YOU BETTA WERK: Using Wearable Technology Performance Driven Inclusive Transdisciplinary Collaboration to Facilitate Authentic Learning

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ABSTRACT

Working or WERKing on a wearable technology project in a transdisciplinary group can be an effective way of learning new skills and collaboration techniques. This paper describes a case study of running a wearable technology group project within an undergraduate course entitled Wearable Technology and Society. The computational media students in the class collaborated with outside performance artists (drag queens and a street dancer) to create interactive performance garments. Design methods such as the use of boundary objects aided in communication of ideas and cooperation across disciplines and cultural barriers. The requirement that the interactive garment function appropriately in a real performance lent urgency and gravity to the experience, motivating cohesive and expedited problem solving in the transdisciplinary group. The use of these methods on a project with real world outcomes and consequences facilitated an authentic learning experience for the students involved.

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CCS CONCEPTS

• **Human-centered computing** → *HCI design and evaluation methods.*

KEYWORDS

Wearable Technology; Project-Based Learning; Authentic Learning; Performance; Transdisciplinary Collaboration; Boundary Objects

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1 INTRODUCTION

Wearable technology, and especially wearable technology associated with the arts, is an area of study and design that requires the convergence of many different skill sets and expertise.

Often the people that have these disparate skill sets come from different disciplines and cultural persuasions (a computer scientist and a fashion designer). When these people come together because of a united goal or interest (wearable technology for performance) the transdisciplinary teams that evolve often produce rich and authentic learning environments. In this paper we describe a case study of transdisciplinary teams producing wearable technology performance garments. This process prompted skill transfer between disciplines, as well as growth and broadened insights in cultural understanding. The transdisciplinary teams were created within a college course, with the project serving as a mechanism for achieving learning outcomes related to wearable technology and society. The simple Arduino empowered wearable interactions they created may not be that novel technology-wise; however, what is of interest is how the barriers and opportunities afforded by the use and creation of technology reinforced course concepts.

Figure 1: Drag Queen collaborator in student created interactive headpiece "La Mandragora".

1.1 A Note on Gender Pronouns

Throughout the course of this paper there will be quotes from students discussing their process with drag queen collaborators. The collaborators self-identified their performance personas under the term "drag queen." While in costume they tended to refer to themselves in female pronouns and while out of costume they typically used male pronouns. Students describe the drag queens using male and female pronouns at different times, depending on the meaning or thought behind the reference. The drag queens seemed amicable and lenient on the interchangeable use of pronouns with the exception of if a person was talking to them directly while they were in drag (where they preferred the use of female pronouns).

1.2 Performer Engagement

The performers were approached by the instructor and asked if they would like to be involved with the course as mentor/collaborators on a wearable technology performance project. Performers were not affiliated with the university. The instructor explained general time commitment and scope of the project. The performers were given the final output of the project (including electronics and garments) to use in performances as they saw fit. Consent was acquired by all participants to use the outcome of the course and projects for research purposes.

2 BACKGROUND AND RELATED WORK

Authentic learning is a term used in many different ways. Here we embrace a meaning of the term that focuses on learning by working with materials and on activities aligned with (and in collaboration with) the outside world [47]. By working with the users (performers) on their class projects, in what closely resembles a participatory design process [16], the students get a taste of what working on a transdisciplinary project team will be like in the 'real world'.

This case study might also be recognized as problem-based learning as it meets many of the goals of problem-based learning [27]. This project work might also be described as a participatory cooperative prototyping case study, especially in moments were students and drag queen collaborators are making together as a means of design iteration and communication [5]. DiSalvo describes a number of ways that learning theory enable participatory design [16]. Methods of education such as reflection ("engaging metacognitive processes") and exposing pre-existing knowledge and misconceptions here become opportunities to educate not just enable participatory design.

In any case this type of authentic project experience is needed to prepare students for careers in technology which require more and more transdisciplinary working relationships. Martin et al explain on page 61, "Practitioners in these fields gain their interdisciplinary team experience by trial-and-error and sheer luck, if at all. The deeply disciplinary nature of universities does not prepare students for working on the types of design teams that are required for successful wearable computing systems." [35].

We use the term transdisciplinary throughout this paper to describe those from different and distant disciplines working together. Interdisciplinary may also be used by others (in this paper in quotations) to describe a similar working group, but might also denote individuals from different but closely related disciplines working together.

