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# Development of STEM Integrated Flipped Classroom Learning Program to Improve Students' Systems Thinking Skills

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**Abstract:** This research develops a Flipped Classroom integrated with STEM with the ADDIE model to improve systems thinking skills. The research subjects were 31 students at Al Kautsar Middle School in Bandar Lampung. At the beginning of the research, it was found that 70% of teachers had not used the flipped classroom, 65% had not integrated STEM, 73% had not understood systems thinking skills which was carried out on 30 teachers, and performance analysis was carried out on 60 students, with the results of 72% learning traditionally, 73% had not integrated STEM and the average value of systems thinking skills is 40. Validators stated that the development instrument was valid with values of 92.12 and 92.52% when limited testing was carried out. Assessment of learning implementation was 89% and assessment of student performance was 88%. The program is effective in improving systems thinking skills in terms of an N-Gain of 0.58 and an effect size of 0.22 in the medium category. Effectiveness is supported by practicality 88%, positive teacher response 88%, and positive student response 81% with very high criteria. The research results concluded that the STEM-integrated flipped classroom program was effective and practical in improving systems thinking skills.

**Keywords:** Flipped classroom; STEM; System thinking

## Introduction

21st century education demands learning that reflects the four life skills called the 4C, namely Critical Thinking, Communication, Collaboration, and Creativity (Erdoğan, 2019; OCDE, 2018) and is an important aspect of today's education (Ayu, 2019; Roychoudhury et al., 2017). Furthermore, Ponto et al. (2011) call Critical Thinking and Problem Solving the term systems thinking. Systems thinking is a complex holistic approach and is a system in the real world that focuses on the dynamic interrelationships between components and behavioral patterns that emerge from these reciprocal relationships (Bausch, 2002; Evagorou et al., 2009; Hammond, 2017; Jacobson et al., 2006; Mandinach & Cline, 1993). These skills have also been applied in various science and life contexts, including learning about experimental safety systems (Zhang et al., 2019), climate change (Meilinda et al., 2019), respiratory systems (Nuraeni et al., 2020), flood mitigation (Dzulkarnain et al., 2019), fundamental biological principles of homeostasis (Mor & Zion, 2019), waste management systems (Kubanza & Simatele, 2018) historical systems for the formation of the earth (Rispoli, 2020).

Apart from that, many positive things can be gained from applying systems thinking skills, including growing the ability to solve problems and other more difficult skills (Andriani & Hamdu, 2021; Meilinda et al., 2018), increasing the ability to analyze problems in a structured manner, making conclusions (Richmond, 1994), analyzing the dynamics of a model or system (Rebs et al., 2019) and helping students link relationships between seemingly unrelated problems into interrelated ones (Clark et al., 2017; Rustaman, 2021). This ability is to the demands of climate change material which is complex material so that understanding variations, causes, and effects requires systems thinking skills

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(Abbott, 2014; Roychoudhury et al., 2017; Shepardson et al., 2012).

In school learning, complex material such as climate change is often presented using reduction methods, and analyzed separately, this results in students having difficulty studying the relationships between components, understanding interaction patterns, modeling, and predicting and reconstructing a system (Laszlo & Krippner, 1998; Wilensky & Resnick, 1999). The characteristics of climate change material, which is quite complex and has depth in the material, require more learning time so that students can master the desired competencies (Raved & Yarden, 2014; Riess & Mischo, 2010). Therefore, a learning program is needed which is a relationship of meaning that is designed and implemented purposively. A program can be understood as a group of activities intended to achieve one or several related outcome goals (McDavid et al., 2018). One learning program that is efficient in utilizing time and does not reduce the essence of the level of depth and complexity of the material is the Flipped classroom (Bergmann & Sams, 2011).

