Advances in Intelligent Systems and Computing 790

WonJoon Chung · Cliff Sungsoo Shin
Editors

Advances in Interdisciplinary Practice in Industrial Design

Proceedings of the AHFE 2018 International Conference on Interdisciplinary Practice in Industrial Design, July 21–25, 2018, Loews Sapphire Falls Resort at Universal Studios, Orlando, Florida, USA

Springer

Advances in Intelligent Systems and Computing

Volume 790

Series editor

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ISSN 2194-5357 ISSN 2194-5365 (electronic)
Advances in Intelligent Systems and Computing
ISBN 978-3-319-94600-9 ISBN 978-3-319-94601-6 (eBook)
https://doi.org/10.1007/978-3-319-94601-6

Library of Congress Control Number: 2018947369

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Printed on acid-free paper

This Springer imprint is published by the registered company Springer International Publishing AG part of Springer Nature
The registered company address is: Gewerbestrasse 11, 6330 Cham, Switzerland

Advances in Human Factors and Ergonomics 2018

AHFE International
Applied Human Factors and Ergonomics Conference
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9th International Conference on Applied Human Factors and Ergonomics and the Affiliated Conferences

Proceedings of the AHFE 2018 International Conference on Interdisciplinary Practice in Industrial Design, held on July 21–25, 2018, in Loews Sapphire Falls Resort at Universal Studios, Orlando, Florida, USA

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Preface

Industrial design has been one of the fastest growing and demanding areas which made significant contributions to our lives and societies. Traditionally, industrial designers focus on the aesthetics of products' form and style as well as ergonomics. This tradition has expanded its boundary to other subject matters such as service design, human–computer interaction and user experience design, sustainable design, and virtual and augment reality. This is a strong indication that interdisciplinary collaboration across disciplines became an essential and critical practice in design.

The International Conference on Interdisciplinary Practice in Industrial Design (IPID) aims at exploring and broadening the interdisciplinary practice in industrial design. The conference includes discussions on (1) a theoretical investigation as well as professional practice to foster interdisciplinary collaboration across disciplines, (2) design projects through interdisciplinary collaboration, (3) design process with external public and private sector partners with a solid record of interdisciplinary development experience, and (4) design methods and techniques to investigate productive and effective interdisciplinary collaboration in design. A total of four sections are presented in this book:

I. Inclusive Design,
II. Interdisciplinary Design,
III. Creativity in Design, and
IV. Human-Centered Design: Collaborative Design and Emotional Intelligence.

Each section contains research papers that have been reviewed by members of the International Editorial Board. Our sincere thanks and appreciation to the board members as listed below:

Young Mi Choi, USA
KwangMyung Kim, Korea
Miso Kim, USA
YoungAe Kim, USA
Jiwon Park, USA
Scott Shim, USA

We hope that this book, which is the international state of the art in the Interdisciplinary Practice in Industrial Design, will be a valuable source of theoretical and applied knowledge enabling human-centered design of a variety of products, services, and systems for global markets.

July 2018

WonJoon Chung
Cliff (Sungsoo) Shin

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Inclusive Design

Design Education as an Inclusive Pedagogy

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Abstract. This paper summarizes an inclusive pedagogical experience from the perspectives of design educators and students. It is an overview of a new Collaborative Innovation Minor at an established design program at a major university and a narrative case study of a capstone course- Collaborative Design Development to discuss how non-design students were able to embrace unfamiliar content in cross-disciplinary environment. The author will discuss inclusive pedagogical framework of minor defined by three key design foundations: Design Intent and Opportunity, Conceptualization, and Implementation, each employing its own relevant tools, methodologies, and design approaches. This Collaborative Innovation Minor inspired cross campus participants to engage in design learning from a holistic, user-centered, and interdisciplinary approach.

Keywords: Design education · Collaborative design · Design method
Design thinking

1 Background

Today, the role of design is expanding beyond traditional boundaries with multifaceted challenges and exposure to complex wicked problems. Designers are now invited early in the process to frame the problem and establish empathy with human-centered intentions. They frequently facilitate projects that require creative sensibility and mapping of holistic sequential experience [1]. Such an immersive shift has resulted in considerable growth in the emerging areas of industrial design, design research, UX design, interaction design, social innovation, entrepreneurship, and more. Consequently, creative strategies that originates from the roots of design process—commonly known as "design thinking"—is now being implemented in business and social studies. Utilizing a methodology arising from design's natural heritage, design thinking brings together divergent stakeholders in a dynamic, iterative and deeply human process that accelerates innovative thinking and making.

