as a learning theory used in the discovery learning model (Affandi et al., 2022; Großmann & Wilde, 2019). Hence, it is possible to integrate STEM and discovery learning learning in a learning module to promote students' critical thinking skills in Differential Equations Course. However,

there is no module that has been developed based on STEM-discovery learning in the differential equations topic (Khotimah et al., 2021b).

Nieveen (1999), in Plomp (2013) argued that a high-quality intervention should meet the validity, practicality, and effectiveness requirements. If the intervention is not practical, there is no need to conduct any effectiveness test. There are many research that have been conducted to test the validity, practicality, and effectiveness of the module (Ahyan et al., 2014; Rahmatsyah & Dwiningsih, 2021; Rahmi et al., 2018; Retnowati et al., 2020; Savran Gencer & Dogan, 2020). However, none of them was a STEM-Discovery Learning Module in differential equations. Hence, it is needed to test the validity, practicality, and effectiveness of the STEM-Discovery Learning Module.

There is a relationship between students' collaboration and critical thinking skills. The students' collaboration can promote critical thinking skill development (Dinh & Salas, 2017; Fung et al., 2016; Loes & Pascarella, 2017; Rodríguez-Sabiote et al., 2022). However, the study on the relationship between students' collaboration and critical thinking skills has not been found in Differential Equations Course.

There is also a relationship between students' critical thinking skills and achievement, encouraging critical thinking skills could raise the students' achievement (Ghanizadeh, 2017; Vierra, 2014; Wicaksana et al., 2020). On other hand, students with a good learning achievement can demonstrate good reasoning and critical thinking skills in the problem solving (Pu et al., 2019; Ramnarain, 2015). Meanwhile, Kanbay et al. (2017), Mohammadi et al. (2016) and Tafazzoli et al.(2015) found no relationship between students' achievement and critical thinking skills. The relationship between

students' critical thinking skills and achievement in the Differential Equations Course has also not been found.

In addition, there is a strong relationship between students' collaboration skills and achievement. Teamwork or collaboration can encourage students to reach significantly better achievement (De Prada et al., 2022; Lozano-Rodríguez et al., 2020; Park et al., 2015; Sanyal & Hisam, 2018). Meanwhile, Beigi and Shirmohammadi (2012) argue that there was no relationship between the teamwork and achievement. The relationship between students' collaboration skills and achievement in the Differential Equations Course has also not been found.

1.4 Purpose of the Study

The purpose of the study is to develop a valid and practical STEM-Discovery Learning (STEMDISLEARN) module; to test the effectiveness of STEMDISLEARN module on the college students'critical thinking skills, collaboration skills, and achievement in the topic of Differential Equations; and to test the relationships between critical thinking skills, collaboration skills, and achievement in the topic of Differential Equations.

1.5 Objective of the Study

Specifically, the objectives of the study are described as follows.

1.5.1 To develop a valid and practical STEMDISLEARN module in the topic of Differential Equations.

1.5.2 To test the effectiveness of STEMDISLEARN module on the college students' critical thinking skills.

1.5.3 To test the effectiveness of STEMDISLEARN module on the college students' collaboration skills.

1.5.4 To test the effectiveness of STEMDISLEARN module on the college students' achievement.

1.5.5 To identify the relationship between college students' critical thinking skills and collaboration skills in the topic of differential equations.

1.5.6 To identify the relationship between college students' critical thinking skills and achievement in the topic of differential equations.

1.5.7 To identify the relationship between college students' achievement and collaboration skills in the topic of differential equations.

1.6 Research Question

Based on the objectives of the study, the research questions are described as follows:

1.6.1 Is the STEMDISLEARN module valid and practical?

1.6.2 Is the STEMDISLEARN module effective in enhancing college students' critical thinking skills?

1.6.2.1 Is there any significant difference in the mean scores of college students' critical thinking skills between the experimental group and the control group before treatment?

1.6.2.2 Is there any significant difference in the mean scores of college students' critical thinking skills between the experimental group and the control group after treatment?

1.6.2.3 Is there any significant difference in the mean scores of college students' critical thinking skills in the experimental group before and after treatment?

1.6.2.4 Is there any significant difference in the mean scores of college students' critical thinking skills in the control group before and after treatment?

1.6.3 Is the STEMDISLEARN module effective in enhancing college students' collaboration skills?

1.6.3.1 Is there any significant difference in the mean scores of college students' collaboration skills between the experimental group and the control group before treatment?

1.6.3.2 Is there any significant difference in the mean scores of college students' collaboration skills between the experimental group and the control group after treatment?

1.6.3.3 Is there any significant difference in the mean scores of college students' collaboration skills in the experimental group before and after treatment?

