FingerTrips on Tangible Augmented 3D Maps for Learning History

Iliana Triantafyllidou, Athina-Maria Chatzitsakiroglou, Stergiani Georgiadou, and George Palaigeorgiou(✉)

University of Western Macedonia, Florina, Greece
iliarozed@gmail.com, achatzitsakiroglou@gmail.com, stellageol23@gmail.com, gpalegeo@uowm.gr

Abstract. History education offers students the opportunity to learn about the past and make connections with the present. However, primary school students consider history lessons to be boring, dull and sterile. Integrating ICT in history teaching can enhance historical thinking and historical understanding, and may promote the exploration of the past with a critical approach rather than the passive accumulation of information. The objective of this study was to design and examine a low-cost augmented 3D tangible model of a historical site, in which students could interact with historical content through a virtual field trip by using their fingers. Twenty-six 6th grade students participated in a pilot study in order to evaluate the effectiveness and the efficiency of the proposed learning environment called FingerTrips. Participants played with the augmented model in 10 sessions and in groups of 2 or 3 members. Data were collected with an attitude questionnaire and semi-formal group interviews. Students' answers revealed that the FingerTrips environment enhanced their engagement and motivation in history learning, and made them feel as active participants in the historical event presented. Students considered their interactions as a real fieldtrip on the historical landscape model with the help of their fingers. Such an approach is closer to student's interactive experiences and expectations, gamifies learning, and exploits embodied learning affordances, in order to achieve efficient, effective, and enjoyable learning.

Keywords: Tangible interaction · Mixed reality interface · History learning FingerTrips · Virtual field trip

1 Introduction

History education gives students an opportunity to learn about the past and to make connections with the present, providing them with information that they can use to develop social understanding and make informed decisions about their social life [1–3]. In recent years, historical learning has moved from knowing facts, dates, and events, to the concept of "historical understanding", which in turn involves learning historical content, applying research methods, analyzing and evaluating resources, and reaching conclusions based on the given information [2, 3]. Students are encouraged not just to learn facts, but to familiarize themselves with the way historians work: they must

M. E. Auer and T. Tsiatsos (Eds.): IMCL 2017, AISC 725, pp. 465–476, 2018.
https://doi.org/10.1007/978-3-319-75175-7_46

collect sources, divide them into primary or secondary ones, analyze and interpret them, and construct their own, subjective, meaning about what the sources "are telling" to them [2, 3].

Although history is regarded as an important bridge between the past and the present, students usually consider history lessons to be boring, unattractive, "dull and sterile" [4]. Additionally, they have difficulties in historical understanding, since developing historical thinking requires the execution of complex cognitive tasks [5]. Students face challenges in reading primary sources, they are not familiar with historians' heuristics, they cannot advance their understanding beyond the facts presented, they confront difficulties in interpreting historical events, and they usually oversimplify them because of their limited or misapplied knowledge of the historical context in which these events had happened [5, 6]. Moreover, when describing historical changes, students confuse the concepts of time, change, and continuity [6, 7].

Researchers have thus shifted their focus of interest to a variety of teaching methods that aim at promoting historical thinking. For example, interdisciplinary lessons that combine History with other disciplines, such as Geography, Maths, Music, and Art, can prove to be ideal in promoting students' motivation and interest towards history thinking [8]. Field trips can also give the opportunity to both students and teachers to visit a historical site and become familiar with the area, make hypotheses about the relation between the place and its historical meaning and to evaluate their hypotheses, thus thinking and working like historians, in order to -ultimately- develop their historical thinking [9–13].

Several studies have suggested that the use of ICT may motivate students and help them develop historical thinking [1]. ICT seems to offer a lot of affordances that address history teaching needs, such as the use of video documentaries, exploiting the web for seeking historical sources and information, utilizing Web 2.0 technology for collaborative historical research, etc. [1, 2, 4]. Similarly, virtual field trips are ICT-supported field trips that have emerged as alternatives to traditional field trips. Virtual field trips range from simple teacher-directed class projects that involve navigating in online museum archives [14] to drone-based field trips [15], where students study an area of interest through the lens of a drone transmitting video in real time.

