Journal of Innovation in Educational and Cultural Research

Volume 6 Issue 4 Year 2025 Pages 692-704
ISSN 2722-9688 | e–ISSN 2722-9696
http://jiecr.org | DOI: 10.46843/jiecr.v6i4.2326

Pre-Service Teachers' Perceptions of the Contributions of Field Trips on Climate Change Education

Eko Yuliyanto[1*], Supriyanto[1]
[1]*Universitas Muhammadiyah Semarang, Indonesia*

*Correspondence to: *ekoyuliyanto@unimus.ac.id*

Abstract: Numerous methodologies have been employed to enhance competencies in climate change education. However, applying and systematically evaluating field trips as a pedagogical approach in climate change education must be explored. It is essential to explore pre-service teachers' perceptions regarding the impacts of their participation in field trips. This study evaluated the significant changes observed in pre-service teachers following field-trip-based learning. The field trip program was evaluated using the Most Significant Change (MSC) evaluation model. The results identified several themes of substantial changes in pre-service teachers. This study concludes that field trip-based learning facilitates positive transformations in pre-service teachers, as evidenced by their favorable responses following the field trip and their reflective insights on the conceptual understanding of climate change. This research contributes to scientific understanding by demonstrating that sea level rise, which has led to the submergence of villages along the northern coast of Java, serves as a valuable contextual framework for field trips to study the impacts of climate change. In recognition of the limitations, future research should broaden its scope to include field trip activities in diverse geographical settings.

Keywords: climate change education; evaluation; experiential learning; field trips; most significant change approach

Recommended citation: Yuliyanto, E., & Supriyanto. (2025). Pre-Service Teachers' Perceptions of the Contributions of Field Trips on Climate Change Education. *Journal of Innovation in Educational and Cultural Research*, 6(4), 692-704.

INTRODUCTION

To cultivate a well-prepared generation, it is important and strategic to educate pre-service teachers in educational institutions on behaviors that prevent the causes of climate change (Nurramadhani et al., 2022). However, Climate Change Education (CCE) for pre-service teachers faces numerous challenges. These include 1). pre-service teachers in Finland being unable to differentiate between small-impact and large-impact climate change mitigation actions (Tolppanen et al., 2021); 2) pre-service teachers' low level of concern about climate change in the Philippines (Competente, 2019); 3) pre-service teachers' lack of understanding of the concept of climate change in Ghana (Nyarko & Petcovic, 2021); 4) pre-service teachers' insufficient comprehension of climate change education concepts in Spain (Corrochano et al., 2022); and 5) pre-service teachers' inability in Finland to engage in climate change mitigation actions, coupled with a tendency to blame other parties (Tolppanen & Kärkkäinen, 2021). Pre-service teachers' insufficient understanding of climate change will adversely affect their pre-service teachers' self-efficacy of mitigation actions (Jurek et al., 2022). These findings indicate a pressing need to enhance the overall conceptual understanding of climate change in higher education.

Pre-service teachers' conceptual problems necessitate a comprehensive understanding of climate change, the capability to engage in mitigation efforts, and the ability to adapt to changing conditions (Ferguson, 2022). One proposed solution is for universities to develop low-carbon education programs (Nurramadhani et al., 2022). These programs should enhance knowledge to reduce misconceptions (Khalidi et al., 2020; Nyarko & Petcovic, 2021) and utilize contextualized learning resources (Corrochano et al., 2022). These efforts should also consider students' backgrounds (Skarstein, 2020) as well as internal, external, and demographic factors (Wang et al., 2021). Few higher education institutions develop programs to enhance pre-service teachers' competence in climate change education (Wang & Vasques, 2022). Chemistry education programs, for example, present a strategic opportunity for fostering pre-service teachers' climate change education. Researchers from various countries, including Indonesia, have studied climate change education. The chemistry education curriculum in Indonesia includes courses on global warming and climate change, positioning these programs advantageously. Additionally, the paradigm within chemistry education emphasizes learning chemistry and applying it to preserve local, national, and global environments (Sjöström et al., 2020). This perspective endows pre-service chemistry teachers with a moral responsibility to educate others about climate change (Jiang et al., 2018).

Several recommendations proposed by Filho et al. (2021) for universities to enhance climate change education include organizing multidisciplinary courses, strengthening curricula, training academic staff, and integrating climate change topics in both education and research. Additionally, improving the professionalism of teachers in teaching climate change is specifically emphasized (Winter et al., 2022). It is imperative to enhance

the quality of pre-service teachers by ensuring they possess the necessary knowledge, attitudes, and skills to effectively engage in climate change mitigation (Wang & Vasques, 2022).