1.6.3.4 Is there any significant difference in the mean scores of college students' collaboration skills in the control group before and after treatment?

1.6.4 Is the STEMDISLEARN module effective in enhancing college students' achievement?

1.6.4.1 Is there any significant difference in the mean scores of college students' achievement between the experimental group and the control group before treatment?

1.6.4.2 Is there any significant difference in the mean scores of college students' achievement between the experimental group and the control group after treatment?

1.6.4.3 Is there any significant difference in the mean scores of college students' achievement in the experimental group before and after treatment?

1.6.4.4 Is there any significant difference in the mean scores of college students' achievement in the control group before and after treatment?

1.6.5 Is there a relationship between college students' critical thinking skills and collaboration skills in the topic of differential equations?

1.6.6 Is there a relationship between college students' critical thinking skills and achievement in the topic of differential equations?

1.6.7 Is there a relationship between college students' achievement and collaboration skills in the topic of differential equations?

1.7 Research Hypothesis

Based on the research question, the hypotheses in this research are formulated.

In the second question, the null hypotheses formula are as follows:

H_{01}: There is no significant difference in the mean scores of college students' critical thinking skills between the experimental group and the control group before treatment.

H_{02}: There is no significant difference in the mean scores of college students' critical thinking skills between the experimental group and the control group after treatment.

H_{03}: There is no significant difference in the mean scores of college students' critical thinking skills in the experimental group before and after treatment.

H_{04}: There is no significant difference in the mean scores of college students' critical thinking skills in the control group before and after treatment.

In the third question, the null hypotheses formula are as follows:

H_{01}: There is no significant difference in the mean scores of college students' collaboration skills between the experimental group and the control group before treatment.

H_{02}: There is no significant difference in the mean scores of college students' collaboration skills between the experimental group and the control group after treatment.

H_{03}: There is no significant difference in the mean scores of college students' collaboration skills in the experimental group before and after treatment.

H_{04}: There is no significant difference in the mean scores of college students' collaboration skills in the control group before and after treatment.

In the fourth question, the null hypotheses formula are as follows:

H_{01}: There is no significant difference in the mean scores of college students' achievement between the experimental group and the control group before treatment.

H_{02}: There is no significant difference in the mean scores of college students' achievement between the experimental group and the control group after treatment.

H_{03}: There is no significant difference in the mean scores of college students' achievement in the experimental group before and after treatment.

H_{04}: There is no significant difference in the mean scores of college students' achievement in the control group before and after treatment.

In the fifth question, the null hypotheses formula are as follows:

H_{05}: There is no a relationship between college students' critical thinking skills and collaboration skills in the topic of differential equations.

In the sixth question, the null hypothesis formula is as follows:

H_{06}: There is no a relationship between college students' critical thinking skills and achievement in the topic of differential equations.

In the seventh question, the null hypothesis formula is as follows:

H_{07}: There is no a relationship between college students' achievement and collaboration skills in the topic of differential equations.

1.8 Conceptual Framework of Research

The study aims to develop a valid and practical STEMDISLEARN module; to test the effectiveness of STEMDISLEARN module on college students' achievement, critical thinking skills, and collaboration skills in Differential Equations; and to test the relationships between students'achievement, critical thinking skills, and collaboration skills in Differential Equations Course.

The STEMDISLEARN module in this study was developed by using ADDIE (Analysis, Design, Development, Implementation, and Evaluation) model. Moradmand et al., (2014) stated that he systematic instructional design paradigm known as the ADDIE serves as a dynamic and adaptable design for creating powerful teaching and learning resources. The development of the STEMDISLEARN module involves the fundamental constructivism and constructionism theories in learning since these are very related with the disciples of STEM and discovery learning model (Ah-Namand & Osman, 2018; Ariyana et al., 2018; Torlakson, 2014). The four disciplines of STEM include: 1) science, represent knowledge and concepts, 2) technology, a skill or a

system used for managing society, organization, knowledge or designing and using in artificial tool that can facilitate work, 3) engineering, the knowledge to operate or design a procedure to solve a problem, and 4) mathematics, the science that connects quantities, numbers, and spaces that only require logical arguments without or accompanied by empirical evidence (Torlakson, 2014). The STEM approach will be carried out by using the discovery learning model (Ariyana et al., 2018) in the differential equations topic which consists of stimulation, problem oriented, data collecting, data processing, verification, and generalization. In this development phase, the valid and practical STEMDISLEARN module also will be tested.