It is no surprise academia has caught up with this demand and is offering students unique opportunities to engage in innovative creativity. The majority of design programs are established around traditional core competencies (such as ideation, visualization and prototyping) but more leading-edge contents are being delivered in cross-disciplinary platforms to ensure inclusive education. Melsop [2] writes "many Universities are rethinking the traditional pedagogy to encompass nonlinear methodologies and divergent valuable in higher education."

© Springer International Publishing AG, part of Springer Nature 2019
W. Chung and C. S. Shin (Eds.): AHFE 2018, AISC 790, pp. 3–8, 2019.
https://doi.org/10.1007/978-3-319-94601-6_1

2 Context

A design program at the College of Liberal Arts launched a new minor in Collaborative Innovation couple years ago. This minor in Collaborative Innovation is conceived of as a dynamic catalyst for process-based, cross-disciplinary collaboration between various academic departments in Liberal Arts and wider interests across the university. The initial constituency of undergraduate students was drawn from within Liberal Arts, but ultimately that constituency has expanded to include students from Engineering, Business and Science, all of whom are involved in bringing successful solutions to complex problems. Building a strong core competency in design thinking and collaborative innovation is intended to fulfill growing demand for this skill among these various communities, attracting broad and diverse student enrollment and re-establishing the primacy of a humanistic, collaborative approach to the complex and integrated challenges facing a rapidly changing world.

The Minor offers a course sequence starting with a large, introductory, lecture-based design thinking course that also fulfills a general university requirement while acting as a feeder for the Minor itself. Participants then cycle through a series of courses introducing various skillsets implicated in design thinking, including research methods, visualization, rapid prototyping and entrepreneurship. The Minor culminates in the capstone course that brings students' various disciplines together in fruitful collaboration to address industry-sponsored projects addressing real world questions.

3 Framing the Curriculum

The Collaborative Innovation Minor curriculum was established on five sequential phases of design pedagogy: Gateway, Inspiration, Ideation, Implementation and Capstone. It resembles the Design framework published by the Neilson Norman Group (Fig. 1) in 2016 [3]. The Gateway and Capstone courses were specifically developed for the Collaborative Innovation minor, but the mid-tier phase classes were cross-listed from Design curriculum to provide a cost-effective yet stable platform for the department. As design education forges new teaching and research alliances across the university, it is important to provide inclusive opportunities with introductory skill-driven courses but at the same time to maintain exclusive values of design major curriculum to avoid pedagogical conflicts. The Collaborative Innovation Minor effectively integrates existing design courses to establish a curriculum that delivers the following learning goals: (1) Understand various assets of a multi-disciplinary environment through an iterative and systematic approach. (2) Identify project scope and design objectives and methodically plan for its execution, including the development of design principles and strategies. (3) Apply design-thinking strategies to evaluate, conceptualize and synthesize "integrated" design proposals. (4) Develop creative design proposals that integrate contextual solutions. (5) Construct a design solution (i.e., a service, product, environment or information) from a human-centered, holistic approach focusing on user experience.

The core principle of the minor is to offer a non-designers fundamental skills and knowledge to facilitate collaborative partnership with experts from diverse areas. Following are the sequential phases of the Collaborative Innovation Minor described in detail.

