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Engineering Calculus: Fostering Engagement and Understanding in a Virtual Setting

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ABSTRACT

In this paper, we focus on resolving three key challenges during COVID-19 distance learning: engagement, understanding, and assessment. In particular, as a case study for an undergraduate Engineering calculus course, we develop the Desmos activities and the Think Alouds to provide effective solutions for these challenges.

Keywords: Polar curves with Desmos, Think Alouds Assessment, Engineering Calculus, Synchronous Teaching.

INTRODUCTION

The authors of this paper are multi-disciplinary faculty involved with teaching and learning of mathematics across three departments—Engineering, Mathematics, and Teacher Education—and two countries, China and the United States. In Spring 2020, COVID-19 brought us unparalleled challenges as our courses went online. In this paper, we discuss new approaches developed for a second semester calculus course for engineers focusing on three key challenges:

- **Engagement:** *In what ways can we support learner engagement in a virtual setting?*
- **Understanding:** *How do we continue to promote conceptual understanding of content?*
- **Assessment:** *How can we effectively assess students' thinking and understanding?*

METHODS

Engagement

The second author taught one section of a calculus course to thirty-six engineering students in a distance learning format. Course content was delivered using CANVAS, a learning management system. To foster student engagement, the instructor taught the class synchronously via the web conferencing tool Zoom. Students logged into the class lecture using a Zoom link within CANVAS. During the live sessions, the instructor mimicked the face-to-face instruction that students experienced prior to the pandemic, highlighting in-the-moment solutions of calculus problems with a document camera. Additionally, the instructor provided her students with opportunities for one-on-one and small group interactions, consistent with research recommendations (Buelow, Barry & Rich, 2018; Halverson & Graham, 2019). Students used live chat to discuss class work and engaged in weekly small-group projects (4 per group) in pre-assigned break-out rooms. Students were required to document and submit written work along with a recording of their break-out sessions each week.

Understanding

At the time instruction moved online, engineering students were studying polar curves. Prior to the pandemic, she used this worksheet to investigate content. During the pandemic, we worked together to create an online version using Desmos Activity Builder (Ebert, 2015). Individual questions from the worksheet were reimagined as screens in the Desmos activity (similar to slides in a Powerpoint). Students accessed Desmos through a link provided in CANVAS. Meanwhile, the instructor monitored their activity through the Desmos dashboard (see Figure 1).

The Dashboard reveals the overall progress of each student at any time during the activity. Clicking on particular cells, instructors can see students' work in-progress for any task. In addition, instructors can pause the activity, restrict student access to specific screens, and anonymize student names. Figure 2 provides a sample item taken from our original worksheet along with a revised version

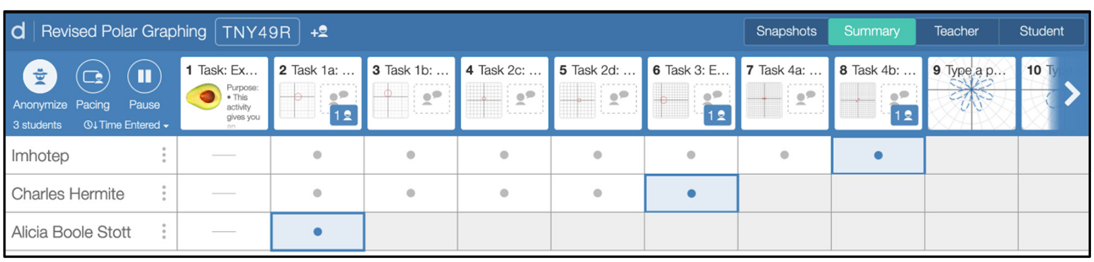

Figure 1. The Desmos Dashboard.

