Investigating Student Learning and Sense-Making from Instructional Calculus Videos

Aaron Weinberg
Ithaca College

Matthew Thomas
Ithaca College

Jason Martin
University of Central Arkansas

Michael Tallman
Oklahoma State University

Abstract

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

Motivation

- "Flipped" classrooms have been hailed as effective instructional formats providing innovative ways to incorporate active learning into the classroom [e.g. 17].
- This format often relies on instructional videos to move the presentation of new content to out-of-class.
- Relatively little is known about how students watch and learn from videos.
- Although numerous reports attest to the efficacy of a flipped classroom, few studies provide empirical data to support claims of their efficacy.
- Prior research [e.g. 8] has focused primarily on students' affective response to the video watching process or their retention of information presented in a video rather than on characterizing the depth of the students' understanding.

Research Goals

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 these videos, and how this relates the other aspects described above [e.g. 14, 15];
- How various 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: To understand the ways individuals perceive, act within, and make decisions in situations [e.g. 3; 4; 7].

- A *conceptual frame* is "a mental structure that filters and structures an individual's perception of the world by causing aspects of a particular situation to be perceived and interpreted in a particular way" [16, p. 169].
- *Gaps* are "questions that must be answered [by the student] in order for the student to engage in or construct meaning for the mathematical situation or activity" [16, p. 170].

Quantitative and Covariational Reasoning: Characterization of the mental actions involved in conceptualizing calculus situations.

- A *quantity* is a mental attribute, or quality, of an object or phenomenon that admits 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 Principles

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]

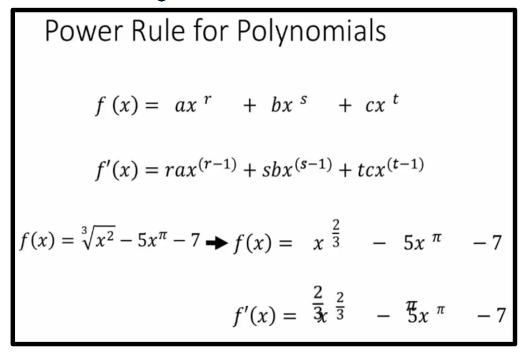
Procedurally-Focused Videos

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

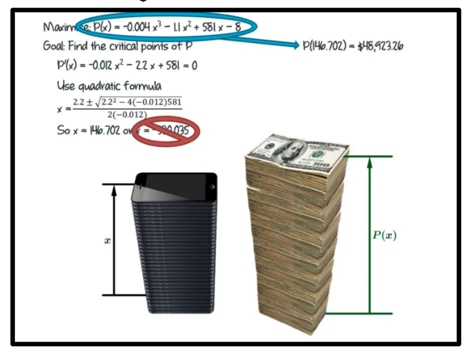
Recommendations from STEM Video Research

- 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].

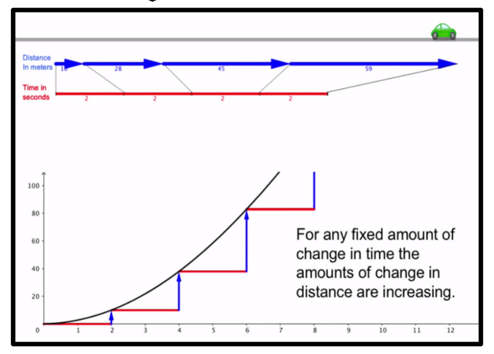
- Exponents Move Down for f'
- Address Difficulties with Roots
- Spacing Between AOIs



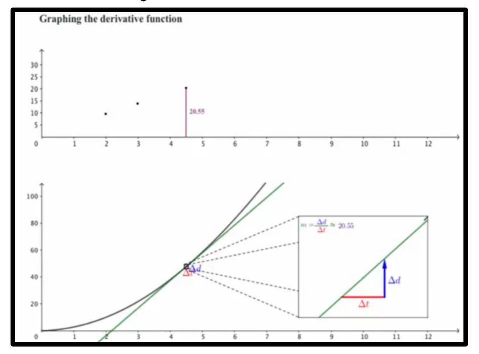
- Stacks Change Heights
- Highlighting Appears
- Inputs Move into Function