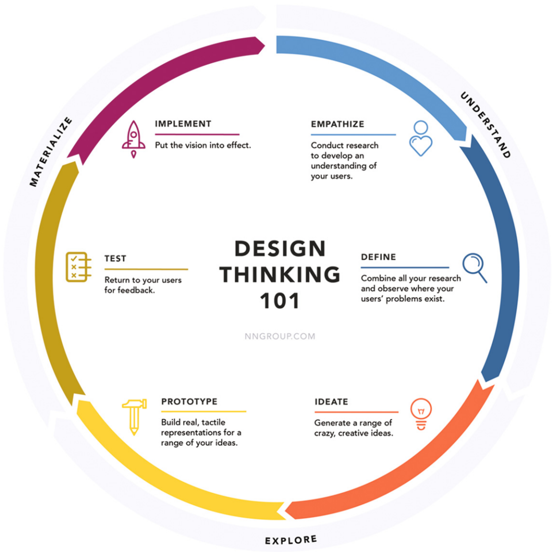

Fig. 1. Design-thinking framework by Neilson Norman Group

3.1 Gateway

Phase 1 Course Options: Design Matters
This introductory course provides the foundation for understanding the assets of design as students engage in articulating the tenets of design thinking methods and apply methodologies to identify problems and develop experiences and product solutions. As a unique hybrid course, students familiarize themselves with the design thinker's toolkit through readings, discussions and short exercises during seminar meetings while deploying these methods and techniques on a series of hands-on collaborative small group projects of longer duration during the Lab sessions. This course is intended for undergraduate students of any discipline interested in learning how the methodology and tools of design thinking can ignite innovation and address problems and challenges across the diverse topics.

3.2 Inspiration

Phase 2 Course Options: Design Research
Inspiration requires discovery and empathy. Thus, the Design Research course is structured with several activities or "modes" that are instrumental in initiating criteria prior to solving problems. The modes during this phase include sensing, reframing, understanding the context and people, and finding opportunities. This course is conceived of as a way to close the gap between research and design and provide students

confidence in framing problems based on informed analysis. Students use clustering, matrices, and stakeholder journeys to discover design opportunities. Though Melsop [2] notes the methodologies can be explored in a sequential order, students are constantly reminded that design processes are non-linear and encouraged to revisit "modes" to redefine intent and refine design opportunities. Students will look for patterns that repeatedly emerge from multiple analyses, but more importantly, will come to understand how to capitalize on their unique backgrounds and contribute to a broader interpretation of emerging patterns.

3.3 Ideation

Phase 3 Course Options: Rapid Visualization, Fundamentals of Design
The third phase of the curriculum focuses on concept development and communication techniques. In these courses, students are exposed to rapid sketching, rendering and presentation techniques as a tool for developing, refining and communicating three-dimensional concepts to others. Visualization skills empower students to facilitate discussions and communicate abstract ideas for further exploration. Learning goals are: (1) Visually communicate concepts clearly and persuasively. (2) Demonstrate creativity in expression, design and conceptualization. (3) Develop and master artistic skill through practice and application.

3.4 Implementation

Phase 4 Course Options: Intro Product Development, Digital Solid Modeling, Web Design, Interaction Design, Social Design
The next phase of the Minor consists of courses that highlight design development, prototyping and final presentations. According to Udell [4] "a prototype is a functional or semi-functional demonstration of a system or project. It can be used to discover issues in the planned execution or plan for a project, prove a strategic approach, or test the value of an idea from a specific aspect." With prototypes, students are naturally exposed to collaborations and interactions which serve as a way to synthesize disparate ideas and incompatible solutions. Prototypes takes many forms, from short animated films and digital models to website framework. However, they all have a common thread of demonstrating ideas in tangible forms to get feedback from users, and in doing so, students will realize that objects and information with adequate service enhance overall experience. In the end, students are able to capitalize on their iterative progress and actively engage in finalizing their ideas.

3.5 Capstone

Phase 5 Course Options: Collaborative Design Development
The capstone project is often incorporated into a curriculum for "assessing how successfully the major has attained the overall goals" (Wagenaar [5]). A similar approach

is adapted into the Collaborative Innovation Minor to assess convergence of expertise from business, political science, entrepreneurship, engineering, science, anthropology, and graphic and industrial design. Collaborating teams of undergraduate students begin with an identification of need and ultimately conclude with comprehensive proof of concept, innovative function, and an appropriately resolved, aesthetically pleasing product or system. [6] Understanding the relative pain points of a particular situation through stakeholder journeys and narratives will encourage students to see various ways that service, technology and objects impact different individual experiences. The insights from multiple exercises are collaboratively translated into guiding principles which are intended to be distillations of more complex discoveries.

