Augmented Dance Education

By
Tiam B Morrow-Rogers

Submitted in partial fulfilment of the requirements for the degree of

Bachelor of Industrial Design

School of Applied Technology
Humber College of Technology and Advanced Learning

Supervisors: Catherine Chong, Sandro Zaccolo

Consent for Publication in the

Humber Digital Library (Open Access)

Consent for Publication: Add a (X) mark in one of the columns for each activity

Activity		Yes	No
Publication	I give consent for publication in the Humber Library Digital Repository which is an open access portal available to the public	☐	☐
Review	I give consent for review by the Professor	☐	☐

Student Signature : _____

Student Name : Tiam Bennett Morrow-Rogers

Augmented Dance Education

Tiam Morrow-Rogers

« Bachelor of Industrial Design »
Humber College of Technology and Advanced Learning
2020

Abstract

As other sports and recreational activities receive an increasing amount of support for the health and safety of the athletes, dancers seem to receive little to none. Often times there is a presumption that dancing is a leisurely activity, however, it is quite a common occurrence for professional dancers to require an immense amount of physical therapy due to the high injury incidence rate. Dance has many repetitive motions that can cause injuries to cascade over time. Unless something is done to reduce the occurrence rate of dance injuries many youths will have the later stages of their life affected by the injuries. In this thesis, a solution will be developed to help deter the occurrence rate of injuries in young professional dancers.

Acknowledgements

This project was made possible with the support, guidance and knowledge of peers, advisors, and professors. I would like to thank the following for helping me pursue this thesis topic and developing me as a designer.

I would like to thank Catherine Chong and Sandro Zaccolo for being the primary advisors to this thesis. Their knowledge in design research, concept generation, and design development was immensely helpful.

I would like to thank my peers and fellow classmates for the feedback, support and interesting perspectives on the work I developed. Often they served as the most immediate response to questions and concerns I had during various points in the project.

Finally, I would like to thank my mother (Jacqueline Morrow), whose stories and experience as a dance teacher helped drive the foundation of this study. I hope that someday dance educators receive the proper educational model and tools required to prevent injuries.

Table of Contents

List of Tables

List of Figures

Chapter 1: Problem Definition

Figure 1 - Jeffery Erhunse Retrieved from https://unsplash.com/photos/bkk41petoD4

1.1 Problem Definition

Dance is a timeless representation of art and music expressed through the movement of the body. Many young girls turn to dance as a recreational sport or extracurricular activity. Of this demographic 81% report injuries within the first year of learning and 58% suffered a substantial injury affecting both performance and day to day tasks (Rogier Van Rijin Feb. 2019). These injuries can have a cascading effect that can be detrimental to their adult lives.

This thesis report will take a look at contemporary dancers, how their injuries occur and current methods of injury prevention. The research will be focused on developing a conceptual design solution that will reduce the risk of injury. It is also important to keep the solution ergonomic and intuitive to use.

1.2 Rationale and Significance

The risk of dance injuries for learning students is extremely high with an 81% occurrence rate in the first year. It is not uncommon for knee, back and ankle related injuries to severely impact an individual's life.

Dance injuries are often overlooked compared to other similar sports injuries. Although there is a lot of similarity in the therapy for these injuries, the prevention is often neglected. Primary injuries can cascade into long term pain and even disability. How may we reduce the risk of injury for learning contemporary dancers? Current aids for dancers look to reduce joint strain and often require significant space, or complete re-installation of flooring. Alternative

solutions such as resistance bands only give physical strength training along with linear motions. Braces prevent hypermobile users from overextending but are not usable on a stage. One notable cause of injury is poor confidence. This thesis looks to do a detailed study of the ergonomics and injuries of dancers in their first years of study.

1.3 Background, History and Social Context

Dance has been present in humanities cultured for several thousand years with the first archaeological evidence coming from 9000-year-old cave paintings in India. Modern dance styles originate from Europe during the renaissance. Despite the demanding physical requirements and expectations of dancers, dancing has been modernly perceived as weaker activity. This may be one of the reasons it has failed to receive attention and research on injuries compared to sports such as football or rugby.

Classical dance styles had many flowing movements compared to their modern counterparts with jerky sometimes violent actions. Contemporary dance is one such example that sought to revolutionize this and introduced unconventional movements. Like many other sports that have been pushed to their extremes by modernists, dancers may find themselves pushing too far. Many teachers suggest that all dancers learn classical dance styles such as ballet first to better understand body control. It is common for new dancers to be interested in jumping into the most modern dance style and although ballet remains the most popular, contemporary, modern and jazz are closely following.

Technology in the dance space has remained relatively stagnant. Where soccer, football and other popularized sports seem to always receive new gadgets and studies dance receives relatively few, with several studies even making note of such.

Chapter 2: Research

Figure 2 - Mehmet Turgut Kirkgoz Retrieved from https://unsplash.com/photos/yPPu9FBmTQ0

2.1 User Research

This thesis is based on a research topic to be studied using various research methods. The research topic being looked at is to look at ways in which injury occurrence in learning dancers can be reduced. Resources such as the Humber Library, Google Scholar and other library databases will be used.

Focus points of information include user demographics, surveys, user needs, full-bodied interaction design and benchmarked projects.

2.1.1 User Profiles / Personas

For the key demographic and user groups, four different personas were recognized. The dancers themselves, dance teachers, parents and physiotherapists may be involved in the dancer's training. It was important to define four different personas, as their individual needs and interactions with the student were very intertwined. Students often find themselves depending on parents, teachers and physiotherapists.

2.1.1.1 Primary User

<table>
<tr><td rowspan="6">  </td><td>Name</td><td>Jennifer White</td></tr>
<tr><td>Age</td><td>15 - 18</td></tr>
<tr><td>Occupation</td><td>Student/Dancer</td></tr>
<tr><td>Family</td><td>Parents, one sibling</td></tr>
<tr><td>Schedule</td><td>Tuesday, Thursday</td></tr>
<tr><td>Duration</td><td>140 mins, 2 times a week</td></tr>
</table>

Table 1 - Fictitious User Profile 1

This fictitious persona is to focus on the user's needs and allow the product developed to aid those needs. Based on the research conducted, learning dancers that start to push themselves and incur injuries are between the ages of 15 - 18. This is largely due to high school students seeking social activities outside of school. Some of the dancers aim to professionally study dance after graduating high school.

2.1.1.2 Secondary User

	Name	Jacqueline Green
	Occupation	Dance Teacher
	Involvement	Instructs classes
	Schedule	Monday - Saturday
	Duration	12 classes, 140 mins each

Table 2 - Fictitious User Profile 2

This secondary user has the most amount of interaction with students. It is their role to look for injuries before it occurs and ensure safe practice. Dance teachers are also the user group looking to push the students the most. Teachers may have to see hundreds of students a week, often teaching many classes. A common occurrence is some students being neglected not at the fault of the teacher, who may not be able to focus and attend to all the students.

2.1.1.3 Tertiary User One

	Name	Anna White
	Occupation	Accountant
	Relationship to Student	Parent
	Family	Two Children
	Involvement	Drops student off

Table 3 - Fictitious User Profile 3

The first of the two tertiary users is the parent. Parents have the most intimate relationship with the student. Often parents are asked to buy the student materials and aid in ensuring the student is able to attend class. Their budget as such is an important factor when checking the feasibility of solutions.

2.1.1.3.1 Tertiary User Two

	Name	Jasmine Orville
	Occupation	Physiotherapist
	Relationship to Student	Helps with injury prevention

Table 4 - Fictitious User Profile 4

Physiotherapists act as yet another tertiary user. Physiotherapists may help students better understand how muscles move or help provide relief for cramps amongst other aids. In the event of an injury, physiotherapists often help rehabilitate the user.

2.1.2 Current User Practice

This information is to help understand existing practices, activities and ergonomics involved in protecting the dancer. The data collected will help guide the design process in the necessary direction.

User research was collated from interviews, forums, emails and phone calls.

2.1.3 Activity Mapping

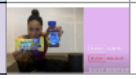
	Preparation	Set Up	Task 1	Task 2	Task 3	Task 4	Task 5	Task 6	Completion
User Goals	Eating	Getting Dressed	Warm-Up	Stretching	Set-Up	Routines	Short Break	Routines	Done Practice
User Actions	Eat healthy meal	Put on shoes and other necessary clothes	Jumping jacks Running	Various stretches to prevent potential injury	Pulling out any relevant equipment	Follow instructions Rehearse dance	Usually short break before continuing	Follow instructions Rehearse dance	Pack-up go home
User Thoughts	Wants energy		Not enjoyable seems tedious	Streches suck They really help	Balance bars Crash mats etc.	Listen to instructor	Thirsty, tired hungry	Listen to instructor	Excited to go home an relax
Story Board Photos									

Table 5 - Activity Mapping

2.1.4 Human Factors of Existing Products

Many dancing aids are generic in size, proposing a one size fits all solution. Mostly this is effective, as varied sizes of treadmills don't necessarily benefit anymore of the user group. There are however a few exceptions where scale is questionable in its motive, such as barres. Barres have a typical height and it's been stated that this height range is what all dancers should train at.

Product	***Human Factors***
	-Arm rests at suitable height for majority of users -inclination is adjustable

	-dance shoe choice varies by genre
	-Bars are roughly 34” and 44” off of the ground -Follows a standard height
	-Springstep flooring provides comfort in jumps
	-Various sizes, adjusts slightly to account for different size feet
	-Can be joined with other panels for larger users -Panels can stack to improve dampening

Table 6 - Product Benchmarking Human Factors

2.1.5 Safety and Health of Existing Products

Existing products focus on flexibility and breathability. It is important that the device is tolerable to sweat or able to be washed to prevent bacterial issues. Flexibility lets the user be uninterrupted in their movements and flow naturally.

Product	***Health and Safety***
	-Heart rate monitor -Automatically turns off when safety chord is pulled
	-Structure discourages pronation
	-Base prevents wobbling
	-gives good padding for jumps
	-Promotes proper ankle movement
	-Pads floor dancers when practising rolls and falls

Table 7 - Product Benchmarking Health and Safety

2.2 Product Research

A wide selection of products was initially examined. Looking for common themes amongst the benefits and what focus areas various solutions missed was the methodology for finding opportunities. Everything from floors to clothing was considered. Interestingly many products lacked some of the wants and wishes noted in chapter 3 of this thesis.

2.2.1 Benchmarking-Benefits and Features

Product	***Features and Benefits***
	-Quiet Motor -Device Holder -Charges device -Shock-absorbing cushioned deck
	-Mesh and suede -Quick drying -Breathable -Flexible mid section -Padded collar
	-Adjustable system for kids or adults -Portable and lightweight -Curved Legs for additional stretching -Wider Base, for more stability when leaning
	-Adjustable in size -Timestep flooring -Springstep subflooring -Optimized for dance -Reduces joint strain
	-One size fits both feet -Up to 11" foot arch circumference -Minimizes risk of injury -Breathable neoprene, comfortable and flexible
	-Thick tri-density padding -Closed-cell foam -Lightweight and portable -Sweat-resistant

Table 8 - Product Benchmarking Features and Benefits

2.2.2 Benchmarking Functionality

The majority of products that dancers use to focus on reducing ankle and knee strain from continuous jumps and movement. The alternative approach that some take is strength exercise tools such as rubber bands of different strengths.

All products benchmarked had an individualistic characteristic to them, where their purpose was intended for a sole user and didn't provide a function to the 3 other personas.

Product	***Functionality***
	-Cardio training
	-Helps prevents splints and cramps -Some shoes provide extra motion to the dancer such as the pointe step mainly seen it a specific style of ballet shoe
	-Aids with stretching exercises and routines
	-Creates an ideal surface for dancers to continually jumping without causing excessive strain to dance students and teachers

	-Supports the ankle to promote uni-directional movement
	-Prevents harsh landings when practising rolls

Table 9 - Product Benchmarking Functionality

2.2.3 Benchmarking Aesthetics

Product	***Aesthetics***
	-commonplace, standard form -Some blue accents -Mostly black
	-Black, minimal, contemporary Not meant to attract attention to any single dancer, these shoes are supposed to be applicable in most scenarios.
	-Wood bars -Black metal structure
	Typically wood, or marley covered flooring. -black or grey marley surface

	-Black fabric
	The bright blue is clearly discernable from the otherwise black or grey flooring

Table 10 - Product Benchmarking Aesthetic

2.2.4 Benchmarking - Materials and Manufacturing

Existing products utilize various different materials depending on the task. Breathable fabrics are necessary for any clothing that is tightly fitted to the body. Marley flooring is key for durability, flexibility and spring to reduce strain.

Product	***Materials and Manufacturing***
	*-ABS plastic, injection molded* *-Rubber treads* *-Metal mechanism and internal components* *-Steel frame*
	*-breathable mesh* *-Flexible rubber sole* *-Nylon*

	*-Wood* *-Steel*
	*-wood*
	*-fabric, nylon and neoprene* *-velcro*
	*-medium density polyethylene foam*

Table 11 - Product Benchmarking Materials and Manufacturing

2.2.5 Benchmarking Sustainability

Product	***Sustainability***
	*-Energy efficient motors*
	*-Nothing notable* *-Product makes no effort to be sustainable*
	*-Used materials, wood and steel are both relatively durable and have a long product life span*
	*-With proper care, a long product life span is feasible* *-Costly to replace, and sometimes causes immense waste*
	*-Nothing notable*
	*-Non sustainable polyethylene foam*

Table 12 - Product Benchmarking Sustainability

2.3 Summary of Chapter 2

Initially research was kept very broad. There were many areas to consider, such as therapy, exercise, practice, structural/environmental solutions and even clothing. The overall conclusion from Chapter 2 was that the product developed must sufficiently benefit and bridge the gap between the range of identified users.

Some key things to remember when proceeding with the project was to have anything close-fitting to the user be a breathable and washable material. A common feature across all products was the bacterial protection and ease of cleaning.

In sustainability there are lots of improvements that can be made, however, many existing products are particularly harmful to the environment as it is.

Chapter 3 Analysis

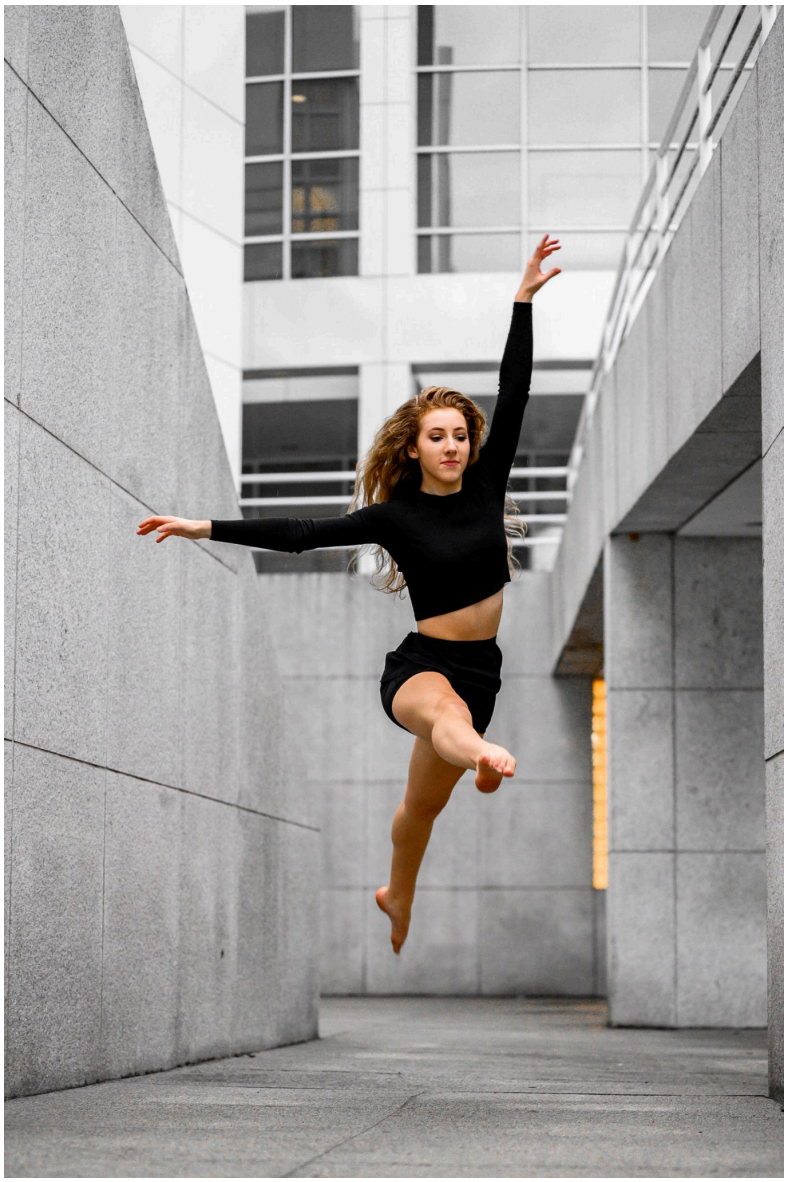


Figure 3 - Jefferey Erhunse https://unsplash.com/photos/0XWHaJ73wts

3.1 Needs Analysis

This section will look at the three categories of needs for a user. Wants and wishes, latent needs and immediate needs were charted out to define potential goals for the product developed.

Wants + Wishes	Latent Needs	Immediate Needs
Parental Support	Better indicators of movement	Consistency in practice
Fun Activity Potential	Communication between teacher and therapist	Feedback from the teacher
Access to Environment		Attentiveness to all students

Table 13 - Needs Analysis

3.1.1 Needs / Benefits Not Met by Current Products

Current products do not meet the needs of communication and indication. Generally, most products do not have any exciting aspects to them as well.In interviews with a teacher, a common need expressed is to be able to view and assist all the students equally, which was a challenge due to the large class sizes.

3.1.2 Latent Needs

Communication was one of the more notable needs mentioned in interviews and research articles. Being able to have a direct dialogue between the personas allows for a more thorough understanding for the student. The therapist to teacher interaction seemed to lack intimacy the most.

Falling in a similar category as communication, teachers find themselves watching students' movements very closely to look for indicators that may cause potential injury. One issue is teachers don't have a way of checking through every student. Solutions that either portray indicators much more clearly or allow the teachers to review and search for indicators seem much needed.