The implementation of the flipped classroom begins with providing a video before learning, while in-class learning is used to discuss and discuss material that is not yet understood (Cho et al., 2021; Nwosisi et al., 2016), so it is considered an ideal model theoretically and practical and appropriate taught both fully online and mixed (Campillo & Miralles, 2021; Khan & Abdou, 2021). Research trends show that 80% of flipped classrooms have been implemented in various worlds of education (Akçayır & Akçayır, 2018). This can be understood, because the implementation of the flipped classroom has several positive values, including being able to improve computational thinking skills, working with groups, and learning motivation and problem-solving abilities (Ramadhani et al., 2019; Bordes et al., 2021; Gong et al., 2020 ), improving learning outcomes (Busebaia & John, 2020; Ramadhani et al., 2019; Suryawan et al., 2021), and creating a more effective and active classroom environment (Bates & Ludwig, 2020; Murafer et al., 2021; Tomas et al., 2019), as well as making students more ready to learn (Goedhart et al., 2019).

The Flipped classroom learning program will be more effective if combined with a Learning Management System (LMS), this is because it allows students to access material more flexibly without space and time limits (Hew et al., 2020; Kollmann, 2006). Various LMS can be used in learning today, such as home learning, Google Classroom, Teacher's Room, Zenius, Moodle, SiajarLMS, and Edmodo (Pratomo & Wahanisa, 2021), but the researcher chose Google Classroom to elaborate on the flipped classroom because several considerations, including; it is free, easy to use, and is an innovative and effective online platform (Albashtawi & Al Bataineh, 2020; Ugwoke et al., 2018).

In its application, the flipped classroom can be integrated with an approach that combines science, technology, engineering, and mathematics which is presented proportionally like STEM so that the learning that takes place is more effective (Bybee, 2013). Besides that, the integration of STEM in learning has many positive impacts including; is an approach that is in line with technological advances (Ramadhani et al., 2019; Widayanti et al., 2019), and can increase student engagement, motivation, collaboration, and performance (Ng & Chu, 2021; Sudianto et al., 2019), able to improve reasoning skills (Fitriani et al., 2017; Pertiwi & Abdurrahman, 2017), so that it will influence students' critical thinking and problem solving (system thinking) (Gómez & Suárez, 2020; Reynders et al., 2020; Wahono et al., 2021), more meaningful learning (Fan et al., 2021), and requires students to be able to build their concepts from the results of investigations and problem-solving (Putri, 2019).

Based on preliminary study data analysis of 30 public and private middle school science teachers in Lampung Province, it was stated that 70% of teachers did not understand the meaning, stages, and ways of implementing a flipped classroom, and 65% did not understand, integrate, use STEM learning and 73% did not understand the indicators, and have not applied systems thinking skills. In line with this, preliminary study data analysis of 60 students in Lampung Province also stated that 72% of learning was carried out traditionally, 73% had not integrated STEM and the score obtained by students regarding systems thinking was still low, namely 40.

Referring to this background, we need an adaptive learning program used today and liked by students so that active and effective learning can be created, and can improve students' skills, one of which is systems thinking. Based on the explanation stated above, researchers are interested in developing a flipped classroom learning program that is integrated with STEM to improve students' systems thinking skills on climate change material.

## Method

The research method used in this research is the research and development of the ADDIE model developed by Branch. The ADDIE model consists of five main stages, namely analysis, design, development, implementation, and evaluation. The stages of the ADDIE model can be seen in Figure 1.

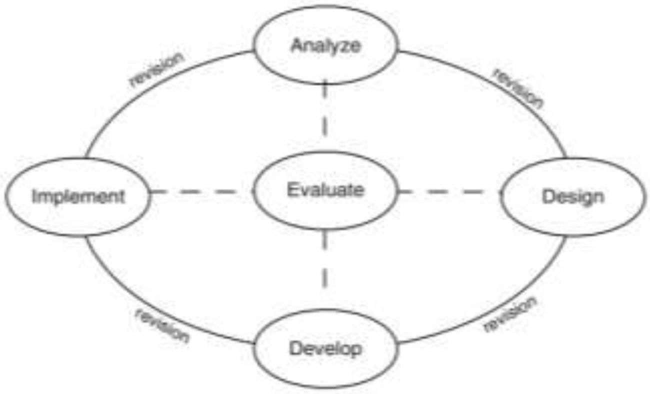


**Figure 1.** Stages of the ADDIE development model

*Analysis*

At this stage, an analysis of teacher performance in teaching and an analysis of student needs are carried out. Performance analysis by giving questionnaires to 30 science teachers from public and private schools spread across 15 districts/cities in Lampung and analysis of student needs by giving questionnaires to 60 class VII middle school students from state and private middle schools spread across 15 districts/cities in Lampung.

