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Construction of spatial orientation meanings during an outdoor activity with use of dynamic screen-based spatial representations

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Using spatial representations like maps or graphs can be often challenging for both children and adults. Nowadays new kinds of spatial representations provided by digital devices create a new unexplored context of interacting with space and thus constructing spatial meanings. Even though many researchers argue that geospatial technologies are promising tools in supporting students' spatial thinking, the research on the field remains limited. In this paper I discuss the results of a case study, which is a part of a broader study-in-progress, during which 3 12-year-old children used a GPS application to navigate physically in an unfamiliar space. The dynamic link between the digital representation and children's embodied experience created rich opportunities for the development of spatial meanings. The results of the study, implicate that the integration of geotechnologies in carefully designed activities can support spatial thinking and conceptualization.

Keywords: Spatial orientation, GPS, primary students, embodied learning.

Introduction

Though the development of spatial cognition has been a subject of research for over half a century, these days the interest on the topic has been revived. This comes as a result of the growing number of studies in the field concluding that spatial thinking is not only malleable through carefully designed educational interventions (Uttal et al., 2013) but also very important to be improved (Newcombe & Frick, 2010), as it constitutes an important factor of success in many academic fields, especially mathematics (Uttal et al., 2013). Thinking spatially has been associated with measuring skills (Logan & Ramful, 2017) and geometry concept development (Pittalis & Christou, 2010). Cheng and Mix (2014) explain that many aspects of mathematical thinking are actually spatial. For example, the number line is a spatial representation of numbers' relations. However, spatial training is almost absent in formal schooling and simple spatial tasks like using maps to navigate unfamiliar places remain challenging for students and adults (Newcombe & Frick, 2010). At the same time the technological progress transforms the way we interact with space. In the digital age spatial thinking includes the ability to use new multiple representations of spatial and orientation concepts provided by geospatial tools, the use of some of which like GPS is now considered basic cultural knowledge. Even though many researchers argue for the potential of geospatial technology to support students' spatial thinking (Kerski, 2015), the research on the field remains limited and sparse (Schulze, 2021).

The case study presented in this paper is a part of a broader design-based research which aims to describe the process in which children develop spatial meanings when using dynamic screen based spatial representations in outdoor realistic contexts. Based on recent approaches that emphasize the impact of one's sensory and bodily experience on learning (Duijzer et al., 2019), my design included an outdoor socially orchestrated educational activity where children used spatial information

provided by a GPS application in combination with their direct experience while they physically navigated in an unfamiliar space. In this context, the study aims to provide answers to a) whether and how the use of GPS spatial representations supports children's spatial thinking during an outdoor navigational activity, and b) what kind of spatial thinking processes and meanings do children develop when using dynamic screen-based representations in outdoor educational settings.

Spatial Orientation

Bednarz et al. (2022) explain that one can think spatially when he/she is able a) to use and communicate effectively spatial concepts, b) to use spatial representations like maps, in order to extract and communicate spatial information and c) to reason about space and the spatial relations of the objects in it. During spatial orientation tasks, one has to interpret spatial information about the location, direction and distance of an object or a landmark (e.g., exit of the building) in relation to either her/his own location or the location of another object or landmark in space in order to reorient (Fernandez-Baizan et al., 2021). Hence, including all three aspects of spatial thinking, spatial orientation requires: a) the use of directional spatial concepts, b) the use of spatial representations like maps or building outlines and c) the development of reasoning processes which guide navigational decisions.

According to research, when people navigate physical or simulated space they perceive, thus describe, their position and direction either egocentrically, using as reference their own body, or allocentrically, using as reference the position and direction of someone or something else (Newcombe & Frick, 2010). The egocentric approach during navigation tasks relies on vestibular, kinesthetic, and optic systems, thus it derives from our embodied experience during navigation, where our body and senses play an essential role in making sense of the spatial environment. It is limited because of our inability to perceive the space beyond our senses, thus, to use distant landmarks to orient ourselves. Conversely allocentric approach during navigation depends on allothetic cues like the position of landmarks, or cardinal directions (Fernandez-Baizan et al., 2021). Allocentric representations like maps or building outlines are also insufficient to provide all the information needed for effective navigation, unless they are combined with information about the location and direction of the observer, which is provided by egocentric representations. Rebutting the traditional developmental approach (Newcombe & Frick, 2010), recent research proposed that egocentric and allocentric navigational systems coexist and codevelop in children having a complementary function in supporting spatial conceptualization (Newcombe, 2019), opening new questions about how children combine spatial information from different sources to develop spatial meanings (Burgess, 2006).