Several strategic approaches can be adopted to facilitate pre-service teachers' behavioral changes in climate change mitigation. These include (1) emphasizing personally relevant and meaningful information and (2) employing active and engaging teaching methodologies. Literature also advocates prioritizing the relevance and meaningfulness of information for pre-service teachers and promoting active and constructivist learning methods (Arik & Yilmaz, 2020). Various methodologies have been employed to enhance competence in climate change education, including teacher training programs (Favier et al., 2021), exposure to visual representations of climate change impacts (Liu et al., 2021), training aimed at enhancing future-oriented thinking skills (Ferguson, 2022), and engagement in direct environmental problem-solving activities (Nazarenko & Kolesnik, 2018), implement place-based learning and involve learners in activities (Mbah et al., 2021), real-world experiences, problem-based learning, and case studies (Martínez et al., 2022).

Climate change mitigation encompasses a spectrum of activities integrated into daily routines. Trott (2022) underscores that contextual problem-based topics can effectively heighten climate change awareness, necessitating the establishment of appropriate learning contexts or situated learning environments (Renkl, 2001). Engaging pre-service teachers in learning through real-world problems to comprehend climate change represents a significant step forward in fostering a deeper understanding of the issue (Ghanem, 2022). Providing pre-service teachers with experiential learning opportunities can effectively enhance their understanding of climate change and foster proactive responses to its challenges in the future (Kiers et al., 2020). Climate change presents various challenges, including rising air temperature trends (El-Geziry, 2022), landscape dynamics (Wigand & McCallum, 2017), and shifts in precipitation patterns (Gerçek, 2024). These tangible issues provide a relevant and contextual foundation for teaching climate change concepts. Various forms of experiential learning include project-based or problem-based learning, service learning, place-based learning, field trips, and internships (Backman et al., 2019). Field trips can be conducted in lakes (Güler & Afacan, 2018) and national parks (Jelle et al., 2019). Despite these diverse applications, there remains limited utilization of field trips as a method to enhance pre-service teachers' understanding of global warming and climate change.

Investigating field trips as a tool for enhancing pre-service teachers' understanding of global warming and climate change necessitates a methodological approach prominently involving evaluation. The evaluation of field trip programs can be effectively conducted using Kirkpatrick's model, chosen for its capability to assess program achievements at the individual level over the long term (Kirkpatrick, 1994). To delve into this, participants must critically reflect and analyze the outcomes and transformations they have made during the field trip experience (Choy & Lidstone, 2013).

Kirkpatrick's model effectively measures impacts through quantifiable outcomes but needs to be more comprehensive in capturing unexpected outcomes and personal transformations. This limitation can be addressed by incorporating the Most Significant Change (MSC) technique, which allows for identifying and analyzing unanticipated changes and individual growth. Previous research has utilized the MSC technique to evaluate the impact of interventions on participants (Ghadirian et al., 2021; Wells et al., 2024). MSC offers several advantages: 1) it promotes in-depth self-reflection among participants; 2) it generates qualitative data driven by participant narratives, encompassing a diverse range of outcomes; and 3) it enhances understanding of how learning integrates into participants' professional and personal contexts (Henry et al., 2022). The utilization and evaluation of field trips employing the Most Significant Change (MSC) technique to enhance pre-service teachers' understanding of global warming and climate change remain limited. This underscores the necessity for further research into implementing field trips for pre-service teachers, focusing on evaluating the significant changes observed in such activities. In alignment with the study's objectives, the research questions (RQs) adopted were "What are pre-service teachers' perceptions regarding the impact of their participation in field trips?". The findings of this study are expected to contribute to scientific knowledge by demonstrating that sea level rise, which has resulted in the submergence of villages along the northern coast of Java, provides a meaningful contextual framework for field trips designed to examine the impacts of climate change.

