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Reflecting on Adapting Visual-Oriented Classes for Blind and Low-Vision Students

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Reflecting on Adapting Visual Oriented Classes for Blind and Low Vision Students

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Introduction

Engineering and design courses are often visually oriented with examples demonstrated in textbooks, on slides, and on white/black boards. Additionally, mathematical formulae are conveyed visually in instructional material, in ways that are difficult to describe in words i.e., using the hierarchical placement of numbers and variables in an integral or fraction. Such material creates an access barrier for students who are Blind and/or Low Vision (BLV), and students who use screen readers due to disabilities. While screen readers and tactile braille displays provide access to written content by converting text to audio or braille, there remains a gap for converting engineering and design pedagogical content into accessible forms.

Tactile graphics translate visual images into physical, three-dimensional models that a BLV person can feel, similar to braille [1]. For pedagogical content, these are usually slightly raised graphics on a paper medium for practicality and portability ([2], [3]). Translating visual content into a tactile graphic requires reducing the content into just the most important features, and often requires sighted subject matter expertise ([4]–[6]). Other work has explored using larger, higher fidelity three-dimensional models ([7], [8]). Additionally, few tools exist for BLV people to create their own visual content, and most tactile graphic systems require a sighted person's assistance ([9]–[11]). These methods also have varying efficacy depending on the age at which the student lost vision and their own mental models and exposure to graphics.

Students in the United States are entitled to reasonable accommodations under the Americans with Disabilities Act and section 504 of the Rehabilitation Act. Many students with disabilities are unable to access their education due to inaccessible courses and campuses [12]. While most universities have a dedicated office to ensure disability accommodations, students and instructors report that formal disability offices do not provide adequate support [13]–[16]. Improving inclusive instructional design is important for educational and disability justice.

This research project was sparked by necessity when a BLV student enrolled in a design engineering course which has historically been taught as a visual design class, and the instructors were surprised by the lack of resources available for such situations and the need to make ad hoc adaptations. We thus describe the adaptations we made to this course and another Ergonomics course in a similar situation to provide a starting point for instructors who find themselves in similar situations. We document our approaches and methods from instructor, student, and assistant perspectives and make recommendations.

We are a mixed ability team of students and instructors who have been working together over the last year to adapt highly visual engineering and design pedagogical content to be accessible for BLV students. The instructors are not BLV, but some of us identify as disabled and/or neurodivergent. In addition, it is important to note that there are a variety of preferences for language to describe disability [17]. In this paper, we will use person-first and identity-first language interchangeably, to reflect this variety and the different preferences of the authors.

Courses

This paper covers adaptations made to two courses. The first is an Introduction to User Centered Design course (hereafter referred to as MUCD), which is taken by every incoming Master's student in our department in their first quarter. It uses a studio model with shared lectures, readings, and assignments across four 30-40 person studios. The course has traditionally been taught as a visual design class with weekly sketches, graphical depictions of design ideas, and a final project with visual artifacts, rendering it highly inaccessible to BLV students.

The second course is an elective Ergonomics and Biomechanics elective course (hereafter referred to as BMEB) offered jointly to undergraduate and graduate students. It uses a traditional textbook and uses physiology, anatomy, and mathematical diagrams which are highly visual, alongside pedagogical observational/visual methodologies to assess ergonomic risk. The major course deliverables are problem sets, a literature review research paper, and an ergonomic evaluation project, which are similarly inaccessible to BLV students as above.

Approach

We used an autoethnographic, research-through-design process [18] similar to Turns [19] and Mack et al., [14] to surface and analyze the pedagogical designs used to adapt courses for students who are BLV. The authors co-constructed a series of question probes to elicit experiences from the two classes, and the first author conducted follow up conversations with each of the other authors. The authors also collected artifacts from the two courses.

This authorial team is comprised of a professor who was the instructor (hereafter referred to as IN) of both MUCD and BMEB, a BLV student (hereafter referred to as ST) who took both of these courses, a student assistant (hereafter referred to as SA) assigned to ST by the university's Disability Resources office, a graduate student co-Instructor (hereafter referred to as GI) who worked with IN in the BMEB course, and an observer who was not a participant in the courses but documented the experiences for this paper. For anonymity purposes, we do not associate these positions with authorial order in this paper.

Adaptations Implemented

Though the pedagogy of the MUCD course was based on visual design and as such could not be entirely overhauled, IN and ST worked together to design adaptations of specific course components. IN was made aware of a possible BLV student in their course a few weeks prior to the start of class, when the university's Disability Resources office asked them for copies of a course textbook. However, since MUCD did not use a textbook, that was the extent of support that the Disability Resources office offered. IN therefore had to design ad hoc adaptations to accommodate ST, with no resources, external support, or precedence for this situation.