There are also strong motivations for choosing drag queens and performance artists as collaborators. Benford et al state that "Artists' uses of emerging technologies are often highly innovative and unusual, stretching the technology in unforeseen ways, highlighting new design values and approaches that are sometimes contrary to received wisdom in HCI (e.g., ambiguity or discomfort as we discuss later), and opening up new areas of application" [3]. Drag queens are notorious for innovative use of props and "gags" in performances, and this innovative culture can act as an exciting motivating factor in problem-based group work.

Zeagler et al describe a performance motivated transdisciplinary group project process similar to the work described in this paper (albeit without the education focus) [57]. Many of the findings from that paper have relevance here, including the use of boundary objects in the creative design process. Both case studies "document the use of drawing and

artifacts framed as disciplinary boundary objects [48] allowing for discussion and shared understanding, leading to a productive team process." Sun et al showcase another example of an exploration into prototype creation through an interdisciplinary workshop [51] They work with textile artists to realize beautiful aesthetic prototypes while also validating their fabrication process outlined in the paper. Jones et al also discuss the unique nature of co-designing wearable and e-textile prototypes [30]. Their solution was also to create a platform or prototyping toolkit for creating together called 'Wearable Bits'. There are other examples of using e-textiles and toolkits for the democratization of technology and for educational purposes [7–9, 31, 37, 39, 44]. The students in the wearable technology and society course read and discuss these topics with the hopes that they use some of these techniques in working with their artistic collaborators.

> "This is an analytic concept of those scientific objects which inhabit several intersecting social worlds and satisfy the informational requirements of each of them. Boundary objects are objects which are both plastic enough to adapt to local needs and the constraints of the several parties employing them, yet robust enough to maintain a common identity across sites" -Star and Griesemer page 393 [48]

Also of interest is the motivation and urgency provided to the project work through the emotional weight of the design prototypes importance to a live performance. Related work within the wearable technology and electronic textile community was covered at length within the course content. The students were exposed not only to established techniques for making wearable tech (and even specific performance projects) but also to theory on the use of transdisciplinary group work to create wearable technology.

3 WEARABLE TECHNOLOGY AND SOCIETY COURSE DESCRIPTION

The Wearable Technology and Design Course was created to give computational media students an opportunity to learn about wearable technology and create a wearable technology prototype. It is a three credit hour lecture course assessed mainly through group project outcomes.

The course goals read as follows: Upon Successful completion of this course, students will be able to:

- Articulate and interpret the complex cultural and transdisciplinary forces surrounding wearable technology
- Recognize and describe trends in wearable technology development and use
- Design and prototype a wearable technology artifact that integrates concepts and techniques discussed in this course

In the course, students complete the course readings and content, while working in parallel on a group project with a performance artist collaborator external to the university.

3.1 Readings and Course Content

Outside the project work, students in the course completed a number of readings which were supported by in-class discussion. We are including all reading content and topics for the course here so that the course could be replicated with ease.

At the beginning of the course readings from Fashion Foundations Early Writings on Fashion and Dress were complemented with excerpts from The Presentation of Self in Everyday Life [23, 29]. Discussions during this portion of the course focused on why we wear clothes, what it means to choose our own attire, and how we use clothing to fit within a society. As the students were to work with performance artists, we examined the use of costume and dress as a form of function and expression in the arts. This aided in their initial meetings with their collaborators. We also began to discuss the parallels to how we now use technology in the same ways.

Moving on from fashion foundations the class read from The Trend Forecaster's Handbook supplemented by reading The Strength of Weak Ties [25, 45]. Students lead discussions about the process of trend forecasting and how it related to fashion and technology. Students also created a trend cartogram of wearable technology as they saw it in the marketplace. As we were having these discussions in class the students also began contemplating how the use of interactive technology could aid performance, enhancing the experience for both the performer and the audience.

The next portion of the course dealt directly with parts of wearable technology on a more practical level. It was important to give the students some practical knowledge of making and crafting as they began to flesh out their project ideas. This took the form of short skill workshops inside and outside of class, and readings also supported this effort:

- Where to wear wearable technology [54]
- Designing for wearablity [21]
- Social acceptability considerations [17, 18, 43]
- Accessibility [56]
- Challenges of wearable computing [49, 50, 61]
- Electronic textile techniques [34, 36, 40–42, 58, 60]
- Practical textiles and sewing and making [19]
- Sensors for wearable technology [24, 33]

The final section of the course focused on using wearable technology as a means for transdisciplinary collaborations and methods for transdisciplinary collaboration. It is during this portion of the course where the students were most actively engaged with their project work. It was important that at this stage the students receive guidance on how to best work in transdisciplinary teams and also to reflect on the process they were currently undertaking. It was also important for the students to think about the ramifications of design and its place within society. Readings were on topics such as:

