CONCEPT MAP IN PRIMARY SCHOOL: A PILOT STUDY WITH SMAPP

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ABSTRACT
Augmented Reality (AR) is increasingly recognized as a tool to enhance active learning and conceptual understanding in primary education (Dhaas, 2024; Chang et al., 2025). The present pilot study aimed to investigate whether SMapp, an NFC-based application for exploring augmented reality concept maps developed by Smarted Srl, can effectively support knowledge acquisition in primary school students. Twenty-two fourth- and fifth-grade students (11 males; mean age = 9.68; SD = 0.72) from Istituto Comprensivo "Alfano-Quasimodo" di Salerno participated in individual study sessions with SMapp. Knowledge acquisition was assessed using a pre-post questionnaire. Results showed a significant improvement in post-intervention performance compared to pre-test scores, suggesting that SMapp is an effective tool for supporting the acquisition of disciplinary knowledge and promoting active learning in primary education.

KEYWORDS
Augmented reality; learning outcomes; primary school students.

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1. Introduction

In recent years, Augmented Reality (AR) has increasingly been recognized as a promising educational technology for supporting meaningful learning processes, particularly in primary and K–12 educational contexts. A growing body of literature highlights how AR can enhance conceptual understanding, promote active engagement, and improve learning outcomes by integrating digital information with physical learning materials (Zhang et al., 2022; Chang et al., 2025). In particular, AR systems that combine paper-based supports with mobile devices have demonstrated strong potential in maintaining alignment with traditional classroom practices while enriching them with interactive and multimodal content (Buchner et al., 2022; Nikou, 2026).

From a pedagogical perspective, this tangible–digital integration has been associated with improved learning performance, as it enables students to interact with content in a more contextualized and exploratory manner. Recent evidence suggests that AR-based learning environments can support deeper cognitive processing by making abstract concepts more concrete and visually accessible, particularly for young learners in primary education settings (Zhang et al., 2022; Nikou, 2026).

The effectiveness of such systems can be interpreted through Cognitive Load Theory (Sweller, 2011; Paas et al., 2003), which posits that learning depends on the optimal management of working memory resources. CLT distinguishes between intrinsic load, extraneous load, and germane load. Educational technologies that reduce extraneous load while fostering germane load are considered more effective in supporting knowledge construction and learning performance.

Complementing this framework, embodied cognition theory suggests that learning is grounded in sensorimotor experiences and that physical interaction with learning materials can strengthen conceptual understanding (Wilson, 2002; Barsalou, 2008; Lindgren & Johnson-Glenberg, 2013). Within AR environments, the combination of bodily interaction, spatial exploration, and multimodal feedback may support the formation of more stable and integrated mental representations, thereby enhancing learning outcomes.

Within this theoretical context, the present study focuses on SMapp, a mobile augmented reality system that integrates paper-based concept maps with multimedia content accessible via smartphone interaction (see Methods section for a detailed description). By overlaying digital information onto physical concept maps, SMapp enables students to engage with educational content through an integrated tangible–digital environment. This design is expected to facilitate learning by making information more accessible, reducing unnecessary cognitive effort, and promoting active exploration of concepts. Preliminary evidence on the system suggests positive pedagogical feasibility and classroom integration from teachers' perspectives (Lella et al., 2025). Additionally, preliminary findings from a pilot study currently in press (Sarno et al., in press) suggest that SMapp is positively accepted by primary school students and elicits high levels of positive emotional engagement during learning activities. The study reported no significant differences across gender or grade levels, indicating that the system may provide an accessible and intuitive learning experience for diverse groups of learners. These findings further support the educational potential of integrating physical materials with augmented reality technologies, not only in terms of usability and feasibility, but also with regard to students' affective involvement and engagement in the learning process (Sarno et al., in press)

Unlike previous work primarily focused on technology acceptance and user experience (Lella et al., 2025; Sarno et al., in press), the present study shifts the focus toward the educational effectiveness of SMapp in terms of learning outcomes. In addition to cognitive outcomes, the present study also considers students' situational interest toward the learning topic as an exploratory affective measure. Interest is conceptualized as a key component of learners' motivational engagement, which may be influenced by interactive and immersive learning environments. To this aim, a brief pre-post assessment of interest in the topic was included to capture potential changes in students' affective responses following interaction with SMapp.