Beyond adding manually alt-text to the entire set of slides for the course, IN also needed to design adaptations around the weekly sketching activities, a core component of the class where students were asked to keep a sketchbook to document potential solutions to design flaws they encountered in their worlds and bring in weekly sketches to share in class. For the first few weeks, the adaptation was such that SA would describe other students' sketches to ST and ST would verbally give examples of flawed designed systems that they encounter on a daily basis with potential redesigns. Sighted students were also encouraged to add a QR code that linked to a digital image description, in keeping with practices on making visual material such as posters accessible [20]. Students also converted their own paper-and-pencil sketches into 3-D versions using crafting supplies (see Figure 1), such that ST could interact with them.

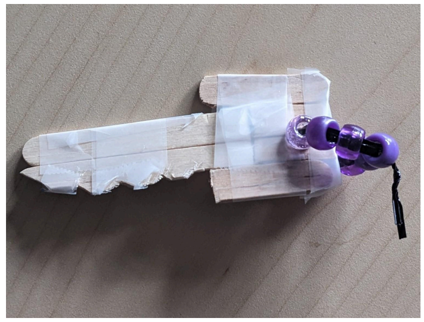

Figure 1: An example of a sketch of a key converted into 3-D form, building the key out of ice-cream sticks and clear tape, with a keyring made out of thread and purple beads

In subsequent weeks, IN arranged for a tactile printer, which would take sketches on paper and convert them into 3-D versions (see Figure 2), such that ST could interact with them. ST also started "sketching" in the way that they were given access to crafting supplies such as Play-Doh, ice cream sticks, cardboard and other materials, which they could use to put together a redesign of an existing flawed system. IN purchased stencils[1] of commonly-used digital devices such as iPhones and laptops, so that ST could learn and practice design skills such as utilization of screen space and layouts with SA's assistance.

Figure 2: Example of how tactile printer creates 3-D versions of sketches. It takes as input a card (green card on the left, showing image of a pair of scissors) and outputs a 3-D version (white card on the right, showing a pair of scissors with raised edge on scissor handles and blade, as well as the word `scissors' in braille)

To make the group projects and peer critiques more accessible, IN changed some core components of the class and placed ST on a team with students who wanted to work on an accessible project. The entire class was challenged to pick projects that were not app or screen based and to add tactile and audio components. Instead of the typical visual storyboard assignments, students were assigned to make audio stories. Finally, the final deliverables required a screen reader accessible powerpoint slide and a captioned video.

[1] https://www.uistencils.com/

BMEB was a significantly different course than MUCD which required different adaptations. Having worked with ST in MUCD before, IN could prepare for adaptations slightly better in BMEB, and rely on GI for support. One significant adaptation that was made was for IN and GI to acquire models of human skeletons of different sizes, such that instead of showing on a screen how design choices influenced ergonomic risk by straining portions of human anatomy, IN could obtain a more tactile experience. In some instances, where a more detailed version of the human skeleton was required beyond what is commercially available, IN and GI took ST to the university's medical school library, where such skeletons were available.

Another important adaptation that was required was to make the diagrams within the course textbook accessible to ST, given the importance of understanding the ergonomics. The university's access technology center printed out all the diagrams within the textbook using a paper tactile printer, generating a set of accessible diagrams (see Figure 3) that they then bound into a booklet for ST. However, the diagrams in the textbook were too complicated for this sort of translation sufficing, and IN had to pick the few most important images to translate into simpler diagrams for further explanation (see Figure 4).

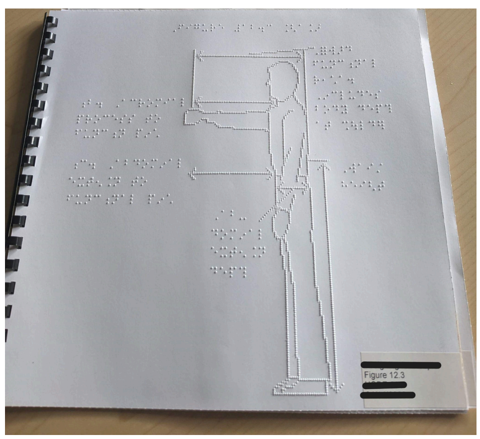

Figure 3: Example of a 3-D print of a diagram within the course textbook, showing a human standing upright with left arm raised at shoulder height, and braille text describing image annotations such as bidirectional arrows spanning distance between eyes and outstretched fingertip, and text describing measurements. The image is too complicated for this tactile representation.

