FAILING TO REWIND: STUDENTS' LEARNING FROM INSTRUCTIONAL VIDEOS

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In this study we investigate how students watch and learn from a set of calculus instructional videos focused on reasoning about quantities needed to graph the function modeling the instantaneous speed of a car. Using pre- and post-video problems, a survey about the students' sense-making and data about the students' interactions with the video, we found that many students did not appear to make significant gains in their learning and that students appeared to not recognize their own moments of confusion or lack of understanding. These results highlight potential issues related to learning from instructional videos.

Keywords: Technology, Instructional Activities and Practices, Post-Secondary Education

In recent years, "flipped" classrooms and massive open online courses have been promoted as effective ways to deliver content to students and to support active learning in the classroom (e.g., Schroeder, McGiveny-Burelle, & Xue, 2015). Although there is increased interest in using these techniques and a growing body of research literature on student learning in flipped classrooms (e.g., Maxson & Szaniszlo, 2015), there is still relatively little empirical data to support the claims of the efficacy of these instructional innovations.

With a few exceptions (e.g., Weinberg & Thomas, 2018), there have been virtually no studies that have investigated how students utilize the out-of-class resources or how students' experience with the videos supports their construction of particular mathematical meanings. Instead, the research has been based on an implicit empiricist epistemology, assuming that not only do students actually watch and learn from the out-of-class resources, but that the students uniformly construct the meaning the instructor believes the video to convey. Thus, it is important for us to investigate how students engage with and learn from instructional videos.
Our research questions are:

- How often do students pause or re-watch sections of the videos?
- What do students learn from watching instructional calculus videos? How is students' learning connected with their video-watching activity?
- What aspects of the calculus videos do the students find confusing? How is this connected to their learning?

Theoretical Framework

Sense-Making Gaps

Sense-making research (e.g., Dervin, 1983) has been used in the fields of information systems and, more recently, in mathematics education (e.g., Weinberg, Wiesner, & Fukawa-Connelly, 2014) to understand the ways individuals perceive, act within, and make decisions in situations. From this perspective, students experience gaps—moments of confusion or questions that must be answered or overcome in order to construct meaning for the video. Gaps are not a feature of the video, but rather are a product of the interaction between the video and the student's knowledge, beliefs, and purpose for watching the video.

Covariational Reasoning

To make sense of dynamic situations modeled by calculus, students construct relationships between conceived quantities that co-vary (i.e., change together), that is, they develop and apply *covariational reasoning* (e.g., Thompson & Carlson, 2017). Carlson, Jacobs, Coe, Larsen, and Hsu (2002) defined this as "the cognitive activities involved in coordinating two varying quantities while attending to the ways in which they change in relation to each other" (p. 354).

Methods

Video-watching was assigned in three of the authors' first-semester calculus classes. There were 29 volunteer student participants, with only 23 also completing the post-video survey. We describe student activity and learning from one set of three instructional videos that focused on graphing derivatives. The first video described how to use ideas about amounts of change to construct a distance-versus-time graph; the second video described how to construct and graph rates of change; the third video provided another example of constructing a graph of speed. All the videos were hosted on the Ximera online platform (https://ximera.osu.edu/), which recorded the timestamp of each student interaction with the videos—playing, pausing, and skipping backward or forward. In order to (potentially) identify places where students experienced a gap, we classified each pause and skip-back as a "revisit"—a place where the student felt that some aspect of the video was either important, unclear, or confusing.

Prior to watching the set of videos, students were presented with a graph of a cubic function $y=g(x)$ and asked to solve three problems related to approximating values of $g'(x)$. After watching the videos, the students were shown a graph of a quartic function $y=f(x)$ and asked to solve eleven problems that were similar in nature to those in the pre-video assessment. In order to further identify students' gaps, the students completed a sense-making survey in which they were asked to describe aspects of the video that were confusing or could use additional explanation. We used thematic analysis (Braun & Clarke, 2006) to generate initial descriptions and categories of the students' responses.

Results

Student Learning

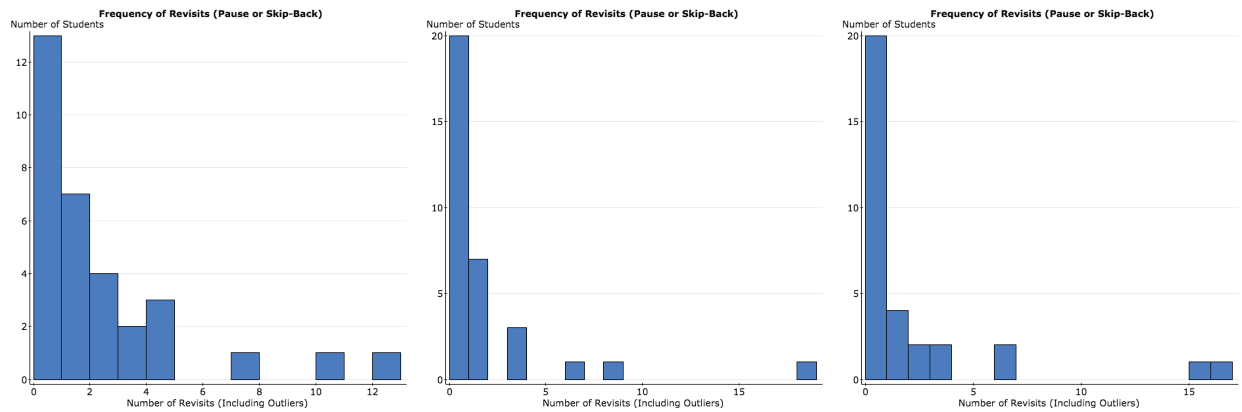
As shown in Table 4, the students correctly answered 41% of the pre-video problems and did not improve their scores significantly on their first attempt at the post-video problems ($t(28) = 0.9184$, $p=0.3662$)). Their mean score on their second attempt at the post-video problems was 82%, which was significantly higher than their pre-video scores ($t(28) = 7.7617$, $p<.0001$). The students' mean normalized gain (Bao, 2006) scores was 4.9% when comparing the pre-video problems and first attempt at the post-video problems and was 63% with the second attempt.

