Teaching Geometry with a Human-Centered Design Approach

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Calls for changing the high school math curriculum in the U.S. emphasize the use of authentic problems (NCTM, 2018). Geometry instruction can provide a special opportunity for students to apply math to real-world scenarios. Our study analyzes geometry teachers' engagement in creating and implementing a high school geometry lesson using the Human-Centered Design (HCD) framework (Lawrence et al., 2021). The framework emphasizes empathy and iteration for identifying and solving authentic problems. Three U.S. high school geometry teachers are participating in a lesson study cycle following four steps as specified by (Lewis et al., 2006): (1) **studying** instructional materials, (2) **planning** a research lesson to observe student thinking, (3) **teaching** the lesson by one team member in a 9th grade geometry class, and (4) **reflecting** on evidence of student thinking during the lesson using videos from the lesson. Our research question is: *How do geometry teachers who are participating in a lesson study cycle use the HCD framework to plan and teach a problem-based lesson?* We aim at providing a description of how teachers relied on lesson study and the HCD framework to attain specific learning goals for their geometry students.

This study is related to the MACAS conference in significant ways. First, the research lesson focuses on a math problem situated in the context of graphic arts. The context is intended to foster students' creativity in applying geometric concepts related to circles. Second, the HCD framework extends the learning goals for students. Besides applying math to solve a problem, students are expected to develop their appreciation for using math in design processes centered around stakeholders' needs and constraints. Finally, the teachers' lesson study engagement is an example of their key role in embracing holistic and interdisciplinary approaches to education. Altogether, the MACAS conference provides a great opportunity for us to expand the ideas in this study and draw connections with international audiences.

Methods and Theoretical Framework

We use a design-based research methodology to design, implement, and evaluate the four lesson study sessions (Easterday et al., 2018; McKenney & Reeves, 2012). Three experienced high school geometry teachers were recruited to participate in a lesson study cycle. The teachers, all from public schools in a Midwestern state in the U.S., had never participated in lesson study before. The authors of this proposal facilitated the sessions. To demonstrate elements of HCD and to foster the teachers' creativity and interactions in the sessions, we provided them with prototypes of problem-based geometry lessons. Currently, the teachers have participated in two sessions in relation to the first two lesson study steps: studying instructional materials and planning the research lesson. In the two remaining sessions, the teachers will continue to plan the research lesson and discuss videos of student thinking during the lesson.

We will segment the videos of the sessions with teachers into intervals, which is a unit of analysis noting changes in the activity structure of the session (Herbst et al., 2011). In each

interval, we will identify (1) references to the HCD framework, (2) who makes the reference (the teachers vs. the facilitators) , and (3) the purpose or effect of the reference in relation to the lesson study step. For example, a reference to **"empathy"** by **a teacher** may have the effect of **changing the problem's introduction** so that students feel empathy towards stakeholders **during the planning step**. Overall, the HCD framework specifies empathy and iteration as two key elements of a design challenge (Brown, 2008). We use the framework to see whether and how teachers referred to these elements of the framework during the lesson study cycle.

Preliminary Results and Implications

In the first session, the teachers learned about the HCD framework and examined three prototypes of geometry problem-based lessons. Table 1 provides information about the prototype lessons. In the second session, the teachers started planning the research lesson. They opted to combine the mathematical content of circles and geometry constructions in the "Designing an Analog Watch Prototype" and the context of "Designing a New Restaurant Logo." The rationale for the selected math content was that students had prior knowledge of constructions and that they can apply properties of circles to their design. The rationale for the context about making a logo for a restaurant was the authenticity of the context, students' love for food, and the opportunity for students to be creative. In terms of HCD, the teachers decided to focus on **iteration** so that students create and refine a prototype by incorporating peer feedback. The teachers critiqued the framing of the "Designing a New Restaurant Logo" lesson, which involved a fictional character, Dakota, who worked at an advertising agency. They stated that the students in the research lesson should not be living vicariously through Dakota and instead could be positioned as experts in the problem. The subsequent discussion led the teachers to frame the problem as one where students were helping a small business owner of an existing or imaginary local restaurant. The teachers hypothesized that the students would be more invested with this new context and show empathy by relating to local needs in the community. Therefore, even though the teachers focused on iteration, they embedded empathy in the framing of the problem, an important characteristic of HCD.

The MACAS presentation will include a full description of teachers' engagement in lesson study, including their analysis of students' thinking during the implementation of the research lesson. Our work is intended to illustrate how teachers can use the HCD framework to craft problem-based lessons for their students where geometry concepts and instruction are contextualized in authentic real-world applications such as art and design. The HCD framework can eventually motivate students to learn geometry and appreciate its relevance to identifying and solving authentic problems.

Table 1

Prototypes of Geometry Problems with Human-Centered Design Objectives

Title	**Geometric Concepts**	**Human-Centered Design Goals**	**Problem**
Designing an Analog	Circles and geometry	· Awareness of HCD's problem-	Wristwatches are back! A new company is asking for

Watch	constructions	solving approach. · Reliance on connecting with people. · Understanding of users' needs as well as companies' constraints. · Use of math knowledge to make decisions on what qualifies as a feasible idea. · Prototyping a design.	proposals to do a unique production of wristwatches. They launched a competition, and the winner of the best design will earn $5 million dollars plus sale royalties. As one of the participating design teams you decided to approach the task using the human-centered design approach. You started your challenge by exploring the problems through talking to a specific population. You learned from interviews with millennials that many of them are interested in wearing analog watches (yes, the ones that are not digital).
Designing Backpack Patterns	Rigid transformations and triangle congruence	· Awareness of the role of constraints. · Consideration of users' needs as well as executives' constraints. · Use of math knowledge to create designs that meet the company's constraints.	A backpacks company is trying to include its customers in the design process by giving them the option to provide their initials when they buy a backpack so the company can use it to create various patterns that can be tailored to the inside and outside of the backpack. To do so, the company launched a design contest, and the winner will get their design featured in their first advertisement.
Designing a New Restaurant Logo	Rigid transformations and congruence	· Consideration of users' needs as well as executives' constraints. · Use of math knowledge to make decisions on what sketches	Dakota works at an advertising agency. She and her team are currently working on designing a prototype of a logo for a new restaurant. They are putting together some sketches that meet the executives' constraints and they can use to

		meet the executives' constraints. · Use of sketches to collect and integrate feedback. · Appreciate sketching when prototyping.	communicate their ideas to the executives.

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