Based on the theoretical framework outlined above and prior evidence on AR-based learning environments, the present study formulates the following hypotheses:

H1 – Learning outcomes: Students' conceptual knowledge will significantly improve from pre-test to post-test following the learning activity with SMapp. This hypothesis is grounded in previous research demonstrating that AR can support learning performance through active engagement and multimodal processing of information (Zhang et al., 2022; Chang et al., 2025; Nikou, 2026), as well as in Cognitive Load Theory, which suggests that reducing extraneous cognitive load may facilitate learning (Sweller, 2011; Paas et al., 2003).

H2 –Gender and grade differences: Differences in overall learning performance as a function of students' gender and school grade will be examined. In addition, potential differences in pre-test to post-test changes across gender and school grade will be explored.

2. Materials and methods

2.1. Participants

The study involved 22 fourth- and fifth-grade students (11 boys) attending Istituto Comprensivo “Alfano-Quasimodo” di Salerno, Italy. Participants had a mean age of 9.68 years (SD = 0.72) and completed the study individually. All children were native Italian speakers and reported normal or corrected-to-normal vision. The participant sample in the present study overlaps with that reported in Sarno et al. (in press), as the same group of 22 primary school students participated in both studies. However, the two studies addressed different research questions and outcomes. Sarno et al. (in press) focused on students’ acceptance and emotional engagement with SMapp, whereas the present study focuses on changes in conceptual knowledge and situational interest following the learning activity. The present analyses therefore address learning outcomes that were not examined in the previous study.

Informed written consent was obtained from the participants’ legal guardians prior to participation. The research protocol complied with the principles outlined in the Declaration of Helsinki and received approval from the local ethics committee.

2.2. Tool

The instrument whose educational effectiveness in terms of learning outcomes was evaluated in the present study was SMapp, an educational tool developed by Smarted S.r.l. (Naples, Italy; https://smarted.it/smapp-it/) for the creation and exploration of interactive concept maps in Augmented Reality. The system integrates traditional paper-based materials with multimedia digital resources, while preserving the central role of physical supports within the learning process. SMapp includes two complementary components: the Editor function, intended for the authoring of Augmented Reality concept maps, and the Reader function, designed for their interactive consultation and use.

The Editor function allows users to define the structure of the interactive map, including node organization, spatial layout, and the integration of multimedia resources such as speech-based text, images, and videos. Developed for Windows operating systems, the software produces a printable version of the concept map that serves as the physical interface for subsequent interaction. In the current study, this function was employed exclusively by the researchers to prepare the instructional materials.

The Reader function is implemented as a mobile application relying on Near Field Communication (NFC) technology, enabling smartphones to activate multimedia contents associated with the nodes of the paper-based concept map.

At the hardware configuration level, the Reader operates through a physical support containing embedded NFC tags, referred to as the SMapp book (Figure 1). The printed concept map is positioned on top of this support, allowing correct correspondence between the map nodes and the NFC tags underneath. This configuration enables the system to recognize each node and retrieve the related digital content when the smartphone is brought into proximity with it.