METHODS

The Most Significant Change (MSC) evaluation model was utilized (Den Heyer et al., 2021). This evaluation approach relied on the narratives provided by participants, detailing the changes they experienced as a result of the program (Davies, 1998). The most significant changes observed in pre-service teachers following the field trip were identified through pre-service teachers' responses, post-field trip group interviews with 21 pre-service teachers, and reflections. This study evaluated the significant changes observed in pre-service teachers following field-trip-based learning. The following data were utilized to evaluate the impact of field-trip-based learning: *Pre-Services Responses, Post-Field Trip Group Interviews and Reflections.*

The participants were 21 students from the Muhammadiyah Semarang University in Indonesia, also called pre-service teachers, comprising three males and 18 females, engaged in field-trip-based activities. Field

trips are integrated into the lecture activities, with pre-service teachers' participation being voluntary. The selection of pre-service teachers from this campus was based on their status as pre-service chemistry teachers and the proximity of their campus to the site of the sinking village phenomenon. This unique context provides an ideal opportunity to incorporate field trip activities, enabling pre-service teachers to directly observe and learn about the tangible impacts of climate change. The rising sea levels leading to the submergence of villages along the northern coast of Java serve as a valuable context for studying the impacts of climate change. The rise in sea levels has precipitated substantial alterations to the shoreline in the coastal regions of Demak, Indonesia (Prasetyo et al., 2019). The phenomenon of sea level rise is also observed in Bedono village, making it a valuable learning resource for comprehending the impacts of climate change (refer to Figure 1).

Figure 1. The inundated residences of some Bedono Village inhabitants

The educational program consisted of 16 sessions, with the distribution of learning materials detailed in Table 1. Kolb's experiential learning cycle designed the field trip learning activities, encompassing the stages of active experimentation, concrete experience, reflective observation, and abstract conceptualization (Stern & Powell, 2020).

Table 1. *Distribution of Environmental Chemistry Educational Content*

Week	Learning Outcomes	Material	Method
1	Explaining the relationship between earth, sky, and humans in the concept of biosphere unity	Earth, Sky, Humans, and the Biosphere	Lecture
2	Connecting the concepts of environmental science and ecology	Environmental Science and Ecology	Discussion
3	Connecting the concepts of environmental science and ecology	Ecological Crisis	Discussion Field Trip
4	Elaborating on the concept of pro-environmental attitude	Pro-environmental Attitude	Presentation
5	Carefully separating various environmental issues	Environmental Issues and Solutions	Discussion
6–7	Explaining the concept of global warming with concrete evidence	The Concept and Impact of Global Warming	Discussion
8	Submitting a field trip report via Google Forms	-	-
9	Describing the concept of ecological footprint	Ecological Footprint	Discussion
10–15	Designing and implementing solutions to environmental problems	Low-carbon Project	Project
16	Reflecting on the learning process and collecting videos of the Project.	-	-

The environmental chemistry instruction follows a structured sequence of materials, as outlined in Table 1. To facilitate comprehension of ecological crises, pre-service teachers collaborated in groups to identify such crises at local, national, and global levels. Following their analysis, the identified ecological crisis is collectively examined in the classroom utilizing the Jam board tool.

The discussion yielded a consensus that human activities predominantly drive ecological crises. Pre-service teachers were further organized into several disciplined groups to investigate the ecological crisis in a specific area. These groups focused on the issue of ecological crisis, exemplified by the case study titled "A Story of One Family in Demak Surviving in a Sinking Village, Using Boats and Planting Thousands of Mangroves." The case of the ecological crisis is examined using news articles published by national newspapers in Indonesia.

From this article, pre-service teachers acquired preliminary information regarding the submerged village, including the cause of the flooding, proposed solutions, and governmental responses. A field trip was conducted to verify the existence of an ecological crisis reported in the news and observe the actual conditions.

The collection of relevant data is essential to explore pre-service teachers' perceptions of the impact of participating in the field trip. The following data were utilized to evaluate the impact of field-trip-based learning. A post-field trip questionnaire was administered to the participants to gather insights into pre-service teachers' responses following the field trip. A questionnaire consisting of open-ended questions was administered to each pre-service teacher (Romero et al., 2024); pre-service teachers' responses included personal information (name, university, age, and gender), the supportive role of environmental chemistry learning, pre-service teachers' evaluations of their field trip experiences, pre-service teachers' discoveries, notable impressions from the field trip, and pre-service teachers' reflections encapsulated in a single word.

The following is a list of open-ended questions included in the questionnaire: 1) Do field Trip courses enhance the efficacy of environmental chemistry learning activities?; 2) Did you find the field trip course engaging and beneficial?; 3) What new insights or findings did you gain from participating in the field trip course? Please specify; 4. Identify the most compelling aspect of the field course; 5. Describe your fieldwork experience in Sayung with a single word. Semi-structured interviews were conducted to obtain verbal information following the field trip (Manchanda, 2024). These interviews aimed to identify significant changes in pre-service teachers and confirm their understanding of the previously covered material, a prerequisite for participating in the field trip. Each group of pre-service teachers was interviewed for 17–28 minutes. Five groups of 3–4 pre-service teachers participated in these interviews. The questions used in the interviews are presented in Table 2.