One of the projects from this course entered the Disney Imaginations competition in 2017 and won 2nd place out of 336 entries. The proposed concept for "Spirit of Isles" (Fig. 2) is a shamrock-shaped island capable of withstanding all of the seasons located on the campus. Through their research, group members were able to frame critical pain points around the inconsistent Midwestern weather and developed an empathetic concept of outdoor space on our campus that addresses the needs of students, faculty and visitors as a respite from stresses of college life. The project is an example how the dynamic approach inspires students to immerse themselves in an integrative design thinking approach that serves as a catalyst for team-based projects. This team was one of the only interdisciplinary teams in the competition, and judges noted that their presentation touched on diverse aspects of human-centered approach and felt more complete.

Fig. 2. Capstone project from Collaborative Innovation Minor 2nd place in 2017 Disney Imaginations Competition

4 Conclusions

The Collaborative Innovation Minor is relatively new, but within the past two years 32 students have enrolled in the program and there is positive expectation this number will grow significantly in the near future. Students from across the campus have recognized the distinctive attraction of this Minor as it serves as a creative toolbox for their majors. We have been able to attract talented students from the Colleges of Business, Science and Engineering to the Liberal Arts with robust curriculum that prepares them to begin immediate and productive careers across a wide variety of industries where collaborative design thinking is valued at a premium. We're hoping these students promote cross-department and cross-collegiate collaboration, resulting in the spread of divergent thinking across the entire University community. Finally, some of the feedback from the Capstone course reflects the immediate impact on students' thesis work across a wide variety of industries where collaborative design thinking is valued at a premium.

> *"The activities we practiced in the first few weeks were the most useful in my learnings from the class. They are applicable to many fields beyond design and I found it very useful."*

> *"They went along with the lectures really well and definitely helped me work toward my final project in the class."*

In reflection, the demands of collective thinking and creation of team-based experiences are encouraging students to explore design thinking as a tool to enhance their expertise. There is reason to believe design can be inclusively embedded in the core of higher education rather than left as an exclusive training. Conrado [7] states "there are not enough diverse voices, perspectives and experiences shaping the design of the world. While we have made admirable progress, too many entrenched barriers remain that make it difficult for those diverse viewpoints to thrive." The adaptation of design thinking through the Minor platform presented in this paper serves to illustrate a different approach in transforming education into a responsive model. This form of pedagogy is neither definite nor singular in its approach to dovetailing creative collaboration. Rather, the content of the case study and conceptual framework serve as examples for other design educators to learn from and adapt to their teaching methods.

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The Future of Footwear Design & Lasts: Do We Now Really Need Them?

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Abstract. The term last comes from the Old English, “laest,” which means barefoot. The last is an important tool used in the footwear making process. It defines the 3D footwear shape, influencing fit, feel, and comfort. It helps stabilize components during the assembly process. Despite the importance of well-fitting footwear, more than 43 million Americans experience foot pain due to poorly fitting shoes. So, if the footwear last is an important tool for making shoes, and it is a depiction of the barefoot, then something is not adding-up. Is there an opportunity to revolutionize a process that was created 1000’s of years ago? This position paper will review last creation, methods of make, and insights from industry experts, to suggest criteria for the development of a new athletic footwear making process.

Keywords: Lasts · Footwear making · Athletic shoes · New tools

1 Introduction

Like the hand, the human foot is a complex part of the body. Each foot is made-up of 26 bones, 33 joints, and more than 100 tendons, muscles, and ligaments [1]. In tandem, our feet work together to keep us balanced, allow us to walk, run and jump. Whether an athlete, office worker, firefighter or surgeon, humans wear footwear to protect their feet and aid in performance. No matter the end use, shoes are made upon a last. The term last comes from the Old English, “laest,” which means barefoot. The last is the most important tool used in the footwear making process [2]. It defines the 3D footwear shape, and acts as a stabilizing unit for the product to be put together upon. According to The New York Times, the American Academy of Orthopedic Surgeons found more than 43 million Americans experience foot pain attributed to poorly fitting shoes (most of them women) [3]. If footwear lasts are the most important tools for designing and constructing footwear, and millions of Americans experience foot pain, something seems flawed with this design process. Well-fitting shoes are especially important in the sports industry, as athletes rely on their feet to perform. Also, modern day athletic footwear are made differently from dress shoes. Could this product genre be created with different processes and tools? This position paper will review last creation, methods of make, and insights from industry experts to suggest criteria for the development of new athletic footwear making processes and tools.

