Use of Spatial Sensemaking Practices in Spatial Learning

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Abstract: This paper describes an approach to understanding how 11-12-year-old students (N=185) engage in spatial thinking through use of sensemaking practices. There is limited research on nature of students' spatial thinking when learning discipline-specific content knowledge during classroom instruction. We use embodied cognition to examine the kinds of sensemaking practices students use when applying perspective-taking skill to learn seasons and lunar phases, and the teacher's role in shaping those practices.

Introduction

Spatial thinking is important in predicting students' success and achievement in the fields of science, technology, engineering, and mathematics (Wai, Lubinski & Benbow, 2009). However, there is limited research on *how* students learn spatial thinking and what kinds of practices or strategies might be useful in improving students' spatial thinking. We begin to fill this gap in the literature by analyzing the nature of students' engagement in spatial problem-solving, and examining the role of the teacher in supporting students' spatial sensemaking. We analyzed how students from 6th grade science classrooms applied the spatial skill of perspective taking (PT hereafter, Liben & Downs, 1993) to astronomy topics. PT skill has been found to be correlated with students' explanations of astronomical phenomena (Plummer et al., 2016). In this study, we examined physical and interactions (dialogues with peers and teachers) to study the nature of sensemaking practices used in the classroom. This study adapts Ramey and Uttal's (2017) analytical framework of *spatial sensemaking practices*, which they developed to examine students' use of spatial skills to solve engineering design problems. However, the present study identifies practices that capture participants' use of perspective taking when they are making sense of concepts related to seasons and lunar phases. We refer to this framework as *PT sensemaking practices.* This study is guided by the following **research question**: *How do middle-school students engage in perspective-taking sensemaking practices when participating in a seasons and lunar phases curriculum?*

Theoretical framework – Embodied cognition

We used the following principles of embodied cognition in analyzing the nature of PT sensemaking practices: *1. we offload cognitive work onto the environment* (Kirsh & Maglio, 1994)*, 2. offline cognition is body based* (Wilson, 2002), and *3. embodied cognition can manifest in social interactions* (Abrahamson & Lindgren, 2014). These principles were used to connect how participants' actions contribute to their PT sensemaking practices by supporting their cognitive activities.

Context and methodology

The study took place in a suburban public middle school in the Northeastern U.S. A total of 185 students (ages 11-12 years) participated in a 10-day curriculum, which was taught by a member of the research team. The curriculum was designed by our team of researchers to promote the use PT skill while teaching seasons and lunar phases. We videorecorded all 10-days of instruction to capture talk, actions such as gaze and gestures, turn transitions, and collaborative activities, which are otherwise difficult to capture through field notes. Each class period was 45 minutes per day. We analyzed the data using interactions analysis (Jordan & Henderson, 1995).

Findings

We found two main themes for PT sensemaking practices in the classroom – students themselves used practices to aid their perspective taking and the teacher used practices to support students' use of perspective taking. The analysis revealed three PT sensemaking practices that were unique to the teacher - a) *PT questioning,* b) *eliciting students' gestures* (Nathan, 2008), and c) *grounding students' thinking with gestures* (Nathan, 2008). We found four PT sensemaking practices common to both students and the teacher – a) *using gestures* (enhancing speech, complimenting speech, with bodily movement), b) *PT epistemic actions* (physical and virtual object manipulation, Kirsch & Maglio, 1994), c) *PT representations* (sketching), and d) *using fixed objects as proxy*.

PT questioning refers to a question asked either by the teacher or the student that requires PT skill to answer it. e.g. "who [on earth] should see the sun [rising] first?" This question requires the students to imagine the sun's path from an earth-based perspective and then connect it to space-based perspectives, to visualize which part of the earth would face the sun first as it rotates. *Eliciting students' gestures* refers to prompts for students to use gestures to support their sensemaking. *Grounding students' thinking in gestures* refers to instances when the teacher used gestures to emphasize meaning of students' responses by making their thinking visible.

From the common PT sensemaking practices observed, *using gestures* refers to participants using their hands to simplify visualization of different perspectives. *PT epistemic actions* include practices when the participant manipulates objects in the environment to reduce cognitive load. Examples include using a model earth and rotating it to figure out the directionality of its rotation instead of mentally visualizing. *PT representations* refers to translating mental visualizations with a drawing. For instance, the teacher drew a sketch of earth and sun model to show how the sun's rays hit a specific location on earth because of its tilted axis. *Use of fixed objects as a proxy* refers to a visualization practice such as using a wall-clock as a proxy for the North Star, which was then used as a reference to determine direction of earth's tilt by visualizing a space-based perspective.

Discussion

This research study examines how 6th-grade students and their teacher engaged in perspective taking through sensemaking practices and how those practices are enabled by elements of their learning environment. The principle of embodied cognition - *we offload cognitive work onto the environment* – suggests that use of external tools or objects helps in simplifying cognitive processes. We saw evidence of that when students, as well as the teacher, used earth models to simulate earth's motion that simplified application of PT skill. The second principle – *offline cognition is body-based* - suggests that gestures are useful in externalizing thinking processes. The word "offline" suggests processes in the world that are removed from the context. Body-based actions such as gestures or movement, become a part of the learner's "toolbox," providing ways to organize their thinking and cognition. In our study, we found that this principle was operationalized when students and the teacher communicated through gestures and used gestures for externalizing their mental visualizations of space- and earth-based perspectives. We also observed that the teacher encouraged students to use their models and gestures to clarify their thinking and helped in breaking down the process of using PT skill. Thus, embodied cognition sometimes *manifested through social interactions* (Abrahamson & Lindgren, 2014).

A close examination of students' actions, interactions, and the teacher's enactment of the curriculum provided insight into how spatial information is communicated and is used for constructing explanations of astronomical phenomena. In essence, gestures, speech, external objects, and linguistic prompts together seem to create fluidity in students' spatial thinking as they engage in constructing explanations, follow teacher prompts, and collaborate with peers. This study has implications for how students' spatial thinking can be effectively fostered through intentionally designed learning environments, curriculum, and instruction that leverage students' spatial skills to support their spatial learning using principles of embodied cognition.

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