Table 2. Open-ended Questions

Questions
What is an ecological crisis?
What causes an ecological crisis based on your observations?
What is a field trip?
In your opinion, how was the field trip organized?
In your opinion, what are the benefits of a field trip?
In your opinion, what are the constraints of a field trip?
What skills did you master after the field trip?
What are your criticisms and suggestions for implementing field trips in learning?
What action would you take next to deal with these problems?
What do you know about environmental chemistry?
What role does yesterday's expo play in your learning?
What do you conclude from this field trip activity?

At the final meeting, pre-service teachers completed an online reflection form voluntarily. Reflection was necessary to explore pre-service teachers' understanding of global warming holistically (Zummo, 2024). In addition, to confirm their understanding of the interlink between low-carbon activities and ecological damage, pre-service teachers were presented with open-ended questions, as provided in Table 3.

Table 3. Reflection Questions

Questions
Write a reflection on environmental chemistry learning!
Are you satisfied with the environmental chemistry learning method?
Explain how your low-carbon activity relates to the ecological damage caused by the rising sea level in Bedono Village, Demak, Central Java, Indonesia!

Pre-service teacher responses to questions 1 and 2 were analyzed using percentage agreement (Olorunfemi et al., 2023), while responses to questions 3 and 4 were examined qualitatively. Additionally, responses to question 5 were further analyzed for word frequency through a word cloud (Rich et al., 2018). After participating in the entire series of field trip learning activities, pre-service teachers underwent an evaluation using the MSC technique. This evaluation was conducted through group interviews. The recorded data were transcribed, coded, and categorized, culminating in conceptualizing the phenomenon (Sutton & Austin, 2015). Pre-service teachers' responses to conceptualization questions regarding their understanding of global warming were analyzed with a focus on the accuracy of their conceptual grasp of the relationship between low-carbon activities and sea level rise (Tolppanen et al., 2021). The data were categorized into two groups: those responses that demonstrated alignment between field trip activities and low-carbon practices and those that did not. Subsequently, the data were presented quantitatively.

RESULT AND DISCUSSION

The field trip learning experience garnered positive feedback from pre-service teachers, who collected responses via Google Forms. Pre-service teachers documented their experiences during the field trip and shared their insights using a questionnaire. All pre-service teachers reported that the field trip fully supported their environmental chemistry learning and expressed satisfaction with the field trip experience. Pre-service teachers also shared new, intriguing discoveries they made during the field trip. Based on qualitative analysis, pre-service teacher responses can be categorized as reflecting the acquisition of new insights, with 17 pre-service teachers specifically identifying the concept of village sinking and three pre-service teachers noting other related knowledge. In addition to acquiring new experiences, pre-service teachers reported encountering particularly engaging experiences during the field trip. Through qualitative analysis of pre-service teacher responses, several categories emerged, including boat rides (7), observation of ecological crisis areas (15), and life motivation (1). The following are excerpts from some pre-service teachers' statements:

> *We could directly find out the actual conditions, history, and impact of rising sea levels. We could also ask the informants questions directly* (P7_VK).

According to pre-service teachers' feedback, the field trip offered stimulating and novel experiences that enhanced learning (Karpudewan & Khan, 2017). When asked to say only one word to describe their experiences with the field trip, they predominantly said "cool," indicating either novelty or a sense of awe and admiration. Following the field trip activity, semi-structured group interviews were conducted to collect verbal data and verify pre-service teachers' learning and comprehension. Recordings from each group were analyzed to identify significant changes experienced during the field trip. The interviews were transcribed verbatim, and an inductive approach was employed, as advocated by Kalman et al. (2017). Text segments were coded and analyzed to identify prevalent themes based on frequency of occurrence. The evaluation using the MSC approach of the field trip learning process revealed several key themes, summarized in Table 4.

Table 4. *The Most Significant Positive Changes*

Main themes	Description	Frequency(f) references by all participants
Thinking	The field trip fostered thinking skills	27
Confirmation	The field trip increased the confirmation ability	10
Action	The field trip fostered positive action	10
Contextually	The field trip provided contextual experiences	3
Empathy	The field trip fostered empathy for others	3

The field trip activities conducted in the inundated village prompted pre-service teachers to engage deeply with the phenomenon of the village submersion in seawater. This engagement signifies an enhanced pre-service teachers' focus on the subject matter studied in the course. The following excerpts of some pre-service teachers' statements illustrate how the field trip they were going on contributed to the development of their thinking skills:

> *Emm, Sir, I am getting better at thinking critically. While I used to think that the ecological crisis was caused only by (events of) nature like global warming, now humans also affect it* (P2_STY).

