The Role of Imagination in Conceptual Change

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Introduction

The field of conceptual change research is broad, and the characterizations of what we consider a "conceptual change" to be in the first place, if such change actually takes place, and what the nature of the learners' understandings are before and after such a change are all worthy considerations. Additionally, interesting debates about the nature and organization of our preexisting notions are bound to confuse the graduate student and seasoned researcher alike. In fact, we can become immediately confounded in simply trying to think about what comprises a "concept" in the first place (diSessa, 2002).

In its original (for our purposes) form, the conceptual change model of learning (Posner et al., 1982) made great strides towards making researchers and teachers of science to think of the learning process not always as a simple accumulation of ideas, but as a process of restructuring the ideas in the first place. This required the learner's dissatisfaction with his previous concept before a radical replacement could occur. Surely, such a mindset allows us to consider learning in a more meaningful manner than a simple collection of ideas stacked atop one another, but it also has limits about the details of the interaction between what a student already knows, believes, and feels and what information he is encountering for the first time. Strike and Posner (1992) acknowledge and suggest epistemological reformulations to their original theory, taking the form of an interactionist conceptual ecology.

This model has found merit in many arenas, and extensions continue as researchers demonstrate how factors such as motivation (Pintrich et al., 1993), intentionality (Sinatra & Pintrich, 2002), and beliefs about learners and the scientific enterprise (Southerland et al., 2006). Additionally, researchers call for a model that is empirically accountable via the conceptual ecology (diSessa, 2002) and have defended its merits (Johnston et al., 2006) when other models are proposed. In this work, we seek to use the strengths of the conceptual ecology, but also extend its use by trying to characterize learners' ability to go beyond their entrenched intuitive understandings and use their imagination and hypothetical skills to entertain new ideas.

In our work, to "imagine" refers to more than the idle thinking of the non-real. It has been shown elsewhere that the use of "pretend" thinking of children – considering fantasies in play for its own sake – is fundamentally different from imagining hypothetical situations (Amsel, Trionfi, & Campbell, 2005).

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By imagining, we mean the entertaining of ideas about the real world but which are not necessarily congruent with the student's own ideas, beliefs, or considerations,. In our data, we ask college students in psychology and physics to "try on" ideas by considering both what they, themselves, would consider to be a correct answer in different circumstances, and also for the student to consider what their professor would consider to be the right answer. How these answers differ and how they correlate with other student performance is considered here, and we suggest that these imaginings on behalf of the student is worthy of further study and further elaboration of the conceptual ecology.

Methods

Two parallel studies of university students were conducted, one in introductory psychology courses, and the other in introductory physics courses.

In the psychology sample, a total of 227 students (39% male; 67% freshmen) were participants. They were selected from six different Introductory Psychology classes taught by full-time professors. Participants in each class were randomly assigned to one of two groups, described below. No differences were found between the groups in demographic-, course-, or discipline-related questions.

Participants completed Friedrich's (1996) PAS questionnaire (see Table 1) which included a series of demographic- (e.g., gender, year in school, marital status), course- (e.g., class enjoyment, 6th week grade, and expected final grade), and discipline-related questions (major/ minor status, likelihood to major/minor, and psychology courses taken). The questions were on the front on the questionnaire, with the PAS items were on the back.

A Likert measurement scale was placed on the top of the back page and ranged from 1 (Strongly Disagree), to 4 (Neutral), to 7 (Strongly Agree). The two different versions of the questionnaire contained the same PAS items, but differed subtly in their instructions, which told the student to consider one of two perspective, what we refer to as the "Self" and "Professor" conditions. For the former, the student was instructed to "*Evaluate each statement from your own personal perspective.*" For the latter, each student was instructed to *"Evaluate each statement from your psychology professor's perspective.*" Questionnaires were disturbed and filled out during the 6th week of the university's 15-week semester.

It's just as important for psychology students to do experiments as it is for students in chemistry and zoology.

Research conducted in controlled laboratory settings is essential for understanding everyday behavior.

Even though each person is unique, it is possible for science to find general laws explaining human behavior.

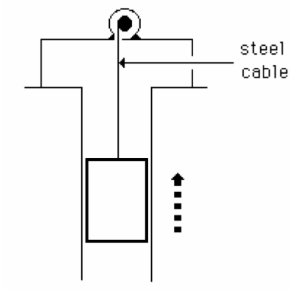
Carefully controlled research is not likely to be useful in solving psychological problems." (reverse scored)

Our ability as humans to behave in any way we choose makes our attempts to predict behavior ineffective. (reverse scored)

Table 1: PAS sample items

In parallel, 42 students in two Elementary Physics (a one-semester course with no prerequisite math course) classes were given a short, online instrument with conceptual questions. Of the five questions, three were from classical Newtonian mechanics and were duplicated from questions used on the well known Force Concept Inventory (FCI) (Halloun & Hestenes, 1985), while the remaining two questions were about the nature of light and relativity and phrased by the authors. An example of one of the questions (originally from the FCI) is shown in Table 2. As shown, the questions for each physics student were posed so that any student would consider *both* her own view as well as her prediction of the instructor's view.