- E-Textiles and making as Democratization of Technology [7–9, 39, 44]
- Wearable Technology as Transdisciplinary Research [22, 35, 55]
- Case Studies, Frameworks, and Performance [13, 57, 59]
- Privacy and Security [12, 26, 32, 38, 52]
- Policy and Law [1, 2]
- The Future [10, 14, 20, 53]

3.2 Group Project

Students were allowed to form their own groups. There were 11 students in the course which formed two groups of four and one group of three. Two of the groups worked with Drag Queen collaborators to development interactive garments for lip-syncing performances. The third group worked with a hip hop street dancer to create a motion capture garment. As the students were able to choose their own groups and pick their collaborator (among the three organized by the instructor), both the performers and the students felt comfortable collaborating together. The performers were external to the university and were approached by the instructor and asked if they would like to be involved with the course.

The project requirements were intentionally open ended, simply requiring the students to create interactive wearable technology. While the user of LEDs and visualizations were to be expected in performance garments, the students were required to ensure that those elements had a functional purpose and some form of real-time interface (input and output).

4 METHODS

Methods the students were asked to undertake in their project work will be covered in the Project Process and Outcomes section. Here we describe methods for teaching, observing, and eliciting feedback from the students and collaborators.

4.1 Teaching

In lecture sessions, the instructor led reading related discussions via question prompts. At points in the course individual students chose to read and present readings, developing their own discussion questions. Certain crafting or sewing skills were taught briefly in skill workshops, however the instructor and collaborators were on hand to help as issues or questions arose. For other skills such as Arduino coding and hardware development students were pointed to campus wide resources and online message boards.

4.2 Experience Reporting and Feedback

Student and collaborator feedback was first collected through an open-ended email questionnaire. Some students submitted additional feedback through discussions and follow-up questions. Student and collaborator direct quotations found throughout this paper were selected from the responses to these questionnaires.

Responses to the questionnaires were compared for consistent themes.

Questions delivered by email after completion of project were open ended and included:

- Could you describe the process of your project and your collaboration with an artist on creating a wearable technology performance garment in your own words?
- How often did you meet or talk to your artistic collaborator?
- How did you meet? In person or via technology?
- How did you communicate your ideas? Talking, illustrations, video, collage, mood boards etc? What seemed the most effective way? How did your artist collaborator communicate with you in return?
- How do you feel about the outcome of your project? What could have made your collaboration better?
- What did you learn from the course lecture that aided in your project development?
- Do you see where any method of communication or other device acted as a boundary object facilitating better understanding between your group members or with your artistic collaborator?
- Were there difficulties in collaborating with your group members or with your performance artist? How did you or your team overcome these?
- In general what was a rewarding part of the experience for you? Why?
- Is there anything about the project or process you would like to point out or focus on?
- Did you have to overcome any cultural barriers? Have you worked with drag queens before? Is there any cultural terminology (rather than just technical terminology) that you had to learn to communicate effectively with your collaborator? Do you think the process of working through the project bridged any barriers in cultural understanding?

4.3 Observation

Much of what is discussed about the student work comes from instructor observation. The instructor for the course has taught transdisciplinary project groups for the last eight years. Their experienced observations highlight the successes and the unique aspects of this particular case-study. The instructor not only evaluated and critiqued the deliverables as the students turned them in, but attended group work sessions with the project collaborators in order to observe and document how the groups were working together. Observations by the instructor were written down immediately following class/group meetings and work was photographed by the instructor consent of the students and collaborators

5 PROJECT PROCESS AND OUTCOMES

Three projects resulted from the course "La Mandragora" (Figure 1), "Drag Duality" (Figure 2), and "Multimodal Interactive Visual Effect (MIVE) Controller".

Project materials were given to the groups and the final project garments were given to the performance artist collaborators. All groups were supplied with SparkFun RedBoards programed with Arduino for prototyping and smaller SparkFun Thing boards, sensors and other hardware as requested.

As students worked with collaborators they were also learning about collaboration methods such as using "Boundary Objects" [4, 11, 46, 48, 57] and how they might be used in a transdisciplinary design process. Students were encouraged to make and draw as a method for effective communication, and were also given some tools such as an electronic textile swatch book [22] to spark discussions and ideation.

