An instrument to quantify how well students can recognize feedback loops in narratives and its use for evaluating pedagogical strategies

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Learning & Teaching Thread

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Problem Statement

We are an interdisciplinary team of cognitive scientists and geoscientists with the long-term goal of understanding and then improving how novices and experts use systems thinking to tackle problems of importance to them. Our domain of interest lies in how systems thinking is accomplished using only the human mind and non-computational tools such as pencil and paper. Our current focus is on feedback loops, as this concept is both hard to teach and learn and central to many natural and social systems.

The first step in applying one's knowledge of feedback loop dynamics to a novel situation is to recognize that the situation that one is confronting is a feedback loop--even though the superficial attributes may be far different from feedback loop(s) previously encountered. We sought to design an instrument to assess a Learning Goal that "learners can recognize feedback loops when they encounter them in familiar and unfamiliar context," comparable to the "Identifying Feedback" construct in the systems thinking assessment frameworks of Stave & Hopper (2007) and Plate & Monroe (2014) and the "causal loop inclusion" attribute of Plate (2010). Additional criteria were that the instrument had to be quick to administer and score, produce quantitative scores that could be compared between instructional settings, and be useable in any discipline where at least one feedback loop was being taught.

Approach

In each item of our 40-item instrument, the participant is provided with a narrative and must state whether or not it is a feedback loop. Items vary by topic (spanning natural and social sciences), complexity (number of elements), whether positive loops foster growth or decay, and whether the outcome of the loop is desirable or undesirable (Fig. 1). Scoring employs a signal detection approach to reveal both sensitivity (d': skill in discriminating loops from non-loops) and bias (c: tendency to over- or under-identify loops). Both c and d' are measured in standard deviations from no bias and no sensitivity, respectively. In its tested version, the instrument covers positive loops only.

	Loop	Non-loop
Desirable outcome	When trees begin to grow in a previously cleared field, the trees that grow the fastest gain access to the most sunlight, and thus the most energy. Using this energy, they can grow even taller and shade out competing trees. This is how a majestic forest, with minimal understory, can be formed.	When trees begin to grow in a previously cleared field, the trees that grow the fastest gain access to the most sunlight and thus the most energy. As trees grow taller, a higher percentage of their mass is in their trunk, and less in their energy-gathering foliage. A massive trunk enables the mature tree to resist falling down in windstorms.
Un-desirable outcome	[...same as above, except last sentence says...] Eventually, the trees grow so tall that they are unstable and vulnerable to windstorms.	[...same as above, except last sentence says...] This leaves less energy available for fighting pathogens.

Figure 1: *Examples of narrative variants in our feedback loop-detection task. Across the 40 items of the instrument each participant sees an even number of loops and non-loops and an even number of desirable and undesirable outcomes, and only sees one variant on each topic.*

Progress and Insights

As a first use of the instrument, we set up an experiment to test whether teaching novices about "reinforcing" and "balancing" feedback loops is more effective than teaching them using the affect-laden terms "positive" and "negative" (Kastens, 2010; Zion & Klein, 2015). Undergraduates in Temple University's psychology participant pool (n=166) were given a definition plus one example of a feedback loop, and were asked to indicate by yes/no forced choice whether each of 40 items was or was not a feedback loop. Half the participants were instructed and tested using the term "positive feedback loop" while the others were taught and tested identically except for use of the term "reinforcing feedback loop."

Our data (Fig. 2) show that the group taught and tested on “positive feedback loops” do show a strong bias towards saying “yes, this is a feedback loop” when the narrative describes a desirable outcome (mean c = -0.59) but not when outcome is undesirable (c=-.05). Using the alternative term “reinforcing” yielded