The 42 students enrolled in the physics course were split evenly across two sections taught by the same instructor and during the same semester. One of these sections, however, was taught in a traditional



An elevator is being lifted up an elevator shaft at a constant speed by a steel cable as shown in the figure above. All frictional effects are negligible. In this situation, forces on the elevator are such that:

7. HOW WOULD YOUR PHYSICS PROFESSOR ANSWER THIS QUESTION?

- o the upward force by the cable is greater than the downward force of gravity.
- o the upward force by the cable is equal to the downward force of gravity.
- o the upward force by the cable is smaller than the downward force of gravity.
- o the upward force by the cable is greater than the sum of the downward force of gravity and a downward force due to the air.
- o none of the above. (The elevator goes up because the cable is being shortened, not because an upward force is exerted on the elevator by the cable).

8. HOW WOULD YOU ANSWER THE SAME QUESTION?

- o the upward force by the cable is greater than the downward force of gravity.
- o the upward force by the cable is equal to the downward force of gravity.
- o the upward force by the cable is smaller than the downward force of gravity.
- o the upward force by the cable is greater than the sum of the downward force of gravity and a downward force due to the air.
- o none of the above. (The elevator goes up because the cable is being shortened, not because an upward force is exerted on the elevator by the cable).

Table 2: Sample physics inventory questions

lecture hall (20 students), while the other section (22 students) was taught in an online format that never met in a formal classroom, and students almost exclusively interacted with the professor via email and other online communication. Both classes were assigned the same textbook, received the same curricular materials, and were given similar exams.

Results

In both sets of data, students demonstrate more sophisticated understandings when they undertake the views of their professor. Additionally, other features of their thinking correlate with the imagining of the professor perspective.

For the psychology students, the average PAS scores were subjected to an oneway ANCOVA (Self vs. Psychology Professor) independent of demographic (age, sex, student status), achievement (self-reported present and anticipated grades in the course), and course/discipline-related (major or minor status, likelihood to major or minor, other psychology courses taken, and class enjoyment) variables. A statistically significant difference ($p<0.01$) was found between the groups' average scores, with those in the Professor condition scoring higher on average (M=5.32) than those in the self condition (M=5.02). (See Figure 1.) These differences are in line with those found by Friedrich (1996) to compare student thinking before versus after a research methods course in psychology. Perhaps more importantly, those students in the Professor had PAS scores which more strongly correlated with their self-reported anticipated final grade ($r=.22$, $p<0.05$) than did the responses in the Self condition ($r=.18$, *ns*).

For the physics students, similar differences are found between the Professor and Self conditions, even though each student was asked to consider both conditions. A total of 20 students (48%), equally distributed from face-to-face (11/20) and online (9/22) classes, gave at least one different response in the Self and Professor conditions. A 2 (Class: Online vs. On-campus) by 2 (Perspective: Self vs. Professor) mixed model ANOVA on correct responses revealed a main effect of Class, $F(1,40)=14.70$, $p<.001$, with On-campus students (M = 43%) outperforming their Online peers (M = 23%). There was also a Perspective by Class interaction effect, $F(1,40)=5.42$, $p<.05$, with an increase in On-campus but a decrease in online students' performance in the Professor condition compared to the Self condition (see Figure 2).