3.1.3 Categorization of Needs

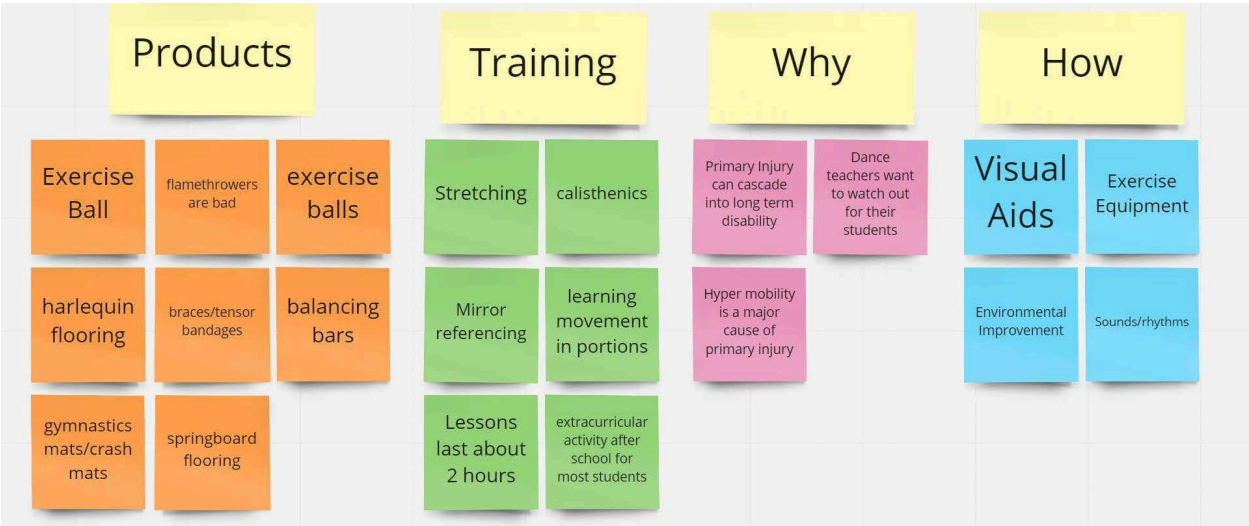
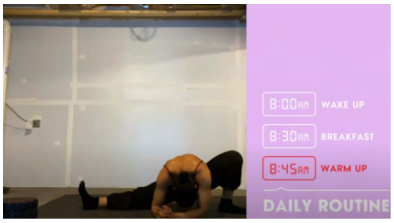


Figure 4 - Categorization of Needs

3.2 Analysis - Usability

Journey Mapping and Empathy Mapping were used to understand where this product may fit into a user's workflow.

3.2.1 Journey Mapping

Storyboard	User Goals	Thoughts
	Eating	Eat a healthy meal to provide energy for the lesson
	Getting dressed	Wear proper clothing that is stretchy, but breathable
	Warm-up	Done before stretching to allow muscles to stretch better
	Stretching	Helps prevent cramping and injuries later on during routines
	Set - Up	Pull out any relevant equipment such as dance barres or crash mats

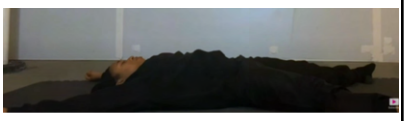
	Routines	Follow instructions and rehearse routines
	Short Break	Usually short break before continuing
	Routines	Follow instructions Rehearse dance
	Done Practice	Pack-up go home

Table 14 - Journey Mapping

3.2.2 User Experience Mapping

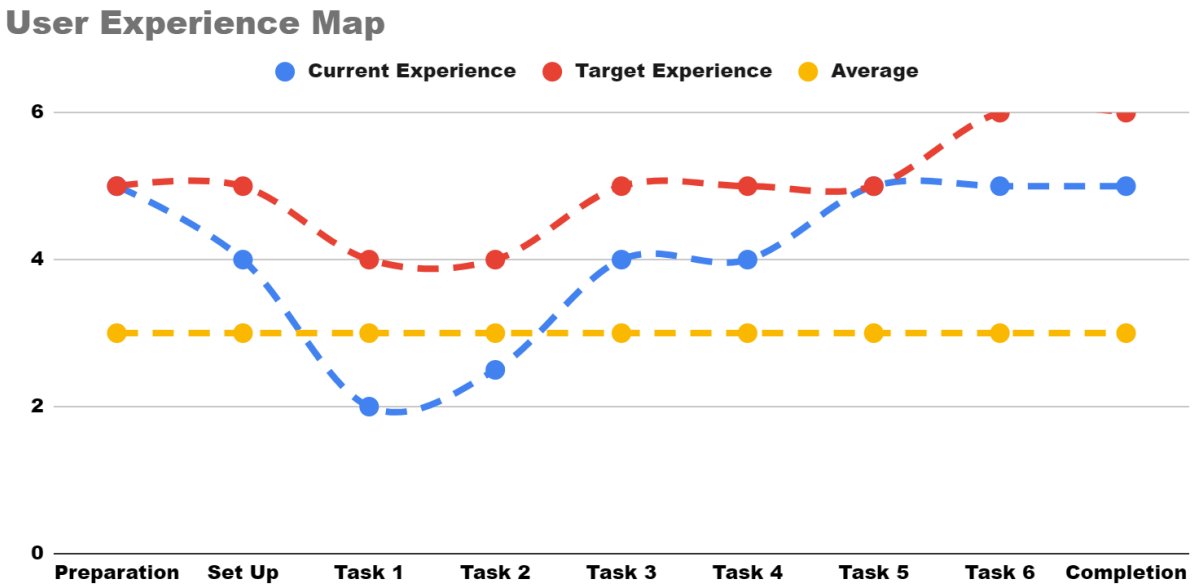


Table 15 - User Experience Mapping

3.3 Human Factors

A 1:1 size mock-up was made to fit a 5’7 female, which is roughly the average height of a dancer. Typically studios prefer students between the height of 5’5 to 5’8 with a secondary preference for those between 5’2 and 5’4. From the “Measure of Man and Woman” by Henry Dreyfuss Associates it was found that 5’8 was about a 95th percentile female. For smaller sizes, the 35th percentile was considered, although most users will fall around the 70th percentile. The model was made to be 90th percentile as it was the easiest size to make a correlation to. This is further summarized in the conclusion of this report.

4 sizes for the smart leggings were decided upon. An extra small, small, medium and large size account for those between the 35th and 90th percentile female. Two sources were referenced for these numbers including the Adidas size guide, The Measure of Man and Woman by Dreyfuss Associates, and the DQYDJ calculator which utilizes the information collected by the CDC. Adidas categorizes a much larger selection of sizes, with XS to XL in petite, standard and tall sizes. Tall was neglected, as its height was for individuals 5’10 and above. Standard met the majority of size expectations. Petite was only used to act as an interpretation point for where the low value may be. This was done as compared to the average individual, dancers tend to be a bit thinner and more athletically toned.

	XS 35th Percentile	S 50th Percentile	M 70th Percentile	L 90th Percentile
WAIST CIR.	24-26"	27"-29"	29"-31"	31"-33"
HIP CIR.	32-34"	34"-36"	36"-38"	38"-40"
INSEAM	28"	29"	29"	30"

Table 16 - Size Chart
Waist circumference, hip circumference and inseam length for various female heights.

In addition to the above dimensions, the hip stand and hip sit were found to be between 8"-10" and 11.6"-15.5" respectively. This range is from the 25th percentile to the 85th percentile but applied from 35th to 90th to account for the slimmer size of dancers. Waists varied from 7.5" to 10.5" across.

It should be noted that it is logical for the rubber stretch sensors to be a standard size of 4 inches. This is large enough to encompass all user sizes and additionally allows a baseline resistance value to reference. The variation in this value is what determines the extent to which a muscle is moved. The max value should be calibrated per individual. The centre of these sensors should be placed as close to the centre of the kneecap as possible. Kneecap vertical positions ranged from 16" to 18.5".

The floor panels were made to be 18" squared. This site isn't cumbersome to move around, but a user could also cover a sufficient space in a reasonable amount of time. Target demographic measurements did not have to be referenced for this. Dance studios are suggested to have 25 square feet per student. With a 4x4 grid of the 18" panels, this creates a 36 square foot space for a single student, with additional sets of panels able to be attached for expanding

the space. The dancer may also choose to arrange the panels in unconventional shapes to increase or decrease width or length.

The leggings themselves seem proportionate in terms of height and width, however, some measurements certainly look off although this may be due to the material used and the inability to assemble it in the correct way. The CAD seemed more accurate than the pattern that was printed out. It is unclear if there was an error in printing. The model was made to be 5’7 with a knee height of 17”. The waist came to around 9.2” with the hip-sit at roughly 15”.

3.3.1 Product Schematic - Configuration Diagram

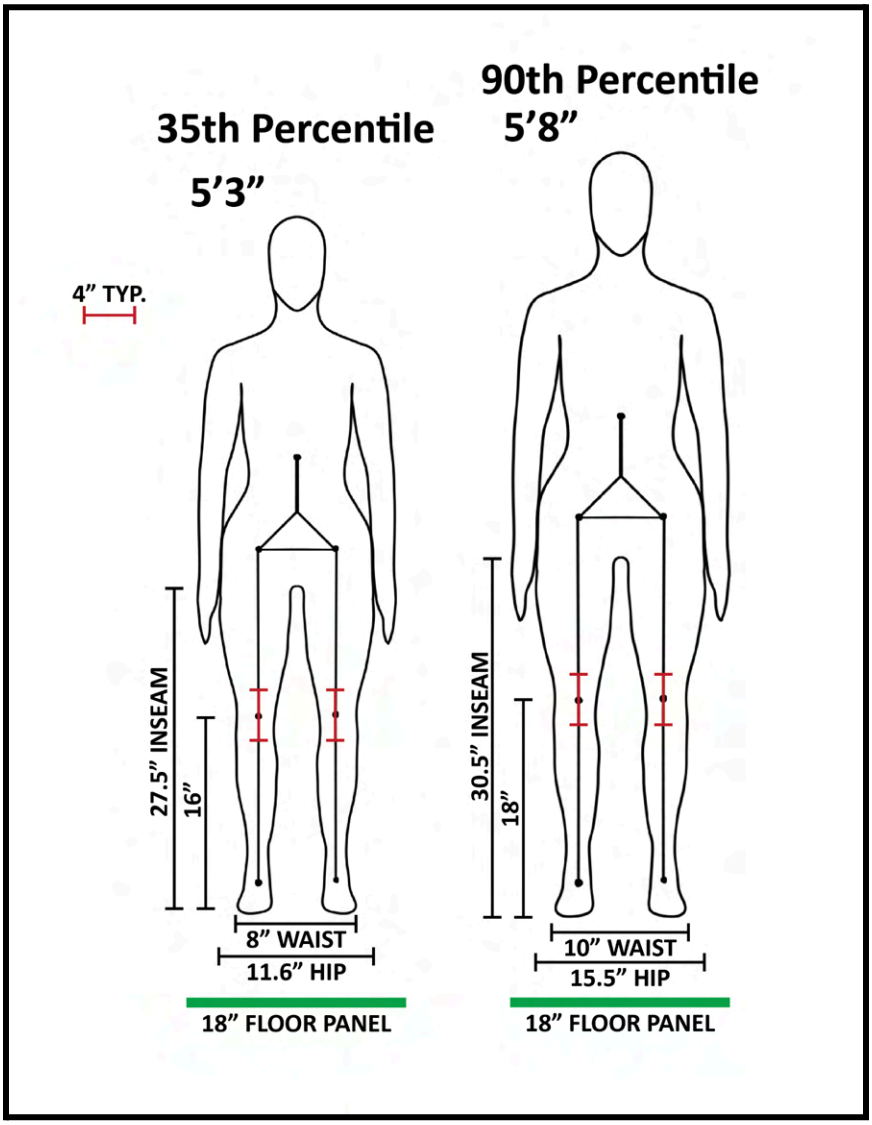


Figure 5 - Configuration Diagram

Data was collected from The Measure of Man and Woman by Henry Dreyfuss and Associates and the Adidas size guide, specified for athletic body types.

3.3.2 Ergonomic - 1:1 Human Scale Study

Figure 6 & 7 - Human Scale Study

3.4 Aesthetics & Semantic Profile

3.5 Sustainability - Safety, Health and Environment

Clothing utilizing recycled plastic is becoming increasingly more common and should be no exception in this circumstance. Taking polyesters and nylons from the ocean and blending them into a sustainable fabric could make the leggings extremely eco-friendly.

The flooring could use similar methods to achieve a low carbon footprint. Sustainable foam options are becoming wildly available and are great alternatives to the composite used in current flooring.

A benefit of modular flooring is the ability to replace a single damaged section. Marley flooring is often rolled out as one sheet, and this effectively makes any damage to it require a new rollout of flooring. Being able to replace an individual section is very beneficial both sustainably and financially.

3.6 Innovation Opportunity

The needs of the user were mapped out to better solutions for the biggest gaps in users' dance training experience. These needs were discovered from all of the user groups to better mesh their collective experience as, from initial insights, the cross-communication between the groups was a concern.

3.6.1 Needs Analysis Diagram

Wants + Wishes	Latent Needs	Immediate Needs
Parental Support	Better indicators of movement	Consistency in practice
Fun Activity Potential	Communication between teacher and therapist	Feedback from the teacher
Access to Environment		Attentiveness to all students

Table 14 - Needs Analysis

3.6.2 Desirability, Feasibility, Viability

The commercial viability of the proposed solution is very dependent on the cost of the electronic components and development. When looking at the most comparable competing product as being mocap suits, this could potentially be a sliver of the cost. Mocap suits tend to be priced upwards of $1800.

This device also has the potential for performance use. There exists an opportunity to use the leggings as not only a protective aid but a visually interactive product. Dancers would be able to have their movements on the stage interacting with objects, lights and other show related apparatus. Integration of tech in theatre has been on an upwards trend, with some looking to even have dancers dance along with robotic arms. Many people have danced alongside the industry-leading KUKA robotic arms.

A recent trend in the fashion industry has been utilizing recycled bottles to create fabric for various clothes. Currently, many t-shirts, shoes and even leggings are being made using this recycled compound material.

Cost restrictions are mostly inhabited by the student and parents' ability to afford the device. Though flooring panels may be provided by the teacher in the environment, the individual would need clothing for them.

3.7 Summary of Chapter 3 - Defining Design Brief

The design brief's intent is to prioritize specific sets of goals. For this thesis, the goal is to develop a system that will mitigate the risk of injury in learning dancers. This brief will be modified and improved throughout the thesis.

Safety	Device improves the safety of students
Ergonomics	Must meet expectations of teachers and students alike
Aesthetics	Should fit in a dance environment
Versatile	The system should be able to adapt to the environment used in
Integration of New Technology	Various new sensors need to be effectively implemented
Comfort	Students have to be comfortable using the equipment/clothing/devices
Convenience	Should be easy to clean and store

Table 17 - Design Brief Breakdown

Chapter 4: Idea Generation

Figure 8 - David Hoffman sourced from https://unsplash.com/photos/90v3asMhhL0

4.1 Initial Idea Generation

The approach to idea generation started with understanding the user needs, existing products and the environment in which the products are used. Common possible injuries were also mapped out to understand where issues occurred. Ideas were initially kept broad to come up with a variety of potential solutions.