Analysis results unveiled that the second theme, field trips, provides a means for reconciling theoretical knowledge with actual conditions. Below are excerpts of some pre-service teachers' statements regarding the enhancement of verification techniques:

> *I mean (it is) not (something that we learn) only from literature but (something that) we can also observe directly. One more thing, Sir, a criticism of yesterday was that the preparation was too abrupt. Yesterday, during the survey, I attended matriculation* (P2_Group 2).

Pre-service teachers also verified information using academic literature in conjunction with the field trip. Table 5 presents the perspectives of pre-service teachers, residents, and literature regarding the causes of the sinking of Bedono Village. Verifying information based on various viewpoints is a valuable cognitive exercise for pre-service teachers. The presence of differing viewpoints stimulates critical thinking as pre-service teachers

strive to ascertain the veracity of information. Educators also play a crucial role in the learning process by providing feedback on the accuracy of pre-service teachers' knowledge.

Table 5. *Views on the causes of the ecological crisis of pre-service teachers, residents, and literature*

Pre-service teachers	Residents	Literature
The submergence of the village is attributed to a combination of factors, including tidal flooding, rising sea levels, coastal erosion, land subsidence, and the broader impacts of global warming.	The submergence of the village is attributed to persistent tidal flooding, declining groundwater levels, coastal erosion, and the structural failure of sea walls in the local area.	Research indicates that tidal flooding is primarily caused by rising sea levels due to global warming, with an estimated increase of approximately 3–5 mm per year.

The field trip activity motivated pre-service teachers to mitigate or adapt to the escalating ecological crisis. Positive actions pre-service teachers took included mangrove planting, social media advocacy, the creation of educational media, and a reduction in the use of motorized vehicles. The following excerpts of some pre-service teachers' statements illustrate their commitment to taking proactive measures:

> *The actions we can take, Sir, are to protect the environment and limit interactions that can cause global warming. Then, there is action on social media, too, because social media is very influential. It can introduce and educate about tidal flooding* (P1_Group1).

Following the field trip, pre-service teachers engaged in low-carbon emissions activities on campus or in their home environments, documented across various media platforms. All pre-service teachers grasped the concept of low-carbon living and implemented it through diverse activities.

The products generated by the pre-service teachers included educational videos, video materials, and posters. The educational topics raised encompassed posters advocating high-protein, low-emission foods like tempeh, promotion of the use of reusable drinking water tumblers, enhancement of home air circulation by opening windows, light and electronic device usage optimization, efficient elevator usage, advocacy of public transportation, the use of reusable shopping bags, and promotion of water conservation practices.

Some pre-service teacher initiatives aim to reducing CO_2 emissions. These actions could bolster pre-service teachers' confidence in sustaining efforts to mitigate global warming, consistent with Wong et al. (2017). Data analysis revealed that three references cited by all participants highlighted the role of field trips in providing pre-service teachers with contextual, experiential learning opportunities. Below are pre-service teachers' statements illustrating the field trip's effectiveness in contextual learning.

> *Yes, you can feel it firsthand, Sir. If we explain it here, it is just floating, which is what flooding is like. If we do not see it firsthand, we do not know, Sir* (P2 _Group 1).

The inundation of Bedono Village constituted a significant tragedy for its residents, eliciting profound sorrow and concern. Such events evoked pre-service teachers' empathy with the emotional distress experienced by the residents. Below are pre-service teacher statements reflecting their empathetic responses toward the residents' plight.

> *Tidal flooding, the ecological crisis brought about by this tidal flooding, and how they feel (about it) increases their sense of humanity* (P1_Group 1).

After the field trip, pre-service teachers engaged in reflective writing encompassing the entire learning series in response to three specific questions. This reflective exercise aimed to assess the efficacy of the field trip in enhancing environmental chemistry education. Furthermore, it gauged pre-service teachers' satisfaction and comprehension of the interrelation between sinking villages and global warming phenomena.

Qs1: Write a reflection on environmental chemistry learning!

Based on reflections written by pre-service teachers, field trip learning demonstrated a positive impact. Pre-service teachers exhibited an enhanced understanding of course materials, developed an appreciation for the environment, acknowledged the environmental impact of human activities, and undertook measures to mitigate the exacerbation of ecological crises. Below are some of the reflections written by pre-service teachers on their learning experiences.

> *This semester, environmental chemistry studies global warming. Global warming can occur due to*

carbon gas emissions from motor vehicles, the greenhouse effect, illegal logging, and others. From learning environmental chemistry, I have developed more respect for the environment. For example, I value food more. I value the electricity use (P9_HZ).