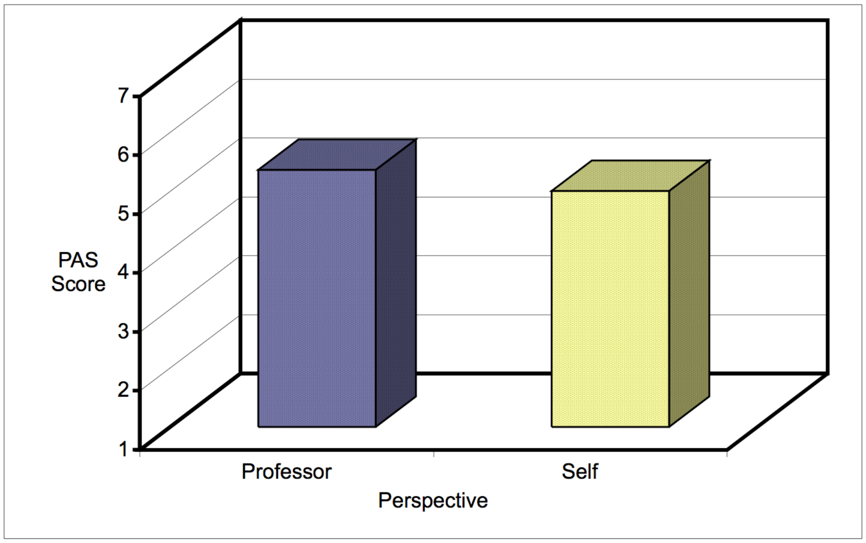


Figure 1: PAS scores for students in the Professor vs. Self conditions

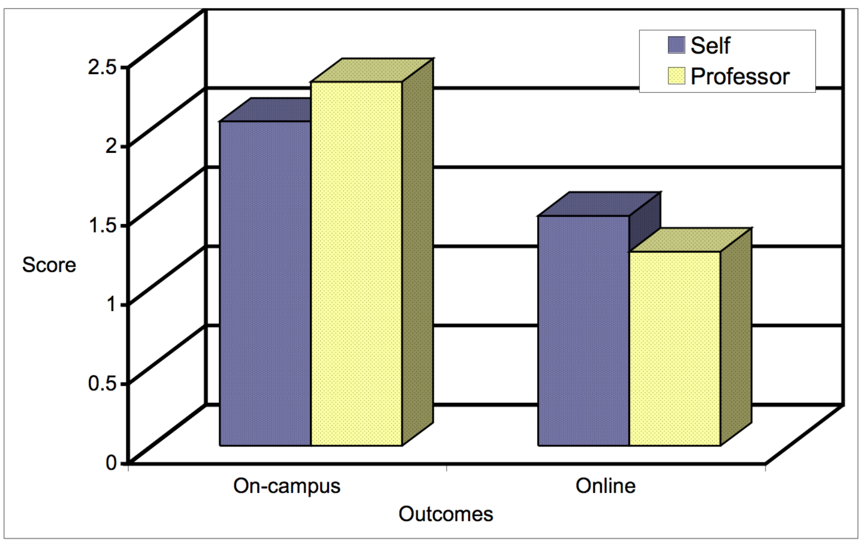


Figure 2: Physics instrument scores in the on-campus vs. online courses, with differences in the self vs. professor conditions.

Discussion

These data, taken altogether, seem to suggest the following. First, we demonstrate that when the students in these studies are asked to explicitly think from the perspective of another (their instructor), they can, as a group, make the distinction between the thinking of the self and that of the other. It is not only a clever skill to be able to consider the conceptions of another individual, but, as our data show, it correlates with better overall understandings of a discipline and the ideas within. The exception to this is in the case of the Online elementary physics student. In that case, not only are students' understandings of particular physics concepts less than their On-campus peers, but taking on the perspective of their professor does not help them.

We suggest that the learners in these cases who do better in the course or on an instrument are being helped when they can accurately imagine the perspective of an expert. They can "try on" the mind of the professor and entertain ideas that they themselves might not believe, and this ability aids in the overall thinking process. Our exception to this is notably the Online physics students, who do *not* have a professor persona to consider, since their curriculum is delivered via the online mechanism.

These data also demonstrate that learners' entrenched intuition-based misconceptions are neither fixed nor necessarily constraints on learning. Students can simultaneously consider two ideas that many science educators may consider theoretically dissimilar and irreconcilable, such as with Newtonian mechanics and as Aristotelian physics. Here, we do not see such distinct lines. Instead we see that students seem to simultaneously think about both sets of ideas – especially the better students – and recognize which is the more informed choice even when it contradicts their own. Other work positing and documenting knowledge in pieces (p-prims) (e.g., diSessa, 1993; 2002) or other less empirically rigorous descriptions of knowledge in the form of "resources" (e.g., Sabella & Redish, 2007) suggests similarly fluid student thinking; and, it has also been demonstrated how different reasoning systems can be spontaneously engaged by adopting different perspectives (Klaczynski, 2001; Amsel et al., in press).

The interactionist conceptual ecology of Strike and Posner (1992) is particularly appealing as a theoretical construct for these data. Additionally, these data are in step with calls for explication of the conceptual ecology (diSessa, 2002; Southerland et al., 2006) and its contrast with other theoretical propositions (see Johnston et al., 2006). What is needed at this point is to further clarify how the role of imagination and perspective fit into the conceptual ecology, but for now we see that this is a fruitful direction to move in.

As we continue to collect more data in studies developed since this work, we have additional questions that our future to consider. First, how explicit are students in thinking about the contrasting understandings of themselves and their professors, and what role does this play in the conceptual ecology? Second, when a student cannot "see" his professor, how does this change the ability to model this kind of thinking? Is the perspective of another requisite of the other person to be placed before a learner? Finally, how does imagination fit into the conceptual ecology? How do we make this a testable piece, rather than a vague and empirically mushy term? We realize that our data, while exciting to consider, represent a simple first step in answering detailed and important questions like these.

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