



Special Session—What Needs to Change in Research on XR in Environmental Education? An Interdisciplinary Panel and Community Discussion Session

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Abstract. XR technology is increasingly being used in environmental, sustainability, and nature education, promising immersion, agency and engagement for learners. Applications of XR in the field have used many different technologies, approaches, and methods and have provided a number of outcomes concerning knowledge, attitudes, and behaviors. However, in a systematic review of the field, identifying the characteristics of the research studies, many gaps were found. This participatory special session at iLRN2025 combines a panel and community discussion session in order to discuss these review results, including the state of the art of the research field, gaps in the field, and potential ways to address them in future research, development, and on a policy level. To start the discussion through a panel discussion, researchers from the iLRN community who were involved in the systematic review and do relevant research and application in the field will be invited to participate. In the next step, the discussion will be given over to the community, to hear more voices and perspectives on the issues. In the final outcome of the session, the participants will come together to collect questions for research on XR-based environmental education, leading to the co-creation of a foundation for future studies, developments and applications.

Keywords: XReality, Environmental Education, Interdisciplinary Panel, Participatory Community Session.

1 Introduction

In order to develop an informed and engaged society capable of making sustainable decisions and addressing environmental challenges, environmental education is essential [1]. Effective environmental education hinges on the interplay between knowledge, attitudes, and behaviors, driving sustained ecological actions. Knowledge of sustainability and conservation fosters environmental stewardship and understanding of human impact on natural systems, but knowledge is not enough to inspire pro-environmental behavior [2, 3]. Environmental attitudes, including values, beliefs, and perceptions, are important to enable the transformation of knowledge into behavior [4]. These attitudes reflect concern for environmental issues and motivation to protect the environment [5].

A key challenge within environmental education is identifying the most effective strategies to build knowledge and support the development of pro-environmental attitudes that inspire long-term sustainable actions. The integration of Virtual Reality (VR) and other Extended Reality (XR) technologies has recently emerged as a novel approach within environmental education, promising to deliver alternative experiences that heighten environmental knowledge, attitudes, and behaviors. Studies show VR's potential to increase nature connectedness [6–8], empathy, compassion [9], and pro-environmental attitudes by illustrating human impact on the environment [10]. Virtual field trips enhance learning objectives and support knowledge retention [11], while triggering empathetic responses towards environmental concerns [12]. Experiential learning in virtual environments deepens environmental knowledge and increases willingness to engage in sustainable behavior [13, 14]. However, integrating XR into environmental education presents challenges such as high costs of VR headsets and the need for pedagogically sound experiences [15].

As these technologies are relatively new in the field, it is crucial to explore interventions and assess their efficacy in fostering critical outcomes. In order to get a systematic overview of the field, a systematic review was executed and published recently [16]. Based on the results from this systematic review, a special session including an interdisciplinary panel discussion and a community discussion will be executed at the International Conference of the Immersive Learning Research Network (iLRN2025). In the following, a short summary of the systematic review will be provided, to describe the basis of the discussion. Then, the structure of the special session will be described, describing the execution plan concerning the panel discussion and the community discussion.

1.1 Results from a Systematic Review on XR-Based Environmental Education

The discussion in the special session will be based on a recent systematic review of the literature on XR-based environmental education. This review explored the current state of the research field, focusing on research concerning actual implementations of an XR system in the field and examining the studies based on different research questions [16]. It sought to understand how XR systems are implemented in environmental education (RQ1), identify the unique technological features and affordances of these systems (RQ2), examine the research methods employed to study XR-based environmental education (RQ3), and evaluate the reported attitudinal, behavioral, and knowledge outcomes (RQ4). Through this review, evidence-based recommendations for embedding XR technologies into environmental education were developed, hoping to guide educators, practitioners, and technologists in enriching environmental education through innovative technology.

More information about the method and results of the review can be found in the paper [16], but we will give a short overview here to describe the basis for and relevance of the discussions in the special session. A total of 29 papers were retrieved through a systematic process and analyzed on the basis of the previously mentioned research questions. The outcomes show a diverse field of research including different XR technologies, topics, educational contexts and pedagogical approaches. The core findings show gaps in the literature concerning the implementation, the technological features, the research methods and the outcomes of the studies. Recommendations for the instructional design based on the results include the more systematic usage and intentional design of specific pedagogical practices, embedding XR experiences within curricula leaning on learning goals and multidisciplinary foci, connecting the usage of XR technologies with well-articulated educational theories and instructional design principles, and focusing on the enhancement of self-efficacy and emotional engagement. Furthermore, when writing up research, more information should be given about the pedagogical strategies and XR technologies including hardware and software information. For study design, it is important to examine not only short- but also long-term implementations and follow-up measurements for long-term effects like knowledge retention, measure behavioral change through actual real-world behavior and not only intentions, and involve more affective variables in research. These insights and conclusions show that there is still a lot of work to be done to improve research on and implementation of XR-based environmental education. To continue the discussion, bring in multiple perspectives, and develop central task descriptions, the current special session will be executed. The outcomes from this systematic review will be used as a basis for the panel discussion. The panelists are asked to prepare for the panel by reading about these results and will bring their own perspectives to the discussion. Central questions that the panel moderator asks are formulated based on the insights from the systematic review. For the community discussion, central questions will be prepared and pre-structured based on the systematic review and novel insights from the different perspectives of the panel discussion.