*Design*

This stage carried out the development of a learning program which included analysis of KI and KD, development of RPP, LKPD, and test instruments which all integrated STEM and in its application used flipped classroom learning assisted by Google Classroom. The test instruments are prepared to refer to indicators of systems thinking skills, namely recognizing interactions, identifying reciprocal relationships, understanding dynamic behavior, differentiating types of variables and information flows, using conceptual models, creating simulation models, and testing policies.

*Development*

At this stage, expert validation is carried out to assess the feasibility of the product being developed. This validation was carried out by 2 science education experts who covered aspects of the suitability of content and construction. Furthermore, improvements were made based on suggestions and input, and trials were carried out on 6 Al Kautsar Middle School teachers in Bandar Lampung. The product is deemed feasible and ready after revisions are made based on input during testing.

*Implementation*

This stage is the stage of implementing a program that is ready with the aim of guiding students to achieve learning goals, ensuring that at the end of learning, students have competency in systems thinking skills. After implementing the integrated STEM flipped classroom learning program, the implementation of the learning was then assessed by observers and the practicality of the learning program was assessed by students, as well as student feedback through interviews.

*Evaluation*

This stage is carried out to evaluate and improve each stage of the learning program development process starting from the RPP, LKPD, and assessment instruments. Apart from that, an evaluation was carried out on the pre-test and post-test scores in terms of n-gain and effect size, students' scientific skills, product creation, teacher responses, and student responses.

## Result and Discussion

This research begins with an analysis stage to determine the extent of teacher performance in the learning process. At this stage three analyses of teacher performance were produced, namely knowledge about the flipped classroom, STEM, and systems thinking. In the analysis of flipped classroom knowledge, it was found that 31% of teachers did not understand the flipped classroom, 32% did not know the stages, and 30% had never applied it in learning. Meanwhile, regarding the integration of STEM in learning, 33% know what STEM is, 33% have integrated STEM, 40% have used a scientific approach, 36% of students design and make products, 35% have used technological equipment, and 35% have used mathematical formulas. Furthermore, regarding the understanding and implementation of systems thinking skills in learning, data showed that 28% understood, 25% knew the indicators, and 27% had used systems thinking skills assessment. Apart from that, a test was carried out using questions with systems thinking indicators which resulted in an average student score of 40. From this analysis stage, it can be said that teachers in Lampung province do not yet understand and use the flipped classroom and STEM integration in learning so students' systems thinking skills have not developed optimally.

At the implementation stage, a pretest and posttest were carried out in the control and experimental classes and then the results were compared to see the effectiveness of the STEM-integrated flipped classroom learning program in improving systems thinking skills. The following are the results obtained in the control and experimental classes.