In this study, we propose that a virtual field trip into an interactive augmented tangible environment representing a historical area of interest may motivate students to be engaged with the critical study of the historical content. Such an experience can make learning enjoying and effective, while it also provides opportunities for embodied learning.

2 Literature Review

Several studies have underlined that the integration of ICT in history teaching can enhance historical understanding and may promote the exploration and critical approach of the past rather than the passive accumulation of information. Apps such as timelines and simulations of historical events allow participants to better understand the concept of time, the successions of historical events, and to capture how knowledge was discovered [7, 16]. Seeking for information, such as photographs, video and sound

clips, or navigating through online newspapers' archives can help students to become familiar with the historical research and the historical thinking [17]. The use of participatory Web 2.0 tools such as blogs and wikis enable students to collaborate and gain much more autonomy in their historical learning process [2]. Moreover, the use of electronic games, i.e. for reconstructing ancient buildings, objects or even entire cities and civilizations, seems to increase students' engagement and interest in the History lesson [18]. However, teaching and learning history with ICT is an area that is still being developed [19], since history is usually thought to be in absolute contrast with technology and in that sense these two areas cannot exist together - although history is a vital subject for the modern world and technology is the main tool of our century.

Tangible User Interfaces (TUIs) for learning have received a lot of attention lately, with few however applications for history learning. TUIs "enable direct, hands-on interaction with physical objects" [20] and are considered a useful mean for enhancing students' engagement and motivation towards learning, as learners have the opportunity to use physical objects in a multisensory environment [20]. Many researchers have suggested that TUIs have a potential for supporting children's informal and formal learning and that they are highly suited to the design and development of learning activities because they leverage both familiar physical artifacts and digital computation. Tangibles can offer a natural and immediate form of interaction that is accessible to learners, promote active and hands-on engagement, allow for exploration, expression, discovery and reflection, provide learners with "tools to think with" and offer opportunities for collaborative activity among learners (e.g. [21–23]). TUIs have been used in several educational settings, as for example in museums [24] for science (i.e. [20, 24]), geography (i.e. [25]) and mathematics (i.e. [26]).

For creating a TUI for a historical place, we also focused on tangible user interfaces representing interactive landscapes. Continuous shape displays [27] in which a continuous physical model is coupled with a digital model are of special interest. For example, in Illuminating Clay [28], landscape models were constructed using clay support while the three-dimensional geometry was analyzed in real time using a laser scanner and it was easy to recognize changes such as shadow casting, land erosion, etc. TanGeoMS [29], is also an analogous geospatial modeling visualization system that combines a laser scanner, projector, and a flexible physical three-dimensional model with a geospatial information system to create a tangible user interface for terrain data. Similarly, the Augmented Reality Sandtable (ARES) [30] is a sand-based research testbed that uses commercial cheap prototyping tools to create a low-cost method of geospatial terrain visualization with a tangible user interface. Projection-Based City Atlas [31] is a low-cost exhibit of a projection-based city atlas. The exhibit could be replicated and reconfigured in accordance with the size of the mock-up and the spatial arrangement of the place where it will be located. Based on the description of events occurring over time, the interactive virtual tour aims to highlight how the urban fabric has changed throughout the historical and political periods that have affected the city. All those approaches take advantage of our natural ability to understand and manipulate physical forms while still harnessing the power of augmenting these forms with useful digital representations.

Moreover, these augmentations merge the digital with the physical and offer a vivid and immersive audiovisual interface for eliciting body activity. In essence, such

approaches allow students to become part of the system they are trying to understand, giving them an insider perspective on the critical mechanisms and relationships that define the domain. New interaction technologies such as mixed reality environments can prove an excellent guide for students to perform physical actions that serve as "conceptual leverage" [32]. Under the umbrella of terms like embodied interaction, full-body interaction, motion-based interaction, gesture-based interaction, tangible interaction, bodily interaction, and kinesthetic interaction, several interactive learning environments based on novel interaction modalities have been developed. These interactive environments try to facilitate an embodied experience of a certain concept, to represent an abstract concept as a concrete instance or operationalize actions as means to express specific content or try to use space as a semiotic resource or even try to promote embodied metaphors. The new mediated environments seem to increase learner engagement since body-based experiences are more perceptually immersive and learners may feel that they are in a more authentic and meaningful educational space [33].