2 Special Session Proposal

2.1 Goals for the Special Session

For the special session proposed in this paper, there are different goals. Firstly, the session aims at starting a more systematic discussion on XR-based environmental education within the iLRN community through the panel discussion. At iLRN2024, the establishment of a special track on immersive learning for sustainability showed the relevance of the topic for the iLRN community, so that many participants are expected for the session. Secondly, the session is supposed to help iLRN participants with similar interests to network during the session. A platform to share contact details will be provided. Thirdly, the outcomes of the session will involve a collection of impressions, experiences, open questions and innovative strategies and ideas from the community, which can be further used to build the foundation for future design, implementation and research. After the session, the results from the brainstorming will be reviewed by the session organizers. We expect to be able to form clusters from the types of impressions and experiences the participants bring to the table, make a list of open questions from the community, and formulate statements concerning innovative and actionable strategies that can be used

to approach the issues and answer the open questions in this field. A submission of the results is planned for a following iLRN conference, so that beyond the session, the insights can be used to inform the research on and development of XR-supported environmental education within and beyond the iLRN community.

2.2 Activities During the Special Session

The session will be open for everyone who is interested in environmental education with XR systems. For an interdisciplinary and participatory session, we would like to encourage participation of a very diverse audience, including both researchers and practitioners. As part of the session, different activities will be executed (see Table 1). In order to start off the discussion, the special session will begin with a panel discussion of about 30 minutes. In this discussion, interdisciplinary and international researchers who participated in the systematic review will be included. Additionally, researchers who work in the field of XR-based environmental education research and development and bring in perspectives beyond the involved researchers are invited. Perspectives and scientific backgrounds of panelists include educational and learning sciences, environmental psychology, instructional design, XR development, and sociopolitical perspectives to ensure an interdisciplinary discussion.

After the panel discussion, the discussion will be opened up to the community, starting with a 30 minutes brainstorming session in small groups of participants based on the topics of the systematic review and topics brought up in the panel. For collaborative brainstorming in the groups, a digital writing tool is provided, e.g., Google Docs, Padlet, or Miro. The session organizers share pre-structured documents with the groups, so that they have guidance to think about the topics. These documents will be shared with all participants and the session organizers. After the brainstorming time, another 30 minutes will be available to share the results of the brainstorming with the whole group, which will be facilitated by the structure of the written output. Participants are also provided with links to a mailing list and a group on a communication platform (e.g., Discord, Slack, or Mattermost) for future communication. They are asked to share these with their networks.

Table 1. Activities planned for the session and their duration.

Session part	Duration	Activities
Panel discussion	30 min.	Panelists discuss the gaps in the literature based on the results from the systematic review and their own experiences. Different perspectives will be brought into the discussion based on different panelists backgrounds. The topics will include: • Instructional design - systematic usage and intentional design of specific pedagogical practices - embedding XR experiences within curricula - formulation of learning goals - implementation of multidisciplinary foci - connection of the usage of XR technologies with well-articulated educational theories and instructional design principles - long-term implementations - focus on the enhancement of self-efficacy and emotional engagement • Manuscript writing - more concrete information about the pedagogical strategies - more concrete information XR technologies including hardware and software • Study design - follow-up measurements for long-term effects like knowledge retention - measurement of behavioral change through actual real-world behavior - involvement of more affective variables
Small group discussions	30 min.	Based on the topics brought up in the discussion, small groups are asked to brainstorm • their impression of the research and implementation gaps • their own experiences in the field, researching and/or implementing • open questions that they see based on the panel discussion and their own experience • strategies for the future, for improving implementations and research A digital writing tool will be provided for participants to write down their brainstorming results. A pre-structured document will help with sharing the ideas.
Presenting outcomes	30 min.	The groups share their ideas with the whole group. They can use their written notes for this. A discussion will be facilitated by the session organizers.

3 Future Steps

The outcomes from the discussion will be made available to all session participants. The research community in the field of XR-based environmental education is in need of more systematic approaches to design, implementation and research. While the systematic review gives first insights into what is missing, the special session will go beyond the literature and to the people. The outcomes of the session are used as a basis for the formulation of future plans for the field, including open questions, potential strategies, innovative ideas and actionable recommendations. The session will also be used to network and connect with other researchers and practitioners within the field. We hope that this session can push the topic towards being present as a constant track within future iLRN conferences. The session organizers will submit the results to a following iLRN conference so that the insights can be used to inform research and development in the field.

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