Climate Change: STEM Project and Systems Thinking for Holistic Solutions

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Abstract. Climate change is an important issue in sustainable development goals. The complexity of climate change requires an understanding of the underlying system as a basis for solutions to overcome it. The main focus of this research is to improve students' systems thinking abilities in facing environmental challenges, namely climate change, by learning STEM project. The method used was pre-experiment with a one-group pretest-posttest design. The instrument used is a systems thinking test. The research involved 235 fourth grade students of state elementary schools in Bandung City who were selected purposively. The data obtained were analyzed quantitatively with paired sample t-test and n-gain. The research results show a significant increase in students' systems thinking regarding climate change and their ability to apply systems thinking in finding innovative solutions. The practical implications of this research highlight the importance of STEM education in forming a generation that has a deep understanding and practical skills in facing future environmental challenges.

Keywords: Climate Change, STEM project, Systems Thinking, Elementary Student

1 Introduction

Climate change has become an urgent global issue and requires a holistic response from the international community [1]. Impacts such as rising global temperatures, changes in extreme weather patterns, and hazards to environmental sustainability [2], [3], indicate the need for collaborative efforts, especially the involvement of the younger generation in understanding and discovering sustainable solutions. In this context, education is considered the key to equipping the younger generation with the knowledge and skills needed to understand, countenance and deliver solutions to climate change [2], [4], [5]. STEM (Science, Technology, Engineering, and Mathematics) education is identified as a practical approach to shaping students' understanding and skills regarding contemporary issues, including climate change [6]–[9].

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The application of STEM projects is the focus of this research, along with the realization that project-based learning can deliver contextual and in-depth student experiences. Project-based learning allows students to investigate and explore solutions to climate change issues in-depth. Within the framework of controlling climate change, STEM projects stimulate and improve students' systems thinking. Systems thinking, as the ability to understand and analyze the complex relationships between components in a system, is considered an essential skill for facing the difficult challenge of climate change.

Student involvement in STEM projects, on the issue of controlling climate change also aligns with the demand for skills-oriented education, where conceptual knowledge, practical skills, and critical thinking are emphasized. STEM projects provide opportunities for students to understand the scientific principles underlying climate change and develop the systems thinking skills that necessary to analyze its impacts. In this case, STEM projects facilitate knowledge transfer and shape students as informed and critical decision-makers regarding climate change.

Previous research shows that implementing STEM projects can create deep and challenging learning contexts where students understand scientific concepts and apply them in real-world contexts. STEM is an effective way to introduce and learn systems thinking [8], make the right decisions regarding scientific and engineering problems [10], [11], and emphasize contextual problem-solving in the real world [7], [12]. Thus, this research aims to explore the potential of STEM projects in improving students' systems thinking abilities, especially within the framework of controlling climate change. With an in-depth understanding of the relationships between components in the climate system, it is hoped that students can become agents of change who are more informed and think critically about the challenges of global climate change.

This research is critical because it contributes to our understanding of the effectiveness of STEM project learning in improving students' systems thinking abilities, mainly when applied to issues that have a global impact, such as climate change. Through this approach, students can internalize scientific concepts in a practical context, increase their understanding of complex climate system interactions, and encourage active participation in overcoming climate change. Thus, this research not only enriches the literature on effective learning strategies but also contributes to global efforts to increase student literacy and engagement in addressing the pressing issue of climate change.

2 Methods

This research investigates the improvement of students' systems thinking regarding the issue of controlling climate change through STEM project interventions. Therefore, the research method was pre-experimental with a one-group, pretest-posttest design [13]. This research did not use a comparison class. Among 235 fourth-grade students from ten classes from three schools in Bandung were involved in this research. The selection of research subjects was carried out using a purposive sampling technique [14] on the basis that the school used as the research location raised the issue of climate change as a project theme.

The research stage began with preparing a STEM project design for fourth-grade students on the issue of controlling climate change. The designed project includes five activities to be implemented over approximately five weeks. Process design engineering guides STEM project activities, which consist of the following steps: a) Defining the problem, b) Examining the problem setting, c) Designing a solution, d) Modeling, testing, and redesigning, and e) Communicating the manufacturing process and the results. The project design is equipped with LKPD that guides student learning activities for each project. Furthermore, the project design and LKPD are validated by experts, including project learning, STEM, and essential education experts. After going through a revision process based on expert validation, a readability test was carried out on students to ensure that the instruments used were appropriate to the developmental stages of elementary school students.

The next step is to develop an instrument about climate change. This instrument was developed referring to systems thinking indicators which include: a) Identifying components and processes in the system, b) Identifying superficial relationships between system components, c) Identifying dynamic relationships between components in the system, d) Organizing components and processes in a relationship framework, e) Understanding the cyclic nature of the system, f) Making generalizations, g) Recognizing hidden dimensions of the system, and h) Temporal thinking, retrospection and prediction [1], [9], [15]–[19]. Each indicator was developed into two multiple-choice questions, so a system thinking test about climate change comprised 16 questions. The instruments used have gone through validation tests, both expert and empirical.

This project was carried out for five weeks. Before the implementation, researchers maintained an initial FGD with ten teachers to ensure an understanding of the objectives and significant steps of the intervention activities. The small group FGD were conducted for each school at the beginning to provide the STEM steps and their implementation in the project. The aim is to improve students' systems thinking regarding climate change. This FGD was carried out via a virtual Zoom meeting for two hours for each school.