Being able to interact more naturally with digital enriched space enhances our spatial thinking, encouraging creativity, analytical exploration, and learning. The interaction in tangible interfaces is mostly done by touch. However, as Elo [34] supports, "insofar as digital interface design aims at haptic realism it conceives of the sense of touch in terms of narcissistic feedback and thus tends to conceal the pathic moment of touching." Elo [34] continues by indicating that the finger has been given the status of a switch but now it seems to be dragging the whole body along. Touch is not only a computational input device but also a human sense which is overly underestimated as a learning means.

2.1 FingerTrips for History Learning

In this study, we propose FingerTrips environment for history learning, in which an augmented interactive 3D model of a historical site aims at helping students relate to the historical content playfully and enable them to conduct interactive field trips over the landscape with their fingers. Our objective was to create a 3D augmented tangible map which would be of low-cost by using mainstream prototyping hardware and software, and which could be easily reconstructed by students and teachers, in order to be highly populated.

For assessing the idea of FingerTrips for history learning, we constructed a 3D model of the historical site of Fort Rupel which was built near the Greek-Bulgarian borders. Fort Rupel is situated on top of a hill and became famous for its defense during the German invasion of Greece in April 1941. The model was made with simple, recyclable materials: newspapers, cardboard, aluminum foils, a plastic box, and two pieces of polystyrene slabs, 120 $\times$ 60 cm each. The polystyrene pieces were used as the model's base. A plastic box and a carboard box were used as the main hill, while smaller pieces of newspaper were used to create paths leading to the top of the hill. Aluminum foil was also placed in different places of the model, in order to improve texture and give a better feeling of the mountains territory. Newspapers were put above it and was covered with paper tape. Finally, all the construction was painted white. In the following two images (Figs. 1 and 2), the augmented landscape is presented.

Fig. 1. The augmented 3D historical landscape of fort Rupel with various accessories.

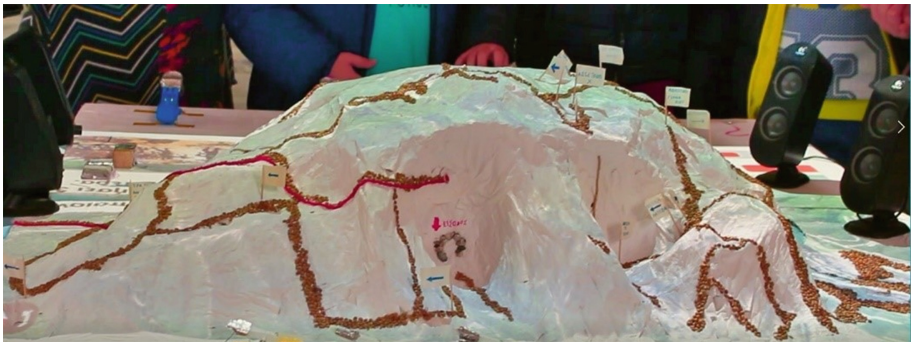

Fig. 2. The back side of the augmented 3D model. Students interacted from all sides

In order to highlight the finger paths on the hill, lentils were glued on the paths. The lentils were also used to help the researchers hide the interaction points in the model, since students were called to explore the environment without knowing were the different events may unveil. With the use of a projector installed in the ceiling, images and animations were shown on the model, resembling the actual historical site.

2.2 Interacting with the Tangible Learning Environment

Learners are the protagonists of the game and role-play historians who have to assist Victor, the main character of the game plot. Victor asks students to help him learn the history of the place, by answering questions and walking together on the model. The students have to go through the paths by crossing bridges or climbing hills with their fingers, but also by reacting to unexpected events. In the course of their finger trip, different surprising events and activities were initiated since hidden interaction points were installed in between the lentils.