Embodied spatial learning outdoors with the use of Geotechnologies

In our days, geotechnologies, like GIS, GPS and Google Earth, are considered to be promising representational tools in supporting spatial conceptualization (Schulze, 2021). Even though the pedagogical value of geotechnologies has been strongly supported (Kerski, 2015), research remains sparse (Schulze 2021), while most of the studies in the field have not been implemented in real educational settings (Hsu et. al., 2018). In my study I propose the integration of a geospatial application in the context of an outdoor socially orchestrated educational activity. As the development

of spatial thinking is directly related to the physical space, the activity is set outdoors. Outdoor activities are experiential and holistic in terms of using all the senses providing this way a multimodal real-world context where one's sensory and bodily experience can be exploited for learning (Kraalingen, 2021). In this context children can see, hear, touch, move and communicate at the same time (Duijzer et al., 2019). The idea that bodily and sensorimotor experiences are fundamental for learning is well supported by researchers in the field of embodied cognition, so embodied design principles were also taken into account. Duijzer et al. (2019) refer to eight factors that mediate learning during embodied designed activities. These are the real-world context, multimodality, linking motion to graph, semiotics, attention capturing, multiple representations, student control, and cognitive conflict. In the next section I discuss how these mediating factors are integrated in the design of the activity.

Methodology

The case study presented in this paper is part of the first cycle (design-testing-evaluate) of a design-based research (Bakker & Van Eerde, 2015). The activities designed for the study took place in the National Garden of Athens and involved the use of GPS applications. In the first activity children explored an augmented reality (AR) contemporary art exhibition ([Seeing the Invisible](#)). They had to follow a path indicated by the exhibition's GPS application in order to reach and see through their devices the digital exhibits. In the GPS application a blue pin point on a digital map represented their position and its blue shadow indicated the direction they were heading to. A green line represented the path the children needed to follow. The application also provided them with a compass on the right bottom of the screen (Figure 1). In the second activity one of the children walked away from the rest of the group. The rest of the group shared their live location with her/him and he/she tried to guide the group where he/she was. During the activities children had to use digital spatial representations in combination with their direct real experience in order to communicate spatial concepts in the context of a realistic goal, reaching a destination.

In my design, outdoor settings provide a real-world and multimodal context as children navigate in a physical space in group, making decisions after discussions and negotiations. As they use representations that are temporally aligned with their own body movements in the physical space (Duijzer et al., 2019) they engage in linking their own motion to the graphical representation in the digital screen. In terms of semiotics, the outdoor and social dimension of the activity makes it possible for children to use oral descriptions and gestures to show locations and directions, while natural locations and characteristics of the environment (e.g., lakes) can capture students' attention, making it also possible for them to use them as landmarks during navigation. Finally, the integration of the GPS application in the activity brings to the table a different allocentric representation of the spatial environment, through the digital map. The coordination of the digital representation with children's direct experience is expected to be a result of cognitive conflicts children face trying to synchronize their movements to the motion of the GPS entity.

Data & Analysis

Data were collected through screen and voice recording during the activity. Analysis was based on the critical episode approach (Angelides, 2001). The critical episodes are instances where children

face an unexpected situation and try to come up with a solution to a problem. The episodes presented in the next session are critical instances where children initially lose their way and combine spatial information from different sources in order to decide on what direction to follow.

Results

During the first activity the use of the digital map proved to be a challenge for the children as they often failed to follow the direction indicated by the GPS application. In the following episode children come from the exhibit of Sarah Meyohas (arrow 1 Figure 1), heading south. In the next node they have to turn left in order to head west towards the direction pointed by arrow 3 in Figure 1. However, the green path appears on the right part of the screen so children turn right, towards the direction pointed by arrow 2 in Figure 1. As the representation of their position via the GPS entity changes every time children move, they notice that they have taken the wrong direction and return to the node, though now heading to a different direction as pointed out by arrow 3 (Figure 1).

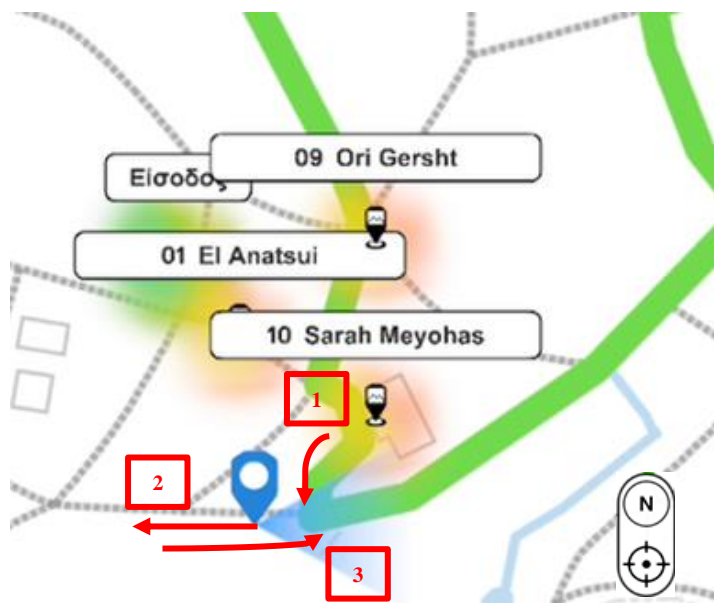


Figure 1: The blue pin point represents children’s position and its blue shadow shows the direction they are heading to. The green line represents the path the children need to follow. In the Episode 1 the group returns to the node where they had taken the wrong direction