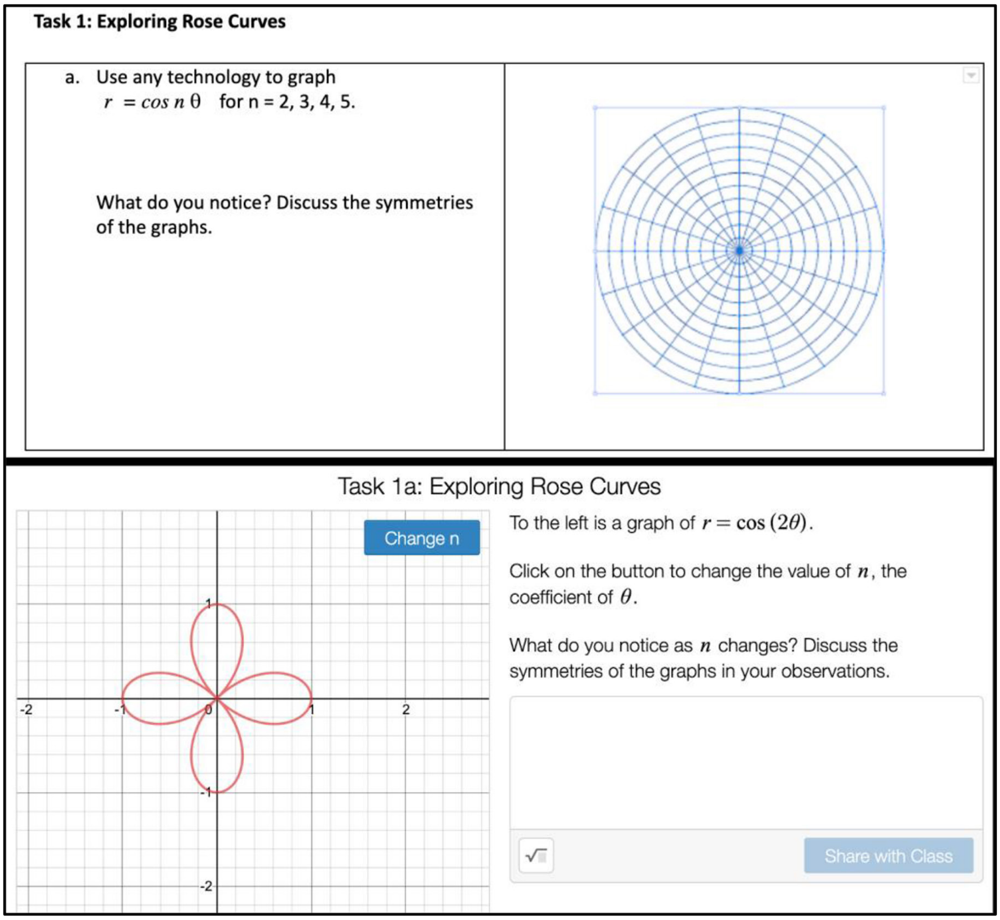

Figure 2. (Top) Rose Curve task; (Bottom) Desmos version of same task.

in Desmos. As the figure suggests, our initial objective was to reproduce the earlier worksheet as faithfully as possible in the online environment.

However, as we gained facility with the software and a better understanding of its limitations and capabilities, we added a modeling task to "create an intellectual need for new mathematical skills" (Carranza, Danielson, Fenton, & Meyer, 2016). As Figure 3 suggests, the culminating task was designed to enable students to test conjectures, make predictions, and extend their understanding of polar curves (Orey & Rosa, 2018).

Assessment

Together, the Desmos Activity and the Think Alouds (Ericsson & Simon, 1993) enabled us to assess our students' understanding both formatively and summatively. The think-aloud strategy "asks

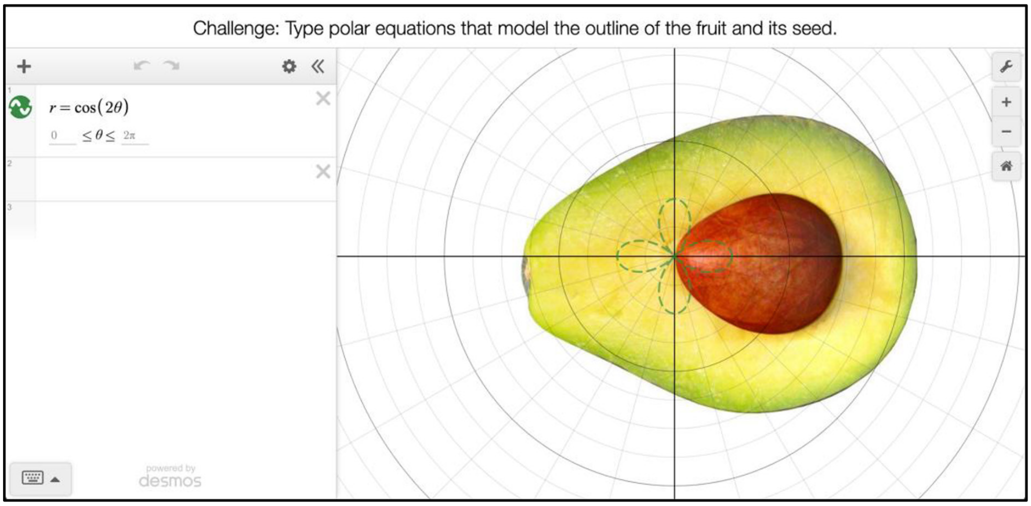

Figure 3. Polar Curves modeling task in Desmos.