In order to promote historical thinking but also to provoke students' engagement, a variety of events and activities have been designed while students walk on the model's paths. For example:

- A song may start to play related to a historical event and students are called to listen it and infer answers to questions about that event or a bear producing sounds may appear running next to their finger, indicating that students need to pay attention to the paths they follow.
- Students may be asked to search for a clue or a place on the model by making and testing their hypotheses.
- A simple multiple-choice question may appear, in order to retain their focus on small details.
- Students may be asked to find rooms inside the fort, thus kneeling down and under the 3D model, in an attempt to create the feeling that the soldiers would have inside the Fort, or they may be called to surrender and find how to do it.

Hence, the journey is a constant swapping of activities, events and FingerTrips. Students interactions on the map were supported by two connected Makey Makey boards whose inputs were embedded into students' journey path and the interactions were programmed with MIT's Scratch. Both platforms are easy to use even for primary school students while the Makey Makey board is an affordable and powerful prototyping solution.

3 Methodology

3.1 Participants

In order to evaluate the FingerTrips approach to learning history, twenty-six (26) 6th grade students, 15 boys and 11 girls, participated in a study in the context of an interactive exhibition related to Tangible and Mixed Reality Interfaces for Elementary Schools. The participants played with the FingerTrips environment in ten (10) groups consisted of 2 or 3 students. Each session lasted about 30 min.

3.2 Procedures

At the beginning of the game brief instructions were given to each group, to help students become familiar with the concept of interacting with the 3D model before starting their FingerTrips game. The researchers offered guidance whenever the participants requested for. At the end of each session, students were asked to complete an online questionnaire about their experience. Seventeen (17) students afterwards, participated in brief group interview in a separate, quieter place.

3.3 Research Instrument

Data collection was based on a questionnaire and a semi-formal group interview. The questionnaire consisted of 22 5-point Likert questions and evaluated the tangible

environment in regards to its usability and attractiveness. Some of the questionnaires' items were derived from AttrakDiff [35] and Flow State Scale [36]. The questionnaire consisted of the following variables:

Ease of Use (3 questions): Measure how easy to use the system is and its learnability;
Autotelic experience (3 questions): Measures the extent to which the system offers internal user satisfaction;
Perceived learning (3 questions): Measures students' perceptions on the educational value of the system;
User Focus (3 questions): Measures the concentration during the use of the system;
Pragmatic Quality (4 questions): Measures the extent to which the system allows a user to achieve his goals;
Hedonic Quality-Stimulation (3 questions): Measures the extent to which the system meets the user's need for innovation and whether it is of interest;
Hedonic Quality-Identity (3 questions): Measures the extent to which the system allows the user to identify with it.

All questions were adjusted to 5-point Likert scale answers, in order to become easier for the elementary students. All variables had satisfactory Cronbach's a (Table 1). The semi-formal interviews took place immediately after the end of each session and aimed at extracting the qualitative assessments of the students and at allowing them to describe in their own words their experience with the FingerTrips environment. The questions were focused on what students liked and disliked and their perceptions in regards to the learning effectiveness and efficiency of the environment. All audio-recorded interviews were transcribed and then encoded and compared within and between cases. Afterwards, the four researchers collaborated to reach consensus for the commonly identified issues.

Table 1. Statistics about the on-line questionnaire.

	Min	Max	Mean	SD	Cronbach's a
Easiness	3.33	5	4.28	0.61	0.69
Focus	1.67	5	4.20	0.77	0.82
Autotelic experience	1.67	5	4.37	0.69	0.78
Perceived learning	1.00	5	4.08	0.69	0.78
Pragmatic Quality	3.00	5	4.03	0.78	0.88
Hedonic Quality-Identity	2.00	5	4.41	0.58	0.76
Hed. Quality -Stimulation	3.00	5	4.40	0.54	0.74

4 Results

4.1 Quantitative Data: Questionnaire

As presented in Table 1, students claimed that they didn't have any difficulties in familiarizing with the FingerTrips style of interaction. They found the environment

easy to use (M = 4.58, SD = .50) and they would like to interact with this environment often (M = 4.16, SD = .61). Moreover, even if they had been using the educational environment in the context of a noisy exhibition, they assessed that they maintained high levels of concentration on the task at hand. That's a proof of the engagement that similar activities and environments can provoke. The high score also on autotelic experience variable validates that the activity was marked by intrinsic pleasure, it was done by the students for its own sake, regardless of external reinforcements.