4.1.1 Mind Mapping

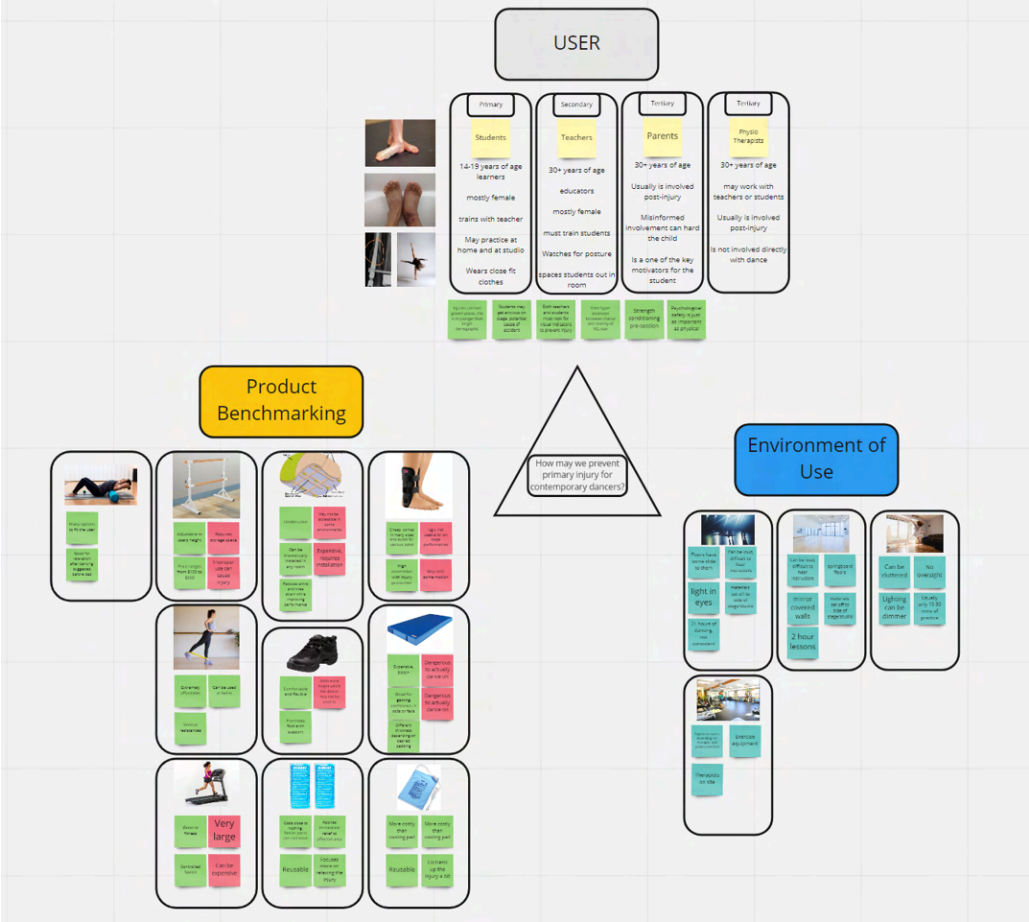


Figure 9 - Mind Mapping General

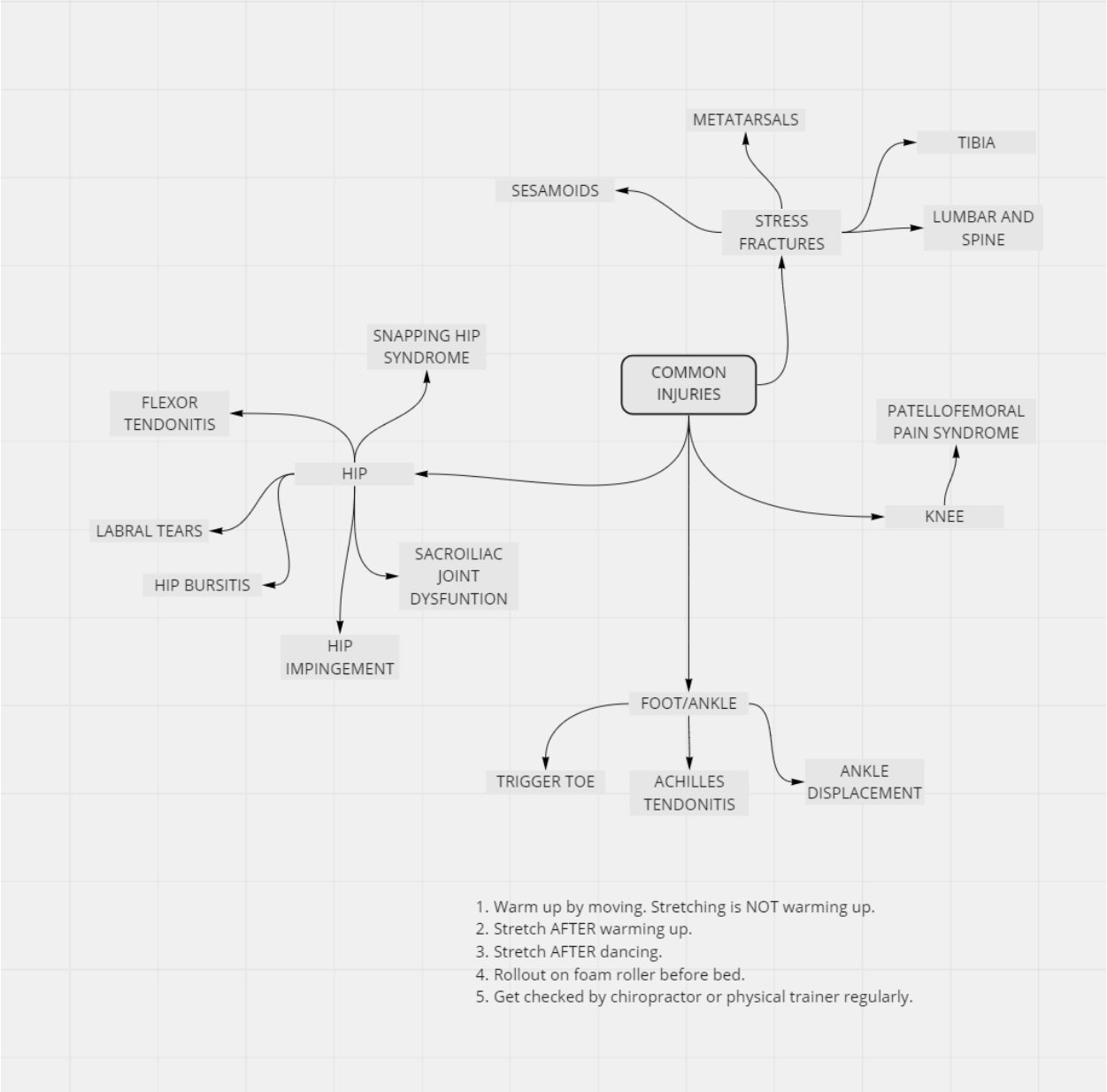


Figure 10 - Mind Mapping Injuries

4.1.2 Ideation Sketches

Portable Dance Barre

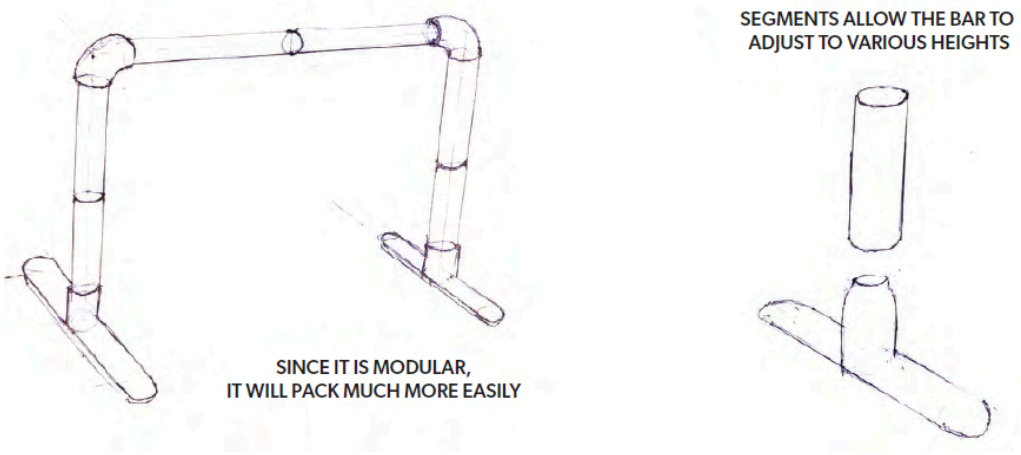


Figure 11 - Ideation 1

Ankle and Knee Braces

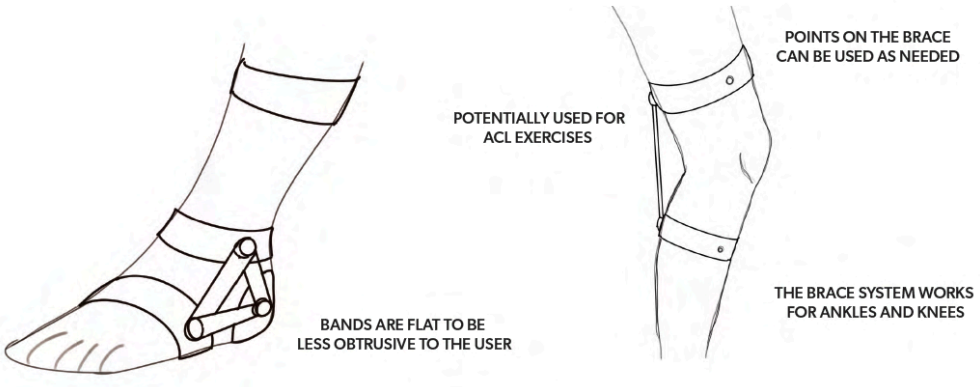


Figure 12 - Ideation 2 + 3

4.2 Concept Exploration

Taken forward from the ideations, the legging concept, the ankle exercise device and floor panels were further developed. The conceptualisation of how these devices function, and how the user may set them up is shown here. One component in this current stage of development that is of concern is the hip-mounted control module. It poses a minor threat to moveability and shifting the device could cause the leggings to disconnect with the method of attachment demonstrated in Figure 14.

4.2.1 Concept One

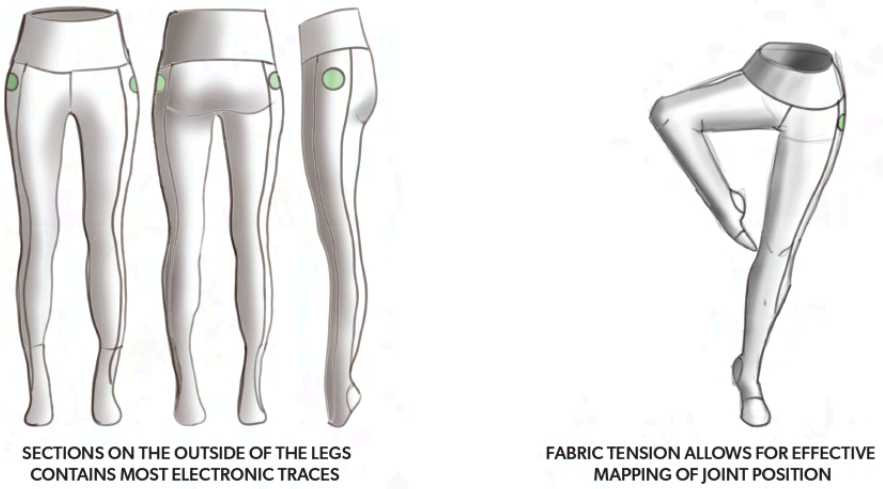


Figure 13 - Concept Leggings

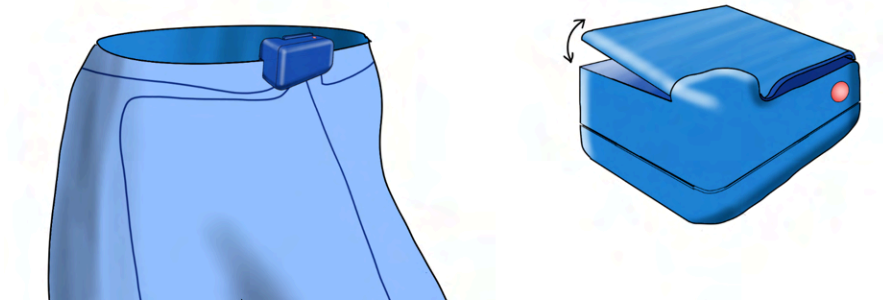


Figure 14 - Concept Leggings Controller

4.2.2 Concept Two

Concept 2 where the floor panel was derived from was initially not a smart device, however it fully built a dance environment including the dance barre.

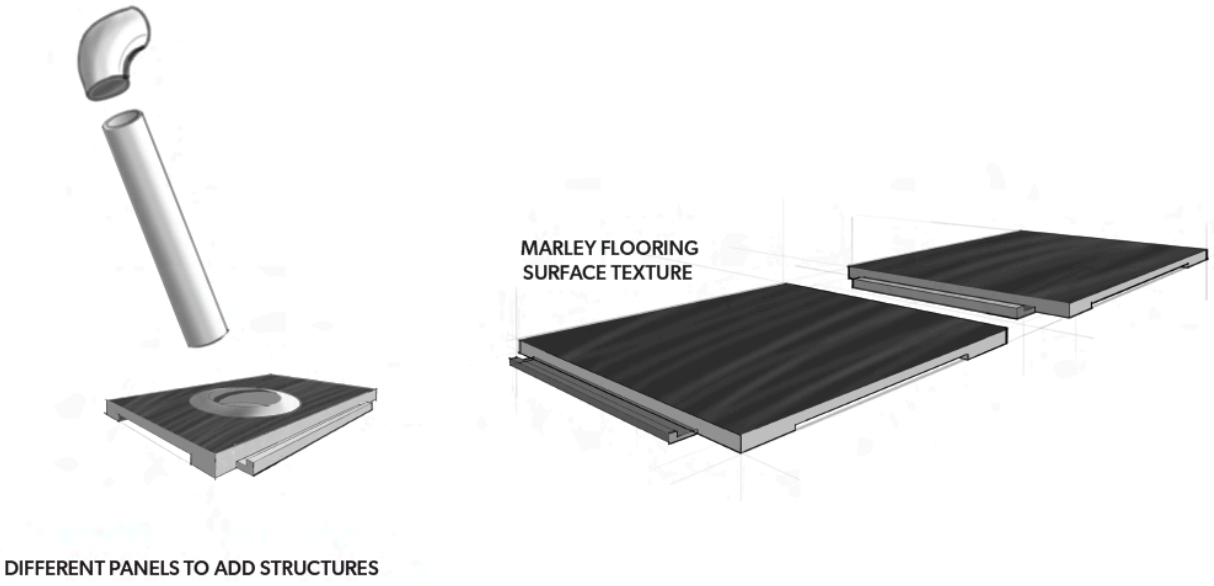


Figure 15 - Concept Environment Building

4.2.3 Concept Three

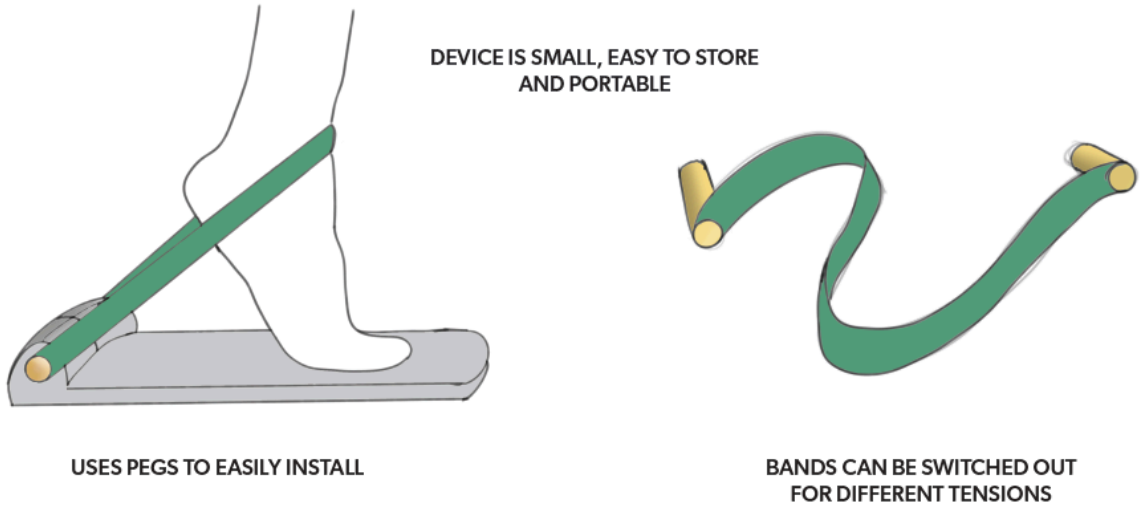


Figure 16 - Concept Exercise

4.3 Concept Strategy

The strategy with these concepts was to provide constant feedback to the user and teachers, which could be dynamically reviewed at any time through an app interface. The floor panel environment building concept works in tandem with intelligent leggings to provide adequate information. Where the leggings can track for overextension and various positional information, the floor panels are able to monitor weight displacement and pronation of feet. The following schematics detail the size of the floor panel in relation to the user and the composition of the floor panel to enable proper function. The exercise device was not carried forward from this phase, and the leggings and floor panel became one unified system.

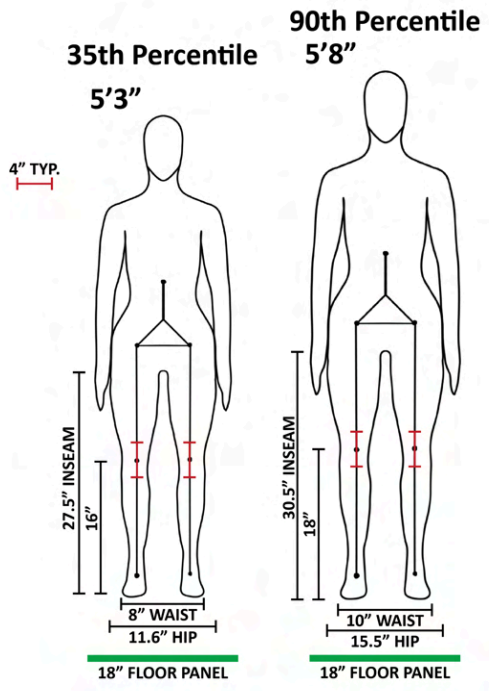


Figure 5 - Configuration Diagram

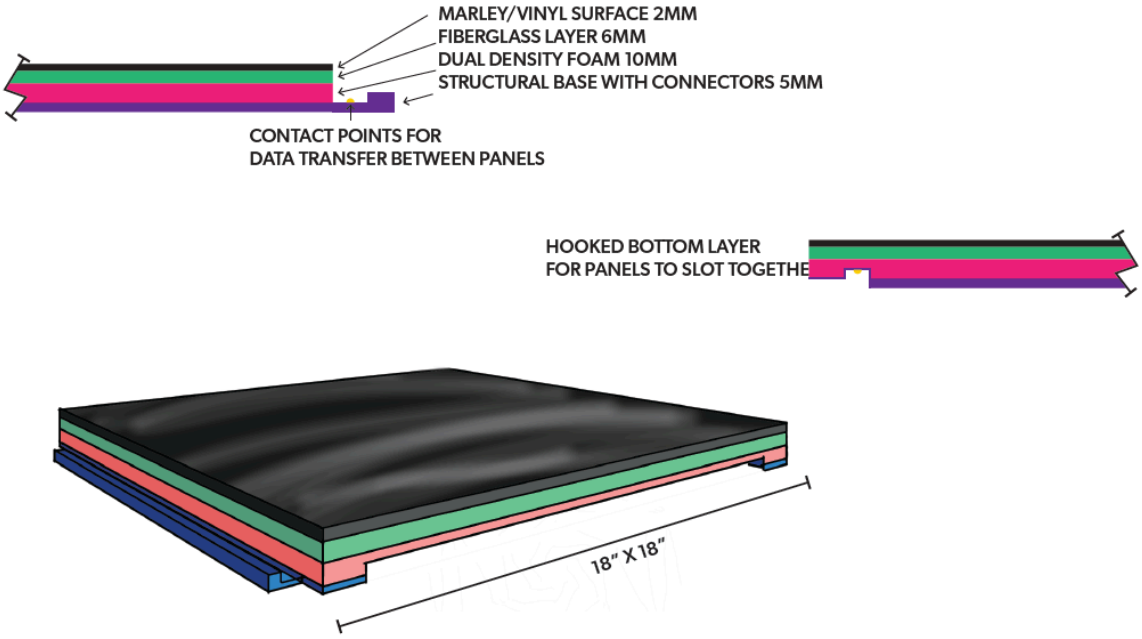


Figure 17 - Concept Floor Panel Layout

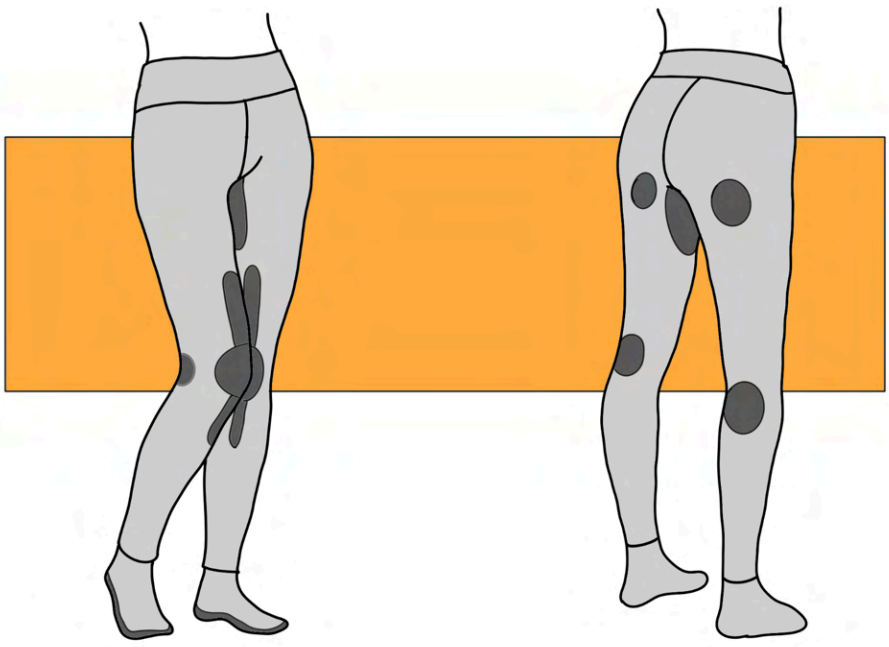


Figure 18 - Legging Sensors Visualized

4.4 Concept Refinement & Validation

Further refinement went into how the floor panel system may be expanded and what form would be easiest for the user to connect pieces. The form of the leggings was also further refined and explored. The necessity for the sensors to be distinguishable to the user was unnecessary, so a stylistic focus was applied instead. The method in which the electronics attached was switched to snap buttons for ease of use, comfort and machine washing. The refined design direction reenvisioned the leggings, and floor panels together, taking both of the concepts to the detail development and finalization stages.