- Car Animates
- Quantities Vary with Direction
- Amounts of Change Depicted

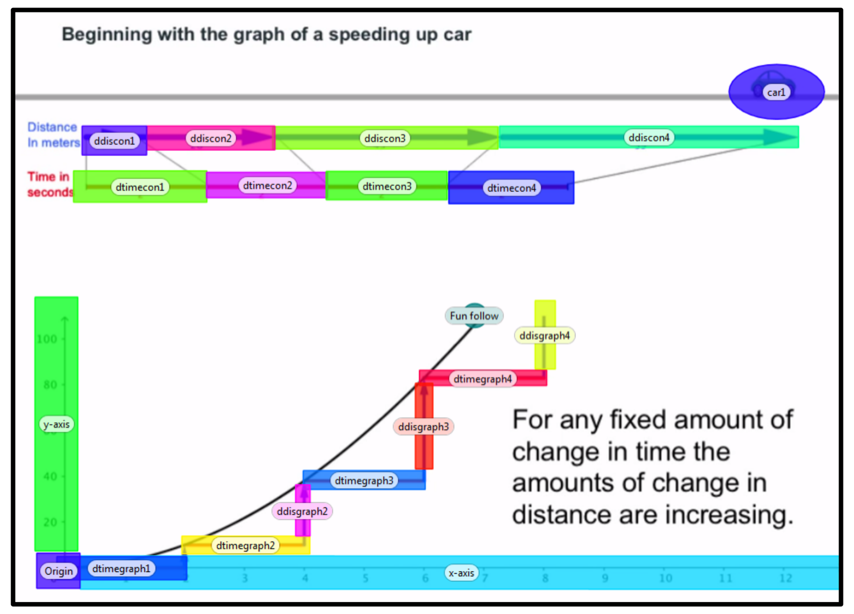


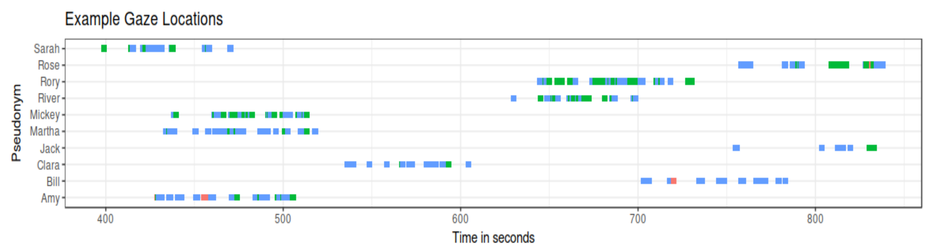
- Dynamic Zoom
- Moves From Point to Point
- Leverages Video with Car