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W. Chung and C. S. Shin (Eds.): AHFE 2018, AISC 790, pp. 9–15, 2019.
https://doi.org/10.1007/978-3-319-94601-6_2

2 Lasts

2.1 Traditional Last Making

Evidence of the use of lasts to create footwear can be found as early as the time of Plato, who compared Zeus's construction of man to the way a shoemaker smoothed creases in leather [4]. In order to create the shape of a new last, the 3D form of the foot is captured. Traditionally, a shoemaker would conduct this task, where the shape of their customer's foot and several key measurements would be documented. A visual inspection of the foot is typically completed first. The shoemaker would notice how the customer's feet are balanced, and determine if they lean towards the medial or lateral side of the body (pronate or supinate). They will look to see if the arches are high or low, and decide if asymmetries exist between right and left feet; as well as the relative position of the ankle to the foot, general shape of the heel, instep, and toes. At this stage, the shoemaker will also note the presence of any malformations, such as bunions or hammer toes. They may palpitate the customer's feet to assess whether they are "bony" or "fleshy," to inform how tightly the final product should fit. The shoemaker will ask the customer how shoes tend to feel for them, seeking feedback such as, "my heel is usually gripped too tightly," or "my toes tend to get squeezed together." [5]. Particular shoemakers may only evaluate their customer's feet at the end of the day, as they can swell from morning to evening, thus, expanding in size. From this initial review, the shoemaker will have a general understanding of their customer's feet and experiences with footwear.

Next, the shoemaker will measure the customer's feet with a ruler and tape measure. This step can be done with or without socks. In general, the following measurements will be collected: total length of the foot from heel to the longest toe, ball girth, waist girth, instep girth, heel-to-ball length, heel curve, and ankle girth [4]. These measurements can be taken while the customer is standing (weight bearing), or seated. In addition to the measurements, a draft of the foot will be taken. This will often be accomplished with a sheet of paper placed below each foot while the customer sits or stands. The shoemaker will trace an outline of each foot with a pencil, at a 90° angle to the paper. The pencil line begins at the heel and moves against the medial side of the foot, staying straight up against the arch, and rounding the toes [4]. Some shoemakers will take imprints of the feet to identify the condition of the arches, and to clarify the location of toes [4]. There are various tools to capture this type of imprint, but fundamentally, an ink footprint is captured. The print will also indicate how the individual distributes their weight across their right and left feet. These prints can also be collected while seated and/or standing, as feet spread to accommodate the load of the body when standing. Historically from this information, lasts were made from wood and hand carved to reflect the "shape" of the customer's foot [4]. This process involved a variety of tools, including axes, planes, files and sandpaper. The invention of the lathe by Thomas Blanchard in Massachusetts, USA in 1819 was a major step for last makers to expedite a time-consuming and laborious process [4]. For the shoemaker, ensuring that the landmarks measured from the foot are appropriately built into the last is as much art as it is science. There is high probability that two different shoemakers would produce different results based upon the same feet as measurements may be collected within a margin of a few millimeters from one another. Additionally, what shoemakers do with those measurements may differ. Some shoemakers might add more ease to the toe box or loosen the shoe less or more depending on whether the foot is bony or fleshy. measurements within a margin of a few millimeters from one another. Additionally, what shoemakers do with that information may differ. Some shoemakers might add more ease to the toe box or loosen the shoe less or more depending on whether the foot is bony or fleshy. They may also make different decisions depending on the type of materials used in the final product.

2.2 Modern Last Making

Two innovations dramatically changed the last making industry in the second half of the 20th Century, including the development of High Density Polyethylene (HDPE) and automation [6]. Beginning in the 1960s, HDPE began to replace wood as the near unanimous choice for shoemakers because it preserves its shape in humid and hot environmental conditions. Shoemakers who still chose to make wood lasts will seal them in polyethylene to prevent expansion, although, this technique has limited success. Along with the invention of HDPE, 3D Computer Aided Design (CAD) tools help reduce the time and effort involved to conceptualize new last designs, and the Computer Numerical Control (CNC) is used to cut and shape lasts today [6].

