Learning with Multiple Representations and Student Engagement in Secondary Education: A Preliminary Review of Literature

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Abstract: Research on learning with multiple representations and the need to develop students' representational competence has increased in recent years. However, studies rarely address instructional approaches to develop students' skills of learning with these resources. It is also the case that the nature of student engagement when they use representations in their learning is rarely examined. We report preliminary findings of a systematic review on the nature of student engagement when using multiple representations. Our analysis resulted in 4 categories of student engagement revealing various levels of learner agency. Results provide insight for research and practice in designing and understanding learning with multiple representations.

The ability to learn with multiple representations (MR) is an essential skill for secondary school students. In the context of science education, learning involves not only understanding concepts and scientific facts but also using the various representational tools and inscriptions that are needed to engage in the processes of scientific inquiry (Gilbert, 2008; Lemke, 1998). Lemke (1998) argued that textual descriptions are not sufficient to learn about science, engage in scientific inquiry and represent scientific understanding of a phenomenon. However, instructional approaches to develop learners' abilities to use multiple representations are limited. Furthermore, despite the complimentary nature of research on multiple representations and student engagement (Gebre, 2018), the two research foci progressed independently. This paper presents a preliminary systematic review of existing literature with the purpose of examining the nature and purpose of student engagement in learning with MR.

Multiple representations and student engagement

Different researchers use different concepts to refer to the use of representations in learning such as "multiple representations" and "representational competence". In this paper, we build on Gebre and Polman's (2016) distinction and use "multiple representations" to refer to the various visual tools (e.g., graphs, drawings, images, text) students use in their learning. "Representational competence" refers to the abilities of the learners to understand, critique and learn with multiple representations (Gebre & Polman, 2016; diSessa & Sherin, 2000). The importance of multiple representations as tools of learning and communication has been highlighted in recent literature (Gilbert, 2008; Namdar & Shen, 2016; Wu & Puntambekar, 2012). For example, Namdar & Shen (2016) argued that the use of multiple representations in learning supports the development of argumentation in science education. However, instructional approaches for representational skills are rare (Wu & Puntambekar, 2012).

Defining student engagement as the nature, extent and quality of students' interaction with the learning context including materials, tools, activities and other people (Azevedo, 2006), we focus on two aspects of engagement: cognitive and agentic engagement. Cognitive engagement is students' involvement in deep learning strategies, complex cognitive activities and active learning processes. It relates to the nature of learning activities and the extent to which the activities are instrumental in fostering learners' abilities to deal with complex problems. Agentic engagement refers to the extent of learners' involvement in making constructive contributions to the flow of learning and instruction including, their agency to make decisions/choices as well as personalizing the learning experience to their needs and contexts (Reeve and Tseng, 2011). Cognitive and agentic engagement are important because studies showed that high engagement has been related to students' involvement in framing learning activities and processes (Schmidt et al., 2018). This study answers the question, "What is the nature of student engagement in learning with multiple representations?"

Methods

We conducted a concurrent abstract search of three databases (ERIC, EBSCOhost and PsycInfo) using terms 'representation' OR 'visual' OR 'drawing' AND 'learning' OR 'achievement' OR 'outcome' AND 'high school' OR 'secondary school'. We used four inclusion/exclusion criteria: a) secondary education, b) MR as a main focus of the study and/or intervention, c) learners' direct interaction with representations and d) assessment of outcomes or satisfaction. Thirty-four articles were selected for further analysis or data extraction (27 in STEM areas, 5 language and arts and 2 in geography). Data extraction involved reading the methodology section of the studies and open-coding the nature of student engagement or interaction (when they use MR) with the purpose of understanding what learners were doing or required to do in the instructional process as reported in the studies.

Results

Of the total 34 studies, only 16 (47%) involved the use of computers as tools of learning and representation (12 STEM, 3 language and arts and 1 geography). Only fifteen studies involved collaboration or group work among learners the remaining 19 studies focused on individual learning. However, collaboration did not depend on computer use (6 studies used collaboration without computers), nor did the use of computers guarantee collaboration among learners (7 studies involved collaboration with no computer use).

Our preliminary analysis resulted in four categories representing the variation in student engagement while using representations: learning from (N=14), manipulating (N=8), representing ideas or processes (N=11) and constructing complex representations (N=4). Note that the total of coded segments adds up to 37 this is because three studies involved more than one activity related to use of multiple representations.

"Learning from" involved the use of expert-generated representations by students in the learning process. What is expected of the learners is to understand, interpret, discuss or write about the representation. For example, Homer & Plass (2010) examined students' learning from simulation diagrams with narration and iconic representations. "Manipulating" involved students in choosing variables and/or values to change in a given model or representation and observe the effects of their manipulation. Five of the eight studies coded as manipulation involved the use of computer in learning. "Representing" involved creating visual images, pictures or drawing to represent a specific idea or data. For example, Smajdek and Selan (2016) required students to create a drawing representing their understanding of a text (provided by teachers) within five minutes of reading. In most cases, teachers provide the task (sometimes including the variables involved). For example, a teacher can ask her students to represent a car in acceleration and students draw their understanding of a speeding car. Finally, "constructing" related to complex representations which involved defining the problem and variables, using evidence or data to support claims, organizing the data and constructing representations. McDermott & Hand (2013) engaged students in producing visualization-embedded writing in a chemistry class with subsequent creation of checklist to assess the quality of "embeddedness" in science communication (p. 226). Similarly, Gebre & Polman (2016) used multiple representations to foster young adults' science literacy.

Discussion

Multiple representations can serve both as learning and communication tools for students to understand phenomenon and express their understanding. However, the manner MR are deployed in learning design determines their role in fostering student-centered and complex learning. Learner agency and complex cognitive activities increase as the nature of student engagement progresses from "learning from" to "constructing" representations. However, the findings imply that learning design with MR has a long way to go in terms of addressing learner agency and attending to the tenets of student-centered approaches to instruction.

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