4.4.1 Design Refinement

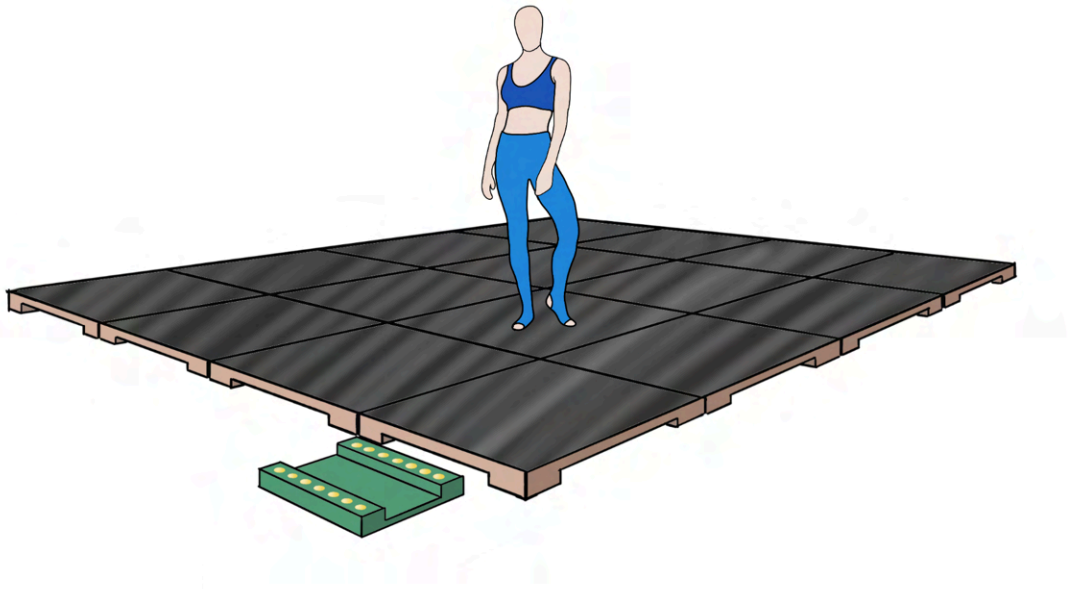


Figure 19 - Design Refinement

4.4.2 Detail Development

The leggings were changed to use snap buttons to attach the control module instead of a clip as a clip would be obtrusive to the user. The snap fasteners allowed for easier electronics integration in the fabric, and a flatter overall design, that the user could roll on if necessary. The form of the bridge pieces was also explored here, and various surface patterns for the leggings.

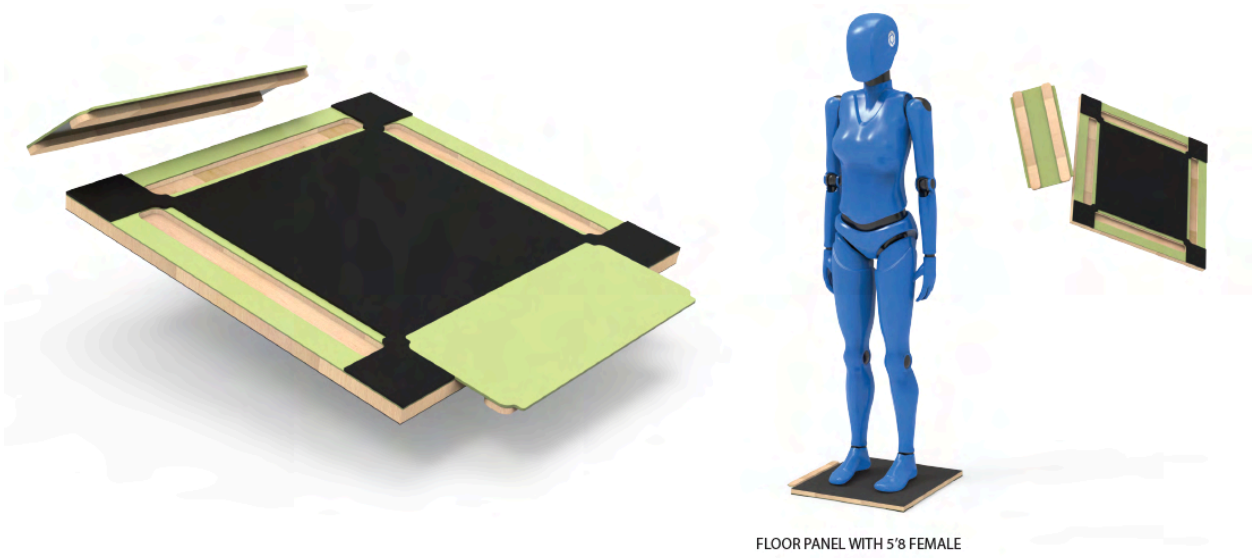


Figure 20 - Detail Development Floor Panel

In figure 20, the bottom view of the floor panel displays the ability of the bridge to easily slot into place. This makes it very easy for a dance student or teacher to assemble or disassemble the panels without the use of tools. With these floor panels, a studio would not have to contract construction workers to redo the floor construction, and instead, it is feasible to easily replace without assistance.

Figure 21 - Detail Development Leggings

The new pouch design uses snap fasteners to reduce the thickness of the control module and make ease of alignment for the electronic pins much easier. The internal wiring in the leggings is also much easier to fabricate in this manner.

Figure 22 - Detail Development Electronics Pouch

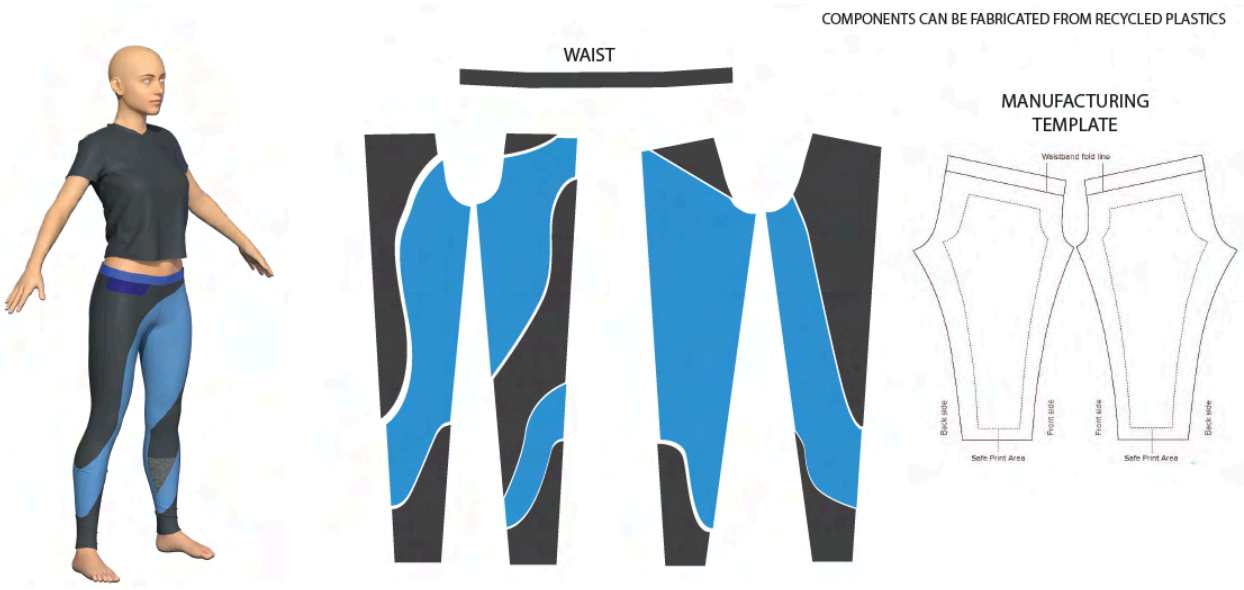


Figure 23 - Detail Development Leggings

4.5 Concept Realization

The fully realised design creates a learning environment for the dancer. Improved edge finishing pieces were designed. Only two different types of pieces are required and connected using loops. The edge pieces, injection molded from strong polycarbonate material, prevent the dancer from injuring themselves on the floor panels straight cut sides. The dancer will be less likely to fall off with this detail. These features were also explored with physical study models. The form was further refined in CAD.

The user experience and user interface design of the app were approached similarly to how smart health devices are monitored. The different products are able to be swiped through, so the information viewed is only the necessary information at any given moment.

4.5.1 Design Finalization

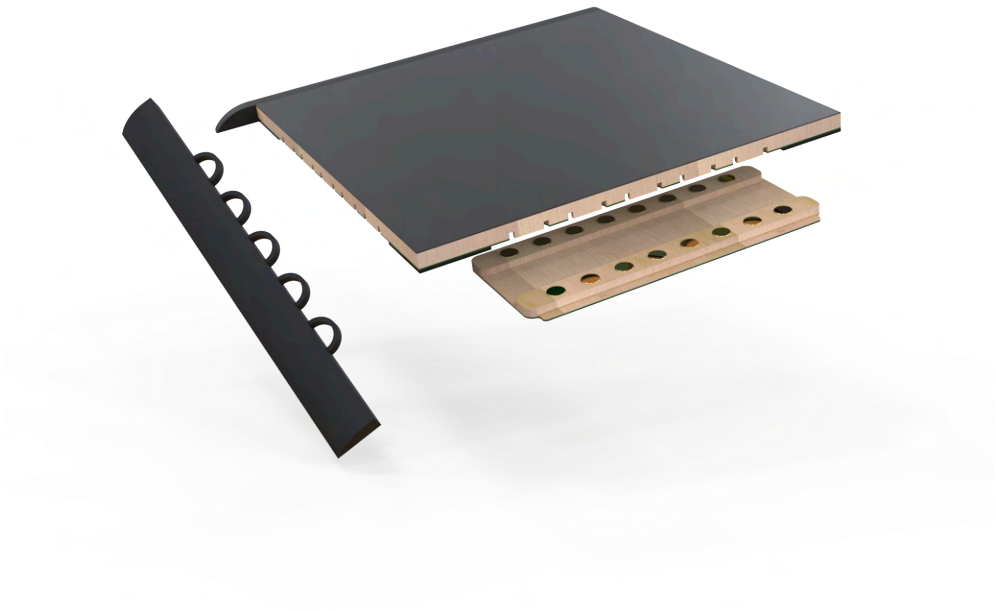


Figure 24 - Finalized Floor Design

In the figure above, the finalized design for the floor panel can be seen. The various layers of the panel and the method in which the side piece fit together create an easy to use system. The extra bump in the bridge piece prevents shifting, and the large gold plated contacts make the ability to connect the panels a minor worry. As the sensors function in a smart manner, that digitally “knit” together if assembled properly, ease of construction was important and so these features were necessary.

Figure 25 - Finalized Legging Design

The control module has a clearly detailed soft-touch power button. The utilization of this button would require a specific pattern to prevent accidental presses interrupting or cancelling the user's recording session.

4.5.2 Physical Study Models

Figure 26 - Sketch Model Wiring

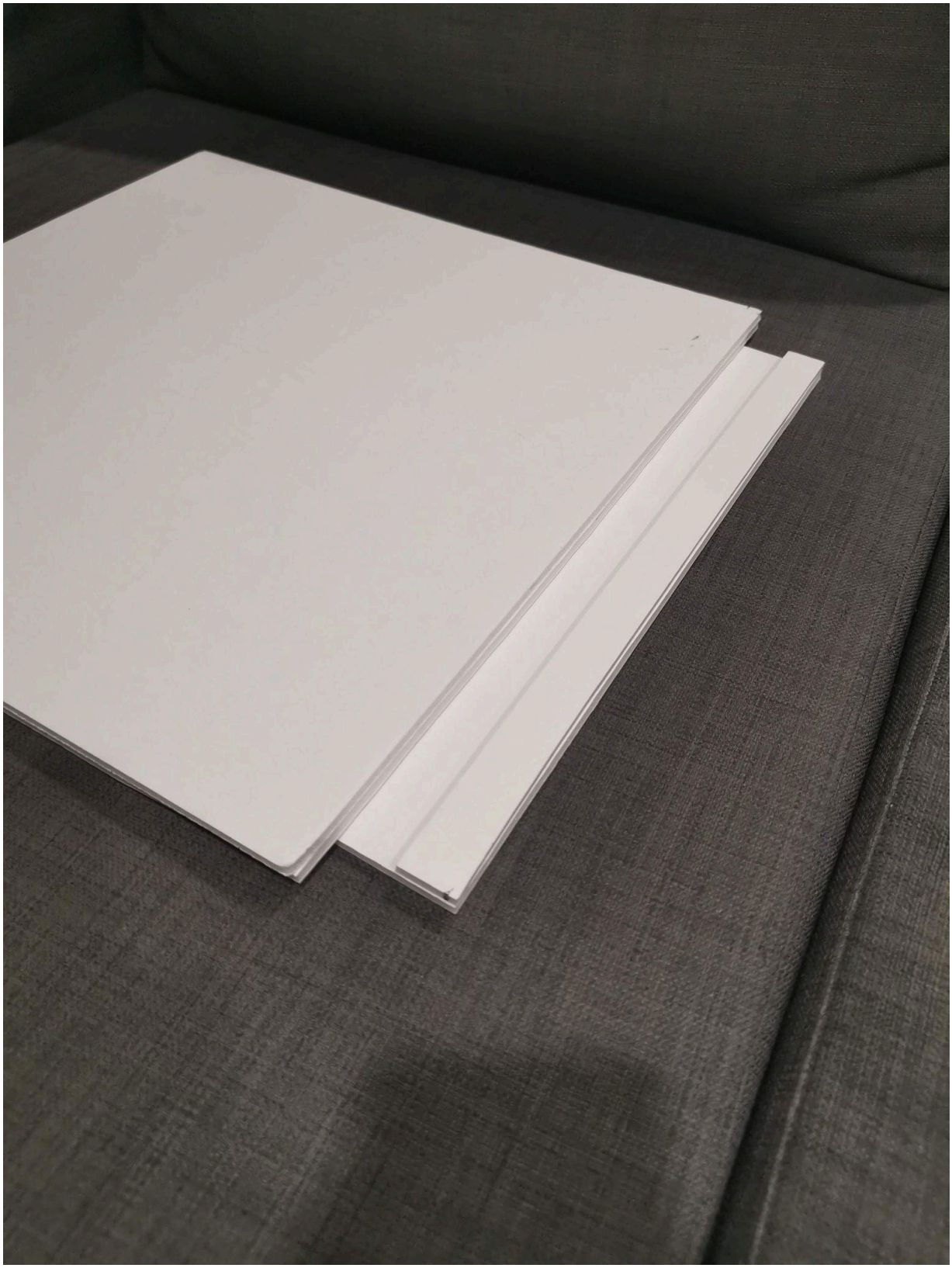


Figure 27 - Sketch Model Floor Panel

Figure 28 - Sketch Model Bridge

How the electronics connected via the bridge was not fully realized until understanding some key layout issues in CAD.

Figure 29 - Controller Connection

Above was a preliminary physical model exploration of the control module electronics, and the leggings made to size.

Figure 30 - Pattern Design 1

Figure 31 - Pattern Design 2

Figure 32 - Human Scale Comparison

4.6 Design Resolution

The resolved design direction had a few new vital directions. The form of the leggings pattern was decided to express motion. Development of the accompanying app was also explored, and how the leggings and floor panels may be represented there.

