Making systems thinking public: Collaborative construction, revision and use of computer-based causal loop diagrams

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Abstract: To solve complex real-world problems in life science, it is important for students to adopt a systems approach. This study examined a 2-week unit that used computer-based causal loop diagramming to foster university students' systems thinking about obesity. Analysis of the causal loop diagrams revealed a significant shift toward a systems approach and showed that it was supported by a construct-revise-use process. The findings suggest the potential of causal loop diagramming to foster systems thinking.

Introduction

As issues grow and increase in complexity, the need to approach them via a systems perspective (Checkland, 2000) arises. A systems perspective entails understanding the whole of a system and the many levels of interrelationships characterizing its parts. Socioscientific issues (SSI) are complex, ill-structured, and controversial social issues with conceptual and/or procedural links to science that often involve contested knowledge and are open to multiple solutions. Systems thinking in an SSI context entails a consideration of and beyond the associated scientific elements, and the interactions within and between domains (Ke et al., 2020). We are interested in supporting students in systems thinking through a computer-based causal loop diagramming tool. Causal loop diagrams (CLDs) are commonly used by systems thinkers for visualizing both the generic and the specific and conceptualizing causal relationships and feedback loops. CLDs externalize users' mental representation of a complex system and are a reliable tool for developing and gauging students' systems thinking. When working as a team, the diagram serves as an artifact around which the team can discuss and develop ideas, from which the diagram can be modified collaboratively. These operative-cognitive iterations support the systems thinking of an individual or group (Knight & Littleton, 2015). This study investigated whether university students' systems thinking about an SSI can be promoted through the use of computer-based causal loop diagramming and explored the scaffolding strategies associated with developing systems thinking through causal loop diagramming.

Method

We examined student learning during a 2-week obesity unit forming part of a general education course. The students worked in groups of three to four and were asked to create CLDs explaining the obesity phenomenon before, during, and after the unit using the Vensim causal loop diagramming software package (https://vensim.com/vensim-causal-loop-diagramming/). The pre-, mid-, and post-unit diagrams (see example in Figure 1) were used to evaluate the students' progressive development of systems thinking about obesity. The students were also asked to submit individual weekly reflections on their learning experiences to deepen our understanding of their shifts and evaluate how they personally felt about their learning experience. A repeated measure MANOVA followed by LSD post-hoc test was used to compare the possible statistical significance of shifts in the students' systems thinking about obesity between the pre-unit, mid-unit, and post-unit evaluations. The inter-coder agreement, as measured by Cohen's kappa coefficient, ranged from 0.71 to 0.995.

Major findings and discussion

This study demonstrates students' development of systems thinking about obesity through causal loop diagramming, as evidenced in the significant increase in the quantities of components at the population level, individual level, relationships described, B-loops and R-loops (see Table 1). The qualitative findings from the reflective memos further reveal that the shift to a systems approach through causal loop diagramming was supported by scaffolds in relation to constructing, revising, and using causal diagrams.

Construct Collaborative learning through constructing CLDs in groups was found to increase the number of variables and interactions identified in the system. This finding is consistent with that of Knight and Littleton (2015) on the affordance of digital tools in supporting individual thinking and "interthinking."

Revise Multiple opportunities to revise CLDs were found to support the development of systems thinking. Cognitively, more variables and interactions between variables were elicited with the input of new information. Operationally, some of the students became aware of the flaws in their diagrams, such as unclosed loops, and learned through the amendments they made.

Use The process of proposing actions and incorporating them into their CLDs gave students the opportunity to predict the consequences of an action and assess its effectiveness. Our empirical findings support that proposing actions in response to obesity (thinking) led to the incorporation of these actions into the CLD (operation); in turn, the incorporation of actions into the CLD facilitated their assessment and prediction of outcomes (further thinking).

Conclusion

The findings of this study demonstrate the potential of causal loop diagramming to foster systems thinking about obesity through the construction, revision, and use of CLDs that serve as epistemic tools for students to make sense of, explain, and predict the obesity phenomenon. During this process, operations and thinking take place. Although the use of systems thinking is reflected in operations, it is fostered at both the operational and cognitive levels and in their two-way relationship.

References

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Table 1

Comparisons of the components, relationships, loops, and actions at pre-unit, mid-unit and post-unit

	Pre Vs Mid		Pre Vs Post		Mid Vs Post	
	Mean differences	LSD post hoc test	Mean differences	LSD post hoc test	Mean differences	LSD post hoc test
Components						
Quantity of components (population level)	2.73	<0.001**	8.69	<0.001**	5.96	<0.001**
Quantity of components (individual level)	0.89	0.047*	1.12	0.02*	0.23	0.19
Quantity of components (microscopic level)	-0.12	0.48	-0.08	0.63	0.04	0.57
Relationships						
Quantity of relationships (arrows)	6.27	<0.001**	13.38	<0.001**	7.11	<0.001**
Web-like causality index (WCI)	-0.03	0.24	0.01	0.79	0.02	0.17
Loops						
Number of "R" (reinforcing loop)	1.16	0.01**	1.39	<0.002**	0.23	0.06
Number of "B" (balancing loop)	0.5	0.051	0.61	0.010**	0.11	0.19

Figure 1

An example of a pre-, mid- and post-unit computer-based causal diagrams