Designing Physical Representations of STEM Concepts With College Students With Cognitive Impairments

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1. INTRODUCTION

The Georgia Tech Excel program's Collaborative Design course involves 12 college students with varying degrees of cognitive impairment. This course is meant to support authentic inclusive design and enable equitable access to design language and processes for these as well as other students with impairments which could range from dexterity issues to intellectual developmental disorders or executive functioning issues. This paper primarily focuses on the research that we conducted to design and run a pilot module within the course that focuses on exploring hands-on physical representations of online physics simulations.

2. BACKGROUND AND RELATED WORK

Design thinking has become a popular approach to introducing design and design processes. There is plenty of existing work that has been done by various institutes and organizations worldwide to teach design thinking to people with disabilities [3, 5]. Multiple web courses also illustrate how to make online content and print media more accessible using features like closed captioning, customizable text sizes and screen-readers [7]. Similar to accessible digital media content, there is also work highlighting the importance of physical prototyping in the design process and how to make it more accessible [2]. The Stanford d.school assigns immense value to effective prototyping as a skill that young designers will use throughout their career [1].

The University of Colorado, Boulder has collaborated with a few organizations that provide day-to-day services for the specific student populations – the National Federation of the Blind, Louisiana School for the Blind, the Excel Program at Georgia Tech for students with intellectual or developmental disorders and the Hillside Learning school for students with learning disabilities. Through this, the students and their teachers have been engaging with the university as co-design partners in their research and design process. This includes adapting, implementing and testing many activities such as the 5 chairs challenge for students with disabilities to prepare them to be active co-designers of learning tools and resources that will ultimately benefit them and their peers [4]. With a similar rationale, the process of assisting student teams in concepting and building the physical representation of a science simulation will give us rich data in terms of research on improving these design thinking processes. Overall, the collaborative design course with the prototyping project will serve as a foundation to diving deeper into this problem area in order to develop supporting materials that are as inclusive as possible. We wish to learn how to conduct and improve these pedagogical interventions by collecting and evaluating student feedback at every stage.

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3. CURRENT IMPLEMENTATION STATUS

At every stage of this course, students have been encouraged to identify and inspect the parts and attributes of a product. The initial class meetings were directed at examining and discussing physical products such as medicine containers, water bottles and toothpaste tubes. Later, we introduced inspection of digital products such as websites and mobile apps. We emphasize the similarities and differences between physical and digital products, and have explicitly structured conversation and activities during class to compare information representations through the visual, auditory, and tactile/haptic modalities. To encourage thinking about accessibility, we discuss the potential issues that a specific impairment might cause when a person interacts with a product's parts and attributes. Along the same lines, multiple times during the course, students have been presented with online simulations followed by a live demonstration of the same concept to compare and analyse both representations and discuss its possible limitations.

3.1 Structure of the project and approach

Many of the PhET Interactive Simulations (sims) include added elements other than visuals such as sound and sonification, keyboard navigation, screen-reader accessible descriptions and mobile-device accessibility [6]. While the PhET developers are constantly updating these sims to add more accessibility features, we decided to work with those sims which possess high feasibility for physical representation and presently have more than one accessibility feature so that students could be taught how to critique these elements as well. Students were asked to individually investigate a pool of ten shortlisted sims and answer questions such as - What buttons/sliders/items could you press/move on the sim? What physics concept did you understand from this sim? Based on their responses and a further in-class demonstration of the sims, every group picked one sim and were then assigned a 'shepherd' (a volunteer graduate student with an expertise in physical prototyping) who would guide their group in this project by conducting weekly meetings outside of class time. The shepherds were provided with a thoroughly detailed syllabus describing the timeline and suggested activities for each phase of the project.

- Week 1 - Understanding the chosen physics concept
- Week 2 - Brainstorming, ideation and sketching
- Week 3 - Concretizing the chosen idea
- Week 4 - Tinkering with materials
- Week 5 - Building the model
- Week 6 - Completion and final presentation

Every week, in a brief stand-up meeting during class, one of the students from each group would talk about their progress on the project so far. This was meant to improve their public speaking skills and their ability to communicate their ideas, thoughts and concerns. Midway through the project, at the end of the third week, we conducted a midpoint check-in to ensure every team was progressing in the correct direction. Students were also asked to fill a peer-review form to rate how their fellow team members had been contributing to the project.

3.2 Identification of needs and expectations of individuals with cognitive impairments

Throughout the duration of the collaborative design course, we have been observing the students during class activities with the goal of identifying successful pedagogical techniques to support their individual learning patterns. We have found that our students work more effectively when instructions are broken down into shorter, concise statements with text and graphic combinations. It has been helpful to provide a variety of examples and demonstrations before the start of an activity and when conveying complex ideas. As with many learners in a college classroom, we have found that our students have limited attention and focus unless there are frequent individual and group engagement opportunities. Some of the students lack motivation to work on this outside class project since they are already swamped with other homework assignments. We also realized after we started the pilot module that many of the students had limited experience with sketching and most of them were unfamiliar with the process of divergent thinking and brainstorming. As a result, we implemented warm-up exercises at the start of project meetings to practice these skills. Constantly trying to keep all these factors in mind, the syllabus for the module is a living document that gets updated as needed to address scaffolding techniques for learning, modify instructions, and arrange the project schedule to meet the outcomes of this project.

3.3 Tracking learning and progress

At a surface level it may seem like the goal of this venture is to teach these students physics concepts through interactive digital and physical simulations. And while we will definitely measure knowledge gain, we are more interested in changing how these students feel about design. We want them to understand and learn how to talk about elements such as parts and attributes of a product. At the beginning of the semester, students were asked to fill in a pre-design survey to measure their level of 'design confidence.' Similar surveys will be taken at different stages of the semester to progressively analyse changes or improvements in their responses. We also ask students to fill activity evaluation forms following every activity conducted in class. Artifacts specific to the physical prototyping project will mainly be a collection of pictures of the students engaging in activities during different stages of the project, the sketches and the prototypes that they produce during the ideation phase and videos of the final demonstration of the prototype that they will create. The students will also be asked to give a video interview to share their thoughts about the course so far, whether they have found it to be useful and if so, in what ways.

4. EXPECTED CONTRIBUTIONS

The collaborative design course, along with the physical prototyping module is a pilot study which will be refined over time to gather documentation and insights which will be useful to special education teachers as a standalone activity or even as a full blown course curriculum. This is an on-going course which is expected to end in May 2020. In its present implementation, this course can be described as an authentic approach to co-designing. A prospective future outcome is to transform this into a participatory design course by making these students fluent in the language of design in order to make them equitable to provide meaningful feedback to the PhET team to develop even more accessible sims. Through this course, we hope to equip the students with skills to tackle bigger issues around inclusion and design especially when it comes to print media which lack sufficient accessibility considerations. The underlying vision is to empower these students by instilling inclusive design advocacy skills in them.

5. REFERENCES

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