The effectiveness of the STEMDISLEARN modules, which were valid and practical, will be tested in the evaluation phase through a quasi-experimental research design. There are two variables in this study, the independent variable, and the dependent variables. The independent variables include teaching and learning based on the STEMDISLEARN module and the conventional teaching approach, and the dependent ones are achievement (Anderson & Krathwohl, 2001; Kemristekdikti, 2019), critical thinking skills (Reynders et al., 2020) and collaboration skills (Britton et al., 2017). The teaching and learning in the experimental group will be carried out using STEMDISLEARN Module, while in the conventional group will be carried out using explanation, questions and answers, and exercises (Djamarah & Zain, 2013). The effectiveness of the module will be seen on the college student achievement, critical thinking skills and collaboration skills. Furthermore, the relationships between achievement and critical thinking skills, critical thinking skills and collaboration skills, and achievement and collaboration skills will also be found in this study.

Figure 1.1. shows the conceptual framework of the research.

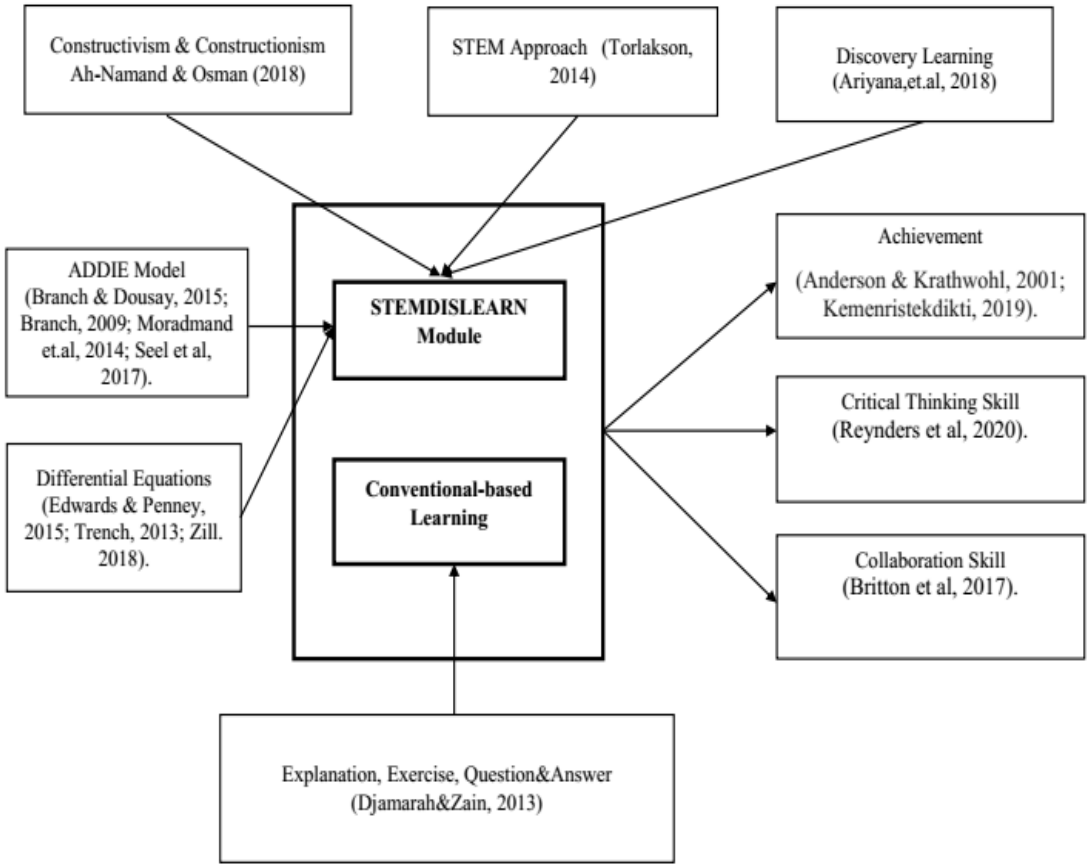

Figure 1. 1. Conceptual Framework of Research

1.9 Operational Definition

The operational definitions in this study include the development of STEMDISLEARN module, conventional learning, differential equations, achievement, critical thinking skills, and collaboration skills.

1.9.1 Conventional Learning

Conventional learning is a learning traditionally, since a long ago this method was used as a means of oral communication between teachers and students in teaching and learning process. The implementation of conventional learning is usually dominated by teachers, meanwhile the students only accept and take notes material presented by the teacher. It is characterized by giving an explanation, distribution of tasks, and exercises (Djamarah & Zain, 2013). In the present study, conventional learning includes explanation, question and answer, and exercises.