The term collaborator was used throughout the course, and as the external partners worked with the students, they were asked to think of the project as a true peer collaboration. It was important to establish this dynamic, so that the students would not view the

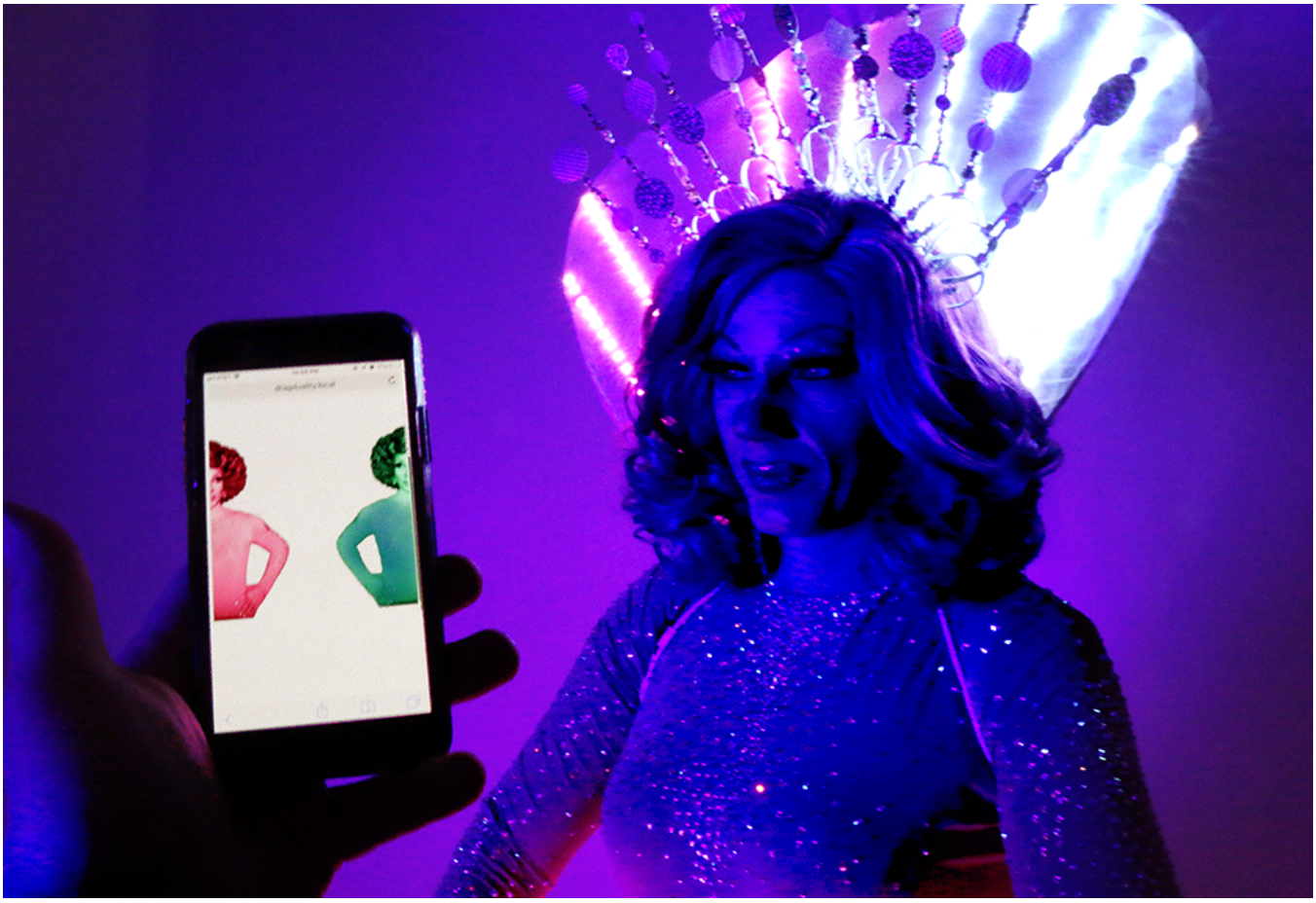

Figure 2: Drag Queen collaborator wearing the "Drag Duality" performance garment created by student group, controlled through a crowd voting web application.

collaborators as mentors or "clients." Unlike a more traditional participatory design process we did not want a facilitator and participant role. The students were also encouraged to leverage the diverse expertise, and perspectives of each team member (including the collaborators), as the goal of this course was not just to develop (and then assess) their technical skills, but also to provide valuable training in transdisciplinary collaboration.