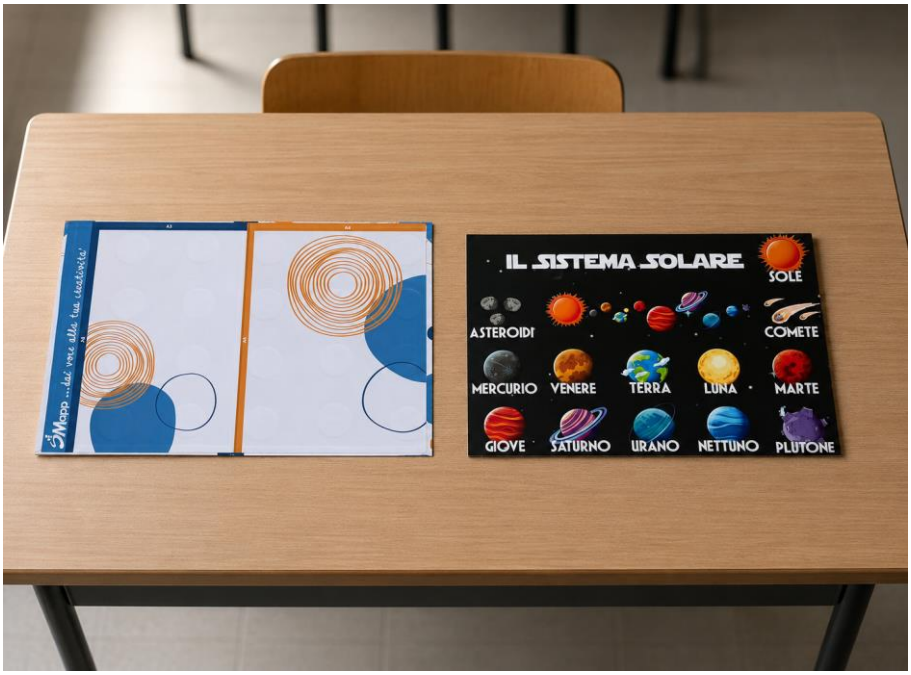


Figure 1: (Physical configuration of the SMapp system, including the SMapp book and the paper-based concept map positioned on it)

Near Field Communication (NFC) is a short-range wireless communication technology that enables data transmission between compatible devices positioned within a few centimeters of one another. Within the SMapp environment, NFC technology allows smartphones to identify individual nodes of the paper-based map and automatically reproduce the linked multimedia materials, including speech-based text, images, and videos. By simplifying interaction procedures, NFC supports active and embodied learning processes, as the physical gesture of approaching the smartphone to the nodes facilitates conceptual integration and information processing (Wilson, 2002; Johnson-Glenberg, 2018).

The interaction procedure consisted of the following phases:

i) enabling NFC on the smartphone;

ii) positioning the map on the interactive surface;

iii) selecting the map through the software;

iv) accessing digital content by approaching the smartphone to the corresponding nodes.

Within the present study, phases i–iii were handled by the experimenters in order to ensure proper system configuration, whereas phase iv was completed autonomously by the students. Consequently, the Reader function represented the primary object of investigation and evaluation. Throughout the remainder of the paper, the term SMapp therefore refers specifically to the Reader function, namely the interactive exploration component.

Overall, the Reader function supports active and multimodal interaction with educational materials through digitally enhanced paper-based concept maps. The combination of physical and digital elements contributes to reducing extraneous cognitive load and promotes meaningful learning processes, consistently with Cognitive Load Theory (Sweller, 2011; Paas et al., 2003). Furthermore, direct interaction with the nodes encourages active engagement, while the embodied action involved in triggering multimedia content supports embodied cognition mechanisms (Wilson, 2002; Barsalou, 2008; Johnson-Glenberg, 2018), facilitating the development of integrated and stable conceptual representations.

2.3. Procedure

Following the acquisition of written informed consent from participants' parents or legal guardians, students individually took part in the experimental activities in a quiet room within the school environment. The overall procedure consisted of two sessions conducted on separate days, aimed at collecting demographic, cognitive, and learning-related data.

2.3.1 Session 1

The first session was dedicated to the collection of demographic information, a neuropsychological evaluation, and an assessment of prior knowledge.

Participants received an age-appropriate explanation of the study procedures and were informed that they would subsequently engage in a learning activity using SMapp, an interactive Augmented Reality concept-mapping tool.

Participants completed a neuropsychological assessment battery including the "Test delle Campanelle Modificato" (Biancardi & Stoppa, 1997) and selected subtests from the BVN 5–11 (Bisiacchi et al., 2005), assessing verbal short-term memory through forward and backward digit span tasks. Data derived from the neuropsychological assessment are not included in the present study and will be reported separately.

Participants then completed an ad hoc questionnaire assessing their baseline knowledge of the Solar System.

2.3.2 Session 2

The second session consisted of the learning activity using SMapp and the subsequent post-test assessment. The experimental setup included the SMapp book, a paper-based concept map, and a smartphone, forming an integrated interactive learning environment (Figure 2).

The concept map content concerned the Solar System and was selected in collaboration with teachers to ensure alignment with the school curriculum. The map was positioned according to predefined alignment criteria ensuring correct correspondence between NFC tags and nodes.

Participants explored the map by bringing the smartphone close to the nodes to activate multimedia content. Exploration began from the "Sun" node and

proceeded horizontally across the map. Students interacted autonomously until completion, with a maximum time of 20 minutes.

After the learning phase, participants completed the post-test questionnaire identical to the pre-test.

Learning outcomes were evaluated by comparing pre-test and post-test scores.



Figure 2: (Experimental setup showing the SMapp learning environment, including the SMapp book, paper-based concept map, and smartphone used for interaction.)

2.4 Knowledge Questionnaire

The assessment of prior knowledge and learning outcomes was conducted using an ad hoc multiple-choice questionnaire developed for the present study. The instrument was not previously validated and was designed to assess conceptual understanding of the Solar System before and after the learning intervention.