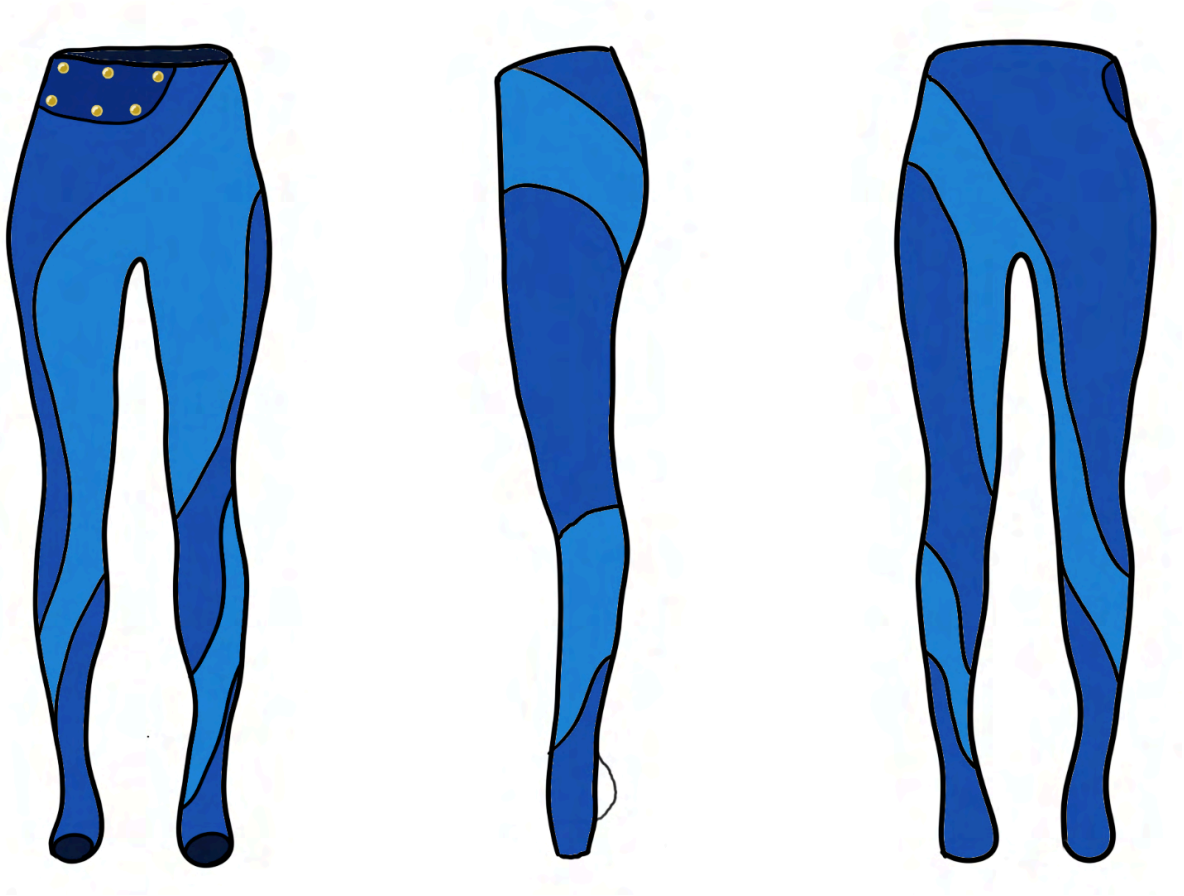


Figure 33 - Legging Finalized Pattern

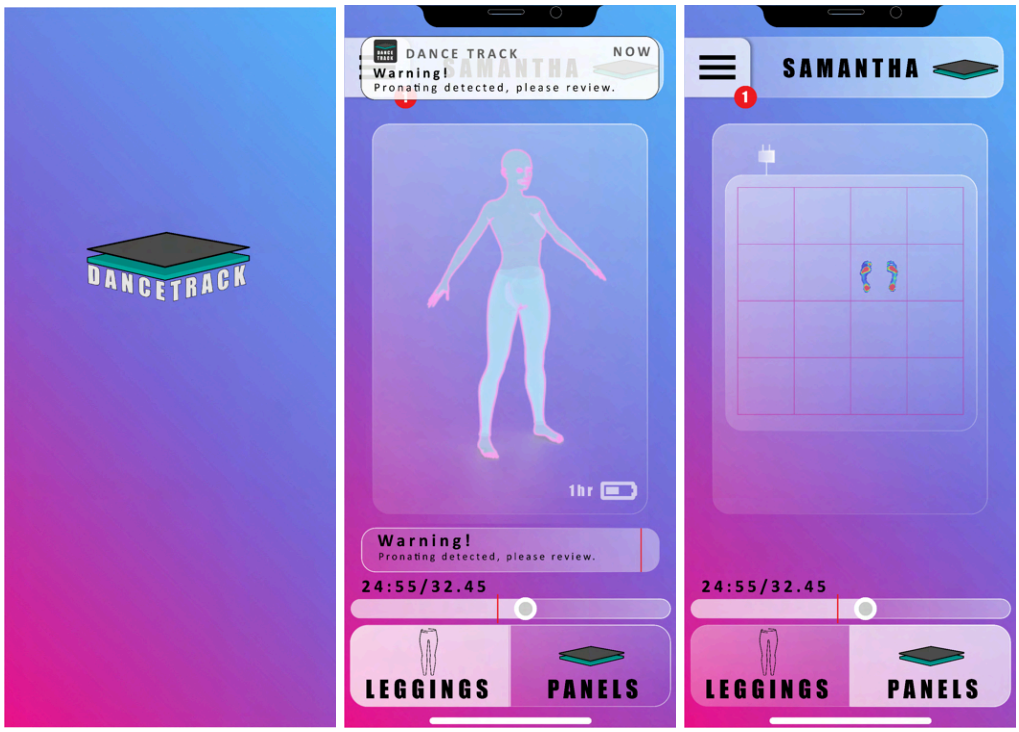


Figure 38 - UX Design Preview

The above slides were the resolved design of the app to accompany the leggings. Glassmorphic design language was used to emphasis the technology focused device. The toggled panel on the bottom let's the dance student dynamically switch between leggings or floor panel view. The timeline scrubber can be used to either see a live view (all the way to the right) or rewind to review a movement. Pop ups provide indicators of where in the timeline an issue was recognized. In the burger menu the user can export and send all their routines to dancers or physical therapists.

4.7 CAD Development

The design in CAD software started off as standardised leggings that were more easily modelled. From here, the approach was to carve out shapes and other details necessary. The software used was CLO3D.

Figure 34 - Initial CAD 1

Figure 35 - Initial CAD 2

Figure 36 - Pouch CAD

The floor panels were modelled using Fusion360. This environment has a much more adaptive assembly environment that was helpful for experimenting with different edge piece designs.

Figure 37 - Floor Panel CAD

Chapter 5 - Final Design

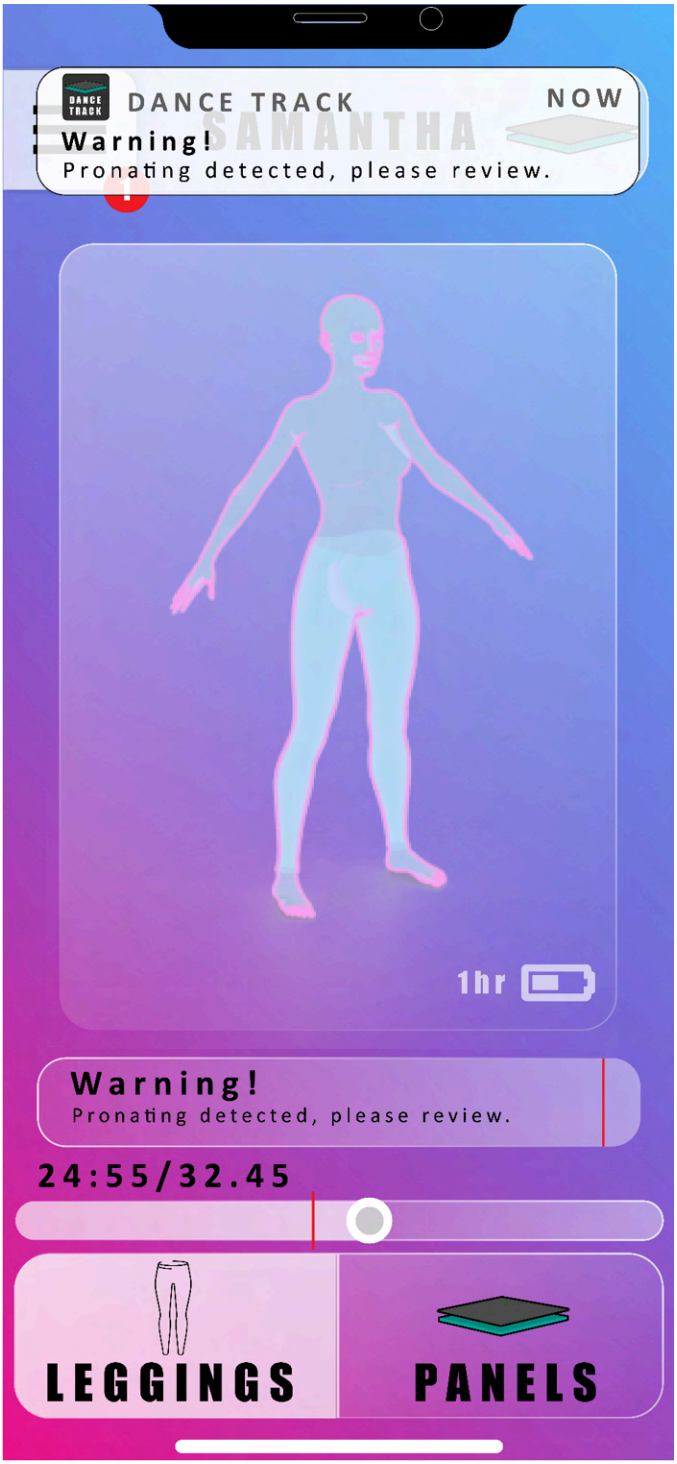


Figure 38 - UX Design Preview

5.1 Summary

The final design allows dancers and dance teachers to create an easy-to-monitor and review environment. This benefits the student and teacher, as, during a given class period, it is unrealistic for the teacher to be able to provide assistance and survey every student present thoroughly. It also gives teachers and students a way to show physical therapists existing issues and, from there, come up with a plan to facilitate recovery or rectify the issue before the injury is caused.

The leggings track all lower-body positional movements and record the data to the app. The floor panels record all weight distribution and foot placement. In tandem, visualised models can be displayed to the user, which will be helpful for learning and practising dance while also significantly improving safety.

5.2 Design Criteria Met

This section details the design criteria of the thesis project. The criteria are answered with an explanation of what full-bodied ergonomics were used, why, and how it was implemented.

5.2.1 Full Bodied Interaction Design

The full-bodied interaction requirement is met by surrounding the user's feet, legs and waist. This was necessary to allow the sensors in the leggings to stretch. A low-cost mocap solution is created by covering the majority of the lower body. Additionally, the pattern on the leggings gives a sense of movement and energy to the user. The detachable electronics pouch is another factor that was mapped out ergonomically. On the hip where the electronics can be placed, it is least likely for the dancer to roll on this area, but it is still functionally accessible for controls and removal.

An example of why the foot wraps of the design are important is the situation where the dance student raises their leg above a certain height. Given that the pull on the fabric may simply pull the leggings up, the sensors would not be able to function properly.

Figure 39 - Final Design No Pouch

The floor panels are sized to create an adequate dance space for users with a 4x4 grid. At 18” a panel, this creates a 36 square foot space. Although a dancer will likely want more than this amount, this is a quantity that a starting amount could start at and be expanded. The space it creates is visibly discreet and otherwise creates an environment similar to a dance studio. The ability to change the form and size of the layout lets the product fit into many rooms and could potentially allow dance students to learn from home. The recorded data could be sent to and reviewed by the dance teacher at a later date, or during the practice.

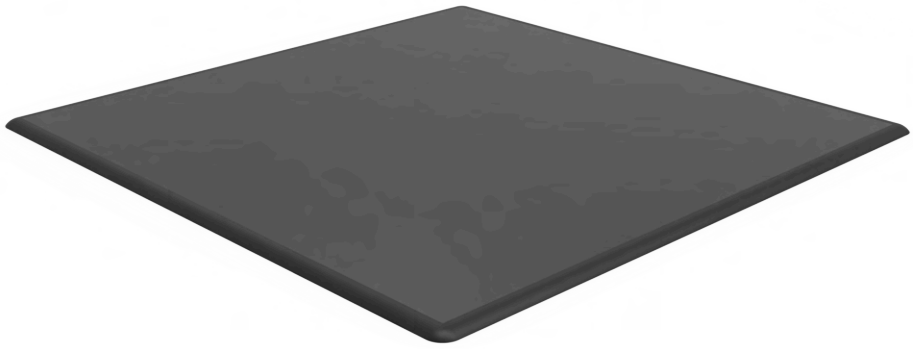


Figure 40 - Final Floor Panel Assembled

5.2.2 Materials, Process and Technology

A variety of methods are used to create the various components of the products. Although a discussion was held with a company about the mesh sensor panel, the methods it is produced are unable to be written in this report. Below the different methods of manufacturing methods are listed as well as the materials involved in the fabrication of the two products.

Laser Cutting	Rubber Base Layer, Plywood Layer Bridge connector,
FR4 PCB Fabrication	Main electronics section, Controller
Injection Molding	Polycarbonate Edge Pieces
Sewing	Leggings, Electronics pouch covering

Table 18 - Manufacturing Methods

Lithium-Ion Battery	Battery for legging control pouch
Recycled Polyester	Leggings and control pouch cover
Marley Surface	Floor panel surface layer
Plywood	Floor panel midsection
Conductive Rubber strips	Legging stretch sensors
Cork Rubber compound	Baselayer preventing slippage of panels
Mesh Sensor Layer	Undisclosed

Table 19 - Materials

5.2.3 Design Implementation

Some things worth noting in the following BOM is the high cost of the mesh sensor layer. Currently, the product is costly on the market. However, as this product gains attention and implementation across more industries, the price should drop substantially. Specific details of the circuit boards, such as the resistors and capacitors, are not currently noted, which is difficult to assess. Their cost would be a fraction of the other components' costs.

Bill of Materials

The costs of some of the components are dependent on scale, and although some of the parts can be estimated on a scaled production, the mesh sensor layer cannot be estimated at this time. Details regarding the fabrication cost, and the scalability have not been fully disclosed. They are expected to be affordable for use in consumer electronics reasonably soon.

Concept Item	**Description**	**Estimated Cost**	**QTY**	**Material**
Marley Flooring	Non-skid matte finish vinyl flooring	$12	16	Matlay Vinyl
Plywood Section Layer	Good combination of flexibility and sturdiness for floor panel midpiece	$10	16	Plywood
Cork Rubber Base Layer	Anti-slip base layer to keep panels in place	$10	16	Recycled Cork rubber compound
Recycled Polyester Blend	Material for leggings sourced from ocean debris or bottles	$35	1	Recycled Polyester

Rubber Stretch Sensors	Conductive Rubber	$5	8	Conductive Rubber
Control Module Circuit Board	Microcontroller for leggings	$50	1	FR4, Silicone
Circuit Layer	Floor panel connections	$100	16	FR4, Silicone
Mesh Sensor Layer	Layer of the floor panel that measures weight distribution and position	$600 ($50 @ scale)	16	
Total Cost		$2522 @ scale		

Table 20 - Bill of Materials

$2522 sounds like a high cost for a dance education device for a student to buy, however there are other factors to consider here. A dancer may not have to buy floor panels, and need only the leggings. Under this circumstance the cost incurred by the student it only about $250 at retail price. Compared to the cost of a mocap suit and the devices necessary to utilize that system this is affordable.