Q_S2: Are you satisfied with the environmental chemistry learning method?

The questionnaire results yielded a score of 4.3 on a 5-point scale, indicating that 86% of pre-service teachers expressed satisfaction with implementing environmental chemistry learning through the field trip approach. The findings of this study are consistent with previous research, indicating that pre-service teachers express a positive emotional response when participating in field trip activities (Kuo et al., 2020).

Qs3: Explain how your low-carbon activity relates to the ecological damage caused by the rise of sea level in Bedono Village, Demak, Central Java, Indonesia!

Based on the analysis of reflections concerning low-carbon activities and the sinking of the village, 14 pre-service teachers provided logical explanations, while four pre-service teachers presented irrational arguments. A clear correlation was established between low-carbon activities and sea level rise, given that efforts to reduce CO_2 emissions could mitigate the adverse effects of global warming, particularly on sea levels. Global warming exacerbates ecological degradation along coastlines, exemplified by the sinking of Bedono Village. The following excerpts illustrate some pre-service teachers' reflections:

Low-carbon activities aimed at mitigating the ecological crisis phenomenon

My activity is to encourage all of us to stop wasting food because wasted food will turn into organic waste, and neglected organic waste can produce methane gas, which can cause global warming. Global warming can cause damage to the sea and beaches, with tidal waves that drown coastal settlements (P9_HZ)

Low-carbon activities that are incompatible with the ecological crisis phenomenon

Regarding low-carbon activities, we help our brothers and sisters affected by ecological crises, such as Bedono Village, Demak (P16_SMS).

Reduce carbon emissions by using less gas. If you bring water to a boil (in a pan with the lid) left open, the heat will spread and, over time, can affect climate change (P20_AN).

This study used the MSC approach to assess the most significant impacts of field trips on pre-service chemistry teachers. While the findings primarily highlight positive impacts, no evidence of negative impacts has been identified. The five identified themes are noteworthy, as two emerged independently of the predetermined learning objectives. This highlights a distinctive advantage of integrating field trip activities into the educational process. Such unanticipated yet beneficial outcomes underscore the potential of field trips and emphasize their importance for further development and utilization in educational contexts. The two themes are contextual learning experiences and empathy development. Each theme was further examined and discussed in detail to establish its connection with findings from previous research, thereby enhancing the depth and rigor of the analysis.

The field trip to the inundated village encouraged pre-service teachers to actively engage with the phenomenon of seawater submersion in the area. This active involvement reflects an increased concentration and interest in the topics covered during the course. This aligns with the definition provided by Krepel and Duvall (1981) of a field trip: it is an educational excursion wherein pre-service teachers engage directly with the environment, displays, and exhibits (Oktay, 2024). Through such interactions, pre-service teachers develop experiential connections with ideas, concepts, and subject matter. The phenomenon of submerged houses captured the pre-service teachers' interest, prompting them to observe the situation closely and investigate its underlying causes. Following the field trip, 17 out of 21 pre-service teachers demonstrated an awareness of the sinking village phenomenon. This engagement indirectly encouraged pre-service teachers to delve deeper into climate change. A critical point of discussion was the question: What causes sea level rise? This inquiry became the focus of classroom discussions post-visit. Through these discussions, pre-service teachers identified uncontrolled global warming, driven by human activities that emit excessive CO_2, as the primary contributor. This global warming leads to the melting of polar ice caps, resulting in rising sea levels.

Climate change and global warming are pivotal topics that must be incorporated into pre-service teachers ' education. Various educational models have been developed, including the bicycle model of climate change education (Cantell et al., 2019). Within this model, critical thinking skills constitute a significant component of the effective implementation of climate change education. As field trips play a crucial role in fostering these thinking skills, implementing field trips will enhance climate change education initiatives. This field trip is consistent with previous research indicating several benefits of field trips in learning contexts, such as enhancing learners' contextual knowledge (Jelle et al., 2019) and increasing their interest, knowledge, and

motivation (Powell et al., 2023; Truong & Nguyen, 2024).