1.9.2 Differential Equations

A Differential Equation (DE) is an equation involving one or more dependent variable and their derivatives with respect to one or more independent variables (Simmons, 2017; Zill, 2018). In this study, the DE refers to the topics: a) introduction of DE, involving definition, classification, and solution of DE; b) first order DE, which consists of separable DE, initial value problem of DE, homogeneous DE, and DE with linear function coefficients (non homogeneous DE); as well as c) first order linier DE including integrating factor method, Lagrange method, and Bernoulli DE (Edwards & Penney, 2015; Simmons, 2017; Zill, 2018).

1.9.3 Critical Thinking

Critical thinking (CT) skills is analyzing, evaluating, synthesizing relevant information to form an argument or reach a conclusion supported with evidence (Reynders et al., 2020). In this study, CT skill was measured from the scores of DE CT skills test given to the students in the control and experimental groups, before and after teaching and learning. The CT skills test was built based on the indicators of CT as suggested by Reynders et al. (2020), which are analyzing, evaluating, synthesizing relevant information to form an argument or reach a conclusion supported with evidence. Analyzing is interpreting the information to determine meaning and to extract relevant evidence. Evaluating is determining the relevance and reliability of the information that might be used to support a conclusion or argument. Synthesizing is connecting or integrating the information to support an argument or reach a conclusion

1.9.4 Collaboration Skill

Collaboration or teamwork is a working process of two or more students for common goals through individuals' accountability and interdependent behavior (Riebe et al., 2017). In this study, collaboration or teamwork skills were measured from the scores of a teamwork skills questionnaire given to the students in the control and experimental groups, before and after the teaching and learning of DE. The teamwork skills questionnaire was built based on to these indicators: contributing to team, facilitating contributions of others, planning and management, fostering a team climate, and managing conflict (Britton et al., 2017).

1.9.5 Achievement

Achievement is the abilities that students had after receiving the learning experience. In this study, achievement involves the college students' cognitive process dimension scores in remembering, understanding, applying, analyzing, evaluating, and creating (Anderson & Krathwohl, 2001; Kemenristekdikti, 2019). It was measured from the scores of DE achievement test given to the students in the control and experimental groups, before and after teaching and learning. The achievement test was built based on the six cognitive levels.

1.10 Limitations of Study

This study has several limitations. First, the topics of DE used in this research were three of five topics, which are introduction of DE, first order DE, and first order linear DE. The module was developed, and an experiment was carried out to determine its effectiveness on these three topics. Second, the research used a quasi-experimental research design. Third, the variables in this study were limited to achievement, critical thinking skills, and collaboration skills.

1.11 Importance of Research

Theoretically, the results of the study are expected to contribute to the knowledge of STEMDISLEARN module-based learning that can produce generations of 21st-century

learning skills, especially the critical thinking skill and collaboration skills. Besides, it can be used to enhance the college students'achievement in differential equations. Practically, the results of the study are beneficial for the lecturers, college students, institutions, and government.

1.11.1 Lecturer

The results of this study can help lecturers provide guidelines for learning activities in the differential equations course. They can improve college students' achievement, critical thinking skills, and collaborative skills and provide opportunities for lecturers to develop the STEMDISLEARN module further on other learning topics or learning modules by using different methods and approaches.

1.11.2 College Students

By using the STEMDISLEARN module, college students can have a more meaningful learning experience because it provides opportunities for students to integrate the learning material in science, technology, engineering, and mathematics. The learning activities carried out by the college students with the module can improve the achievement, critical thinking, and collaborative thinking skills as learning skills of the 21st century.

1.11.3 The Institution

The results of this study are useful for institutions to improve the learning quality in higher education through the integration of science, technology, engineering, and mathematics in teaching and learning mathematics in higher education, and to support 21st-century learning skills.

1.11.4 The Ministry of Education

The development of the STEMDISLEARN module is based on the needs of teaching and learning skills in the 21st century. For the Ministry of Education and Culture, the result of this study can be useful for developing higher education curricula by integrating science, technology, engineering, and mathematics to face up the challenge of the 21st century.

1.12 Summary

The chapter has discussed the introduction, research background, problem statement, purpose of the study, objective of the study, research question, research hypothesis, conceptual framework, operational definition, limitations of the study, and importance of the research. It is needed to develop a valid and practical module based on STEM-Discovery Learning model (STEMDISLEARN Module); to test the effectiveness of STEMDISLEARN module on the college students' achievement, critical thinking

skills, and collaboration skills in the topic of differential equations; and to test the relationships between college students' critical thinking and collaboration skills; between college students' critical thinking skills and achievement; and between college students' collaboration and achievement. The next chapter will discuss the literature review needed in developing the STEMDISLEARN Module and testing the module effectiveness on the students'critical thinking skills, collaboration skills, and achievement.