Students' answers show that FingerTrips environment can address the problem of engagement with the historical content. Moreover, students were also positive in regards to the learning efficiency of the environment and the possibility of exploiting it in the school. They claimed that they would learn faster (M = 4.35, SD = .98) than with current methods in school and would learn more and better (M = 4.15, SD = 1.19). As also shown in the minimum values of each variable (see Table 1), there were also a few students which were negative towards the FingerTrips environment. This is something that has to be investigated further. It is important to note that the interaction in FingerTrips is social, with students moving around the table, discussing alternatives, taking decisions and interacting with the landscape, and that can work positively for the learning results and negatively, in some cases, in how stressful the students consider the activity.

Students' answers in the mini AttrakDiff questionnaire validated that they considered the functions of the environments as appropriate to achieve the goal of understanding the history of Fort Rupel (pragmatic quality). Moreover, the variable hedonic quality, which is a measure of pleasure (fun, original, engaging) and avoidance of boredom and discomfort, had very high scores. Students' answers show that the environment made them identify themselves with it (Hedonic Quality-Identity) and believed that it offered inspiring and novel functions and interactions (Hedonic Quality-Stimulation).

4.2 Qualitative Data: Interviews

Students reinforced in the interviews the quantitative results already presented. The majority of the students stated that they enjoyed the FingerTrips environment and that they would like to work more often with similar environments. When asked to identify the characteristics that differentiate the specific approach for learning about history, they mentioned several themes.

The most repetitive comment was related to the authenticity and the realness of the learning environment. Students felt that they were living the historical events, that they shared the emotions of the protagonists, that they got a sense of the landscape and the way it formulated causes and effects. The 3D multimedia character of the presentation did manage to involve them more.

- "we thought that everything was real."
- "we saw airplanes, bears."
- "[you understand that] if you lived that, you would have been scared."
- "it was like the war was happening right that moment."
- "it was like reality, as we lived that."

Some students stated that they liked the environment just because it was 3D and that the details of the landscape representation were impressive.

- "I liked it because it was 3D and everything was alive."
- "The landscape had a lot of details."

Students also indicated that they enjoyed the proposed interaction style with the augmented 3D model. The continuous touching of the model, the transitions between activities on the mountain and the contextualization of the finger walking with unexpected events was intriguing and engaging.

- "I liked it a lot because we went on the mountain and we climbed and we had to search the right answer and touch it with our hand."
- "I liked that I had to do different things, to walk over the paths while planes and tanks appeared from nowhere."

Students also perceived FingerTrips learning environment as an effective one, they indicated that the required collaboration was appealing and that the game-based character of the interaction was fun.

- "It is easier to remember [with FingerTrips]."
- "It was big [refers to duration], but we liked the fact that we learned a lot."
- "I really liked our collaboration, the fact that we were trying to find the compasses and all these things together."

Regarding the difficulties students confronted, only a few issues were identified. One student said that he had difficulty in understanding the questions, while another found the paths on the model "a little bit confusing". Most of the participants had a problem hearing or understanding the story or the question presented, but they said they didn't face any major difficulty since they could also read the text of the question on the 3D-model's surface. Two of the participants said they didn't like the way they got feedback as "you had to listen to same things again, and it was a little boring". All these issues could be addressed better in a following version of the environment.

5 Discussion

In this pilot study, the FingerTrips environment succeeded in engaging the primary school students with historical events, made them feel as active participants in the event, and they also thought that they did make a fieldtrip on the historical landscape model with the help of their fingers. The environment provoked them to search, think, discover and study history as historians would. Students claimed that the environment was motivating and effective and that they would like to use more often similar approaches in their classroom since they would learn faster and more things.

Affordable augmented interactive 3D landscapes with FingerTrips can give life to history and offer a participatory experience for students, a much-needed quality in history learning. It is of equal importance that this approach can be followed by students and teachers by themselves since they can design, develop and build interactive landscapes for the historical events they prefer. The event-based programming of

Scratch environment, together with the ability of Makey Makey to make any conductive material to an interactive element, enable students and instructors to easily design and program FingerTrips with a variety of events and activities over an augmented map.