According to pre-service teachers' feedback, the field trip facilitated engagement in new experiences and stimulated pre-service teachers' critical thinking (Raje et al., 2024). This statement aligns with David A. Kolb's theory, which posits that new concepts can emerge from immersive experiences. The Experiential Learning Cycle, outlined by Kolb (2015), underscores the notion that learning is a process whereby knowledge is generated through transforming experiences. The benefits of field trips in fostering comprehensive and in-depth knowledge highlight their potential as a practical pedagogical approach. These advantages can serve as a valuable reference for university administrators in integrating field trips into academic programs, particularly in institutions that prepare future educators. In this context, experiential learning took the form of a field trip to a village threatened by inundation due to rising sea levels attributed to global warming. Pre-service teachers in the course have been engaged in discussions concerning the ecological crisis, focusing on local phenomena near Semarang, such as the submersion of houses in coastal villages along the north coast of Java, including Bedono and Demak. While the damage has been conveyed through news reports and visualizations provided by lecturers, pre-service teachers have yet to have the opportunity to observe the phenomenon firsthand, limiting their comprehensive understanding of its significance.

The field trip provides pre-service teachers with a multidimensional experience, allowing them to verify ecological damage through direct engagement of all five senses. This immersive approach significantly enhances their understanding of the phenomenon of sea level rise, fostering a deeper and more robust comprehension. This alignment enhances pre-service teachers' confidence in their understanding. Ultimately, this verification process increases the meaningfulness of the learning experience, particularly regarding global warming (Hügel & Davies, 2024). This finding is consistent with the research of Monroe et al. (2017), which identified two prevalent themes in environmental education: 1) a focus on personally relevant and meaningful information and 2) the use of active and engaging teaching methods. The field trip enhanced pre-service teachers' understanding of the ecological crisis and its underlying causes, empowering them to devise solutions. The root cause identified through pre-service teacher discussions is global warming. Mitigation and adaptation strategies aimed at curbing CO_2 emissions are advocated as essential measures to mitigate its exacerbation. However, it is noted that possessing knowledge does not automatically translate into action, as evidenced by Malaysian pre-service teachers who possessed strong knowledge and positive attitudes but demonstrated limited engagement in mitigation and adaptation practices (Nayan et al., 2020).

During the field trip, pre-service teachers encountered striking phenomena that evoked a profound empathy for the affected communities. This experience motivated pre-service teachers to engage in various climate change mitigation efforts tailored to their contexts. One notable initiative involved developing educational media to raise community awareness. The educational topics raised encompassed posters advocating high-protein, low-emission foods like tempeh, promotion of the use of reusable drinking water tumblers, enhancement of home air circulation by opening windows, light and electronic device usage optimization, efficient elevator usage, advocacy of public transportation, the use of reusable shopping bags, and promotion of water conservation practices. The activities undertaken by the pre-service teachers align with findings from several previous studies, which indicate that Low-carbon education needs to focus on improving knowledge to rectify misconceptions (Nyarko & Petcovic, 2021), utilizing contextual learning resources (Corrochano et al., 2022), enhancing attitudes toward climate change and global warming phenomena (Mashfufah et al., 2018), boosting self-efficacy, and increasing low-carbon action intensity (Yli-panula et al., 2022). Improvements in education should consider pre-service teachers' backgrounds (Skarstein, 2020) as well as internal, external, and demographic factors (Wang et al., 2021).

Climate change and global warming are phenomena that are quite abstract to explain. Therefore, to study these phenomena, it is necessary to utilize other phenomena relevant to pre-service teachers ' conditions. To actively have a closer look at the impact of climate change and global warming, it is necessary to engage in experiential learning activities such as field trips to places affected by climate change and global warming. For example, the north coast of Java, in proximity to Semarang City, is an area affected by flooding due to sea level rise at a rate of around 11.9 mm/year (Handoko & Hariyadi, 2018). This impact damaged various community facilities, such as housing (Anindita et al., 2021). This phenomenon becomes contextual if used in teaching pre-service teachers in the Semarang area, Central Java, Indonesia. Trott (2022) states that using topics based on contextual problems can raise awareness of climate change. Field trips allow pre-service teachers to observe phenomena firsthand and engage with the community, serving as a crucial component of the learning process. This concept aligns with the theory of situated learning, situated cognition, cognitive apprenticeship, and legitimate peripheral participation (Hendricks, 2001). Situated learning, developed by L. S. Vygotsky in 1932, is grounded in the principle that learning arises from social interaction (Rambusch, 2006).