5.1 La Mandragora Design

La Mandragora is a light sensitive headpiece adorned with flowers and tendrils. As the spot light hits the drag queen wearing the headpiece the flowers bloom, and as the queen moves into the dark LED enhanced tendrils unfurl (Figure 3). Light sensors located within the headpiece trigger servo motors that operate the flowers and tendrils.

5.1.1 La Mandragora Team Composition. The La Mandragora team consisted of one male student and two female students. The students were third and fourth year undergraduates majoring in computational media. They worked in collaboration with a drag queen performer. This group's mentor was perhaps a little more distant when learning about the technology, but helped extensively in the construction of the final head piece aesthetic.

Figure 3: La Mandragora in the dark with tendril unfurled.

The students noted that:

> "Throughout the process of creating our prototype, we've learned a great deal about hardware and circuitry as none of us had any prior experience with either. This includes learning how to set up a microcontroller with Arduino, how to wire a motor to a microcontroller, how to solder, how to power a motor with a battery, how to set up LED lights, and the basics of how to code in Arduino."
>
> "It was interesting to brainstorm with the artist that will be wearing our headpiece. We began with a generic prompt, a wearable technology for drag queens, but we soon realized that each queen has their own unique style of performance. For a queen that likes to move around a lot (a dancing queen, for lack of a better term), our idea would not have worked at all. However, our collaborator tends to stand still or move slowly on stage, and so our device is quite well-fitting for her."

5.2 Drag Duality Design

Drag Duality is a dress and headpiece put on a light show, but the audience gets to decide which song and performance (and thus which light display) they see. The audience uses a web application to vote and the dress reacts accordingly (Figure 2). The dress color, patterning and song switch back and forth in real time as the audience votes change immediately before the performance is chosen by the audience.

5.2.1 Drag Duality Team Composition. The Drag Duality team consisted of four female undergraduate students in their third and fourth year of a computational media program. One of the students was an exchange student from Denmark. The students worked with a incredibly hands on drag queen who was not only interested in the aesthetic outcome of the garment, but also its function and use of technology.

> "As the audience votes between two options of performance LED lights embedded into the skirt and headdress displays both colors in competition giving a preview of the winning duality. At the end of the voting period, the lights indicate which side of the duality has the most votes. The voting works on a local network or via a website, and the SparkFun ESP32 Thing can then count the votes and display the winning color." Quote from student description of project in report assessment.

Students in this group worked and communicated with their drag queen collaborator quite frequently. Much of the design work was created, communicated, and validated through drawing. At times they drew while co-located as a method of supporting the design process in real-time, and at other times they used asynchronous methods such as email to exchange sketches with each other.

The students note:

> "Throughout this semester, our group has learned about how to work the LED lights, soldering, how much power the lights will need (a lot!), connecting the microcontroller to Wifi, and hosting the user interface on a website. We are using the SparkFun ESP32 Thing, which is a wifi-compatible microcontroller. We decided to go with this device over the Arduino because it allows us to use the controller as a server to easily receive data from our hosted voting system. For our prototype, we were able to implement the interaction of the LED lights and an interface through Wifi. About halfway through the semester, we could get the lights to turn white or rainbow colors. Some issues we ran into were some defects in the LED lights not changing to the correct color."
>
> "Some issues we ran into were the actual fabric choice and final design. The design is also greatly influenced by the performance environment. After attending a show, we realized some constraints and observations that would influence our design. The space was small and similar to a bar setting. It was dimly lit, which meant we had to stay away from dark colors in the garment that would be less visible. In the audience during the show, there was minimal movement, but there were some distractions like people whispering. There was a DJ in the back of the

Figure 4: Student drawing given to drag queen collaborator explaining design concept. Showing a basic design of the garment including the dress, the collar, the bustle, and the headdress.

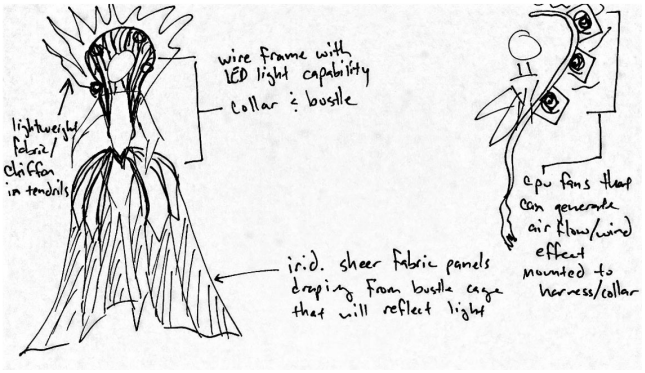

Figure 5: Annotated drawing from drag queen in response to the student ideation sketch with material ideas and possible construction methods.

space, but the environment was pretty noisy overall, so we knew from the beginning that our device could not be something that played sound unless we worked with the DJ."