The modern manufacturing process for last making has several steps. First, a block of HDPE is shaped into an oversized, generic, foot-like form from which a lathe performs a rough cut. The last is attached to the lathe at points known as "toe and heel dogs," which are removed after the lathe cut. Next, the surfaces are cleaned-up by hand using a file [7]. Size information will be stamped near the top portion of the last. Some manufacturers will add RFID chips containing information about the last [8]. Commonly, a hinge is added to the last so it can "break" open and be removed from the final, assembled shoe. A blow torch will be used to smooth and seal the surface of the last without reshaping its form. Quality assurance processes will be performed throughout the last manufacturing process. Typically, toe and heel curves will be lined up against templates to ensure consistency. At this point, the last is finished and used over and over in the manufacturing process, until it is deemed to be damaged or no longer desired by the manufacturer. A single last may produce hundreds of thousands of shoes.

3 How Traditional Dress Footwear Are Made

In the late 1500's a new method of making footwear was created, where the leather upper was sewn to a welt, and then the welt was sewn to a separate outsole [9]. Most of us would identify this type of construction as a modern-day men's dress shoe. What is interesting, is that this construction has changed very little over the last 500 years; outside the invention and use of modern day shoemaking tools (e.g., post-bed sewing machine and skiver). To construct a traditional dress shoe from a last, the shoemaker will begin with drafting patterns. This step was historically performed by taking measurements from the last to hand draw patterns shapes onto oak tag or paper, using a ruler, French curve and pencil. Today, a shoemaker is likely to apply a layer of masking tape to the last, from which the upper pattern will be drawn upon with pencil. With some finesse, the masking tape shell can be removed from the last and flattened into two-dimensional pattern shapes. Either way, the shoemaker creates patterns that reflect the last shape. Once the patterns are completed, the general steps for making traditional single sole leather welted dress shoes are as follows [4, 10] (Table 1):

Table 1. Traditional single sole leather welted dress shoe making process.

Step	Process
1.	Leather is inspected and approved (for quality and ability to make footwear)
2.	The upper patterns are cut from the approved leather. That may include skiving or paring pattern pieces to make sure the leather is not too thick in areas where it attaches to other pieces
3.	The upper pieces (including liner) are sewn together (usually with a post bed sewing machine)
4.	Reinforcement pieces (e.g., heel and toe counters) are attached to relevant upper pieces (usually with glue)
5.	The insole is shaped and tacked into the last (this operation could be completed prior to the upper being constructed)
6.	The sewn upper is placed on the last and nailed all around to the insole
7.	The upper is hammered around carefully, to shape it to the last
8.	A leather welt is prepared and hand stitched to the upper and insole (with 2 needles). The assemblage hammered out and trimmed
9.	A leather rand is measured, notched and matched to the welt and hammered onto the assemblage with wooden pegs
10.	A metal shank and leather midsole is added to the bottom of the insole for support and structure
11.	A leather outsole is prepared and hand stitched together through the welt, insole and upper (with 2 needles)
12.	The heel (wooden or rubber) is added, shaped and additional rubber may be added to the back of the heel for added durability
13.	Finally, shoe is cleaned, smoothed and finished up with dying (adding color), polishing, waxing, ornamentation and laces
14.	The shoe will be removed from the last and an insole cover will be applied to the foot bed/insole

4 How Athletic Footwear Are Made

Athletic footwear were historically made with canvas uppers attached to vulcanized rubber outsoles, using the same tools as dress shoes. They were called "Sand Shoes" and were revolutionary as they replaced heavy and expensive leather shoes, enhanced athletic performance and provided a casual aesthetic [11]. Since their incarnation, performance features, including durability, cushioning, stability, and traction have been designed into athletic footwear to aid in performance. The general steps for making athletic footwear are as follows (once patterns are drafted from a masking tape last shell) (Table 2):

Table 2. Traditional athletic making process.

