Investigating Student Learning and Sense-Making from Instructional Calculus Videos

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Abstract

Growing interest in "flipped" classrooms has made video lessons an increasingly prominent component of post-secondary mathematics curricula. This format, where students watch videos outside of class, can be leveraged to create a more active learning environment during class. Thus, for very challenging but essential classes in STEM, like calculus, the use of video lessons can have a positive impact on student success. However, relatively little is known about how students watch and learn from calculus instructional videos. This research generates knowledge about how students engage with, make sense of, and learn from calculus instructional videos.

We Investigate

- The ways students interact with video lectures, including how they pause, skip, and re-watch portions of the videos;
- The aspects of the videos students attend to – and report attending to – as they watch;
- The ways students make sense of and learn from videos, and how this relates the other aspects described above [e.g. 14, 15];
- How ways of structuring the video-watching experience, such as providing an outline, can influence each of these aspects [e.g. 6].

Theoretical Perspective

Sense-Making: The ways individuals perceive, act within, and make decisions in situations [e.g. 3; 4; 7; 16]. The mental structure applied during sense-making filters and structures their perception of the world and underlying mathematics [16, p. 169].

Quantitative and Covariational Reasoning: Characterization of the mental actions involving mental attributes of phenomenon that admit a measurement process [e.g. 13].

- ***Covariational reasoning*** is "the cognitive activities involved in coordinating two varying quantities while attending to the ways in which they change in relation to each other" [1, p. 354]. Mental actions include:
  - Coordinating quantities and direction of change
  - Coordinating amounts of change
  - Attending to the average and instantaneous rate of change

Research-Based Video Design

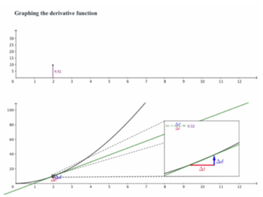
Recommendations from STEM Video Research
- Highlight essential material [9].
- Keep video length small by breaking the lesson into learner-paced video sets [9].
- Use a conversational style of speaking [9].
- Explicitly address conceptual difficulties [10].
- Encourage students to take notes [12].

Conceptually-Focused Videos
- Highlight quantitative and covariational relationships supporting the development of mental actions [e.g. 1]
- Show smooth continuous variation of quantities [2]
- Multiple representations and scaffolding [e.g. 11]
- Leverage student's experiential realities [e.g. 5]

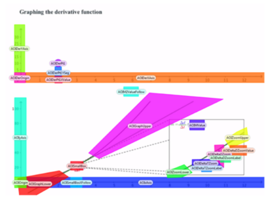
Procedurally-Focused Videos
- Leverage affordances of the video medium (e.g., highlighting & moving).

Eye-Tracking Analysis

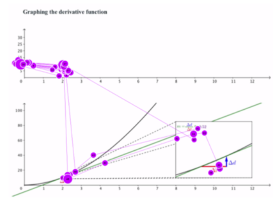
Original Video



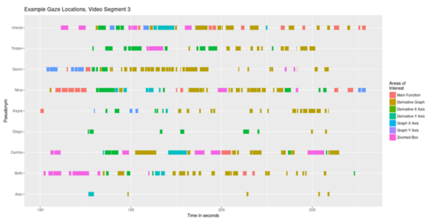
Defining Areas of Interest



Fixations



Analyzing Fixations Within Areas of Interest

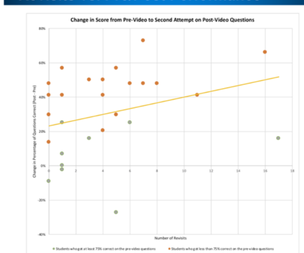


Online Data Collection

Pre/Post-Video Questions

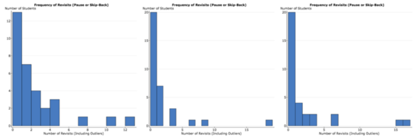
	Mean	Std. dev.	Change from Pre (p-value)
Percent Correct Pre	50.862069	27.126324	
Percent Correct Post on First Try	46	17.58449	.3211
Percent Correct Post after Second Try	81.965517	15.107904	<.0001

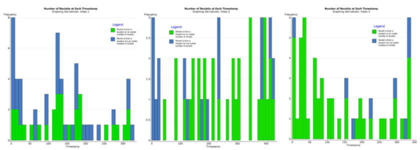
Revisits vs. Pre/Post Performance



Slope = 1.680415, p-value (2-tailed) = .1089

"Revisits": Frequency & Timestamps





Post-Video Survey Results

- Main ideas in the videos were:
  - Value of derivative is the slope of the tangent line
  - Increasing/decreasing function values correspond with positive/negative derivative values
- Nearly all students felt that the videos were clear
- Most students praised the "visualizations," "animations," and "real-world example" (a speeding-up car)

Data Collection

Participants
- First-semester university calculus students

Video Topics
- Eight sets of 1-3 videos on common calculus topics

Method
- Online Data Collection on Ximera (All Students)
  - Experimental pre-video treatments: Students see
    - Outline of main ideas
    - Post-video questions
    - Additional video demonstrating confusing aspects
  - Pre- and post-video conceptual questions
  - Watch 1-3 short videos (Ximera records all user actions)
  - Post-video descriptions of
    - Main ideas
    - Confusing & helpful aspects
- Interviews (~12 students per video set)
  - One-hour clinical semi-structured for each video set
  - Same video sets and pre- and post-video questions as online data collection, using a think-out-loud protocol.
  - ***Eye-tracking*** synchronized with video & audio recording
  - *Sense-Making Protocol: Identifying Confusion*
    - Each student identifies moments in the video that were confusing or where they had to think for a bit to understand what was happening. For each moment the student mentions, they "rewind" the video to that moment and following questions are asked:
      - What did you find unclear or confusing at this point in the video?
      - Were you able to clarify this on your own?
  - *Sense-Making Protocol: Engaging Challenges*
    - Researchers identify 4-5 moments in each video set based on key ideas or conceptually complicated aspects (e.g., requiring covariational reasoning). After playing the videos, we replay each of these moments and ask students to describe what was being shown in the clip and discuss why it might be important.

Acknowledgments

- This material is based upon work supported by the National Science Foundation under Awards DUE # 1712312, DUE # 1711837 and DUE # 1710377.
- Kara Graham and Will Glostner for their help with data collection.

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