From tacit knowing to explicit explanation: Mining student designs for evidence of systems thinking

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Introduction and Framing
It has become increasingly clear that students’ experiences in schools do not match the kinds of experiences they are likely to have once they have completed school. The push to support “21st century” skills stems from this mismatch, and which skills need supporting is the topic of significant conversation. In this paper, we focus on one particular aspect of 21st century skills, which involves understanding the world not as a simple set of cause-and-effect experiences, but rather as a set of complex systems. Systems thinking generally refers to a way of understanding the world as a set of systems that are made up of many elements, each of which have distinct behaviors, which change and interact, giving rise to emergent behavior. The advantages to understanding the world as a set of systems are many, but a chief advantage is that systems thinking allows students to understand and interpret the world across content areas (Goldstone & Wilensky, 2008). Unfortunately, supporting students to develop systems thinking has proven to be a significant challenge. First, systems thinking ideas are difficult (Hmelo-Silver & Pfeffer, 2004) and is also often counter-intuitive (Wilensky & Resnick, 1999). Systems thinking requires students to look for myriad contributions to system behaviors as opposed to simple cause and effect. Indeed, a key concept of systems thinking involves understanding that a small change can lead to a significant outcome—an idea that flies in the face of many core assumptions we have about the world. Linda Booth-Sweeney (2001) points out that most of our experiences in the world, particularly as children, are explained in terms of causality, and we have very few opportunities to experience the world as a set of systems.

Despite these challenges, the advantages of supporting students to understand systems are clear. The question is how to best go about doing it. The purpose of this poster is to examine what students can learn about systems when they engage tasks that require systems thinking to support their successful completion. In contrast to most existing approaches to teaching students about systems, which involves teaching students explicitly about systems, this poster considers data from a project that sought to support students’ nascent understandings of systems thinking by engaging them in experiences that would support their tacit understanding of principles of systems thinking. Specifically, we present a case-study analysis of two students engaged in a video game design unit using a platform called Gamestar Mechanic. Our goal is not to demonstrate the efficacy of the unit for supporting all students to engage in systems thinking. Instead, this study is exploratory in that it interrogates what kinds of thinking about systems might be possible in the context of designing video games.

Methods
This paper focuses on two intentionally selected cases that present a contrast between ways that students demonstrated their understanding of systems. The cases are drawn from a project that examined how students engaged systems thinking concepts across different design-based modules. This study took place in the context of a two-week summer camp in a major city in the Midwestern United States. This camp was free to all students, but was voluntary, and thus students who participated in the camp had chosen to be there.

The four cases from this study were selected based on initial observations of their engagement; because part of the data collection methodology involved interviewing students, cases were initially selected based on observations of who would be talkative in those interviews. From those ten cases, four were intentionally selected for further analysis based on indicators that they had some understanding of elements of systems thinking. Students were working on designs in the context of a module that focused on how to design videogames as an explicit focus; a secondary focus of the unit involved thinking of games as systems, and considering how to design well-functioning systems. Language of game design was overlapped with language of systems thinking. Students were thus introduced to the idea of systems thinking in the following terms: systems are made of up elements, which have particular behaviors, whose interactions shape and change the behavior of those elements and the resulting emergent dynamics of that system.

Two methods of coding were leveraged for this analysis. First, videotapes and designed games were reviewed using an emergent coding approach. This initial coding phase was concerned with characterizing students’ thinking about their games, particularly with respect to the key ideas about systems that were covered in instruction. This process resulted in coding categories that documented: the number of components included in a design; the number of interactions among components included in the design, and evidence of intentionality
(with respect to the design of interconnections among components). We then examined the existing literature to consider what other indicators of systems thinking had been developed. We leveraged the coding scheme from Jacobsen (2001) that included eight categories, four of which were reflected in our data.

**Results**

The results of our coding is presented in two parts: what can be said about students’ tacit understanding based on the games they designed, and what can be said about their explicit understanding based on interviews conducted with the students about their games.

**Tacit understanding**

Students’ designed games reveal quite a bit about what they (at least tacitly) understand about systems, and looking comparatively across the two games helps to highlight particularly significant differences. In the case of Levon, his game included seven elements. The system interactions (i.e. the elements whose behaviors interact) are generally relatively simple; there are four interactions and they are relatively simple cause and effect. There is evidence of intentionality with respect to designing for interaction; for example, all “prey generators” are located in the corners, while all “predator generators” are included in the middle of the space. Based on this game, we could conclude that this student appears to have at least a tacit understanding of fundamental elements of systems thinking, although there isn’t a sense of more sophisticated understandings about the ways that systems function in general. In contrast, Waylen’s game suggests an understanding of more systems thinking concepts. His game includes more elements (ten), although the number of elements alone is not indicative of conceptual understanding. In addition, Waylen’s game has almost twice the amount of system interconnection between elements, several of which represent fairly complex relationships (i.e.- shows levels of interconnection responsible for emergent outcomes for meeting the game’s goals (i.e.- prey & time limit), energy, health). Taken together, this suggests that Waylen has some kind of understanding that in a system, control is decentralized and based on system interactions. There is no simple way to “win” Waylen’s game; instead, myriad criteria need to be met in order for the game to be complete.

**Explicit Understanding**

In contrast to what students’ designed games suggest about what the students understand about systems, interviews with the students, which required that they explicitly discuss their reasoning, were quite different. While Waylen struggled to describe his thinking in the context of designing his game (discussing only the simplest of interconnections between elements, which did not reflect the complexity of the game), Levon’s interview revealed more understanding of systems than was suggested from his game. Specifically, in Levon’s interview he described how his design worked in ways that indicated that he understood that outcomes have multiple causes, rather than single, when he described how particular interactions among components would change behaviors in the game.

**Conclusions**

In this poster we examined what students can demonstrate they know when they engage tasks that require systems thinking to support their successful completion. We considered differences between what students can explicitly state about what they know about systems, as well as what they can demonstrate that they know tacitly through their designs. This is exploratory work that seeks to understand what students’ systems thinking might look like in this dramatically different context. However, even in this exploratory phase, two primary conclusions are clear. First, the activity of designing games can indeed support students to develop some sophisticated intuitions about systems, and second, that gaining insight into those intuitions, from the perspective of an analyst, is not a trivial task. Indeed, differences between what students can show that they know through their designs, versus what they can say that they know through interviews, suggest that assessment practices must be broad in order to capture a full picture of student thinking.

**References**