Revisits

The histograms in Figure 5 show the number of "revisits" (i.e., times each student paused or skipped backward) for Videos 1, 2, and 3. This shows us that, particularly in Video 2 and Video 3, most students never revisited during the video; in Video 1 roughly half of the students paused at least once. There were a handful of students for each video who revisited relatively frequently (i.e., their number of revisits was an outlier for the video).

Table 4: Student scores and normalized gains on the pre- and post-video problems

Group	Mean Pre-Video Score	Mean Post-Video Score (First Attempt)	Mean Post-Video Score (Second Attempt)	Mean Normalized Gain (Pre to First Post)	Mean Normalized Gain (Pre to Second Post)
Overall	41% (*SD*=30%)	46% (*SD*=17%)	82% (*SD*=15%)	4.9% (*SD*=37%)	63% (*SD*=34%)
Students with >50% on Pre		56% (*SD* =16%)	90% (*SD*=11%)	-22% (*SD* =32%)	47% (*SD* =49%)
Students with <50% on Pre		41% (*SD* =17%)	78% (*SD* =16%)	19% (*SD* =31%)	71% (*SD* =20%)



Video 1 Video 2 Video 3

Figure 5. Histograms of number of revisits by students per video.

Comparing Revisits and Learning

We performed a linear regression on the normalized gain scores (on pre-video problems to post-video problems) versus the number of revisits produced positive slopes; for the purpose of performing this regression, we eliminated one high-leverage data point (one student had a total of 46 revisits). When comparing the pre-video and first attempts at the post-video problems, the slope was not significantly different from zero (β =-.353, $t(26) = -0.353$, p=0.727); this was also the case for the second attempt at the post-video problems ($\beta = 0.00943$, $t(26) = 0.649$, p=0.522).

Survey Results

On the sense-making survey, 16 out of 23 students said that the video didn't need any additional clarification; these students only averaged getting 48% of the post-video problems correct on the first try, and only 85% after the second try. Of the six remaining students, three suggested clarifications that weren't directly related to graphing the derivative or the presentation of the video. The remaining three students indicated confusion about the triangle depicting amounts of change in distance and time together with a secant line; the relationship between the function increasing/decreasing and the derivative graph; and the relationship between the shape of the graph of the function and the shape of the derivative graph, respectively.

Discussion

The results for the students' performance on the pre- and post-video problems—in particular, their relatively poor performance on their initial attempts at the post-video problems—suggest that the students' learning was not particularly significant. Potential explanatory factors, such as the frequency of pausing or skipping backward (an indicator that the student experienced gaps in their understanding) were not associated with the students' normalized gain scores.

Most students never revisited the videos. In their responses to the sense-making surveys—which were written after the students had completed and received feedback on the post-video problems, the students indicated that they generally felt that the videos were clear. We found this surprising since the students tended to struggle with the post-video problems.

There are several potential explanations for these results. Perhaps the explanations in the video could be improved or there could be better alignment between the mathematical content of the video and the pre- and post-video problems. However, it also could be because the students didn't experience gaps or recognize their own lack of understanding thereby neglecting to revisit moments within the video that were critical for their own learning. Students' insistence that the videos were clear—even after they struggled with the post-video problems—could be attributed to either their inability to reflect on their own understanding and a propensity to attribute their struggle to a perceived inherent difficulty of mathematics.

Despite creating instructional materials guided by research-based recommendations, the students did not appear to construct an understanding of the underlying concepts sufficient for successfully solving to the post-video problems. This calls into question the effectiveness of instructional videos as stand-alone teaching tools. Moreover, that students did not experience gaps or recognize their lack of understanding exposes one of the most commonly-proposed benefits of a flipped class—the students' ability to re-watch videos. If students do not recognize their lack of understanding, they will not take advantage of this aspect of a flipped classroom. The scope of conclusions we can draw is limited by the relatively small sample size, the focus on a single calculus topic, and the use of a single set of videos. It is important to further investigate these conclusions by exploring how students watch, interact with, and learn from other instructional videos and other mathematical topics.

Acknowledgments

This material is based upon work supported by the National Science Foundation under Grant Nos. DUE-1712312, DUE-1711837 and DUE-1710377.

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