The situated learning framework encompasses several key components, including articulation, authentic context, authentic activities, authentic assessment, expert performance, multiple perspectives, opportunities for collaboration, reflection, and scaffolding. It also focuses on learning outcomes such as social skills, problem-

solving abilities, and knowledge application (Zheng, 2010). Situated learning establishes a context that mirrors real-world application scenarios, ensuring the learning experience fosters genuine problem-solving skills (Renkl, 2001). Numerous studies have demonstrated the benefits of situated learning, including enhanced learner performance, improved problem-solving skills, higher metacognitive awareness, coherent artifacts, higher motivation levels (Huang et al., 2011), and the facilitation of skill and knowledge acquisition (Hedegaard, 2009; Marsden et al., 2010). Experiencing the emotions of residents during field trip activities had a positive impact. It heightened pre-service teachers' sensitivity toward the sinking phenomenon of Bedono Village. This empathetic capacity has the potential to evolve into the ability to envision future solutions to mitigate global warming. Envisioning future impacts of global warming fosters a more substantial commitment to significantly reducing carbon emissions. This aligns with prior research suggesting prospective educators should enhance their capacity for future-oriented thinking (Ferguson, 2022).

Addressing climate change necessitates tangible actions, yet the outcomes of such efforts often need more immediate, observable changes (Molthan-hill et al., 2019). Therefore, raising awareness about the local impacts of climate change is crucial for preparing prospective educators to mitigate its effects (Lee et al., 2015). This approach aligns with Nazarenko and Kolesnik (2018) and Rousell and Cutter-Mackenzie-Knowles (2019), emphasizing the importance of directly involving pre-service teachers in environmental problem-solving. Engagement in contextual problem-solving is expected to enhance attentiveness and stimulate meaningful actions in addressing the future impacts of climate change and global warming. Recognizing the benefits of field trips is essential, particularly in enhancing learning about climate change. Class visits to outdoor settings can lead to cognitive and affective learning (Li et al., 2024). This finding aligns with previous research, demonstrating that field trips can enhance learning motivation and contribute to the meaningful acquisition of knowledge, facilitating successful knowledge retention and understanding (Powell et al., 2023).

The nature of the field trip, its structure, the novelty of the setting, the pre-service teacher's prior knowledge and interest, the social context of the visit, the agendas of the teachers, the experiences of the pre-service teachers during the field trip, and the existence or lack of preparation and follow-up all have a fundamental impact on the learning outcomes. However, field trips are not "better classroom settings" and are not the most excellent way to teach discrete facts or complex concepts. Instead, they are best used as opportunities for inquiry, discovery, firsthand knowledge, and unique experiences (DeWitt & Storksdieck, 2008).

After the lesson, pre-service teachers participated in a reflective exercise. The outcomes revealed that while pre-service teachers expressed satisfaction with the learning process and reported engaging in mitigation actions, some still needed to improve regarding these actions. Addressing misconceptions such as these necessitates improvement efforts. Consistent with prior research, several specific strategies are recommended to enhance climate change education: (1) engaging in deliberative discussions, (2) interacting with scientists, (3) correcting misconceptions, and (4) implementing school or community projects (Monroe et al., 2017). Rectifying misconceptions is expected to bolster knowledge and foster behavioral changes to mitigate the impacts of global warming. Moreover, to effectively translate knowledge into action, it is imperative to imbue low-carbon activities with quantitative literacy (Dósa & Russ, 2020). While establishing low-carbon communities is crucial, focusing on individual empowerment remains paramount (Lin, 2022).

The novelty of this research lies in its findings that field trips serve as an effective pedagogical approach for fostering critical thinking among students by enabling them to compare theoretical concepts with real-world observations in climate change education. Additionally, field trips enhance students' motivation to learn about climate change. This research contributes to the advancement of science, particularly in enhancing the quality of climate change education for pre-service teachers. Given the complexity of climate change as a subject, it is essential to develop effective instructional approaches. One such approach is the integration of field trips into the learning process. Field trips have been shown to enhance critical thinking skills, facilitate the verification of theoretical concepts with real-world observations, reinforce climate change mitigation efforts, and foster empathy for pre-service teachers.

CONCLUSION

Pre-service teachers hold diverse perceptions regarding the impact of their participation in field trips. Pre-service teachers exhibited considerable enthusiasm about the field-trip-based learning process. Evaluating this field trip program using MSC revealed a range of pre-service teachers' noteworthy transformations. These changes included enhanced critical thinking skills, heightened motivation to address global warming, and a strengthened linkage between theoretical knowledge and practical applications. This study advances scientific knowledge by showing how sea level rise, which has caused settlements along Java's northern coast to submerge, provides an invaluable backdrop for field visits to investigate climate change's effects. Furthermore, field trip learning significantly contributed to deepening pre-service teachers' understanding of ecological crises, notwithstanding occasional instances of pre-service teachers' inadequate reasoning. Future research should broaden its scope to include field trip activities in diverse geographical settings.

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