Assessing Systems Thinking Across Disciplines: A Learning Progression

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Abstract: Learning progressions are a promising framework that can serve the basis for designing assessments to measure students' knowledge about complex systems. Using an innovative approach to simulation-based assessments, we investigated students' experiences related to their performance on three simulation-based science assessments. Simulations and scenarios in which systems and system models were contextualized connected authentic real-world experiences that were relatable. These experiences may have enabled elicitation of evidence to map student performance onto the LPs.

Keywords: Learning Progression, Systems and System Models, Simulations, Assessments

Introduction

Complex systems are difficult for students to comprehend due to their hierarchal levels of organizations and hidden micro/macro level structures (Hmelo-Silver et al., 2007; Yoon et al., 2019). Nonetheless, systems and system models are important tools for observing and explaining phenomena and foundational to developing scientific literacy (Sabelli, 2006). Further, systems and system models are a crosscutting concept (CCCs) highlighted in the Next Generation Science Standards (NGSS; NGSS Lead States, 2013). In light of this, policy documents, such as NGSS have called for science education standards, curricula, and assessments to be informed by learning progressions (LPs) to promote students understanding of complex systems.

Learning progressions highlight students' progressively sophisticated understanding and suggest how their thinking and reasoning may shift from naive conceptions and beliefs to those consistent with current scientific models and theories. LPs represent a promising framework for developing assessments and integrating systems and system models, allowing both large-scale and classroom-based assessments to be grounded in models of how understanding develops over time (Corcoran, et al., 2009). However, the complexity of systems and system models make it difficult to assess using static tools. Computer-based science assessments (e.g. simulations) offer a new way to deliver complex tasks in an authentic, enriched contexts, permitting students to demonstrate their knowledge and skills in ways called for in the NGSS. Specifically, simulation-based assessments can present systems and system models in rich and authentic task environments that display key features of complex science systems, enabling students to visualize and experience complex representation of this cross-cutting concept (Quellmalz et al., 2012). In our study, we designed an LP for systems and system models that guided the development of simulation-based assessments to examine students' understanding of complex systems. Here we address the following research question: *To what extent do students' experiences relate to their performance (LP levels) on three simulation-based science assessments?*

Methods

A multiple case study methodology was employed that follows a phenomenological design to delve into students' experiences. Three cases were selected from a larger study, which were representative of a high performing student, an average student, and low performing student based on their LP levels. All students in the larger study, conducted in a rural US public school district, completed three simulation-based assessments in the domains of ecosystems, earth systems, and human body systems. The ecosystem assessment required students to explain how to maximize corn yield after a corn rootworm infestation. In the earth system, students had to rationalize how the distribution of water between two watersheds causes different consequences in both water supply and crop yield. While, in the body system assessment, students had to determine the best nutritional strategies to employ to address "Anika's" hunger and energy levels while engaged in a dance class. All students' responses were assigned a level on the LP with a 1 representing the least sophisticated understanding and a 5 representing the highest level of understanding (Liu et al., 2020).

Findings

Three unique cases were selected for the case study to demonstrate the diversity of LP levels, gender, and grades. Each case described (Table 1) highlights students' experiences in relation to their performance (LP).

Table 1: Cases and description

Cases	LP levels	Description
Chris Male (6th)	Level 3 – across all assessments.	• Chris had moderately high sophistication in describing localized and central mechanism that explains the observed phenomena. • Enjoyed the simulation, modeling tools, & the videos in the assessments. • He was able to relate because "when I was back in town, we used to have a garden and rabbits and lots of other things would get into it and a lot of our vegetables."
Anna Female (8th)	Body system - Level 2 Ecosystem – Level 1 Earth system – Level below 1	• Anna's lack of understanding about earth system content and the assessment challenges she discussed shed light on her LP level on this assessment. • She stated, "It was water and then crops and then human uses. I was really confused on that and I watched the video over and over. I just don't get it." • Anna enjoyed the simulation, graphs, & loves dance video games.
Jack Male (9th)	Body system & Ecosystem - Level 3 Earth system – Level 2	• Jack's experiences articulate his strong connection with the concepts covered in the two assessments (body & ecosystem) as he performed at a higher LP. • He enjoyed the modeling tools, simulations, and the graphs. • Jack stated, "well, from where I am, it was a small farming community, and basically, that's all of Indiana is a farming community. I play a lot of video games too."

Conclusion and implications

In this study, we examined the extent to which students' experiences relate to their performance (LP levels) on three simulation-based science assessments. The simulation-based assessments and scenarios provided learners with real-world experiences that were relatable and also helped learners grasp the embedded concepts in the assessments. Simulation-based assessments allowed to create dynamic scenarios that replicated a natural system which supported students' interest and engagement. Each simulation scenario allowed students to make authentic connections to their prior experiences that facilitated elicitation of evidence to map student performance onto the LP levels. This study provides an exemplar of how to assess students' understandings of systems and system models. The hypothesized LPs also provide educators and researchers with a framework LP that can be employed to create instructional tools and assessments to discern students' understanding of crosscutting concepts.

References

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