5.3 Final CAD Rendering

Figure 41 - Final Render with Pouch

Figure 39 - Final Design No Pouch

5.5 Technical Drawings

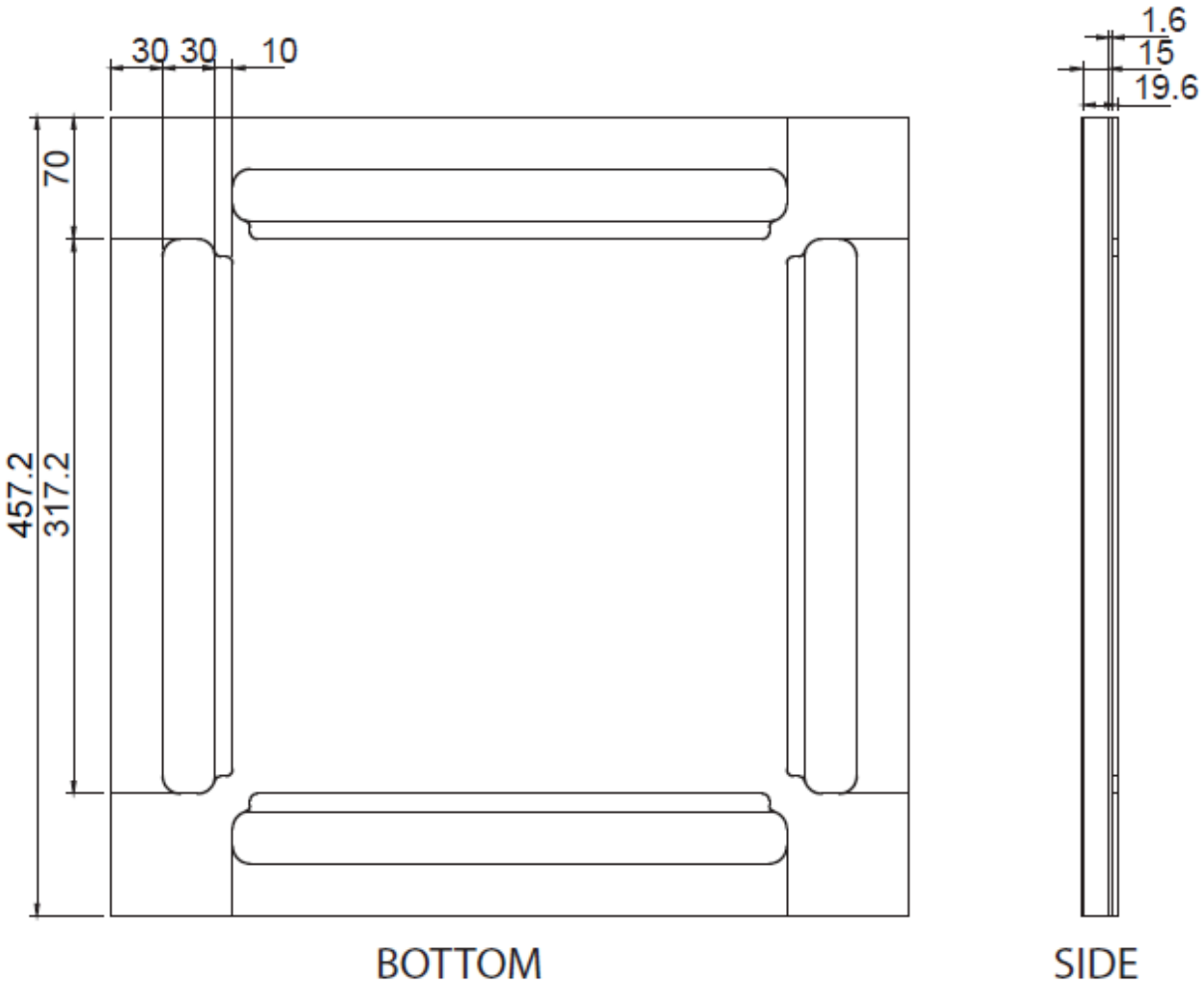


Figure 42 - Floor Panel Technical Drawing 1

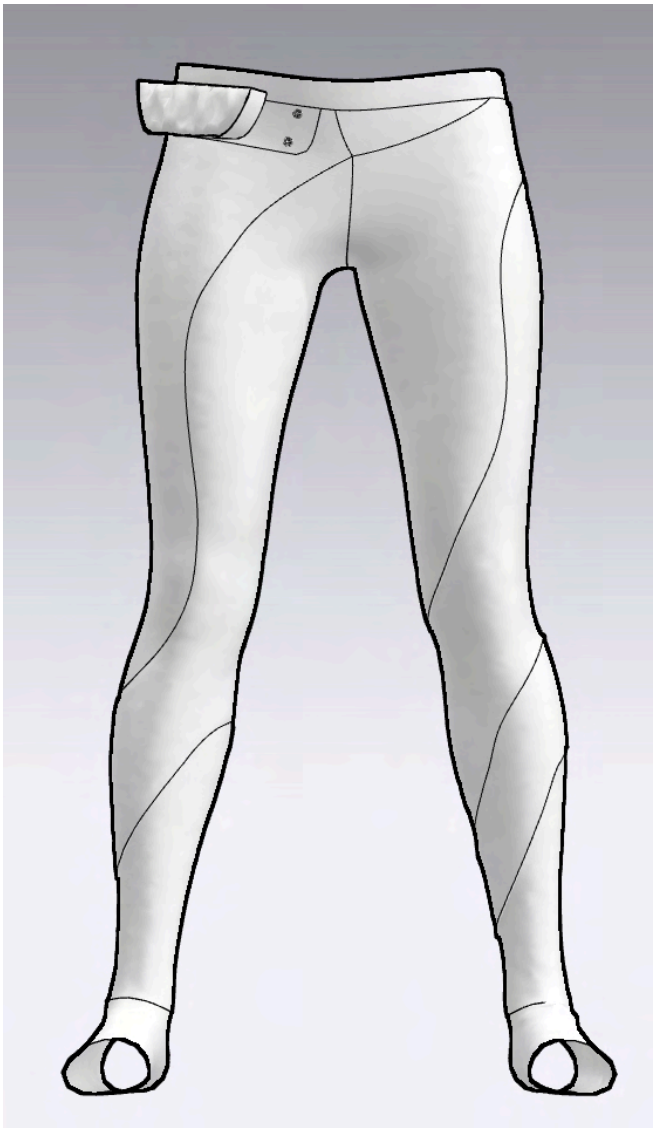


Figure 43 - Leggings Technical Drawing 2

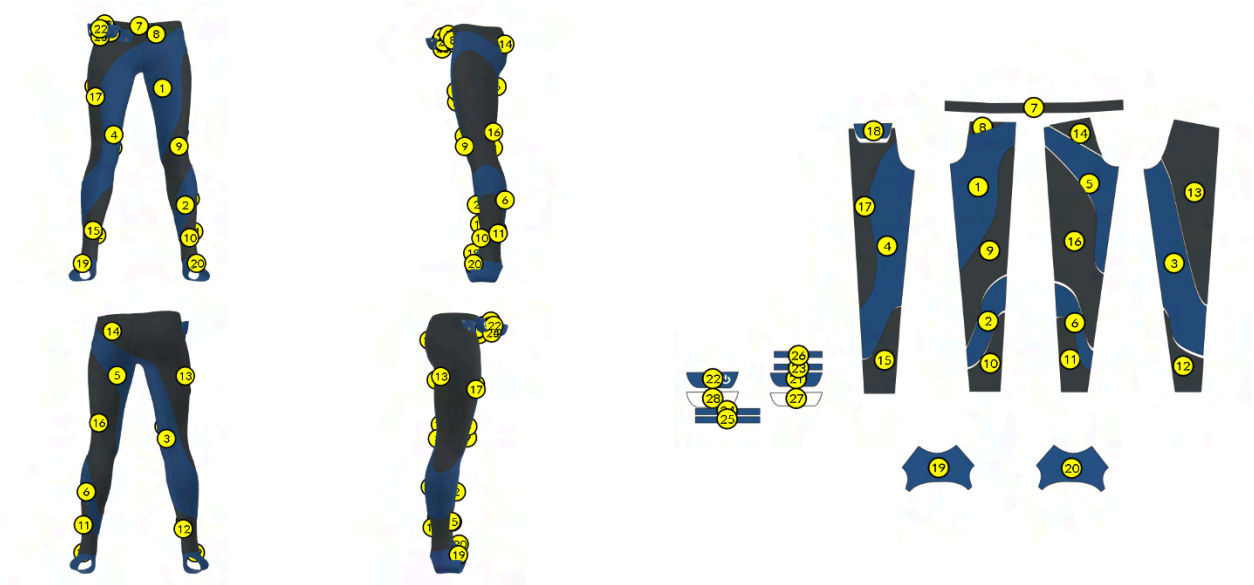


Figure 44 - Cutters Must

The cutters must provide pattern and assembly information to the seamstress. This template provides information such as material quantity, size, position and stitching type.

Dimensions of modelled leggings are based on the 90th Percentile female.

	XS 35th Percentile	S 50th Percentile	M 70th Percentile	L 90th Percentile
WAIST CIR.	24-26″	27″-29″	29″-31″	31″-33″
HIP CIR.	32-34″	34″-36″	36″-38″	38″-40″
INSEAM	28″	29″	29″	30″

Table 16 - Size Chart

5.6 Sustainability

The leggings are manufactured using recycled polyester. These materials can be ethically sourced and aid ocean clean up projects. One pair of leggings may use between 20 and 30 plastic bottles. There are several companies today which already pursue these alternative green materials for their clothing, but none have been directly targetted towards dancers. The effectiveness of the breathability of the material has been proven by athletes.

Dance flooring can be quite wasteful, as it's assembled in large rolls, which the entirety of has to be discarded if damaged. This product reduces waste caused by damaged dance flooring by creating a modular floor system. Additionally, the base of the floor panel uses a recycled cork-rubber compound material which is extremely durable and offers a controlled amount of bounce to the panels.

Most modern dance supplies don’t have very accountable materials. The majority of dance safety products use foams that are unsafe for the environment, or just simply use standard cloth material, which while not harmful is neither innovative for the space.

Chapter 6 - Conclusion

With the growing competitive atmosphere of dance, it is important that dance education receives the same amount of care and preventative practice towards injury that other sports receive. Lack of innovation in this field has not only held back dancers, but also the entertainment industry as a whole. There are many other suitable applications for augmented dance equipment to show value.

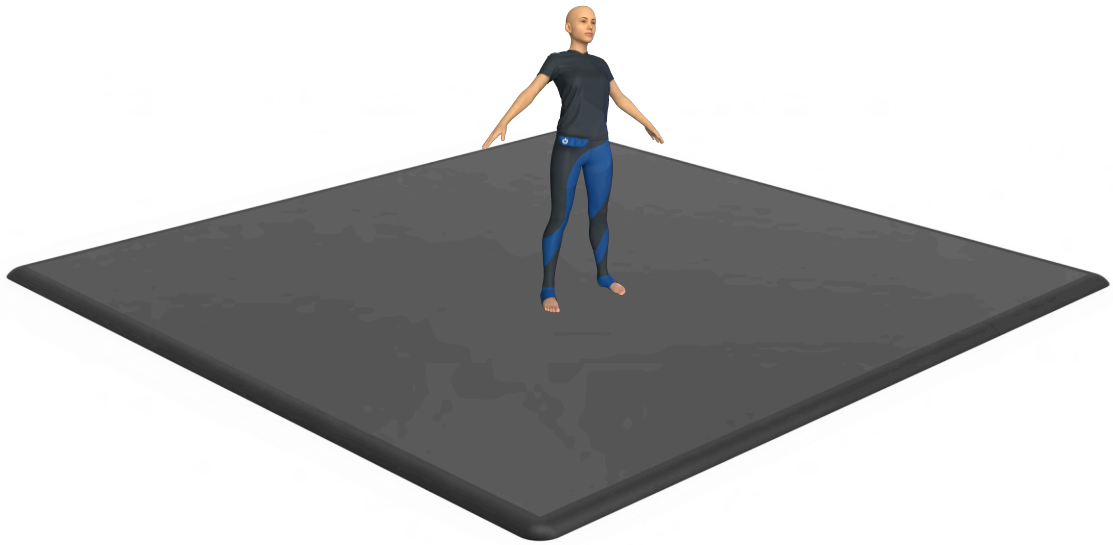


Figure 45 - Floor Panel with Dancer

Dancer within the designated dance space provided by the floor panel in the figure above. The Augment Dance Education system creates a complete solution that allows for clear transparent communication through the three categories of user groups.

Figure 46 - Leggings no avatar

References

Adidas loungewear essentials high-waisted logo leggings - black. adidas Canada. (n.d.). Retrieved April 19, 2022, from https://www.adidas.ca/en/loungewear-essentials-high-waisted-logo-leggings/GL0633.html

Barelds, I., van den Broek, A.G. & Huisstede, B.M.A. Ankle Bracing is Effective for Primary and Secondary Prevention of Acute Ankle Injuries in Athletes: A Systematic Review and Meta-Analyses. Sports Med 48, 2775–2784 (2018). https://doi-org.ezproxy.humber.ca/10.1007/s40279-018-0993-2

Brownell, L. (2020, July 15). *Soft and stretchy fabric-based sensors for Wearable Robots*. Wyss Institute. Retrieved April 19, 2022, from https://wyss.harvard.edu/news/soft-and-stretchy-fabric-based-sensors-for-wearable-robots/

Capezio Women's Rockit Dancesneaker, black, 9.5 b-medium : Amazon.ca: Clothing, Shoes & Accessories. Capezio Women's Rockit Dancesneaker, Black, 9.5 B-Medium : Amazon.ca: Clothing, Shoes & Accessories. (n.d.). Retrieved April 19, 2022, from https://www.amazon.ca/Capezio-Womens-Rockit-Dance-Sneaker/dp/B000QJD5ZM/ref=asc_df_B000QJD5ZM/?tag=googleshopc0c-20&linkCode=df0&hvadid=293019916058&hvpos=&hvnetw=g&hvrand=27596273251186477 24&hvpone=&hvptwo=&hvqmt=&hvdev=c&hvdvcmdl=&hvlocint=&hvlocphy=9000984&hvtargid=pla-511488748954&th=1&psc=1

Dance related injuries by the numbers. Nationwide Children's Hospital. (n.d.). Retrieved April 19, 2022, from https://www.nationwidechildrens.org/research/areas-of-research/center-for-injury-research-and-policy/injury-topics/sports-recreation/dance-related-injuries-by-the-numbers

Dancer demographics and statistics in the US - zippia. (n.d.). Retrieved April 19, 2022, from https://www.zippia.com/dancer-jobs/demographics/

Diana P A M van Winden, Rijn, R. M. V., Richardson, A., Savelsbergh, G. J. P., Oudejans, R. R. D., & Stubbe, J. H. (2019, February 1). *Detailed injury epidemiology in contemporary dance: A 1-year prospective study of 134 students*. BMJ Open Sport & Exercise Medicine. Retrieved April 19, 2022, from https://bmjopensem.bmj.com/content/5/1/e000453

Height percentile calculator by gender (United States). DQYDJ. (2020, September 4). Retrieved April 19, 2022, from https://dqydj.com/height-percentile-calculator-for-men-and-women/

Henry Dreyfuss Associates. (2019, March 16). *The measure of man and woman human factors in design*. Ephemeralopulence Free Read Ebook. Retrieved April 19, 2022, from

https://ephemeralopulence.blogspot.com/2019/03/the-measure-of-man-and-woman-human.html

ketc9, N. P. B. S. (2013, April 16). *Dancer injury | living St. Louis*. YouTube. Retrieved April 19, 2022, from https://www.youtube.com/watch?v=WIfiy5aZ__Y

Klassen, B. (n.d.). YouTube. Retrieved April 19, 2022, from https://www.youtube.com/?gl=ES

Meet the Millers. (2021, January 12). *She's hurt. dislocated knee cap at dance. | meet the millers family vlogs*. YouTube. Retrieved April 19, 2022, from https://www.youtube.com/watch?v=CQFq9gy6ORM

MissAuti, T. and M. T. V. (2021, July 7). *How dancers can prevent injury- advice from a dance medicine specialist!* YouTube. Retrieved April 19, 2022, from https://www.youtube.com/watch?v=96xEhOx6pJQ

Russell, J. A. (2013, September 30). *Preventing dance injuries: Current perspectives*. Open access journal of sports medicine. Retrieved April 19, 2022, from https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3871955/

T101 treadmill. Horizon T101 Treadmill | 2021 Best Buy | Horizon Fitness. (n.d.). Retrieved April 19, 2022, from https://www.horizonfitness.com/horizon-t101-treadmill?irclickid=x8BzQBTcZxyIUte3ydQLk08EUkGXmByeXy2I0o0&irgwc=1&utm_source=impact&utm_medium=1201867&utm_campaign=Online+Tracking+Link&utm_term=&utm_content=Forbes+Media

twinstalkballet93, T. C. D. (2017, October 28). *Top tips for injury prevention! - twintalksballet*. YouTube. Retrieved April 19, 2022, from https://www.youtube.com/watch?v=zRh9c3F2PZ4

twinstalkballet93, T. C. D. (2021, September 30). *Two former pro ballet dancers share what they wish they knew about training earlier*. YouTube. Retrieved April 19, 2022, from https://www.youtube.com/watch?v=0ZMmuOWuXXY

Appendix

A - Discovery

An article was initially sourced to further define issues that occur to dancers.

Search engine: Google

Keywords Used In Search: Dance Injury Review

Findings:

van Winden DPAM, Van Rijn RM, Richardson A*, et al*Detailed injury epidemiology in contemporary dance: a 1-year prospective study of 134 students*BMJ Open Sport & Exercise Medicine* 2019;**5:**e000453. doi: 10.1136/bmjsem-2018-000453

Summary Statements:

1. 97% of students reported an injury in their first year
2. 58% suffered substantial injuries
3. Ankle and foot made up 30% of injuries
4. Knee was 15% of injuries
5. Lower back was 17% of injuries
6. Injury prevention programmes are suggested to focus on the ankle, foot, lower back and knee

B - Conceptual Research - User

User Profile

Primary User	Dance Student
Secondary User	Dance Teacher
Tertiary User	Physical Therapist, Parents of Student

Findings:

Gender	Female 73.4%
Age	29.8 Average Age
Professional Training Age Range	14 - 17
Ethnicity	49.8% White
Starting Salary	$28,000 for professional, unpaid for student
Dance Instructor Average Salary	$48,750
Lesson Frequency	Twice a week
Locations of Practice	Dance Studio, Home, Gym

Demographics

Dance students that are most susceptible to physical change, and permanent damage that can have later effects in life are between the ages of 14 - 17. These students are typically unpaid and are paying a studio for the education, though some may become professional in this age range.

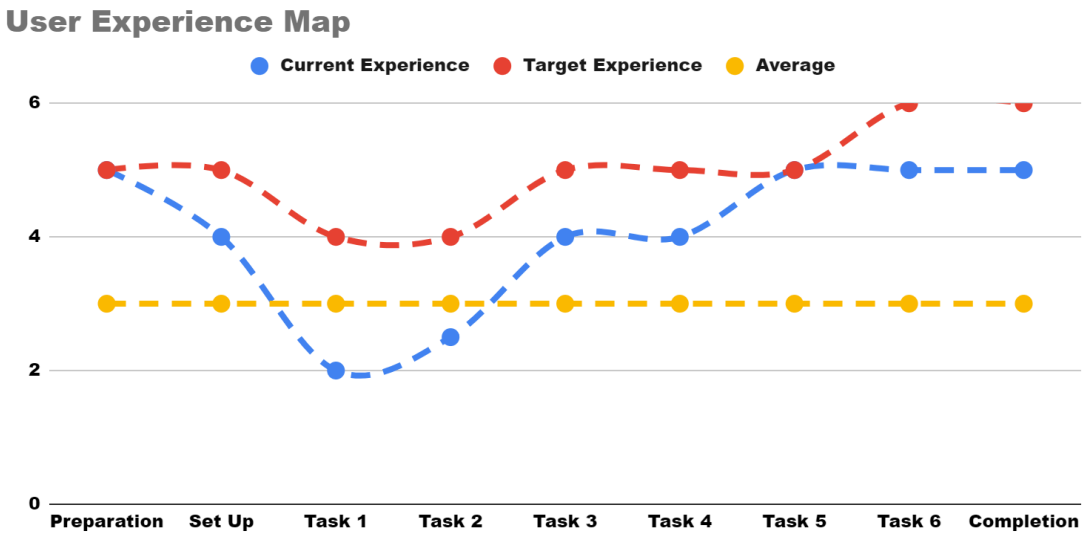
User Behaviour

Dance students tend to have 1-2 classes a week. There may be more if the dancers study more than one type of dance, such as ballet and contemporary.

This study focused on data from contemporary dance. However, from interviews, it was suggested that ballet act as the starting point for dancers. One cause of injury for many dancers was the lack of foundational knowledge of ballet.