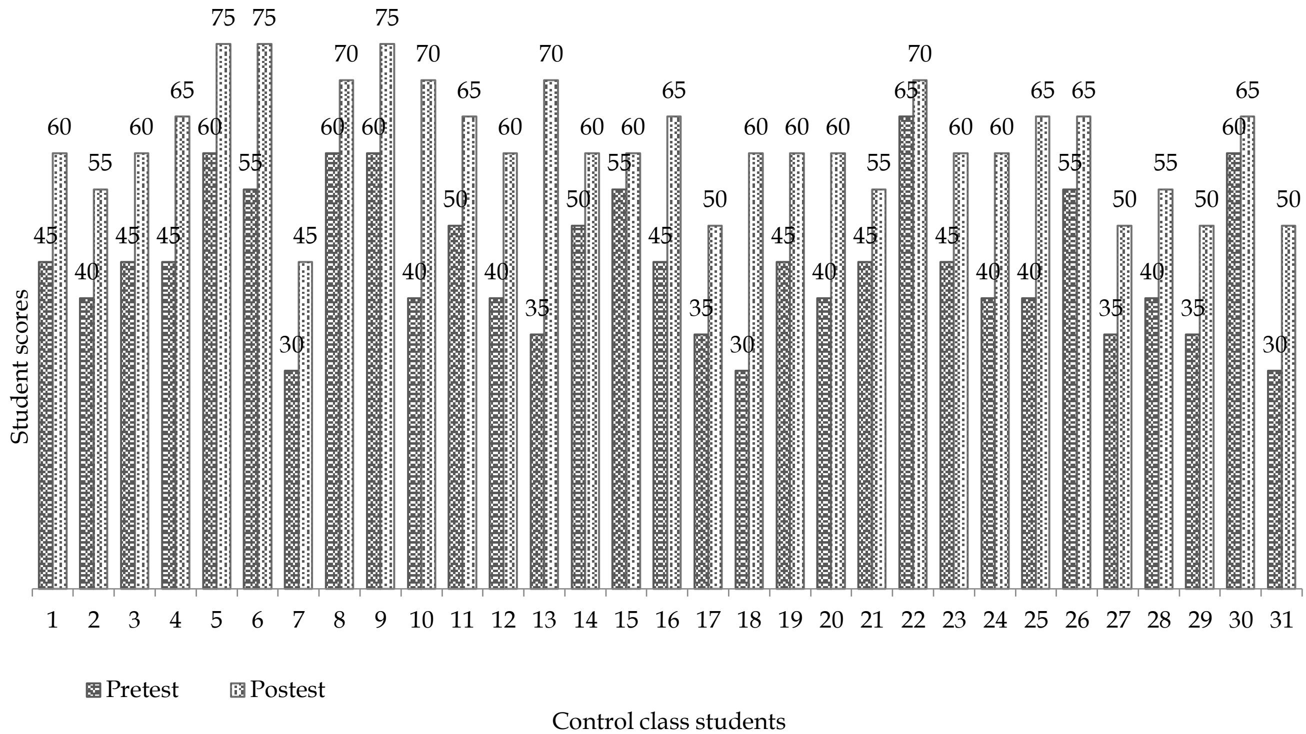


**Figure 2.** Control class pretest and posttest scores

Based on this data, the increase in value is measured by the n-gain value. From calculations in the control class, the average n-gain was 29.42, which is included in the low category.