Step	Process
1.	The upper patterns are cut. Uppers can be made from variety of different materials, including: leather, synthetic leather, single layer knits, spacer meshes, etc.
2.	Reinforcement pieces (e.g., heel and toe counters) are attached to relevant upper pieces (usually with hot melt or adhesive)
3.	Upper pieces are sewn together (usually with a regular sewing or post bed machine). Some uppers today cab be put together with a serger or cover stitching machine
4.	The upper is sewn to the Strobel board or bottom (with a Strobel stitching machine)
5.	The upper is placed onto the last
6.	A pre-molded outsole or outsole parts are glued to the midsole
7.	The outsole and midsole together are glued to the upper
8.	The entire lasted shoe will get pressed together and go through a heated oven to finalize shape and cure parts together
9.	Finally, the last is removed from the finished athletic shoe. Laces and sock liner are added

5 Comparisons Between Dress and Athletic Footwear Making

Although athletic footwear making was derived from traditional dress shoe making, over time it has evolved to the point where the authors propose that different tools and processes could be established. Athletic uppers are different in that they can be made from a variety of materials, including: athletic grade leather (typically softer), synthetic leather, single layer knits, spacer meshes, etc. These materials behave very differently from dress shoe leather, as they can stretch and even be engineered to stretch or lock-out in specific regions of the upper pattern. Hand stitching is at no time involved when attaching upper pattern pieces together, and because of the suppleness of these materials, parts can be stitched together with industrial sewing machines and other apparel-type sewing machines, including cover stitchers, sergers and regular single needle machines (without the post). Athletic shoe uppers and bottoms can also be put together with a Strobel seamer, where a welted dress shoe will use a time consuming hand stitching process with 2 needles. They are never hammered into shape or nailed together, as the athletic shoe upper, midsole and outsole are merely a "glue sandwich," where all parts are attached with adhesive, and can be shaped with heat and pressure. This construction allows for the product to be more flexible, and for softer, thick cushioned foams to be used for midsoles. Athletic shoes tend to have fewer parts, although some may include plastic stability shanks placed into the midsole foam for support during activity, which are simply glued into place. With this method of make, the last is just used to form the heel and toe box, and provides a hard surface on which to apply the midsole/outsole. Could different processes and tools be created for athletic footwear, and could they influence the future of all footwear making?

6 A New Way of Making Athletic Footwear

While today's lasts are a careful blend of art and science, the number of foot injuries due to poorly fitted shoes and fashion driven aesthetics are clear results from this out-of-date method of make. Although the process of using a last to make shoes fits well into the dominant manufacturing ecosystem, its shortcomings negatively impact consumers and custom shoemakers. For example, custom fitted shoes, can cost over USD 1000^{+} per pair [10]. Part of the reason for the high cost is the requirement to develop a last for each custom footwear customer. If the production of a last were expedited or eliminated, would it be possible for consumers to have better fitting footwear, resulting in less body pain, and custom shoemakers to have livelier businesses? Could new technologies in 3D body scanning and computational design, devise a new method of making footwear? Could the new processes and tools be more connected to an actual consumer's foot shape, use less waste and be more cost efficient?

The authors of this paper interviewed a handful of premier custom footwear makers and last makers that work for small and large companies in the United States. All agree the last is the most integral and time consuming part of making a shoe, and the most difficult to properly execute. They also agree that rapid, affordable 3D scanning and printing of a foot-to-last would be a game changer for their manufacturing process and business economics. However, even with the ability to generate new tools, they argue that expert knowledge is still needed to translate the customer's foot shape into a functional last that will create a usable shoe. They also note that narrow, pointed shoes with an unnatural foot shape tend to be viewed as more desirable than shoes made on a natural, foot-shaped last.

The researchers would counter argue that the apparel industry has been exploring this space and although it is not perfect, progress is being made in custom fit products that are attractive on many body types. The body as a whole is harder to fit because there can be so many more variables (height, weight, fat/muscle distribution, etc.). Several new tools have been created in this industry to look at custom products including: 3D scanning, avatar development, 3D pattern making software, 3D design tools and methods of make. There is however, a software program called Shoemaker that is trying to mimic the tools in the apparel industry, but the process stream is not fully utilized by experts that know how to use the tool properly. Perhaps a dying art is making last makers anxious for their careers. Nevertheless, if the last can be more quickly customized, generated, or altogether eliminated, it is possible for a much deeper revolution in footwear manufacturing.