Figure 6: Completed Drag Duality garment.

5.3 Multimodal Interactive Visual Effects (MIVE) Controller Design

Unlike the other groups MIVE worked with a street dance performer. Instead of focusing on live audience performances the group was more interested in creating a real time graphical experience that expressed the creativity of the performer's popping dance style in a unique manner while preserving the dancer's authenticity.

This resulted in a hoodie outfitted with accelerometers. The motion data was capture and interpreted via a SparkFun ESP32 Thing and MPU 6050. This group spent a great deal of time trying to solve issues surrounding accumulating, transferring, and processing the large amounts of data produced by the accelerometers and gyroscopes. One challenge was in reducing the latency between sensor readings and visual rendering in order to produce an acceptable real-time effect.

5.3.1 MIVE Team Composition. The MIVE team consisted of one female and three male undergraduate students. Two of the male students were exchange students from Sweden focusing their study on interactive design. The other students were computational media majors. MIVE worked with a street / hip-hop dancer who was interested in how the use of technology could augment his performance for social media content.

Figure 7: Dancer collaborator wearing the MIVE hood dancing as graphical abstract representations of his movements are projected.

6 RESPONSE TO QUESTIONAIRE AND INTERVIEWS

After the completion of the course the students were sent a questionnaire about their collaboration process. Almost all groups met 3 or 4 times over the course of the semester with their performance artist collaborators, using text and email to share ideas in between meetings. One group also used skype video messaging. Students pointed out that they found drag queens have different schedules from college students and perhaps one of the most difficult parts of collaborating was negotiation a time to meet.

"Our teammates' difficulties were typically scheduling-related since we were all taking different course loads and had busy schedules. We overcame

> these challenges by splitting up the work when necessary and meeting to confirm we were all on the same page and had plans for how to proceed."

A common theme across the groups was the use of drawing as a means to aid in communication. When asked to reflect on their potential use of boundary objects, students recalled that drawing was a major method for coming together over an idea and creating a shared meaning.

> "We found that drawings and diagrams were the most effective ways to communicate our ideas. Coming from different backgrounds, it was sometimes hard to communicate with our collaborator and get our ideas across. We exchanged drawings to ensure we were on the same page about our ideas."

> "Drawings were the most useful tool for us to communicate with our collaborator when it came to our project. We were able to visualize the same thing, which was really helpful to ensure we were talking about the same thing. At one point we did not know what a bustle or cage was, but our collaborator and instructor explained through words and drawings."

One of the drag queens described having the student view a performance as a way to get on the same page about what types of wearable technology might be interesting. "Image sharing was used for inspiration/concept work and some performances were observed to familiarize the group with options." The performance artists desire for the student collaborators to understand their art and way they performed was expressed across the projects. The dancer expressed:

> "I showed the team videos of examples I had seen in my dance experience, and showed them some techniques in person. The team recorded our discussions for reference. I also sent them a brief PowerPoint I had made for another project with information on street dance. I felt in-person was the best method for displaying the physical attributes of the popping technique, but showed some examples of other styles for other ideas."

The MIVE group would work together changing the code to create different visualizations on the fly. Working with their collaborator in this way, sometimes physically together in a meeting and sometimes sending him different versions for response over Instagram DM.

> "I felt that coding/programming visualizations for both group members and the artist showed what we wanted to brainstorm about and be creative about. It is an easy way to view and change how we see and think about the outcome for our project."

Lastly, the questionnaire prompted them to discuss how they overcame the potential cultural differences in the group.

- Did you have to overcome any lack in cultural barriers?
- Is there any cultural terminology (rather than just technical terminology) that you had to learn to communicate effectively with your collaborator?
- Do you think the process of working through the project broke down any barriers in cultural understanding?