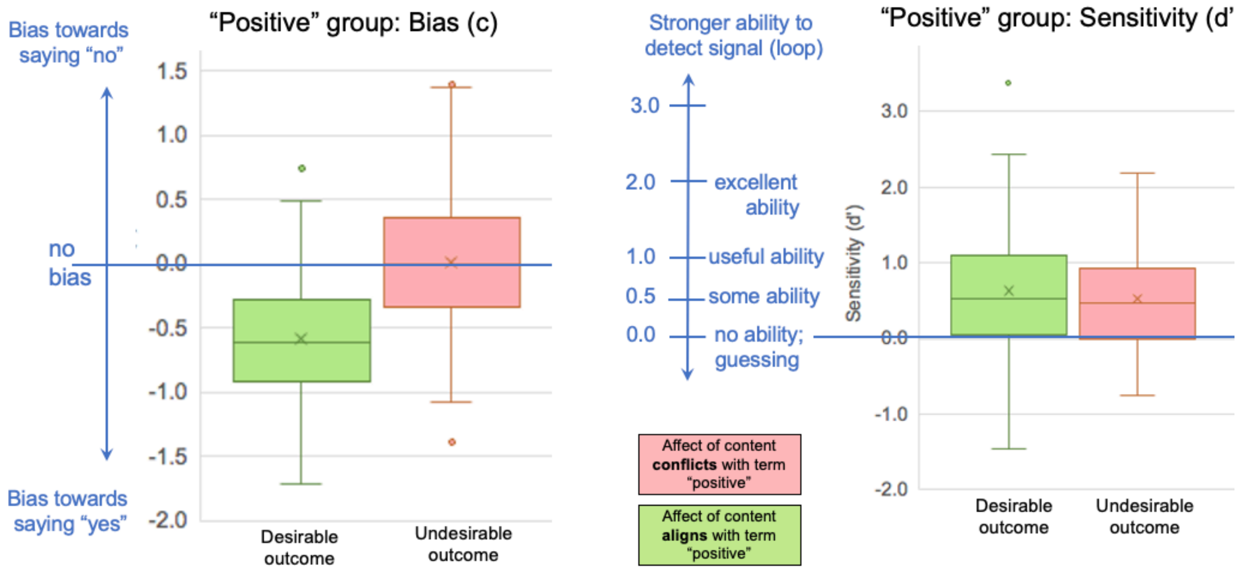

Figure 2: *Results from first use of our feedback loop detection instrument.* ***Left****: Participants showed a bias to say “yes” that a narrative was a “positive feedback loop” when the narrative had a desirable outcome.* ***Right****: Desirable versus undesirable outcome made no difference in participants’ sensitivity (d’), i.e. ability to distinguish loops from non loops. Results from participants taught and tested using the term “Reinforcing” are not shown, but are similar. Both c and d' are in standard deviation units.*

a slightly smaller bias (c = -0.54), but not significantly so. This study has thus confirmed that a suspected pedagogical stumbling block is truly a problem, but that the proposed fix—substituting “reinforcing” for “positive”—is an insufficient solution. The other outcome measure, sensitivity, did not differ significantly by narrative type nor by terminology. Across all participants and both narrative types, d’ averaged 0.62, indicating that participants discriminated signal (loop narratives) over noise (non-loop narratives) above chance, but not robustly well. Thus, our instrument has room to detect substantial improvement in students’ loop detection ability as our research program progresses.

Next steps

We have completed the development of a parallel instrument with negative/balancing feedback loops. Laboratory data collection with this new instrument is scheduled for spring 2022.

In many disciplinary courses, feedback loops are taught as an explanation for one phenomenon of importance for that course, as for example homeostasis is taught in a physiology course. We are designing a suite of six mini-lessons that can be adapted for any disciplinary course to broaden understanding from one loop to a generalizable concept. The underlying cognitive principle is *mutual alignment analogy* (Gentner & Colhoun, 2010; Jee et al, 2010), in which learners work with two or more “cases” that are analogous in deep ways, in ways that have to do with underlying mechanisms and processes rather than surficial attributes and entities. Learners are led to perceive the analogical structural mapping between the cases, and to articulate the generalized “schema” that the cases have in common. Research has shown that “extracting the schema” in this way leads to understanding which is less likely to lie inert, and is more likely to be activated in problem-solving (Gick & Holyoak, 1983; Gentner, 2010; Goldwater & Gentner, 2015). We are planning to test the mini-lessons in college level courses in Psychology, Race & Gender, Environmental Science, and Neuroscience, and to evaluate their effectiveness using our feedback loop detection instruments and student products created during instruction.

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