The questionnaire consisted of 10 multiple-choice items with four response options and one correct answer (Figure 3). The same instrument was administered at pre-test and post-test to allow measurement of learning gains.

Items were developed based on curriculum guidelines and reviewed by teachers and subject-matter experts to ensure age-appropriateness and content validity.

Each correct answer was awarded 1 point, while incorrect answers received 0 points, resulting in a total score ranging from 0 to 10.

Item	Question	A	B	C	D	Correct answer
1	Individua tra i seguenti pianeti del Sistema Solare quello più pesante.	Marte	**Giove**	Saturno	Urano	B
2	Individua tra tutti i corpi celesti del Sistema Solare quello intorno a cui ruotano tutti i pianeti.	Saturno	Terra	**Sole**	Giove	C
3	Individua tra tutti i pianeti del Sistema Solare quello più vicino al Sole.	Giove	Terra	Venere	**Mercurio**	D
4	Individua tra tutti i pianeti del Sistema Solare il secondo più vicino al Sole.	Giove	Mercurio	**Venere**	Marte	C
5	Individua tra tutti i pianeti del Sistema Solare l'unico che si sa con certezza può ospitare la vita.	**Terra**	Plutone	Urano	Marte	A
6	Individua tra tutti i corpi celesti del Sistema Solare quello che, se volessimo raggiungerlo a piedi, distaría da noi circa 10 anni.	Marte	Luna	**Sole**	Giove	C
7	Individua tra tutti i pianeti del Sistema Solare quello che viene chiamato "pianeta rosso".	Venere	Saturno	**Marte**	Giove	C
8	Individua tra tutti i pianeti del Sistema Solare quello più grande e pesante.	**Giove**	Nettuno	Plutone	Mercurio	A
9	Individua tra tutti i pianeti del Sistema Solare quello che insieme a Giove è definito "gigante gassoso".	Plutone	Marte	**Saturno**	Urano	C
10	Individua tra tutti i corpi celesti del Sistema Solare quello che viene definito "pianeta nano".	Marte	Venere	Saturno	Urano	—

Figure 3. (Knowledge questionnaire on the Solar System used at pre-test and post-test.)

2.5 Interest measure

The participants' interest in the topic of the Solar System was assessed using a single-item Likert scale ranging from 1 (not at all interested) to 5 (extremely interested). The item was administered at both pre-test and post-test in order to evaluate potential changes in interest following interaction with SMapp.

Although single-item measures are limited in terms of psychometric reliability, they are commonly used in exploratory and pilot studies to capture global affective responses.

3. Data Analysis and Results

3.1 Data Analysis

A repeated-measures ANOVA was conducted to investigate learning outcomes, with participants' gender and school grade included in the model as between-subjects factors, and learning phase (pre-test vs post-test) as a within-subjects factor. A second repeated-measures ANOVA was conducted to examine students' situational interest in the learning topic, with participants' gender and school grade included in the model as between-subjects factors, and learning phase (pre-test vs post-test) as a within-subjects factor. Interest was assessed using a single-item Likert scale ranging from 1 (not at all interested) to 5 (extremely interested).

Given the relatively small sample size (N = 22), the distribution of participants across the four gender × school-grade combinations is reported in Table 1. Given the small number of participants within each combination, the results should be interpreted with particular caution, especially with regard to interaction effects, which may be associated with limited statistical power and reduced stability of the estimates.

Table 1. (Distribution of participants across the four gender × school-grade combinations.)

School grade	**Male**	**Female**	**Total**
Fourth grade	5	7	12
Fifth grade	6	4	10
Total	11	11	22

The significance level was set at $\alpha = .05$, and partial eta squared (η^2p) was reported as a measure of effect size. Bonferroni post-hoc tests were applied to assess differences among means, and 95% confidence intervals were reported for estimated marginal means and pairwise comparisons.

Although the interest measure consisted of a single five-point Likert-type item and was therefore ordinal in nature, a repeated-measures ANOVA was used to examine pre-post changes and their interactions with gender and school grade within the same factorial framework used for the learning outcome analysis. This choice was based on evidence suggesting that parametric procedures such as ANOVA can be reasonably robust to violations of measurement-level and distributional assumptions for Likert-type responses (Norman, 2010). Nevertheless, given the ordinal and single-item nature of the measure, the results were interpreted cautiously and are considered exploratory.