Systems thinking tests were administered before and after the intervention. The system thinking data is then processed and analyzed by calculating the average of the pretest and posttest and carrying out different tests for the pretest and posttest using the paired sample t-test. Finally, the n-gain is calculated to determine the size of the increase and then compared with the n-gain criteria.

3 Results and Discusssion

Systems thinking is defined as the ability to recognize components that interact in a system so as to be able to see the system as a whole or isolate and focus on each component [20]. Systems thinking seeks to find relationships and patterns in various underlying systems [21]. Thus, systems thinking is the ability to identify components, processes and relationships that occur in a system. In this research, systems thinking data was obtained through testing before and after a STEM project intervention on the issue of controlling climate change. Systems thinking test Refers to systems thinking indicators which consist of 8 indicators.

Table 1. Pre-test and post-test data

Data	Pre-test	Post-test
Subjects	235	235
Minimum Score	0	19
Maximum Score	63	100
Mean	28,86	53,09
Std. Deviation	12.126	14.146
Paired sample t-test	Sig. (2-tailed) = 0,000	
n-gain	0,35	

Table 2 indicates a significant difference between the paired sample t-test and the mean of the initial and final tests. The average increase in the initial and final tests was 0.35 in the medium category. This shows that applying STEM projects to the issue of controlling climate change can significantly improve students' systems thinking. The intervention project learning caused an increase in students' systems thinking. The project learning consisted of five activities carried out continuously for six weeks. Project learning can improve systems thinking because students are challenged to solve climate change problems guided by driving questions. This question allows students to gain insight into the role of the various components involved in the climate system. To solve these questions, students are encouraged to engage in in-depth and sustained inquiry to recognize the interactions and interconnections of each component and process in the climate system. Then, they use scientific practices to make products that solve the problem of climate change. Activities in project learning in this way require students to think about climate change comprehensively. This finding is in line with research results that suggest that project activities with contextually relevant problems and the use of scientific methods to solve them have the potential to foster students' systems thinking [9]. It is even emphasized that project learning is a pedagogical approach to developing various skills, general abilities, and knowledge compilation [22], one of which is systems thinking.

On the other hand, the emphasis on resolving urgent contextual issues is another cause. This project is focused on Sustainable Lifestyle as the central theme. The choice of this theme was based on the topic raised, namely environmental problems, namely climate change, which is recognized as a global challenge today [1], [23]–[25]. Climate change is considered a contextual issue that triggers the learning process. To address climate change, the first step for students is to understand how the climate operates as a system, identify the factors that influence it, and realize their interrelationships [25], [26]. In addition, students are also asked to consider the impact of human actions on system behaviour, understand how a system behaves, and assess how human policies can affect climate change as a system [27]. The following process involves students' ability to organize and interpret broad and varied information related to climate change [28]. Finally, students are expected to be able to offer solutions according to their capacity as elementary school students [26], [29]. All efforts made by students to understand and overcome climate change are identified as systems thinking processes. This aligns with the view that explaining and solving complex phenomena requires systems thinking abilities [30], [31].

Furthermore, the increase in systems thinking was also caused by applying multidisciplinary concepts in project learning with a STEM approach throughout the intervention. Climate change is a complex global challenge [27], [29], [32]–[35]. Efforts to understand and overcome this difficult problem require integration and collaboration across scientific disciplines [25], so that it can be viewed from various perspectives [18], [19], [24], [27], [36], [37] which broad and integrated [38], [39]. STEM, as a combination of science, technology, engineering, and mathematics [40], [41], becomes a bridge between these four disciplines and real-world problems, namely climate change [42]–[44], to encourage significant involvement [10], [45]. Through STEM learning, students investigate climate change as a natural phenomenon that is an object of scientific study. They apply scientific concepts and methods to understand them while also considering human technologies that can be used to design solutions. Product design and construction in STEM involves mathematical patterns and relationships. Therefore, STEM guides students in solving climate change problems by building solid connections between science, technology, engineering, and mathematics so that they can integrate, analyze, and interpret climate change (Sirakaya). Utilizing the integration of concepts, insights and skills from various scientific disciplines in STEM supports the application of systems thinking in learning [[28], [46]–[49].

The engineering design process fundamentally connects all STEM disciplines [50]. It is also one of the factors in increasing students' systems thinking after implementing STEM projects. This process is defined as a systemic process.

4 Conclusion

Involving STEM projects to control climate change can significantly improve students' systems thinking. Involving students in projects that focus on contextual climate change issues opens up opportunities for them to understand the complexity and interconnectedness of various components in the climate system. The driving questions integrated into the project are crucial to stimulating students' deep and holistic thinking. The in-depth investigation into the interactions and relationships between components and the application of scientific methods in designing concrete solutions allows students to develop holistic systems thinking. STEM projects offer hands-on, substantial experience through the engineering design and prototype testing stages. Students' interactions with physical objects link the intellectual realm and form a strong bridge with the practical realm, enriching their learning experience. These findings are consistent with previous research results that highlight the importance of project learning, especially in the context of contemporary issues such as climate change. STEM projects not only create students' deep understanding of climate change but also provide a platform for honing systems thinking skills essential for understanding, analyzing, and responding to complex real-world problems. Thus, implementing STEM projects on the issue of controlling climate change is a practical and relevant pedagogical approach to improve students' systems thinking abilities.

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