Episode 1

- Child 1: *[looks at the GPS] Now? Are we heading up or down [she means North or West]?*
 Child 2: *What? No, we are heading right [she means West]... We came from there [she shows with her hand the direction they came from towards the North and she moves her hand where they are standing now], so now we are heading there [she moves her hand from herself towards the West].*
 Child 3: *No, we turned right last time and it was wrong... when we first arrived here, we turned right so now we have to turn left...*
 Child 1: *But this is the direction we came from... [she shows towards the North]*
 Child 2: *So now... We turn...right... [she means West]*
 Child 3: *Yes! It is different because now we are coming from another direction.*

Child 1: Yes, I get it, because now we are coming from the opposite direction so we take the opposite turn.

What is evident in the above episode is that children use as a frame of reference to define the direction they had to follow, the frame of reference of the screen (Latsi & Kynigos, 2012), defining the right direction as the direction that appears on the right part of the screen and referring to the two directions as up and down as they appear in the top and bottom of the screen accordingly. When they turn right the change in the position of the GPS entity on the screen helps them realize they took the wrong direction. Facing this inconsistency Child 2 employs her embodied experience during a path integration process in order to reason about the direction they had to follow. She supports her reasoning using a gesture to represent their movement. This embodied representation of the path integration process helped children realize that in order to find out which direction they have to follow they have to take into account not only their position but also to the direction they are heading while they are standing in the node. When, later on, Child 1 doubts again about the direction they need to follow to reach some exhibits located on their left, Child 3 reasons about the direction they need to follow also using her previous experience (Figure 2).



Figure 2: The children are following the green path indicated by the GPS application heading in the direction the red arrow is pointing. They decide to head towards the exhibits on their left

Episode 2

Child 3: Now let's go left to see these exhibits, after we can return in the path.
Child 1: Are you sure it is left?
Child 3: Yes, now it is the same. Before it was the opposite because we headed to the opposite direction. And this was moving like this [*she shows on the screen moving her finger from the top to the bottom of the screen in order to show how they moved before*] now we are heading this way [*now she moves her finger on the screen showing how they are moving now*].

It seems that the employment of the Child 2's reasoning in episode 1 helped Child 3 understand how their movement relates to the change in the position and direction of the GPS entity. The coordination of their direct experience with the digital representation made it possible for the children to integrate in their navigational behavior information about allocentric cues, whose position could only be defined using information provided by the digital map.

In the following episode the children have passed Mohammed Kazem exhibit and before reaching the exhibit of Issac Julien CBE RA, they have a stop in order to get some photos. When they decided to go on with their visit they get confused as they are not sure which direction they have to follow (Figure 3).



Figure 3: The group had to head towards Anadol's exhibit

Episode 2

Child 2: Now which way we are going? Maybe here [*she shows the direction indicated by arrow 1 in Figure 2*].

Child 3: Wait, no [*looks at the screen, zooms in and out in order to see the whole map*], we have to go the other way. Look [*she shows in the map*], we have seen these [*she shows to her friend the exhibits on the map*], and the lakes. We came from here, do not rely only on this [*means the representation of their position and direction by the GPS entity*], you have to see the whole map.

In the above episode Child 3 concludes that to find out the direction they have to follow not only requires them synchronizing their body movement with the movement of the GPS entity but also to include information about their relative position and direction. The digital map provided information about the position of the exhibits children had already seen. Using these as reference points Child 3 managed to conclude group's direction and finally reason about the direction they have to follow.

Concluding remarks

The pilot study presented in this paper was driven by two main research questions. According to whether and how the use of GPS spatial representations supported children's spatial thinking during an outdoor navigation activity, the results showed that the design supported children in combining egocentric with allocentric strategies for navigation. Research has not consistently demonstrated whether and how children can combine spatial information provided by egocentric and allocentric representations (Harootonian et al., 2022). At the same time, the ability to coordinate information provided by different representational systems is also an essential element of mathematical activity and conceptualization (Duval, 2006). In this study, the dynamic link between children's movement and the motion of the GPS entity supported them in combining egocentric strategies in navigation, like path integration, with allocentric strategies like the use of landmarks. Consequently, and

regarding the second research question, the development of spatial thinking processes during the task provided the children with opportunities for conceptualization. Children finally realized the relative nature of the concept of direction and the necessity of combining spatial information in order to define it. Concluding, this study shows that the integration of geotechnologies into outdoor education designs can provide opportunities for developing spatial understanding. The design of educational activities in outdoor settings can support the implementation of embodied design principles, where children can exploit their embodied experience while using dynamic spatial representations, providing thus a rich context for them to develop spatial meanings.

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