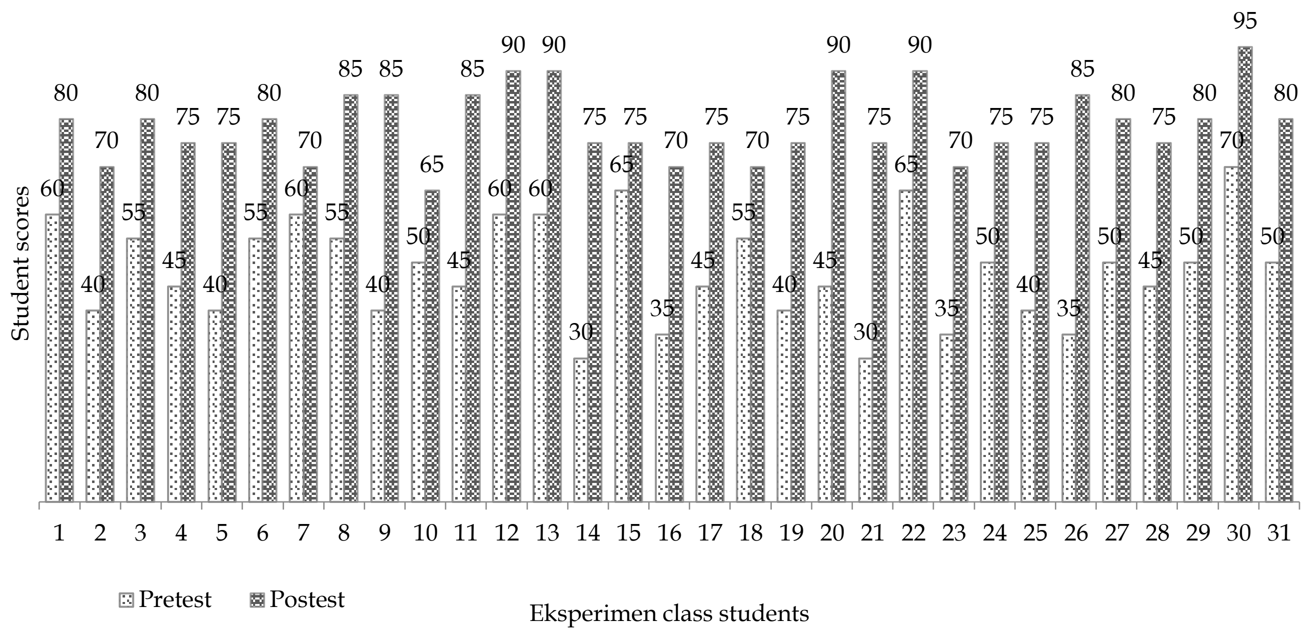


**Figure 3.** Pretest and posttest scores for system thinking skills in the experimental class

Based on this data, it can be seen that the average increase in pretest and posttest scores was 30.3% and the average n-gain obtained was 58.41 in the medium category. The increase in scores occurred in the control and experimental classes. This increase can be seen from the n-gain value. To find out the comparison of the increase in the control class and the experimental class, you can see the following n-gain comparison.

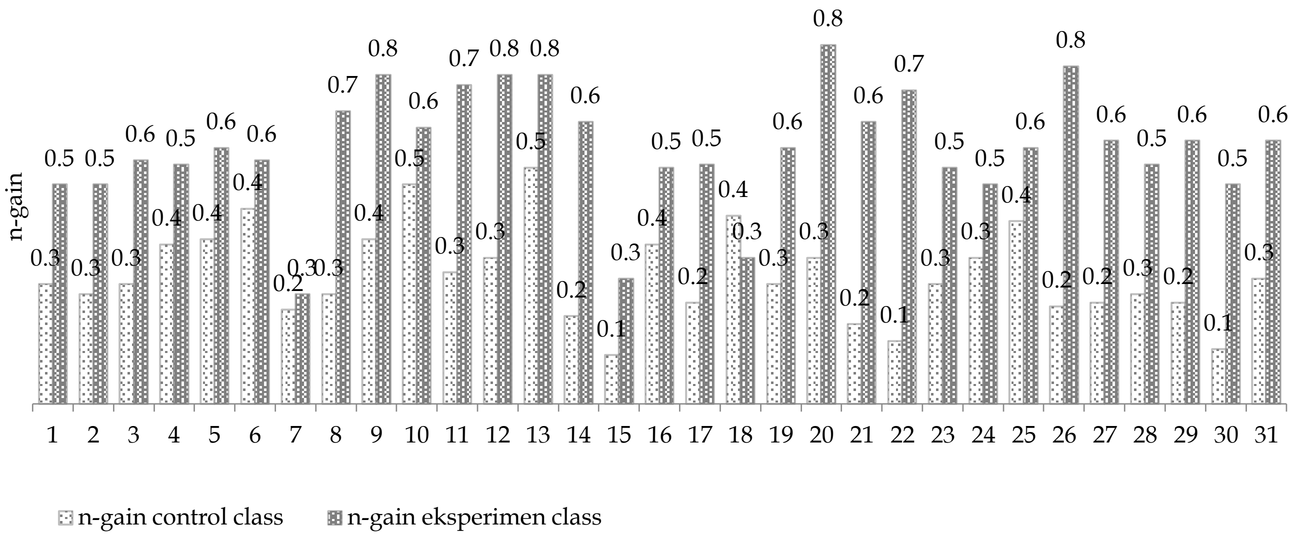


**Figure 4.** Comparison of n-gain in the control class and experimental class

From the Figure 4, it can be seen that the average N-gain for the experimental class is higher than the control class. To find out how big the effect of implementing the flipped classroom learning program is in improving systems thinking skills, an effect size test was carried out. Based on the results of the effect size test calculations, the effect size values are obtained as presented in the following table.