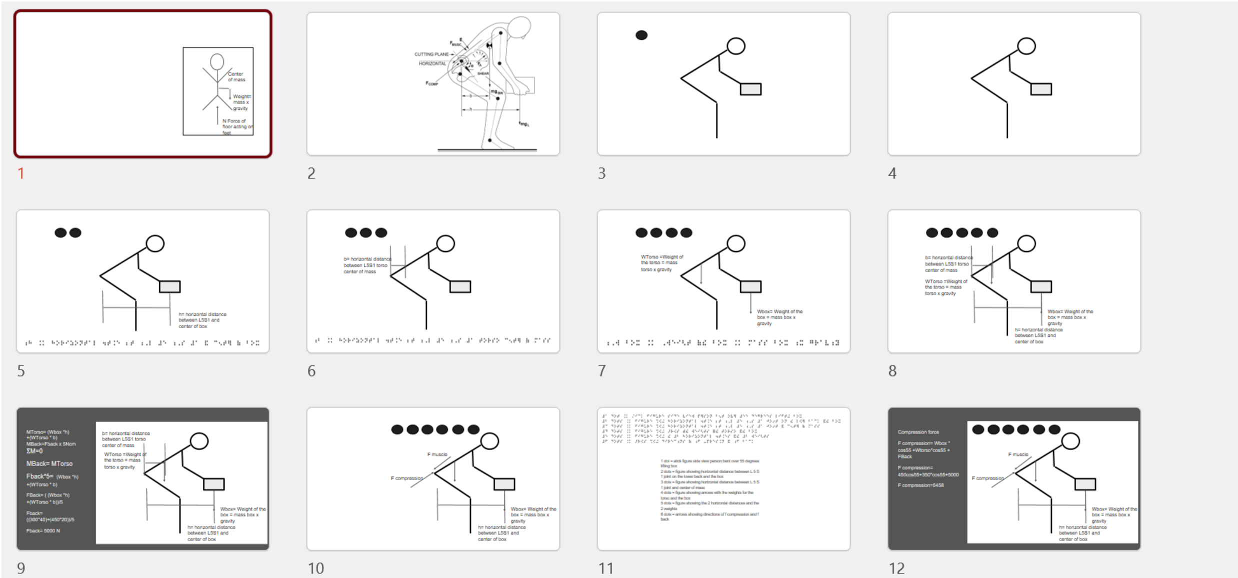

Figure 4: Example of Instructor deconstruction of textbook biomechanics models into simpler diagrams that could be printed on tactile printer with braille. Image adapted from [textbook name redacted for review].

Furthermore, BMEB involved a significant amount of math, which was inaccessible to ST given how the equations in the textbook were not available in braille and could not be easily adapted. The instructional team could not identify effective means to make this accessible, and ST had to rely on SA for support in narrating them and translating the data to a spreadsheet. In terms of doing math for homework or assignments, ST found that Google Sheets was accessible. Once ST learned and understood the equations and their usage, performing the work in Google Sheets made it much easier to simply use different numbers into equation templates and complete assignments.

These are some of the major adaptations implemented across the two courses, over and above other ones such as laying out the classroom such that it was navigable for ST, and allocating them extra time to arrive in class and working on in-class assignments. A full list is provided in Table 1.

Adaptation	*Uses*	*Comments*
Tactile graphic	Diagrams, graphs, simple sketches, schematics	Tactile graphics need to be designed by accessibility and tactile graphics expert and require specialized equipment and time
3-D model	Anatomy, prototypes	The high-fidelity medical models were the most useful for BMEB
Modeling clay	Prototypes, demonstrating ideas in 3D	Translating ideas to clay models has a learning curve for students

Adaptation	*Uses*	*Comments*
Stencils	Drawing elements, providing tactile representations of 2D elements	Stencils were relatively cheap to purchase but required sighted assistance Stencils with braille could be laser cut
Arts and crafts materials such as pipe cleaners, wire, popsicle sticks, glue	Tactile representations of 2D elements, prototyping	These are cheap and easily available, but there is a learning curve for BLV people who have not used them before
Sighted assistance	Explaining visual elements, navigating spaces, describing experiences	Sighted assistance is helpful in absences of true accessibility, but describing or constructing visual design elements ("be my eyes, be my hands") for a BLV student is time consuming and not very effective
Adapting course to be less visual	Learning objectives that can be met in non-visual ways	This is probably the most difficult to implement and could create friction with sighted students
Screen reader accessible course materials	Textbooks, readings, learning management systems, powerpoints	Important for text and simple visuals, but complex visuals do not translate to screen reader
Using spreadsheets for math	Formula based math such as statistics	We found Google Sheets to be screen reader accessible and collaborative for all students
Braille measuring devices	Anthropometry	We were able to purchase some adaptive measuring devices off the shelf that facilitated some independent data collection

Table 1: List of Accommodations used across BMEB and MUCD

Reflections

One of the primary successes of the aforementioned adaptations was that they made what would otherwise have been two incredibly inaccessible courses for ST, accessible. ST talked about enjoying the overall course experience in MUCD, learning design skills and principles they had expected to get out of the course, and delivering a final project that they were happy with. They had similar opinions about their course experience in BMEB.