students to say out loud what they are thinking about when . . . solving math problems" (Teachervision, 2007). We created a *think-aloud prompt* that required students to record audio and video using screencasting software (e.g., screencast-o-matic). Unlike the student data collected in Desmos (which were largely summative—the end-products of student thinking), think-aloud screencasts were a formative assessment—they gave us access to students' extemporary thinking and problem solving. Screenshots and links to two full-length videos are provided in Figures 4 and 5.

Student Assessment - Preliminary Findings

The Desmos activity required students to investigate the influence of different parameters on the shape and types of curves. The Think Aloud protocol enabled students to communicate their mathematical thinking and understanding through their own words without any interruptions or teacher interventions. Analyses of think-aloud videos helped us better understand how students build, organize, and extend prior understanding to create new mathematical knowledge. The Desmos Activity and Think Alouds suggest student growth in understanding of polar curves. For instance,

- In Task 1a and 1b, 2c and 2d, and 4a and 4b, students noted similarities between cosine and sine graphs, with the majority noting that "one is a rotation of the other" (i.e., $\cos(\theta)=\sin(90-\theta)$).
- For tasks 2c and 2d, students tested different values of *a* and *n* for cosine and sine, generating formulas for the number of loops. Students noted the similarity between cosine and sine graphs and that the size of the graph depended on *a*.

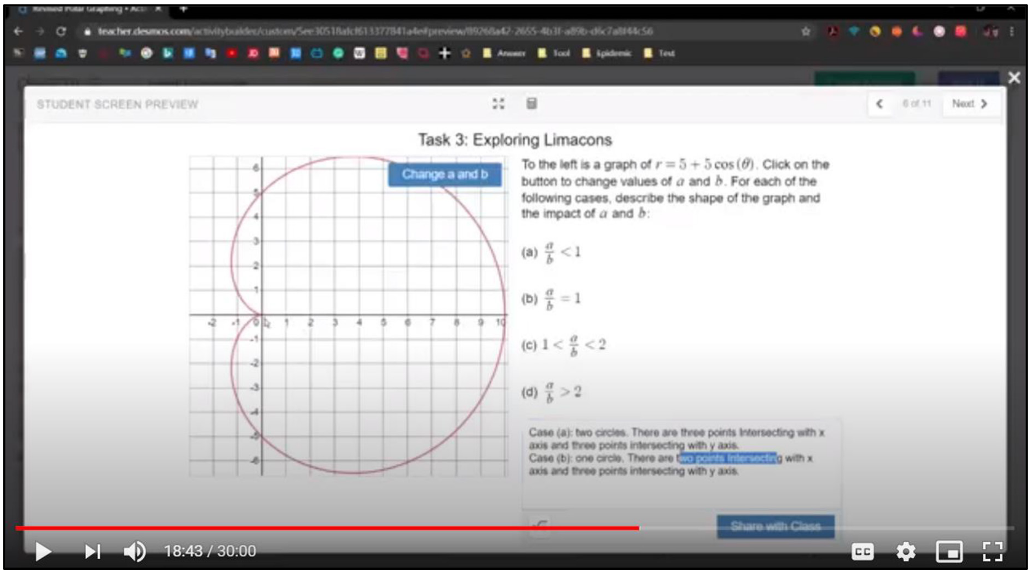

Figure 4. Think Aloud for Student A (video available at https://tinyurl.com/thinkaloud-StudentA)