The preciseness of the 3D model is moderate since a single-layer image was projected into a 3D model while the lentils were positioned approximately over the mountain paths without investing a lot of time in the accuracy of the representation. However, that was exactly what was assessed in the study, that is whether these approximations which make FingerTrips an affordable and feasible solution, achieve satisfying effects on students' motivations and learning.

Our study has several limitations. The most important one is that we present the perceived learning evaluations of the students. Although their views are a good indicator for the acceptability of the proposed interface, they cannot offer definite answers for the learning effectiveness of the environment. Additionally, we do not analyze the underlying embodied mechanism for learning. Our hypothesis that touching the landscape may improve students understanding needs more evidence. This is the basic aim of our future research with FingerTrips for history learning.

References

1. Adesote, S.A., Fatoki, O.R.: The role of ICT in the teaching and learning of history in the 21st century. Educ. Res. Rev. **8**(21), 21–55 (2013)
2. Giannopoulos, D.: Italian presence in the dodecanese 1912–1943: teaching a history topic in weebly environment. Procedia Comput. Sci. **65**, 176–181 (2015)
3. Yilmaz, K.: A vision of history teaching and learning: thoughts on history education in secondary schools. High Sch. J. **92**(2), 37–46 (2008)
4. Boadu, G., Awuah, M., Ababio, A.M., Eduaquah, S.: An examination of the use of technology in the teaching of history: a study of selected senior high schools in the cape coast metropolis, Ghana. Int. J. Learn., Teach. Educ. Res. **8**(1), 187–214 (2014)
5. Nokes, J.D.: Recognizing and addressing the barriers to adolescent' "reading like historians". Hist. Teach. **44**(3), 379–404 (2011)
6. Van Drie, J., Van Boxtel, C.: Historical reasoning: towards a framework for analyzing students' reasoning about the past. Educ. Psychol. Rev. **20**(2), 87–110 (2008)
7. Galán, J.G.: Learning historical and chronological time practical applications. Eur. J. Sci. Theol. **12**(1), 5–16 (2016)
8. Bickford, J.H.: Initiating historical thinking in elementary schools. Soc. Stud. Res. Pract. **8** (3), 60–77 (2013)
9. Cengelci, T.: Social studies teachers' views on learning outside the classroom. Educ. Sci.: Theory Pract. **13**(3), 1836–1841 (2013)
10. Coughlin, P.K.: Making field trips count: collaborating for meaningful experiences. Soc. Stud. **101**(5), 200–210 (2010)
11. Stainfield, J., Fisher, P., Ford, B., Solem, M.: International virtual field trips: a new direction? J. Geogr. High. Educ. **24**(2), 255–262 (2000)
12. Strait, J.B., Fujimoto-Strait, A.R.: The mixed plate: a field experience on the cultural and environmental diversity of the big island of Hawai'i. Geogr. Teach. **14**(1), 5–24 (2017)
13. Stoddard, J.: Toward a virtual field trip model for the social studies. Contemp. Issues Technol. Teach. Educ. **9**(4), 412–438 (2009)