3.2 Results

3.2.1 Learning outcomes

The repeated-measures ANOVA revealed no significant main effect of gender, $F(1,18) = 2.186$, $p = .157$, $\eta^2p = .108$, suggesting that male and female participants did not differ significantly in their learning performance.

A significant main effect of school grade was observed, $F(1,18) = 5.27$, $p = .034$, $\eta^2p = .226$, suggesting that fifth-grade students achieved higher overall learning scores compared to fourth-grade students. Specifically, fifth-grade students obtained higher mean scores ($M = 6.35$, $SE = .61$) than fourth-grade students ($M = 4.46$, $SE = .55$). (Figure 4).

A significant main effect of the learning phase was also found, $F(1,18) = 11.71$, $p = .003$, $\eta^2p = .394$, suggesting a significant improvement in performance from pre-test to post-test. Overall, participants achieved higher scores in the post-

test (M = 6.28, SE = .51) compared to the pre-test (M = 4.53, SE = .47). This pre-post improvement was observed following the learning activity with SMapp; however, in the absence of a control group, it cannot be attributed specifically to the use of the system.

No significant interaction effects were observed between learning phase gender, and school grade. Specifically, the interaction between learning phase and gender was not significant, $F(1,18) = 2.18$, $p = .157$ $\eta^2p = .108$; the interaction between learning phase and school grade was not significant,$F(1,18) = .558$, $p = .465$ $\eta^2p = .030$; and the interaction between gender and school grade was not significant, $F(1,18) = .794$, $p = .385$, $\eta^2p = .042$

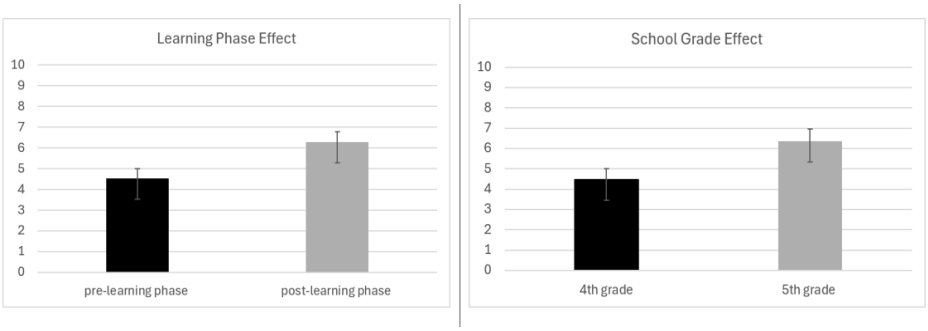


Figure 4: (Results of the repeated-measures ANOVA. The left panel illustrates the main effect of school grade, whereas the right panel illustrates the main effect of learning.)

3.2.2 Interest

The repeated-measures ANOVA did not reveal any significant main or interaction effects (all $p > .05$), suggesting that students' interest remained stable following interaction with SMapp. Specifically, no significant between-subject effects were observed for gender, $F(1, 18) = 0.283$, $p = .601$, $\eta^2p = .015$, scholarship, $F(1, 18) = 0.101$, $p = .754$, $\eta^2p = .006$, or their interaction, $F(1, 18) = 0.424$, $p = .523$, $\eta^2p = .023$. Additionally, no statistically significant pre-test to post-test change in students' self-reported interest, $F(1, 18) = 3.033$, $p = .099$, $\eta^2p = .144$. No significant interaction effects were observed between learning

phase and gender, $F(1, 18) = 0.723$, $p = .406$, $\eta^2p = .039$, or between learning phase and school grade, $F(1, 18) = 2.026$, $p = .172$, $\eta^2p = .101$.

4. Discussion

The present pilot study examined changes in primary school students' learning outcomes and situational interest following a learning activity with SMapp, an augmented reality (AR) learning environment integrating paper-based concept maps with mobile digital content. Overall, the findings showed a significant improvement in conceptual knowledge from pre-test to post-test, alongside stable levels of interest in the learning topic. Given the absence of a control group, however, the observed pre-post improvement should be considered a preliminary finding following the learning activity rather than evidence of the specific effectiveness of SMapp.