The following responses are consistent with the way most students responded to the cultural differences:

> "I think working with an interdisciplinary team from Georgia Tech and a drag queen forced us to break down some barriers to work together and find common language to help us communicate, including words related to fabric, materials, technology, and the construction of our garment"

> "I had a basic understanding of what drag queens do but working directly with one definitely allowed a lot more insight around things I didn't particularly understand. I don't believe there were any barriers we had to necessarily overcome, but our group needed to learn more about the essence of drag queens, what role they play, and how we could help make our collaborator's performance better. I think the coolest thing about the millennial generation, is that we are more accepting and understanding of cultural differences. An important attribute to have when working across different cultures and backgrounds, is general respect for the other party and willingness to learn about one's culture and differences"

> "Something that I never knew about drag queens was that their personas are completely different when in costume. Our collaborator and his drag queen persona have two very different personalities. As an outsider, I did not know all of the work that goes into drag queen performances. Not only do you transform into a beauty queen, you take on a whole different persona. After working with our collaborator to brainstorm a performance piece for his drag queen persona, it was all about understanding that they are essentially two different people."

> "When you're required to work with someone closely, you must get to know them if you want the project to be successful. Stripped down from all cultural differences, our group and collaborator are people who enjoy similar things and can talk about music, movies, fashion etc. Working with people from different backgrounds is important and really allows you to know someone for more than just their cultural difference, but it also allows you to understand them and their culture a bit more, which is valuable to all parties involved."

7 OBSERVATIONS AND DISCUSSION

7.1 Wearable Technology as a Platform for HCI Education

Wearable technology is a subject area that affords a rich opportunity for education. As seen in the Wearable Technology and Society course description wearable technology as a field contains a number of intersecting disciplines. Computer science, technology hardware

design, industrial design, fashion design, garment construction, trend forecasting, and even physiology can all play a part in the design of wearable technology. No one person can be an expert at all of these disciplines. And people attracted to these diverse disciplines may have and diverse natural skill sets, points-of-view, cultures, and work practice.

This means that students working on such projects with outside collaborators are required to become proficient in communicating with those for whom they have little "common ground." Within a technical institution, asking students to work on teams with artists or performers often means that the students are assumed and expected to be the experts in technology (hardware and software) development. However, in many cases the students are still technical novices themselves, and are required to quickly gain skills so that they can step into the role of technology expert.

Students also gain some knowledge from the other subject matter experts in the group. This basic knowledge of disparate disciplines aids in future group work by helping students to be more empathetic and have a broader general knowledge.

> "I learned plenty of fabrics and types of garments, this helped greatly when choosing material for the project. Also, there was a great introduction to different types of sensors and other technology that was very helpful." - student from Drag Duality team.

7.2 Boundary Objects Used in the Creative Design Process

In related work, Zeagler describes using drawing and artifacts as boundary objects to facilitate effective transdisciplinary collaboration in a time constrained project [57]. Here we look at the same types of boundary objects; however, we observe how using them within a creative design process might also facilitate an authentic learning experience.

Describing a method or process as a boundary object prescriptively at the outset of a project can help set up a more cooperative working relationship. Establishing a boundary object also proactively acknowledges boundaries and differences in disciplines and the need for creating shared meaning. Students used drawing, mood boarding (via Instagram), and text to convey their ideas. Drag queens in turn created drawings with the students and annotated ideas (Figures 4 and 5). Sometimes these drawings were depicting similar ideas but acted as transdisciplinary artifacts, validating and confirming thought processes. We observed the teams speaking to each other over the drawing as they were being made. The quickness and movement of a pen stroke conveyed meaning as well, as if the act of drawing was also explaining the direction and intensity of lighting patterns.

Students were taught about boundary objects through readings and course work and as they were working on their projects, they were reminded to try these methods to help effectively communicate. At the conclusion of the project they were asked which methods of design collaboration they considered to be effective boundary objects. In this way the students were not only using boundary objects but were also engaging in a metacognitive exercise about their process. The hope is that this produced learning not only around the subject matter of wearable technology or Arduino hardware making, but also in methodology and design process.

> "We found that drawings and diagrams were the most effective ways to communicate our ideas. Coming from different backgrounds, it was sometimes hard to communicate with our collaborator and get our ideas across. We exchanged drawings to ensure we were on the same page about our ideas." - student from Drag Duality team.

7.3 Performance Driven Collaborative Work

Drag culture instills in its community a 'make it work' attitude. Many drag queens work four or five nights a week, this is in addition to day jobs that help pay the bills. To produce a persona and cultivate a following drag queens often have to create elaborate costumes in a extremely short amount of time with limited budget. This style of working is at odds with a university course group project, which tends to focus on documentation of process and methodical thoughtful design iterations. Therefore, it was the drag queens, not the students who initiated the making. 'Stop talking and start doing'. In working sessions that were originally meant to be planning sessions, drag queens instead began pulling scraps of fabric from their bags, plastic flowers and greenery from bins, and starting gluing and sewing together outfits. Students rushed to finish electronic components in time to fit them within the garments. There were obvious benefits to having group members with this 'let's get to it' mind set.