14. Lacina, J.G.: Technology in the classroom: designing a virtual field trip. Child. Educ. **80**(4), 221–222 (2004)
15. Palaigeorgiou, G., Malandrakis, G., Tsolopani, C.: Learning with drones: flying windows for classroom virtual field trips. In: 2017 IEEE 17th International Conference on Advanced Learning Technologies (ICALT), pp. 338–342. IEEE (2017)
16. Korallo, L., Foreman, N., Boyd-Davis, S., Moar, M., Coulson, M.: Do challenge, task experience or computer familiarity influence the learning of historical chronology from virtual environments in 8–9 year old children? Comput. Educ. **58**(4), 1106–1116 (2012)
17. Hillis, P.: Connecting authentic activities with multimedia to enhance teaching and learning, an exemplar from Scottish history. Aust. Educ. Comput. **24**(2), 21–27 (2010)
18. Bogdanovych, A., Ijaz, K., Simoff, S.: The city of Uruk: teaching ancient history in a virtual world. In: International Conference on Intelligent Virtual Agents, pp. 28–35. Springer, Heidelberg (2012)
19. Fisher, D.: History Teaching with ICT: the 21st century's' gift of Prometheus'? ACE Pap. **8** (7), 46–59 (2015)
20. Ma, J., Sindorf, L., Liao, I., Frazier, J.: Using a tangible versus a multi-touch graphical user interface to support data exploration at a museum exhibit. In: Proceedings of the Ninth International Conference on Tangible, Embedded, and Embodied Interaction, pp. 33–40. ACM (2015)
21. Antle, A.N., Wise, A.F.: Getting down to details: using theories of cognition and learning to inform tangible user interface design. Interact. Comput. **25**(1), 1–20 (2013)
22. Price, S., Jewitt, C.: A multimodal approach to examining embodiment in tangible learning environments. In: Proceedings of the 7th International Conference on Tangible, Embedded and Embodied Interaction, pp. 43–50. ACM (2013)
23. Resnick, M., Martin, F., Berg, R., Borovoy, R., Colella, V., Kramer, K., Silver-man, B.: Digital manipulatives: new toys to think with. In: Proceedings of the SIGCHI Conference on Human Factors in Computing Systems, pp. 281–287. ACM Press (1998)
24. Loparev, A., Westendorf, L., Flemings, M., Cho, J., Littrell, R., Scholze, A., Shaer, O.: BacPack: exploring the role of tangibles in a museum exhibit for bio-design. In: 2017 International Conference on Tangible, Embedded and Embodied Interactions, pp. 111–120. ACM Press (2017)
25. Palaigeorgiou, G., Karakostas, A., Skenderidou, K.: FingerTrips: learning geography through tangible finger trips into 3D augmented maps. In: 2017 IEEE 17th International Conference on Advanced Learning Technologies (ICALT), pp. 170–172. IEEE (2017)
26. Mpiladeri, M., Palaigeorgiou, G., & Lemonidis, C.: Fractangi: a tangible learning environment for learning about fractions with an interactive number line. In: Proceedings of 13th International Conference on Cognition and Exploratory Learning in Digital Age (CELDA 2016), pp. 157–164 (2016)
27. Petrasova, A., Harmon, B., Petras, V., Mitasova, H.: Tangible modeling with open source GIS. Springer International Publishing (2015)
28. Piper, B., Ratti, C., Ishii, H.: Illuminating clay: a 3-D tangible inter-face for landscape analysis. In: Proceedings of the SIGCHI Conference on Human Factors in Computing Systems, pp. 355–362. ACM (2002)
29. Tateosian, L., Mitasova, H., Harmon, B., Fogleman, B., Weaver, K., Harmon, R.: TanGeoMS: tangible geospatial modeling system. IEEE Trans. Vis. Comput. Graph. **16**(6), 1605–1612 (2010)
30. Amburn, C.R., Vey, N.L., Boyce, M.W., Mize, J.R.: The augmented reality sandtable (ARES). US Army Research Laboratory (2015)

31. Rossi, D., Petrucci, E., Olivieri, A.: Projection-based city atlas: an interactive, touchless, virtual tour of the urban fabric of Ascoli Piceno. In: 2014 International Conference on Virtual Systems & Multimedia (VSMM), pp. 310–317. IEEE (2014)
32. Lindgren, R., Tscholl, M., Wang, S., Johnson, E.: Enhancing learning and engagement through embodied interaction within a mixed reality simulation. Comput. Educ. **95**, 174–187 (2016)
33. Dede, C.: Immersive interfaces for engagement and learning. Science **323**(5910), 66–69 (2009)
34. Elo, M.: Digital finger: beyond phenomenological figures of touch. J. Aesthet. Cult. **4**(1), 14982 (2012)
35. Hassenzahl, M., Monk, A.: The inference of perceived usability from beauty. Hum.–Comput. Interact. **25**(3), 235–260 (2010)
36. Jackson, S.A., Marsh, H.W.: Development and validation of a scale to measure optimal experience: the flow state scale. J. Sport Exerc. Psychol. **18**(1), 17–35 (1996)