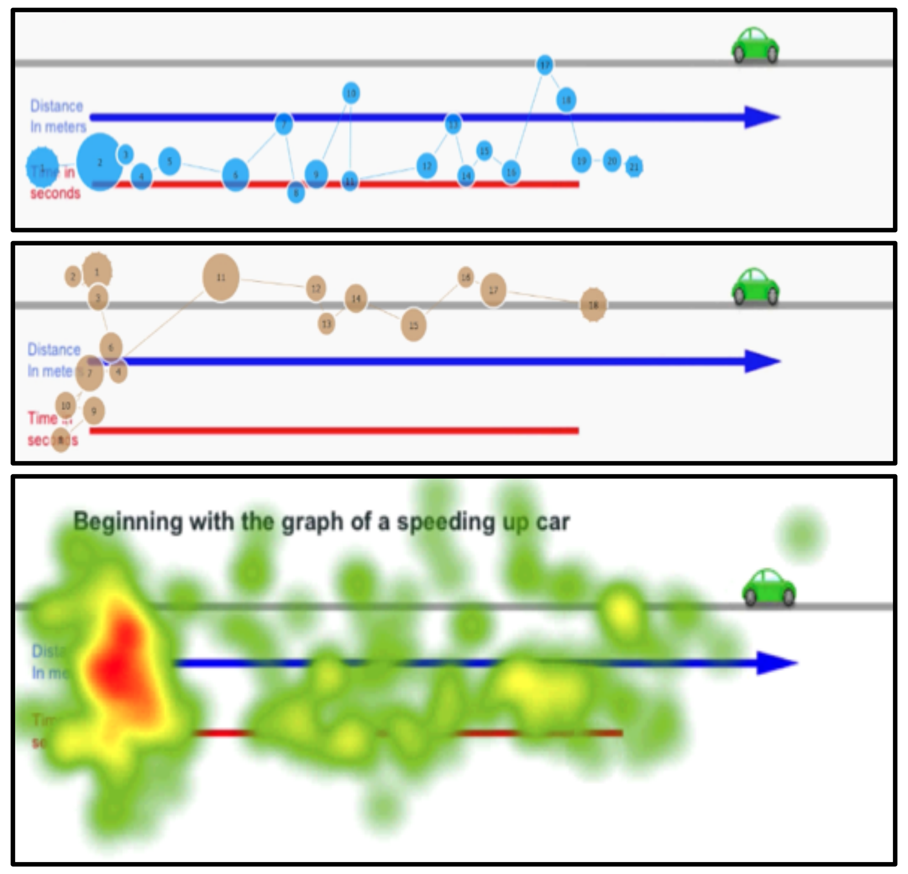
Eye-Tracking Analysis

Areas of Interest





Fixations



Online Data Collection

Subjects

- First-semester university calculus students

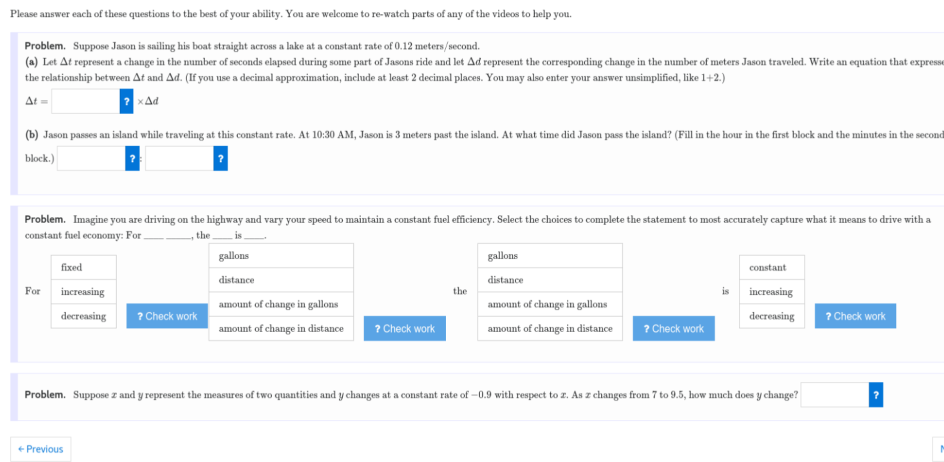
Methods

- Pre- and post-video questions outside of class.
- Three potential pre-video interventions:
  - Outline of key ideas
  - List of post-video questions
  - Extra video highlighting challenging aspects

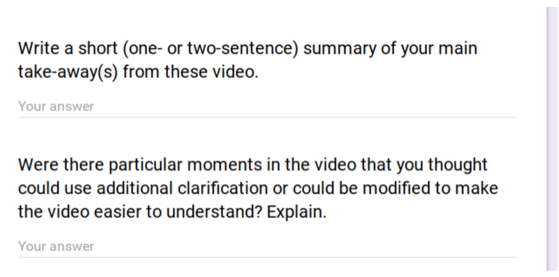
Data Collected

- Responses to post-video sense-making questions
- Responses to pre- and post-video content questions
- Video-watching data using Ximera hosted by Ohio State University:
  - Timestamps for playing video
  - Timestamps for pausing video
  - Timestamps for skipping video

Sample Post-Video Content Questions



Sample Post-Video Sense-Making Questions



Interview Data

Subjects

- First-semester university calculus students

Method

- One-hour clinical semi-structured interviews for each video set
- Same video sets and pre- and post-video questions as online data collection, using a think-out-loud protocol.
- Additional sense-making protocol

Data

- Eye-tracking data synced with audio recording.
- Responses to post-video sense-making questions
- Responses to pre- and post-video content questions

Sense-Making Protocol (Message q/ing):
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:

1. What did you find unclear or confusing at this point in the video?
2. Were you able to clarify this on your own?

Answer "Yes"
a. What did you figure out?
b. How did you figure it out? What ideas or other parts of the video did you think about?

Answer "No"
c. Were there other parts of the video that you think were harder to understand because this part wasn't clear?
d. How did you make sense of these other parts of the video?

Sense-Making Protocol (Abbreviated Timeline)
The researchers identify 4-5 moments in each video set that include 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.

Upcoming Data Collection

Year 1
- Pilot data collection with 8 topics/video sets
- Interview & online data at 3 PI universities

Year 2
- Expand to ~16 topics/video sets
- Interview & online data at 3 PI universities

Year 3
- Expand online data collection to ~15 universities

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