Drag queens are also well known for being opinionated, and expressing those views freely. It was exciting that even though the drag queens had little knowledge of how to create the hardware or software components, they had many ideas of how they might be creatively applied. The drag queens were heavily invested in the quality of the technology outputs and wanted to make sure the group members working on the tech understood the importance of the overall group vision. The drag queens were not going to perform on stage with artifacts that were not working properly or were not aesthetically pleasing.

> "I understood from the get-go that drag queens all have their own unique styles and types of performances, and that it would be important to tailor our project to our collaborator's. I've never worked with drag queens before so I was a little nervous as I'm a pretty shy person and drag queens are often outgoing and friendly, so working with our collaborator definitely brought me out of my comfort zone." - student from La Mandragora team.

This sense of real-world urgency and outcomes with public repercussions added greatly to the authenticity of the learning experience. "There are many appealing strengths to the idea that learning should be organized around authentic problems and projects that are frequently encountered in non-school settings: in John Dewey's vision, "School should be less about preparation for life and more like life itself." [6] This can aid to transfer of knowledge especially when the tasks are not simple and procedural. The fact that the students were asked to think about

their project process, while also actively working on the project aids in transfer.

7.4 Hardware and Software Skill Building as a Barrier and Outcome

When asked what they learned the most from the course many of the students listed skills such as tech hardware creation and overcoming software challenges. Students were pointed to campus resources and the instructor facilitated at least two technology work days with hardware and software experts; however, learning skills was not a major goal of the course. The trials of novices using Arduinos has been documented [15] and perhaps the students felt the most pride in these outcomes because they navigated learning these skills on their own.

> "Creating a device that actually worked was extremely fulfilling, and a huge confidence booster. We'd never worked with breadboards or circuitry or hand-saws or anything. It felt like we were climbing the steepest hill throughout the whole process, having to learn as we went. But in the end, it was all worth it!" - student from La Mandragora team.
>
> "My understanding of Arduino and sensors is the part I see most rewarding. It is valuable knowledge for me and my future work as an interaction designer." - student from MIVE team.
>
> "Having a tangible, super cool, interactive piece that really catches people's eyes. People seemed extremely impressed whenever I'd show them the project. Which gave me incredible satisfaction because I spent so much time learning about hardware, Arduino programming, and combining it all. It's an extremely rewarding feeling when you see a final product of which you put so much time into, become something that people 'ooh' and 'ahh' over." - student from Drag Duality team.

We also found that the level of trust in the technology differed between the performers and the students. The performers became nervous about being able to activate the technology on their own. This parallels the findings by Honauer et al in their exploration of interactive costumes [28].

7.5 Transdisciplinary Project Work in Education as a Means to Promote Understanding Cultural Diversity

We can describe cultural diversity within this case study in a couple of different ways. First there is the cultural differences between disciplines. These types of cultural differences can manifest themselves in process and timelines of work. Different disciplines also have different standards of success. Drag queens even have a term "day drag" describe when the level of craftsmanship has to be more precise because one needs to walk out in the day light with more scrutinizing spectators. Most drag performances happen at night, in dimly lit bars, with an intoxicated audience. In the later scenario the audience is not going to notice if a hem is not perfectly straight, or in this case a couple of LEDs do not light up correctly. Exposing students to different cultures of design process and standards in this way can be important.

Second, and especially in this case study, having students work with queer community collaborators enriches their understanding of sometimes safe guarded culture and references. In education it might not be our job to teach students to have more liberal views, but it should be the job of an educator to expose students to different cultures in an effort to create a shared understanding. By working with each other towards a common goal we learn how to communicate with each other (even though we might disagree).

8 CONCLUSION

The case study and course described in this paper can act as a template for future iterations. Some key points important to remember when putting together such transdisciplinary project groups to create an authentic learning experience are:

- When creating groups try to use terms like experts and collaborators instead of mentor or client.
- Try to find outside collaborators from a discipline with different skills and expertise from the students.
- Exploit these differences and use methods such as boundary objects to allow for true collaboration.
- Remind students to pay attention to the processes and methods they are using for group work.
- Students and collaborators may not have all the skills necessary for completing the project so make sure they have outside resources for help.
- Try to work on projects with real world consequences such as performance driven work.
- Working with collaborators from a different cultural persuasion can help in calling out the illuminating the difference in discipline, and can aid creating a shared cultural understand that will impact student's future work.

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