Students' Ideas About the NGSS Crosscutting Concept of Systems and System Models: Evidence From Parallel Assessments

Dante Cisterna, Lei Liu, Shu-Kang Chen, Peter van Rijn, and Aurora Graf
dcisterna@ets.org, lliu001@ets.org, schen@ets.org, pvanrijn@ets.org, agraf@ets.org
Educational Testing Service

Abeera P. Rehmat, Karyn Housh, and Cindy Hmelo-Silver
arehmat@iu.edu, khoush@iu.edu, chmelosi@indiana.edu
Indiana University

Abstract: We explore the extent a parallel assessment design describes students' performance about the NGSS' Crosscutting Concept (CCC) of *Systems and System Models*, in three science topics. Drawing on learning progressions (LP) and evidence-centered design, the majority of student performances were at level 2 in the LP—which implies students were able to identify some system components and relationships but were unable to explain how they work together to make sense of the associated phenomena.

Keywords: Crosscutting Concepts, science assessment, parallel assessment design

Introduction

Crosscutting Concepts (CCC) are key for achieving science understanding because they operate as connections between domains and practices in science (NRC, 2012) and are part of the science learning framework described in the Next Generation Science Standards (NGSS Lead States, 2013). Given their implications for science curriculum and assessment, more research is needed to understand how CCC operates in student cognition and determine the types of evidence of such cognition across different science topics. The CCC *Systems and System Models* is characterized as "an organized group of related objects or components" in which "models can be used for understanding and predicting the behavior of systems." (NGSS Lead States, 2013; p. 93). The use of system models helps students represent mechanism-based phenomena by showing the arrangement and relationships of multiple components within a system (Windschitl, Thompson, & Braaten, 2008). In this study we describe how assessment tasks that follow a parallel design—organized around a common CCC—can provide evidence of student thinking across science contexts. Thus, the research question for this study is, *in the context of a parallel assessment design, how do students' responses about systems and system models align across science topics?*

Assessment design

To describe the specific knowledge, tasks, and evidence of student learning that are needed for designing parallel assessments, we drew on the NRC Framework (NRC, 2012) and research on student learning of the target science domains. An Evidence-Centered Design (ECD; Mislevy, Almond, & Lukas, 2003) process was used to link student models of disciplinary reasoning to evidence models. We used a Learning Progression (LP; Corcoran, Mosher, & Rogat, 2009) framework to describe the different levels of performance that students are able to develop about systems and system models. We defined LP progress variables including (1) components, (2) relationships, (3) mechanisms, and set five levels of achievement that describe a progression of students' understanding. Our design included three scenario-based assessment tasks in the domains of Earth, Body and Ecosystems. The three assessment tasks have students propose a solution to a challenge and follow a parallel structure and common storyline to gather evidence of systems and system models. In the *Earth Systems* task, students analyze the effects resulting from changes in the water availability of two watersheds; in the *Ecosystems* task, students analyze the trophic interactions in a corn farm; in the *Body Systems* task, students use their understanding of the process of human nutrition to explain how human body systems interact. Key features of the parallel assessment design include items to demonstrate understanding of the systems' components and relationships related to the task contexts and the use of online interactive simulations to guide students collect data, predict, and explain different system outcomes. We conducted successive iterations to refine and improve the assessment tasks, including cognitive interviews to 45 middle- and high-school students.

Results of pilot study

We conducted a pilot study to test the parallel assessments with 204 students from sixth (39%), eight (33%), and tenth grade (28%) from rural school district located in the Midwestern United States. Students had prior instruction with the disciplinary content. The three assessments were administered online and took about 90 minutes to complete. To score constructed-response items, we developed rubrics that were iteratively refined. The Cohen's Kappa interrater reliability for those items ranged 0.63 to 0.86.

Table 1 describes students' responses for a group of constructed-response items focused on systems and system models, across the three assessment tasks. These items are similar as they have students analyze data from parallel simulations. Results suggest that many students' responses were able to identify the systems' components and establish some relationships between components. However, analysis of student responses suggests that the identification of components and relationships was insufficient to help students create robust explanations for mechanisms and processes in relation to the task contexts. As preliminary evidence of the parallel design, the Pearson's correlation between responses to the body systems and earth systems assessments is 0.61, the correlation between responses to the body systems and ecosystems assessments is 0.61, and the correlation between earth systems and ecosystems assessments is 0.71.

Table 1: Score frequencies for the systems and system models LP (n=204; constructed-response items only).

Task	Item	Below Level 1	LP Level 1	LP Level 2	LP Level 3	LP Level 4
Earth systems	Q7	5 (2%)	93 (46%)	78 (38%)	23 (11%)	4 (2%)
	Q8	10 (5%)	70 (34%)	106 (52%)	18 (9%)	0 (0%)
	Q9	14 (7%)	59 (29%)	74 (36%)	25 (20%)	5 (2%)
	Q10	24 (12%)	69 (34%)	84 (41%)	12 (20%)	2 (1%)
Body systems	Q11	40 (20%)	50 (25%)	102 (50%)	12 (6%)	0 (0%)
	Q12	27 (13%)	43 (21%)	119 (58%)	12 (6%)	3 (1%)
	Q13	26 (13%)	33 (16%)	131 (64%)	14 (7%)	0 (0%)
Ecosystems	Q10	13 (6%)	49 (24%)	113 (55%)	25 (12%)	4 (2%)
	Q12	15 (7%)	67 (33%)	109 (53%)	11 (5%)	2 (1%)
	Q14	15 (7%)	69 (34%)	105 (51%)	14 (7%)	0 (0%)

Implications

Across the three assessments, students provided evidence that account for the LP levels of the learning progression, as they represent descriptions of more sophisticated levels of understanding (Corcoran et al., 2009). In the three assessments, the majority of student performances were at level 2 in the LP—which implies that students identified some components and relationships among system components but were unable to explain how they work together to make sense of associated phenomena. Evidence of students' responses suggests that a parallel assessment design has the potential to capture students' understanding of CCC across different science contexts or domains. Given the nature of crosscutting concepts, in which students can identify common aspects about science (Duschl, 2012), designing parallel assessments that uses CCC is paramount as they can "link" science topics and contexts, and potentially determine alignment in students' understandings.

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