**Table 1.** Data from effect size calculations

| Class | Mean n-gain | Standard deviation | Effect size | Category |
|---|---|---|---|---|
| Experimental | 58.41 | 10.8485 | 2.263 | Medium |
| Control | 29.42 | 14.3754 | | |

Based on calculations, the standard deviation in the experimental class is smaller than in the control class, which means that students' scores on average have increased. Apart from that, the effect size value obtained was 2.263 which was obtained from the control class and experimental class values. By the criteria according to Cohen (1988), this value is in the range 2 < d ≤ 8 in the medium effect category. This shows that the STEM-integrated flipped classroom learning that has been developed and implemented has a moderate influence in improving students' systems thinking skills. Interpretation of Cohen's d effect size in this study can also be seen in the following Figure 5.

From the Figure 5, 59.0% of the experimental class scores are above the control class average (Cohen's U3), and 91.0% of the two classes will have equal and overlapping scores, as well as 56.4% of students who were randomly selected from the experimental class, will have a higher score than a person randomly selected from the control class (probability of superiority). Apart from that, to further improve the scores in the experimental class we need to pay more attention to 14.5 people. The effect size data also shows that flipped classroom integrated STEM learning has a big influence on improving students' systems thinking skills. Increasing systems thinking skills occurs in all indicators, the order of increasing systems thinking skills in each indicator starting from the highest to the lowest indicators, respectively, is recognizing the structure and role of components, analyzing patterns and modeling a system, analyzing interactions that occur, occurs in components in a system, and predicts system behavior due to interactions that occur within the system and outside the system.

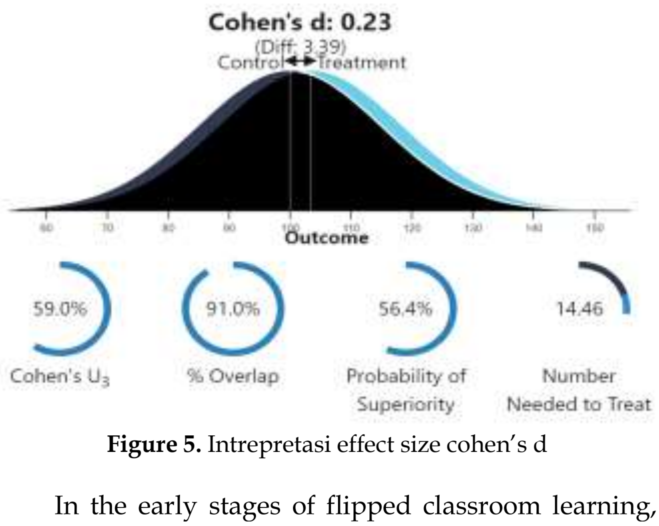


**Figure 5.** Intrepretasi effect size cohen's d

In the early stages of flipped classroom learning, one of the indicators can be seen in student response data which states that 92% of students watched the learning video more than once, which shows that students' enthusiasm for learning is high, this has an impact on a more optimal learning process, this is in line with research results by Förster et al. (2022) which state that one of the successes of the flipped classroom is the seriousness of students who watch the videos sent many times. Other data from student responses shows that 87% of students feel more prepared when studying in class. Because students who have heard information from videos or other sources will be more ready to discuss the information or material than students who have never heard the material at all (Beatty et al., 2019).

Other data states that as many as 82% of students feel motivated to take part in class, 87% admit that learning with a flipped classroom is more interesting and 86% are more active when studying. The various positive effects of the flipped classroom are by research by Hosein et al. (2022), which states that the flipped classroom has an impact on students' cognitive load, engagement, motivation, and attitudes towards learning. The series of positive effects of implementing the flipped classroom on learning makes students want similar learning in the following materials, namely as many as 92% want to learn in the same way.