User Experience Map of a Dancer

Created from interview data provided by Jacqueline Morrow



C - Field Research (Product)

<table>
<tr><td rowspan="2">  </td><td colspan="2">Horizon T101 Treadmill</td></tr>
<tr><td colspan="2">Description:

Hit the ground running with intuitive controls for no-nonsense workouts. Intuitive controls for no-nonsense workouts. Bluetooth speakers and a secure device holder let you work out with your fitness classes, music and entertainment. Ultra-quiet 2.5 CHP motor recalibrates with every footfall with no lags or surges. 55” deck with shock-absorbing 3-zone cushioning supports walking, jogging or running.
Specifications:

• Bluetooth connects to your device to stream media through integrated speakers
• Includes device holder and rapid-charge USB port
• Set-up in 30 minutes or fewer
• Quickly shift speed and incline with one-touch keys
• Durable, 2.5 CHP motor runs at lower RPMs to minimize noise and increase efficiency
• 55" 3-Zone cushioned deck supports runners, joggers and walkers alike
• Effortlessly store between workouts with a one-step hydraulic folding
•Lifetime frame and motor warranty</td></tr>
<tr><td>Benefit</td><td>Example of Benefits</td><td>Example of Features</td></tr>
<tr><td rowspan="2">Reduces
Pain Points</td><td>Reduces strain</td><td>55" Cushioned Deck</td></tr>
<tr><td>Quiet & Efficient</td><td>2.5 CHP motor runs at lower RPMs</td></tr>
<tr><td rowspan="2">Enhances
User Experience</td><td>Entertaining</td><td>Bluetooth</td></tr>
<tr><td>Convenient</td><td>Device Holder + Charger</td></tr>
<tr><td>URL Link</td><td colspan="2">https://www.horizonfitness.com/horizon-t101-treadmill?irclickid=x8BzQBTcZxyIUte3ydQLk08EUkGXmByeXy2I0o0&irgwc=1&utm_source=impact&utm_medium=1201867&utm_campaign=Online%20Tracking%20Link&utm_term=&utm_content=Forbes%20Media</td></tr>
</table>

	Capezio Womens Dance Sneaker ● Split-sole design, Non-marking PU outsole with built-in patented flex points and forepart spin spot, and Flat, boxed toe for toe stands ● Combination PU Nubuck and imitation suede upper combined with breathable SBR nylex mesh ● Perforated arch for ventilation, Padded tongue, collar and Achilles notch, and Contoured, cushioned, removable EVA footbed ● Polyester cotton laces with sport lace system ● Women: Begin 1 size up from street shoe size. Men: Begin 2 sizes up from street shoe size.	
Benefit	Example of Benefits	Example of Features
Reduces Pain Points	Breathable	Mesh and Suede
	Durable for dance movements	Flexible midsection
Enhances User Experience	Comfortable	Padded
	Easy to keep fresh	Quick drying
URL Link	https://www.amazon.ca/Capezio-Womens-Rockit-Dance-Sneaker/dp/B000QJD5ZM/ref=asc_df_B000QJD5ZM/?tag=googleshopc0c-20&linkCode=df0&hvadid=293019916058&hvpos=&hvnetw=g&hvrand=2759627325118647724&hvpone=&hvptwo=&hvqmt=&hvdev=c&hvdvcmdl=&hvlocint=&hvlocphy=9000984&hvtargid=pla-511488748954&th=1&psc=1	

<table>
<tr><td rowspan="2">  </td><td colspan="2">Ballet Barre Portable for Home or Studio</td></tr>
<tr><td colspan="2">Professional Ballet Barres – This premium double ballet bar for kids and adults is made to help enhance your stretching, balance, form, and movements for a variety of activities including ballet, dance, yoga, Pilates, and more.
Quick Adjustable Height – The innovative design lets you easily raise or lower the dance barre height to better suit any height, age, or ability level. Great for beginners and seasoned athletes, it’s made for reliable support.
Portable, Lightweight Design – Crafted with durable, power-coated steel tubes that feature a classic woodgrain look, this scratch-resistant frame is easy to use in your home, a garage, a professional dance studio, in school, or at the gym.
Wide, Stable Base and Feet – Our dance balance bar features slip-resistant rubber feet to keep it from sliding around on slick studio floors and has a wider base to give you more stability when leaning, stretching, or holding forms.
Curved Legs for Enhanced Stretching – Along with the traditional long bar that can be adjusted to support full-body movements the curved legs can also be used for stretching out muscles or working on a routine.</td></tr>
<tr><td>Benefit</td><td>Example of Benefits</td><td>Example of Features</td></tr>
<tr><td rowspan="3">Reduces
Pain Points
Enhances
User Experience</td><td>Portable</td><td>Lightweight</td></tr>
<tr><td>Stable</td><td>Wide base</td></tr>
<tr><td>Suitable for various heights</td><td>Double Barre</td></tr>
<tr><td>URL Link</td><td colspan="2">https://www.amazon.ca/Artan-Balance-US-Portable-Ballet/dp/B07WQQYZHF/ref=asc_df_B07WQQYZHF/?tag=googleshopc0c-20&linkCode=df0&hvadid=335548781193&hvpos=&hvnetw=g&hvrand=612595769880200859 0&hvpone=&hvptwo=&hvqmt=&hvdev=c&hvdvcmdl=&hvlocint=1002473 &hvlocphy=9000984&hvtargid=pla-830610616555&th=1</td></tr>
</table>

<table>
<tr><td rowspan="2">  </td><td colspan="2">Dance Flooring</td></tr>
<tr><td colspan="2">Various options
- Marley flooring, a matte vinyl surface
- Hardwood with springflex subfloor</td></tr>
<tr><td>Benefit</td><td>Example of Benefits</td><td>Example of Features</td></tr>
<tr><td rowspan="4">Reduces
Pain Points
Enhances
User Experience</td><td>Prevents slipping</td><td>Matte surface</td></tr>
<tr><td>Aids with bounce</td><td>springflex</td></tr>
<tr><td></td><td></td></tr>
<tr><td></td><td></td></tr>
<tr><td>URL Link</td><td colspan="2">https://danceequipmentintl.com/sprung-dance-floor-guide/</td></tr>
</table>

<table>
<tr><td rowspan="2">  </td><td colspan="2">Capezio Womens Dance Sneaker</td></tr>
<tr><td colspan="2">Provides adjustable support suitable for sprains and mild swelling from overworked muscles. It features a shorter style that is more suitable for all ages when compared to our other braces. It contains 70% neoprene for its heat-retaining benefits and 20% nylon for added stretch and sweat-wicking components.
Extremely flexible and moves with your body as it progresses through the healing process, providing support and stability. The use of rigid, hard-shell braces when it’s not required can cause further damage to your injury by preventing movement altogether.
Personalized compression with three3 adjustable straps that can fit feet of all sizes. The instep and heel remain open to promote comfortable movement without bunching or pinching. The brace is perforated to allow your skin to breathe while maintaining muscle warmth.
Compression helps to relieve pain and swelling in acute or chronic conditions! It helps promote your body’s natural healing process through increased blood flow & oxygen transfer and by maintaining muscle warmth which all contribute to healthy healing.
One size fits most! With adjustable straps, personalize your fit according to your needs. Brace fits either foot and is suitable for all ages.</td></tr>
<tr><td>Benefit</td><td>Example of Benefits</td><td>Example of Features</td></tr>
<tr><td rowspan="4">Reduces
Pain Points
Enhances
User Experience</td><td>Allows skin to breathe</td><td>Perforate Brace</td></tr>
<tr><td>One size fits most</td><td>Adjustable straps</td></tr>
<tr><td>Heat retentive</td><td>70% neoprene</td></tr>
<tr><td>Moisture wicking</td><td>20% nylon</td></tr>
<tr><td>URL Link</td><td colspan="2">https://www.amazon.ca/Support-Breathable-Neoprene-Sleeve-Adjustable/dp/B01LXAGV0H/ref=asc_df_B01LXAGV0H/?tag=googleshopc0c-20&linkCode=df0&hvadid=293032423357&hvpos=&hvnetw=g&hvrand=1673552241359900606&hvpone=&hvptwo=&hvqmt=&hvdev=c&hvdvcmdl=&hvlocint=&hvlocphy=9000984&hvtargid=pla-492612591263&psc=1</td></tr>
</table>

<table>
<tr><td rowspan="2">  </td><td colspan="2">Capezio Womens Dance Sneaker</td></tr>
<tr><td colspan="2">DURABLE &THICK FOAM PADDING: Exclusive thick tri-density padding provides maximum support and comfort. Hold poses longer with greater stability. Material will not crumble and always lay flat.
TRI-FOLDED GYM MAT: With closed cell foam, multifunctional, non-slip and sanitized - Ideal for yoga, pilates, stretching and rehab.
LIGHTWEIGHT & PORTABLE: Take this mat with you on the go. It easily folds to fit into compact spaces for easy transport and is super lightweight making it easy to carry around, whether to travel or to the gym.
COMFORTABLE: PU Leather Cover is soft and sweat-resistant, Non-slip, Non-toxic, easy to clean, and provides excellent, safer support for planking, calisthenics, and even as a play mat for kids.
Expanded dimension: 70" x 24" x 2" (5cm Thick). Folded dimensions: 24" x 24" x 6". Weight: 5 lbs.</td></tr>
<tr><td>Benefit</td><td>Example of Benefits</td><td>Example of Features</td></tr>
<tr><td rowspan="4">Reduces
Pain Points
Enhances
User Experience</td><td>Pads falls</td><td>Thick Foam</td></tr>
<tr><td>Easily stored</td><td>Tri-fold</td></tr>
<tr><td>Helpful for transport</td><td>Straps</td></tr>
<tr><td>Foam is resistant to crumpling</td><td>Durable Foam</td></tr>
<tr><td>URL Link</td><td colspan="2">https://www.shopperplus.ca/p-359184-gza-00569-gym-mat-fitness-mat-for-gymnastics-yoga-aerobics-martial-arts-lightweight-tumbling-mats-phat?from_pla=google&sku=384678&gclid=CjwKCAjwu_mSBhAYEiwA5BBmfy-dBQc-dkmdfkJsBj7XJ4rBUtsxmHi13Puc2-1iqb9n3b09a7QbAxoCL-MQAvD_BwE#sku384678</td></tr>
</table>

D - Result Analysis

Statement of Need

Dance education is an athletically intensive activity that requires a significant amount of **communication**, **understanding,** and **attention** to help prevent injuries. Most dance equipment or common materials and tools do not provide these needs.

To some users, dance is a **recreational activity**, that may be pursued **leisurely**. The incompatibility of user goals in a dance space can cause dance instructors to misplace or push students pass points which they feel **comfortable**. This is a cause of many injuries.

Specific Needs:

- Feeling confident and safe
- Communication between user groups
- Understanding the users own ability
- Paying attention to environment
- Knowing the different user goals

G - Technical Drawings

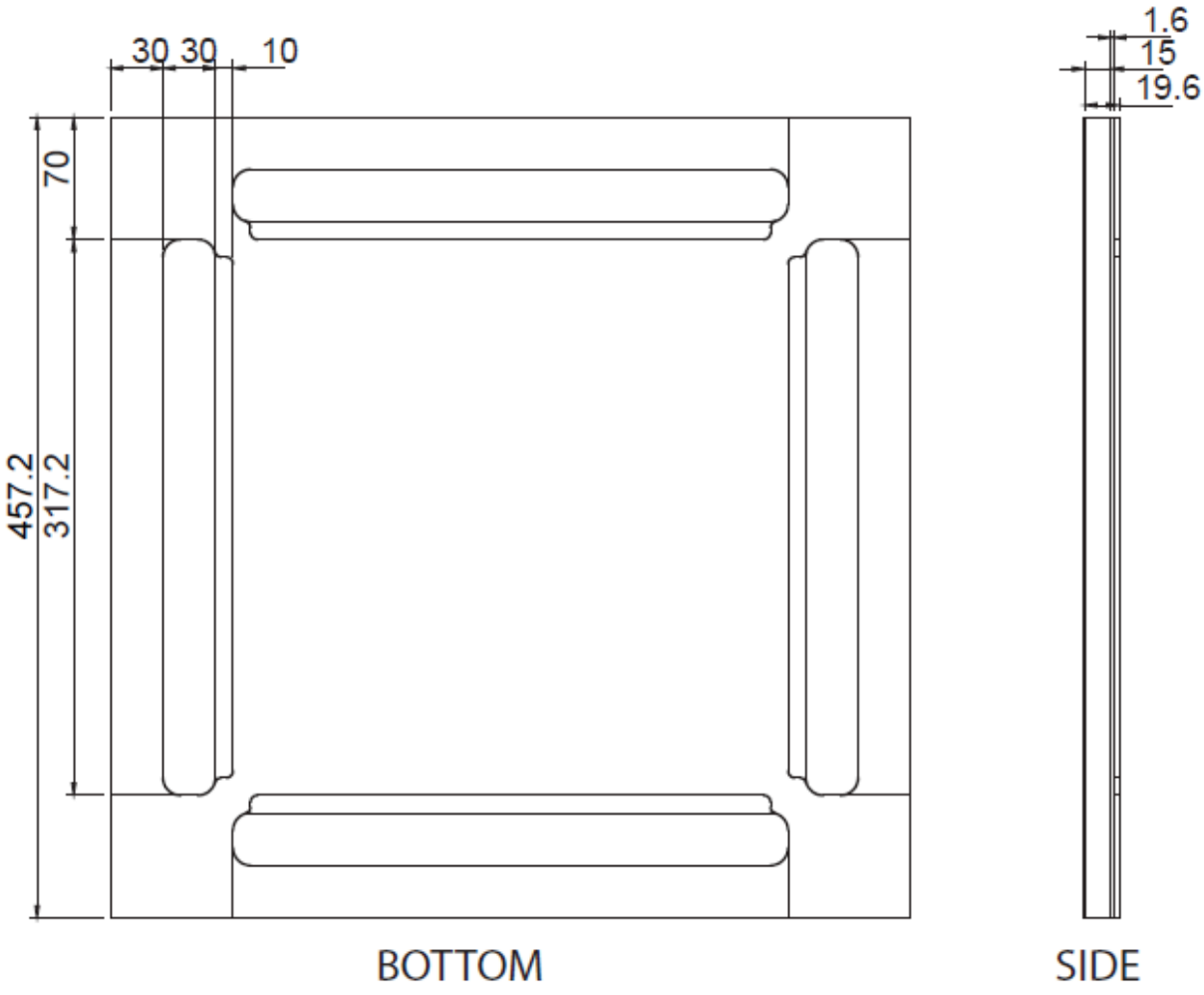


Figure 42 - Floor Panel Technical Drawing 1

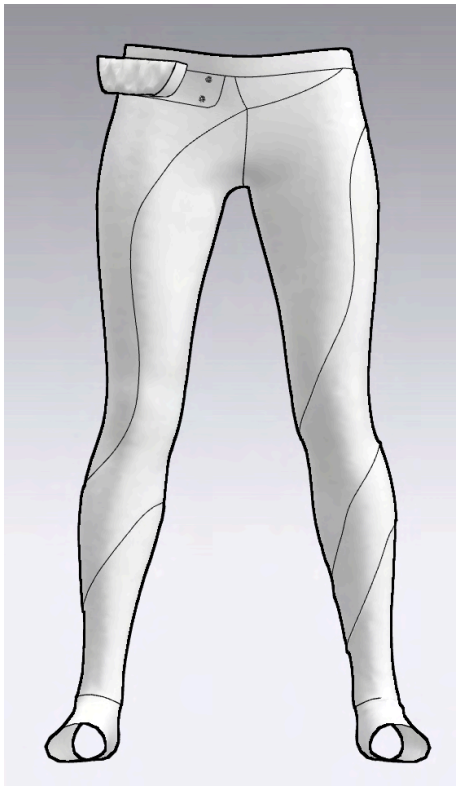


Figure 43 - Leggings Technical Drawing 2

Figure 44 - Leggings Cutouts

Figure 46 - Leggings No Avatar

H - Bill of Materials

Concept Item	Description	Estimated Cost	QTY	Material
Marley Flooring	Non-skid matte finish vinyl flooring	$12	16	Matlay Vinyl
Plywood Section Layer	Good combination of flexibility and sturdiness for floor panel midpiece	$10	16	Plywood
Cork Rubber Base Layer	Anti-slip base layer to keep panels in place	$10	16	Recycled Cork rubber compound
Recycled Polyester Blend	Material for leggings sourced from ocean debris or bottles	$35	1	Recycled Polyester
Rubber Stretch Sensors	Conductive Rubber	$5	8	Conductive Rubber
Control Module Circuit Board	Microcontroller for leggings	$50	1	FR4, Silicone
Circuit Layer	Floor panel connections	$100	16	FR4, Silicone
Mesh Sensor Layer	Layer of the floor panel that measures weight distribution and position	$600 ($50 @ scale)	16	
Total Cost		$2522 @ scale		

Table 20 - Bill of Materials

I - Sustainability Info

Benchmarking Materials

Legging Materials

- Recycled Polyester
    - A clean alternative with equal properties to existing alternatives
- Conductive Rubber Strip
    - The component that has its electrical resistance measured, resistance value infers the position of the component
- Snap Fasteners
    - Simple metal snap fasteners

Control Module Materials

- Lithium-ion battery 2100mAh
    - Provides power to the control module
    - Is rechargeable for multiple uses
    - Easily replaceable
- Recycled Polyester
    - Same as leggings

Floor Panel Materials

- MDF main layer
- Cork Rubber Compound Layer
- FR4 Circuit Layer
- Marley Flooring cover
- Mesh sensor layer

Edge Pieces

- Injection molded polycarbonate

J - Approval Forms and Plans

IDSN 4002
SENIOR LEVEL THESIS ONE

Humber ITAL / Faculty of Applied Sciences & Technology
Bachelor of Industrial Design / FALL 2021
Catherine Chong / Sandro Zaccolo

FTA-2 (B) THESIS TOPIC APPROVAL (TEMPLATE EXAMPLE)
This project/assignment constitutes 5% of total mark for the course

THESIS TOPIC APPROVAL (TOPIC DESCRIPTIVE SUMMARY):

Student Name:	Tiam Bennett Morrow-Rogers
Topic Title:	How may we prevent primary injury for contemporary dancers?