This pre-post improvement is consistent with previous research on AR-based learning environments reporting positive associations between AR-supported learning activities and educational performance (Zhang et al., 2022; Chang et al., 2025; Nikou, 2026). However, the present design does not allow the specific contribution of SMapp to be separated from other factors that may have contributed to the observed improvement. From a theoretical perspective, these results can be interpreted within the framework of Cognitive Load Theory (Sweller, 2011; Paas et al., 2003). The integration of digital content into structured paper-based concept maps may have supported the organization and accessibility of information, potentially reducing unnecessary cognitive demands during the learning activity. However, cognitive load was not directly assessed in the present study; therefore, this interpretation should be considered theoretical rather than an empirically demonstrated mechanism underlying the observed learning improvement.

In addition, the observed learning gains may also be interpreted in light of embodied cognition theory (Wilson, 2002; Barsalou, 2008; Lindgren & Johnson-Glenberg, 2013). The physical interaction required to activate digital content through smartphone movement may have strengthened the coupling between action and cognition, thereby supporting deeper encoding and integration of conceptual knowledge. Nevertheless, sensorimotor processes and embodied learning mechanisms were not directly measured in the present study. Accordingly, embodied cognition should be regarded as a possible theoretical framework for interpreting the findings rather than as evidence of a specific mechanism responsible for the observed improvement.

Regarding H2, no significant differences in overall learning performance were observed as a function of gender. A significant main effect of school grade was observed, with fifth-grade students showing higher overall knowledge scores than fourth-grade students. However, the absence of a significant interaction between learning phase and school grade indicates that the pre-test to post-test change did not differ significantly between fourth- and fifth-grade students. Similarly, the non-significant interaction between learning phase and gender does not provide evidence of differential pre-test to post-test changes according to gender. Therefore, the observed grade-related difference should be interpreted as a difference in overall performance rather than as evidence of greater learning gains among fifth-grade students.

In addition to cognitive outcomes, the present study also examined students' situational interest in the learning topic, as an exploratory affective measure. The absence of a significant pre-test to post-test change in the interest measure indicates that no statistically detectable change in students' reported interest was observed following the learning activity. Given the single-item nature of the measure and the exploratory design, this finding should not be interpreted

as evidence of the absence of an effect on students' motivational disposition. However, given the single-item nature of the measure, these findings should be interpreted with caution.

From an educational perspective, the observed pre-test to post-test improvement provides preliminary evidence of learning following participation in the SMapp activity. However, the study design does not allow the specific contribution of SMapp to be isolated from other factors that may have influenced performance. Therefore, the findings should be considered preliminary and interpreted as evidence of learning following the activity rather than as evidence of the specific effectiveness of the system.

Despite these promising findings, several limitations should be acknowledged. First, the study is based on a relatively small sample size, which limits the generalizability of the results. Second, the absence of a control group does not allow for causal comparisons with traditional instructional methods. Third, the use of a single-item measure for interest restricts the depth of interpretation regarding affective outcomes. Moreover, the use of the same knowledge questionnaire at both assessment points may have introduced testing effects that partially contributed to the observed performance improvements. Future research should address these limitations by employing larger samples, controlled experimental designs, and more robust measures of motivational and affective variables.

5. Conclusions

This pilot study examined the effectiveness of SMapp, an augmented reality learning environment integrating paper-based concept maps with mobile digital content, in supporting primary school students' learning outcomes and situational interest in the learning topic.

Results showed a significant improvement in conceptual knowledge following interaction with SMapp, suggesting that the system may support learning in primary education contexts. No significant gender differences were observed in overall knowledge performance, whereas fifth-grade students showed higher overall scores than fourth-grade students. However, the absence of significant interactions between learning phase and gender or school grade indicates that the pre-test to post-test change did not significantly differ across these groups.

Situational interest in learning topic remained stable from pre-test to post-test, indicating that the learning intervention did not affect students' affective disposition toward the topic.

Overall, these findings provide preliminary evidence for the educational potential of tangible–digital augmented reality environments in supporting learning processes in primary school settings. However, the pilot nature of the study, the limited sample size, and the absence of a control condition limit the generalizability of the findings.

Future research will directly address this limitation by comparing SMapp with traditional instructional approaches, in order to evaluate its added value over conventional learning methods and to better isolate the specific contribution of augmented reality-based interaction to learning outcomes and motivational processes.

Conflict of interest

Smarted S.r.l., the developer of the SMapp system and a co-financer of the present research, contributed to the development of the SMapp system and supported the coordination of the research activities. The academic research

team was responsible for data collection, data analysis, interpretation of the results, and preparation of the manuscript.

The authors declare no other conflicts of interest.

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