To support data on the effectiveness of the learning program developed, researchers tried to see the performance of one of the students who got the highest n-gain score. If we look at the intensity of AD students watching videos, they are among the students who watched the most videos, namely 4 times for the first video and 3 times for the 2nd video. The high viewing intensity is in line with the results of AD students' answers to the online LKPD. In the first online LKPD related to knowledge about greenhouses, AD students answered all questions correctly, the reasons given were also reasonable, and used their language, this shows that AD students understand the material in depth.

Apart from the effectiveness, the success of the learning program is also seen from the practicality of learning which includes assessing students' scientific performance and student responses after the learning process. In the scientific performance assessment, students get a score on each indicator as follows; students determine basic questions 86%, Determining Tools and Materials 92%, Project Design Planning 82%, Preparing Schedules 84%, making products 88%, testing results 91%, Using technological tools 92% and using mathematical formulas 89%. Based on these results, the assessment of students' scientific performance and STEM integration was 88% with very high criteria, which means that the implementation of learning has integrated STEM well.

With STEM integration, it allows students to work actively both in discussion and practice, this is because STEM requires students to be able to plan, design, and create an idea or product in groups. This can of course be done if students are active. The results of student responses of 81% show that the experimental class which was previously passive in learning activities became more active. Students actively learn through groups in completing assignments and making observations. Students are active in searching for and solving problems given so that students discover new knowledge. This is to Vygotsky's theory (Kemendikbud, 2013) Zone of Proximal Development (ZDP) and scaffolding which emphasizes social interaction, namely, cooperation, and exchanging opinions between students and teachers in learning. This is in line with research by Luamba et al. (2022) which explains that STEM integration can improve students' cognitive and psychomotor learning outcomes. Another opinion was also expressed by Suyanto (2023), stating that STEM can make students solve problems, be creative, critical, able to communicate and collaborate.

Learning that integrates STEM allows students to learn more realistically, such as making a mini greenhouse that directly presents ecosystem components and observing the interactions that occur between components. This will be more impressive and meaningful for students than just using pictures or writing in books. The same thing was expressed in research by Agustyaningrum et al. (2022) which stated that the learning process by presenting real objects would be more effective than abstract explanations. Apart from that, increasing systems thinking skills for each indicator occurs because students learn directly related to what is being studied in the surrounding environment (contextual). For example, regarding the use of motorized vehicles which causes an increase in carbon dioxide, cutting down trees, and other factors that cause climate change. This is in line with the research results of Momsen et al. (2022), which state that students' systems thinking skills will improve with real learning or direct practice. This is supported by constructivism theory based on Piaget (1997) which states that cognitive development increases if individuals learn directly from the environment or phenomenon being studied. Apart from that, tools with current technology and various learning resources can increase effectiveness and efficiency in understanding students (Masgumelar & Mustafa, 2021).

After the lesson, research was conducted on student responses to the implementation of the learning program development to determine the practicality of the learning program, and the percentage of student responses was 81% with the criteria very high indicating that the student response to the development of the STEM integrated flipped classroom learning program had very high practicality. In improving students' systems thinking skills, the following is the process of making mini greenhouse products for students.

**Figure 6.** The process of making a mini greenhouse by students and the resulting mini greenhouse products

## Conclusion

From the research results, it can be concluded that the STEM integrated flipped classroom learning program is effective in improving students' systems thinking skills in terms of the average n-gain value obtained, namely 0.58 in the medium category, with the smallest value being 0.25 and the largest being 0.83, and the effect size is 2.26 with medium criteria. Apart from that, this program is practical in improving students' systems thinking skills in terms of the average percentage of teacher performance in managing learning, namely 89% with very high criteria, the average percentage of students' scientific performance, namely 88% with very high criteria, the average skill score Student practicum was 88% with very high criteria, and student response to learning was 81% with very high criteria.

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**Author Contributions**
The main author, Fatoni Latif, contributed to designing and carrying out the research and writing the article. The second and third authors, Abdurrahman and Noor Fadiawati took part in assisting the research implementation process, designing research instruments, validating the instruments, and guiding the writing of the article until completion. All authors have approved the version of the manuscript to be published.

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**Conflicts of Interest**
The authors declare no conflict of interest.

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