Abstract

Dance injuries are often overlooked compared to other similar sports injuries. Although there is a lot of similarity in the therapy of these injuries, the prevention is often neglected. Primary injuries can cascade into long term pain and even disability. How may we prevent primary injury for contemporary dancers? Current aids for dancers to reduce joint strain often require significant space, or complete re-installation of flooring in their home. Alternative solutions such as resistance bands for strength training, or ankle braces are very accessible, however they aren't a full solution. Resistance bands only give physical strengthening, and only in a linear motion. Braces prevent hyper mobile users from over extending, however they cannot be used on stage, and dependency on them could result in issues when it comes to a big performance. An ideal solution should not promote dependency, but rather give the user freedom to confidently perform. One major cause of injury is poor confidence. This thesis looks to do a detailed study at the ergonomics and injuries of dancers in their first years of study. Data will be collected by observation, interviews and surveys. Research into primary injury prevention is relatively minimal and analysis from findings in this thesis would be very helpful to this field. The feasibility of the design can be user tested with a 1:1 scale model. The solution will improve dancers lifestyles and mitigate long term health effects caused by injury.

Student Signature(s):		**Instructor Signature(s):**	
Tiam		Catherine Chong Sandro Zaccolo	
Date:	27/09/2021	**Date:**	01 October 2021

IDSN 4502
SENIOR LEVEL THESIS TWO

Humber ITAL / Faculty of Applied Sciences & Technology
Bachelor of Industrial Design / WINTER 2022
Catherine Chong / Sandro Zaccolo

CRITICAL MILESTONES: APPROVAL FOR CAD DEVELOPMENT & MODEL FABRICATION

Student Name:	Tiam / Morrow-Rogers
Topic / Thesis Title:	**AUGMENTED DANCE EDUCATION TO REDUCE INJURY**

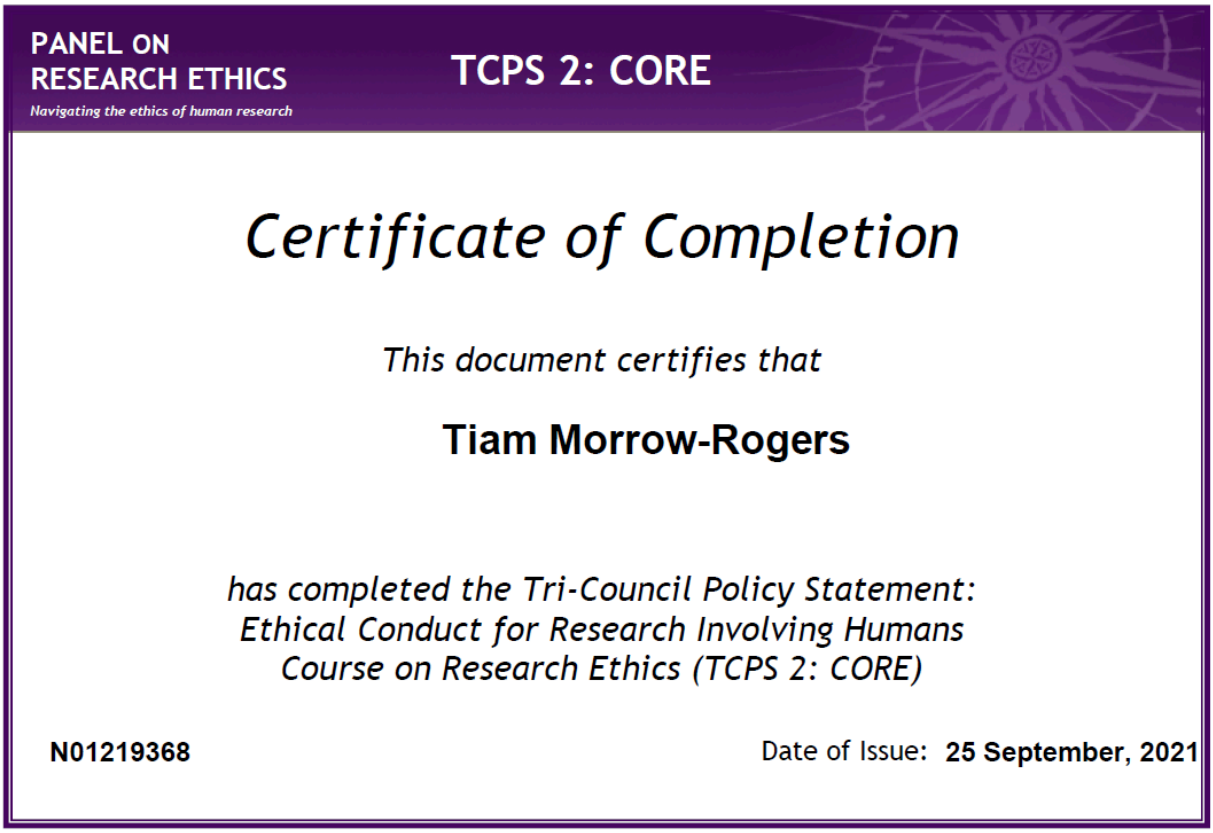
THESIS PROJECT – DESIGN APPROVAL FORM

Design is reviewed and approved to proceed for the following:	X	**CAD Design and Development Phase**
Comment:	- Initial CAD started reasonably as of week #6/February 15th, continue with detailing and refinement. - No review in week #7 and week #8, unsure about development progress - as of week #8/March 8th. - Advised completion latest by week #9 (March 17th). - CAD completion in week #11.	

Design is reviewed and approved to proceed for the following:	X	**Model Fabrication Including Rapid Prototyping / 3D Printing and Model Building Phase**
Comment:	- Cannot approve of model fabrication until CAD development at 90% completion of all components > advised completion latest by week #9 (March 17th). - Once CAD is completed, can move forward to model fabrication from week #10 onward. - Model fabrication in progress, but unsuccessful.	

Instructor Signature(s):	
Date:	29th March, 2022

Chong, Kappen, Thomson, Zaccolo



PANEL ON RESEARCH ETHICS
Navigating the ethics of human research

TCPS 2: CORE

Certificate of Completion

This document certifies that

Tiam Morrow-Rogers

has completed the Tri-Council Policy Statement:
Ethical Conduct for Research Involving Humans
Course on Research Ethics (TCPS 2: CORE)

N01219368

Date of Issue: **25 September, 2021**

Advisor Initiative

Unfortunately, most potential advisors were either unresponsive or not consistently responsive enough. Jacqueline Morrow serves as the primary advisor. The primary advisor also conducted some of their research and provided it.

Contact	Relevance	Form of Contact	Schedule	Contacted
Jacqueline Morrow	Dance Teacher	Video Interview Facebook	Sept. 23rd 2021	Yes
Elizabeth McWilliam	Student	Phone Interview	Interview Planned late October	Via Jacqueline Morrow

Base Interview Questions

1a. Who are we empathizing with?

- **Can you tell me about your background (related to this task)?**

  Dance Teacher since I was 17 years old.

- **How do you feel about doing this task?**

  Depends on the environment and the instructor.

  Some instructors push too hard or demand too much. This is the cause of many injuries.

1b. What do they need to do?

- **What do you need to do?**

  Run physical tests to see where they are. Keep students calm.

- **Why are you doing this?**

  If a student is hyper mobile in a zone they may not have the strength to control their mobility.

2a. What do they see?

- **Physical layout of the activity area / work area**

  Clear bright space, positive welcoming space, no distractions, ages 2-19, floor covered with marley or harlequin flooring which has some slide to it. Mirrors. Portable bars.

- **Layout of area**

  Portable bars stacked to one side, when they come out and organized depending on what way they need to see the mirror.

- **Layout of their tool / aids**

  All set off to the side in a safe space.

• Describe important visual cues while doing this task (if any).

Facial expressions, twitching, flinching. Looking for incorrect movement, which may result in discomfort or injury.

2b. What do they say?

• What's going on in your head as you're doing this task? (What do they say to themselves while doing this task)

Think about the level of risk, sometimes it's necessary to let them take the risk and challenge.

2c. What do they do?

• Can you go through the sequence of activities involved, as if you were instructing an 'apprentice'?

Make sure knees are strong, feet are aligned. Start from the bottom, feet, knees, hips, ribs, neck shoulders then head. Floor exercises, sometimes using devices like bands and therapy balls to get a feel for the movement. Teach them spotting (head whipping). Teach them turns in portions, start off with quarter, half, three-quarter, then full turn.

• Where do you usually go to get your supplies / tools / equipment? Why do you go there?

2d. What do they hear?

Setting guidelines and parameters is a priority.

- **Describe important auditory cues (if any)**

Percussive sounds

3. What do they think and feel about:

A. Pains: fears, frustrations, anxieties

- **Describe any fears, frustrations, anxieties you feel while doing this task**

Fear of scaring the kids.

- **Is there anything you find difficult/frustrating while doing this? Why?**

Making myself understood. This improved with experience. If the student doesn't understand what I describe, the wrong movement may be executed.

B. Gains: goals achieved; experiences enjoyed

- **Regarding your goals doing this task, which were achieved?**

Typically students do achieve the ability to do the movement.

- **How do you feel about the outcome? Why?**

Happy and accomplished that the education was beneficial.

• What was enjoyable about doing this? Tell me about a time doing this task that was really enjoyable?

"What other thoughts and feelings might motivate their behaviour?"

Students think they're built differently sometimes, they may have physical ability but not mental ability.

• Describe anything that would make this:

• easier or less frustrating

Parental support. Encouragement for the students.

• more productive or more enjoyable

Bringing in fun things, like activities during Halloween.

K - Advisor Meetings and Agreement Forms

HUMBER
Faculty of Applied Sciences & Technology
Bachelor of Industrial Design / FALL 2021 & WINTER 2022

IDSN 4002 / 4502
SENIOR LEVEL THESIS ONE & THESIS TWO

PARTICIPANT INFORMED CONSENT FORM

Research Study Topic: Augmented Dance Education
Investigator: Tiam Bennett Morrow-Rogers
Courses: IDSN 4002 & IDSN 4502 Senior Level Thesis One & Two

I, JACQUELINE MORROW *(First Name/Last Name)*, have carefully read the Information Letter for the project Augmented Dance Education, led by Tiam Morrow-Rogers A member of the research team has explained the project to me and has answered all of my questions about it. I understand that if I have additional questions about the project, I can contact Tiam Morrow-Rogers at any time during the project.

I understand that my participation is voluntary and give my consent freely in voice recording, photography and/or videotaping, with the proviso that my identity will be blurred in reports and publications.

Consent for Publication: Add a (X) mark in one of the columns for each activity

ACTIVITY		YES	NO
Publication	I give consent for publication in the Humber Library Digital Repository which is an open access portal available to the public	☑	☐
Review	I give consent for review by the Professor	☑	☐

Privacy
All data gathered is stored anonymously and kept confidential. Only the principle investigator /researcher, Tiam Morrow-Rogers and Prof. Catherine Chong or Prof. Sandro Zaccolo may access and analyze the data. All published data will be coded, so that visual data is not identifiable. Pseudonyms will be used to quote a participant (subject) and data would be aggregated.

I also understand that I may decline or withdraw from participation at any time, without negative consequences.

I understand that I can verify the ethical approval of this study, or raise any concerns I may have by contacting the Humber Research Ethics Board, Dr. Lydia Boyko, REB Chair, 416-675-6622 ext. 79322, **Lydia.Boyko@humber.ca** or Tiam Morrow-Rogers , tiambennett@gmail.com

Verification of having read the Informed Consent Form:

☐ I have read the Informed Consent Form.

My signature below verifies that I have read this document and give consent to the use of the data from questionnaires and interviews in research report, publications (if any) and presentations with the proviso that my identity will not be disclosed. I have received a copy of the Information Letter, and that I agree to participate in the research project as it has been described in the Information Letter.

JACQUELINE MORROW — Participant's Name
Participant's Signature
APRIL 17/22 — Date

3

HUMBER
Faculty of Applied Sciences & Technology
Bachelor of Industrial Design / FALL 2021 & WINTER 2022

IDSN 4002 /4502
SENIOR LEVEL THESIS ONE & THESIS TWO

INFORMATION LETTER

Conditions of Participation

- ✓ I understand that I am free to withdraw from the study at any time without any consequences.
- ✓ I understand that my participation in this study is confidential. (i.e. the researcher will know but will not disclose my identity)
- ✓ My identity will be masked.
- ✓ I understand that the data from this study may be published.

☐ **I have read the information presented above and I understand this agreement. I voluntarily agree to take part in this study.**

JACQUELINE MORROW — Participant's Name

Participant's Signature

APRIL 17/22 — Date

Project Information

Thank you very much for your time and help in making this study possible. If you have any queries or wish to know more about this Senior Level Thesis project, please contact me at the followings:

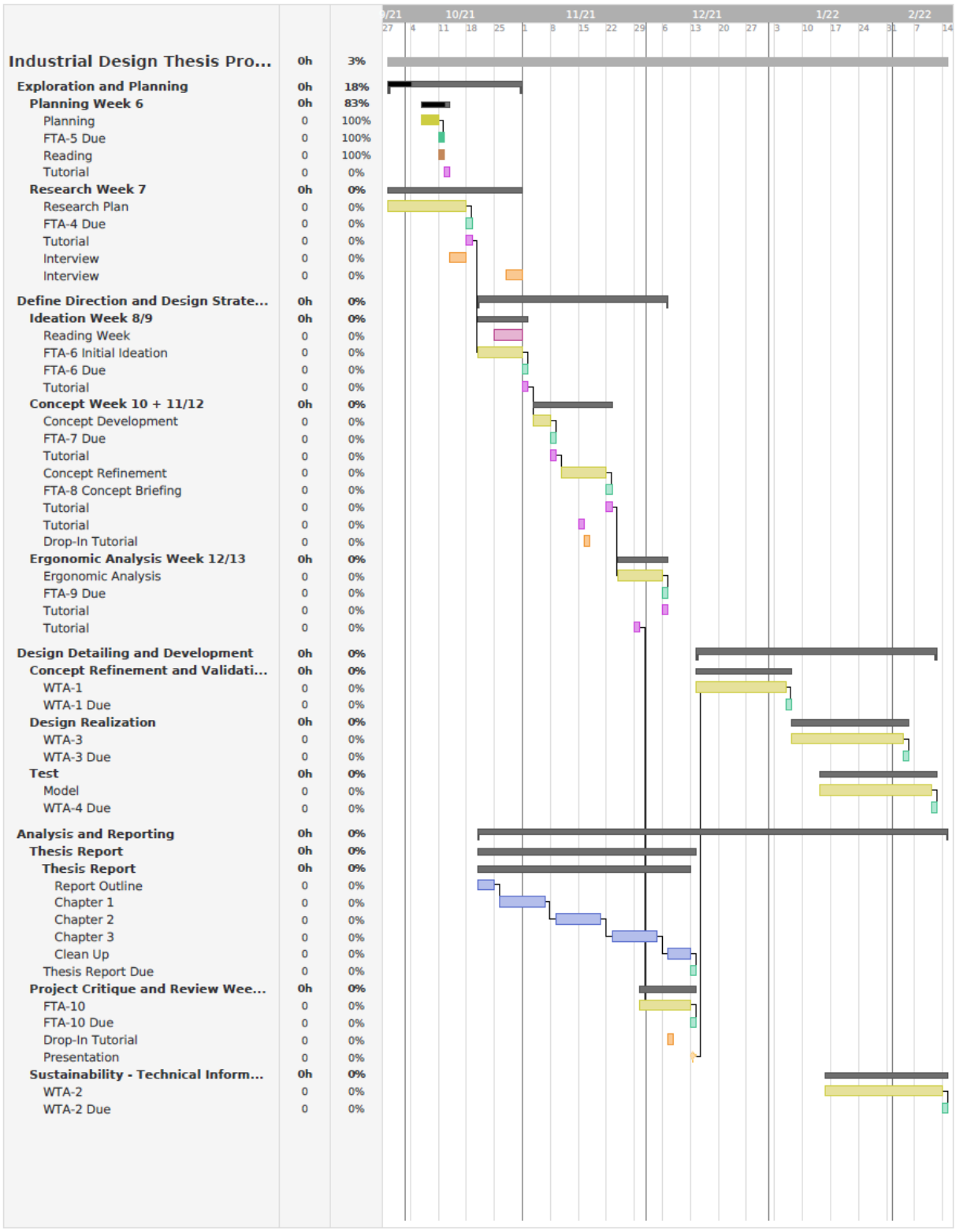
Phone: 647-237-3807

Email: tiambennett@gmail.com

My supervisors are:

Prof. Catherine Chong, **catherine.chong@humber.ca**
Prof. Sandro Zaccolo, **sandro.zaccolo@humber.ca**

2


9/21
10/21
11/21
12/21
1/22
2/22
27 4 11 18 25 1 8 15 22 29 6 13 20 27 3 10 17 24 31 7 14
Industrial Design Thesis Pro... 0h 3%
Exploration and Planning 0h 18%
Planning Week 6 0h 83%
Planning 0 100%
FTA-5 Due 0 100%
Reading 0 100%
Tutorial 0 0%
Research Week 7 0h 0%
Research Plan 0 0%
FTA-4 Due 0 0%
Tutorial 0 0%
Interview 0 0%
Interview 0 0%
Define Direction and Design Strate... 0h 0%
Ideation Week 8/9 0h 0%
Reading Week 0 0%
FTA-6 Initial Ideation 0 0%
FTA-6 Due 0 0%
Tutorial 0 0%
Concept Week 10 + 11/12 0h 0%
Concept Development 0 0%
FTA-7 Due 0 0%
Tutorial 0 0%
Concept Refinement 0 0%
FTA-8 Concept Briefing 0 0%
Tutorial 0 0%
Tutorial 0 0%
Drop-In Tutorial 0 0%
Ergonomic Analysis Week 12/13 0h 0%
Ergonomic Analysis 0 0%
FTA-9 Due 0 0%
Tutorial 0 0%
Tutorial 0 0%
Design Detailing and Development 0h 0%
Concept Refinement and Validati... 0h 0%
WTA-1 0 0%
WTA-1 Due 0 0%
Design Realization 0h 0%
WTA-3 0 0%
WTA-3 Due 0 0%
Test 0h 0%
Model 0 0%
WTA-4 Due 0 0%
Analysis and Reporting 0h 0%
Thesis Report 0h 0%
Thesis Report 0h 0%
Report Outline 0 0%
Chapter 1 0 0%
Chapter 2 0 0%
Chapter 3 0 0%
Clean Up 0 0%
Thesis Report Due 0 0%
Project Critique and Review Wee... 0h 0%
FTA-10 0 0%
FTA-10 Due 0 0%
Drop-In Tutorial 0 0%
Presentation 0 0%
Sustainability - Technical Inform... 0h 0%
WTA-2 0 0%
WTA-2 Due 0 0%