ST also mentioned appreciating the willingness of IN and GI in co-designing their adaptations, especially in cases where instructor ideas did not work as expected. The cooperation between instructors and students to co-design access was also appreciated by GI, who mentioned how ST took time out of their own schedule, outside of class time in BMEB, to accompany them to the medical school library and work with a detailed skeleton of the human body.

While the course was successfully made somewhat accessible for ST, one aspect they found frustrating was how they were forced to spend a lot longer on activities as a result of working with accommodations, as opposed to their non-disabled peers. This was most salient in the usage of the tactile printer in MUCD. While sighted groups of students could simply exchange sketches, look at each other's work and build an understanding of the sketches quickly, ST had to wait for the sketch to be rendered in an accessible 3D format by the tactile printer, which took about 5-10 minutes per sketch. This caused them to be significantly behind other students, who completed the in-class sketching exercises and moved on to other activities.

IN and GI also expressed frustration at the fact that they were required to make all the adaptations on their own, with limited institutional support or resources, beginning with perceiving the need to make such accommodations in the first place. They mentioned how most of the ideas for adaptations they had came either from them reading up relevant literature, or asking within their networks of researchers. Indeed, were it not for the fact that IN's research expertise is in accessibility in engineering, they might not have been able to design such ideas.

Discussion and Implications for Practice

We presented two case studies of adapting engineering and design classes in real time for Blind and Low Vision students. While many humanities and social science courses can be easily adapted through the use of image descriptions and screenreaders, STEM classes contain pedagogical content that cannot be translated through audio alone. Though all of us had some background in accessibility and Universal Design for Learning (UDL) [21], adapting these courses required a significant amount of new knowledge acquisition and a lot of trial and error. ST was familiar with braille, but none of us had ever worked with tactile graphics previously. IN was lucky to know a network of subject matter experts, including some tactile graphics experts located on our campus. We recognize that most instructors in our situation might not have these same privileges, so we share our experiences and recommendations.

We recognize that educational accessibility and justice requires a partnership among instructors, students, and disability support staff. These relationships often break down due to lack of resources and other constraints [14]. We were lucky that in our case the students and instructors were collectively committed to finding a solution, and that our department was willing to provide support to make up for institutional lack. However, we would be remiss if we did not discuss the exceptional amount of extra time and labor spent by disabled students and instructors trying to include them, emblematic of how figuring out accommodations is often left upon individuals with little to no resources [22].

Implications for Practice

We propose a few recommendations for approaching adaptations in engineering and design courses, and particular tools and practices we found to be most effective.

We are strong proponents of Universal Design of Instruction [23], which will account for most students' access needs [22]. A universal approach assigns readings that are screenreader accessible, provides alternative text for images, chooses accessible software for learning, and allows for multiple ways of participating and demonstrating learning outcomes.

When UDL or UDI does not meet a student's access needs, it is helpful to follow user-centered, participatory co-design process [24]. It is important to ask the following questions: What are the learning objectives of the course? Do they make sense for the student's bodymind and goals? [25] What educational experiences has the student had previously and what mental models do they have? What tools and resources are available, and do any of these provide access conflicts for the instructor?

We found that tactile representations were the most effective method for translating visual pedagogical content. We recommend obtaining a Swell Paper fuser[2] for making quick tactile graphics in real time and working with campus or community assistive technology experts for converting textbook diagrams. For more common science images, there are free tactile graphic libraries[3] that conform to BANA or Braille Authority of North America Tactile Graphics Guidelines and Standards[4]. The BANA guidelines provide guidance for deciding whether a tactile graphic is appropriate and design principles for good tactile graphics. For those who are not able to access these resources, it is possible to use rapid prototyping tools to make tactile graphics ([5], [26]). We also recommend using high-fidelity 3D models for anatomy. For digital User Interface Design, UI stencils were effective for communicating visual design elements.

Conclusion

Inclusive and accessible education is an important justice issue, but many instructors do not know how to adapt their highly visual courses for students who are Blind or Low Vision. We have described our experiences adapting a User-centered design course and a Biomechanics and Ergonomics course for BLV students. We also provided recommendations for instructors who face similar challenges in adapting their own courses.

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