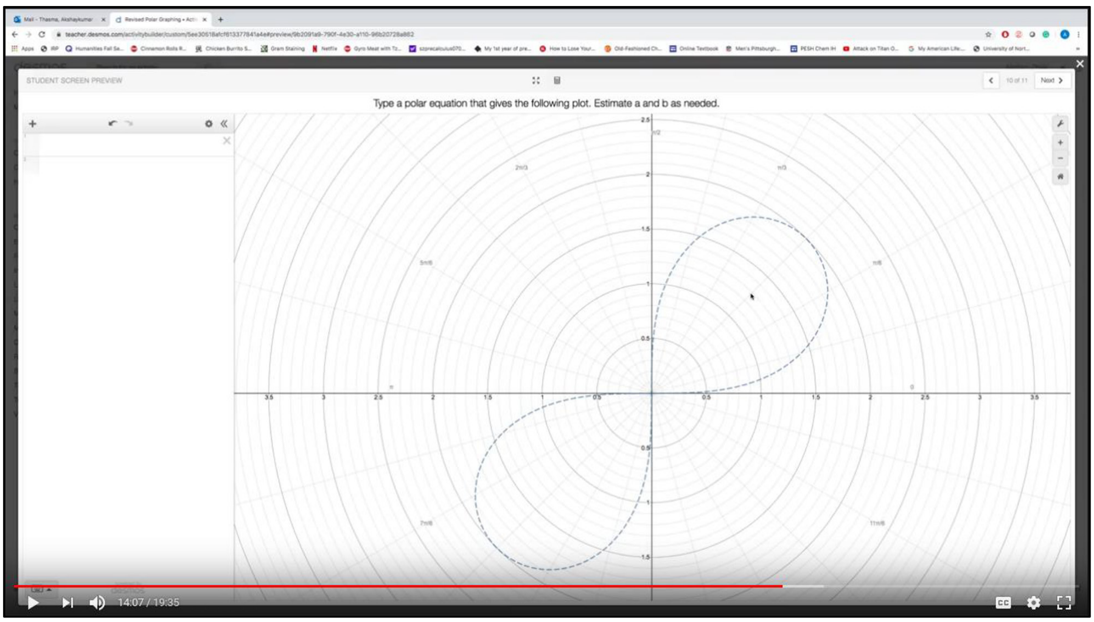

Figure 5. Think Aloud for Student B (video available at https://tinyurl.com/thinkaloud-StudentB)

Table 1. An overview of Assessment Tools and Instructor Checklist.

Activity	Assessment	Instructor Checklist
Desmos	Problem-solving rubrics: Example: https://tinyurl.com/rose-curves-rubric Assessment capability within Desmos Dashboard	• Create a free account on Desmos; • Learn how to use Desmos Activity Builder; • Create tasks on the activity builder; • Test the activity to understand and anticipate difficulties that students might face; • Develop a student instruction sheet and a problem-solving rubric and embed on CANVAS.
Think Alouds	Think Aloud Rubric: Example: https://tinyurl.com/think-aloud-rubric	• Learn how to use Screencast-O-matic and integrate it with CANVAS, if needed; • Test this tool to understand how this will work from a student's point of view; • Develop a student instruction sheet and embed on CANVAS.

- In addition, students concluded that symmetries depend on the value of *n*, not *a*. The prior knowledge gained in Tasks 1a and 1b helped them arrive at this conclusion.

In summary, the Desmos activity helped students identify essential steps needed to solve a task, recognize similar patterns, interpret meaning from tasks, and apply previous knowledge to tackle more challenging questions.

Table 1 provides an overview of assessment strategies for the activities along with an instructor checklist.

NEXT STEPS

Certainly, there are lessons learned and possible recommendations for future teaching.

- For instance, some students faced technical difficulties that prevented them from attending the live class sessions. In future, we will design our course to include a balanced mix of live and asynchronous sessions.
- The set-up and implementation of activities required several hours of instructor time and effort. We suggest teamwork to share responsibility in setting up the tasks so one does not feel overburdened.
- Some students attempted to "game" the activities by typing one or two word explanations or entering answers based on familiar textbook examples. We will rethink how we assess students' work, emphasizing process more heavily than final answers.
- In hindsight, we realize that a rubric will help communicate our expectations and provide more constructive feedback. We will provide a rubric and revise the assignment to make better use of collaboration.
- Note, too, that the think-aloud videos were long (e.g., 30 minutes or more). In large classes, grading such work poses significant challenges. We will assign the activity as a group project to address this challenge and to foster student collaboration.

- We aim to produce self-sufficient learners who are comfortable learning topics and solving problems on their own. To this end, we will integrate Desmos and Think Alouds to provide students with more opportunities to explore difficult content in a self-guided manner.

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