The authors propose 1st investigating new tools and processes for the making of athletic footwear, as this genre is easier to assemble and the sports industry is more accepting to process innovation. So what would be the requirements of new tools and processes to produce athletic footwear? Tools would need to be durable enough to withstand pressure and general impact of the manufacturing process, hot and humid environments, and temperatures of about 140°K. New technologies of automation and computational design have already proven environmentally sustainable and cost effective for companies. Upper technologies, like Nike's FlyKnit technology permits computer-controlled knitting to shape the shoe upper rather than being hand cut. It offers precise engineering of the rigidity of the shoe and claims to reduce waste roughly 80% compared to traditional Nike running footwear [12, 13].

Future R & D efforts by the researchers will include physically prototyping new tooling concepts to evaluate effectiveness for customized athletic footwear products. The researchers will also look at the design of an algorithm to convert 3D foot scans into functional lasts. Footwear is far too important a product category to ignore innovation opportunity that may offer superior product performance, reduced foot pain, and potential cost savings. New technologies may enable deep changes to traditional footwear methods of make—methods that strongly resemble ancient processes and result in daily pain to so many of us who wear shoes.

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Transdisciplinarity as a Core Value: The Richmond Institute for Design and Innovation

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Abstract. "Wicked problems," as coined by Horst Rittel, are "difficult or impossible to solve because of incomplete, contradictory, and changing requirements that are often difficult to recognize." Design thinking, a holistic process based on ethnographic research and iteration, has proven to be a useful approach to solving these multi-faceted problems. However, there are many deterrents to setting up a classroom environment conducive to wicked problem solving. Too frequently, design educators overemphasize technical skills, siloed academic structure prohibits collaboration, and rigid curricula leave no room for interdisciplinary courses. The Richmond Institute for Design and Innovation offers a BFA in product design. The degree is transdisciplinary and interdisciplinary, requiring courses in art, design, engineering, and business. This paper explores the transdisciplinary approach offered by Western Michigan University and several other design programs, documents their successes and failures, and proposes approaches for emerging design programs.

Keywords: Transdisciplinarity · Interdisciplinary · Wicked problems
Design thinking

1 Wicked Problems and Design Thinking

Global warming, nuclear proliferation, and gun violence are several examples of *wicked problems*, or "problems that are difficult or impossible to solve because of incomplete, contradictory, and changing requirements that are often difficult to recognize" [1]. The term, originally coined by Horst Rittel, is more relevant today than ever, as an increasing number of global quandaries threaten economic stability, environmental balance, and human existence itself.

Milton Glaser describes design as "moving an existing condition to a preferred one" [2]. The difficulty with wicked problems, however, is that the underlying problems are often ill-defined, convoluted, and interdependent. Consequently, there are typically no ideal solutions that solve a wicked problem in its entirety. Instead, those who combat these issues must continually improve the situation, gradually improving it over time.

Design thinking, a holistic process based on ethnographic research and iteration, has proven to be a useful approach to addressing these multi-faceted problems. Named due to its origin in the design profession, design thinking slowly gained acceptance as a mainstream approach to problem solving during the second half of the 20th century.

© Springer International Publishing AG, part of Springer Nature 2019
W. Chung and C. S. Shin (Eds.): AHFE 2018, AISC 790, pp. 16–24, 2019.
https://doi.org/10.1007/978-3-319-94601-6_3

In 1999, however, design thinking gained national exposure after the television show *Nightline* featured design thinking in a segment titled, *The Deep Dive: One Company's Secret Weapon for Innovation.*

Design thinking has three distinct stages: inspiration, ideation, and implementation. *Inspiration* is the stage for problem definition, where literature reviews, interviews, observations, and immersion strategies are utilized to best understand an existing situation. *Ideation* is the stage where new ideas are rapidly brainstormed and evaluated on merit. Poor concepts are disqualified while successful concepts are refined. *Implementation* is the stage where the most successful idea is realized, often through commercialization (Fig. 1).

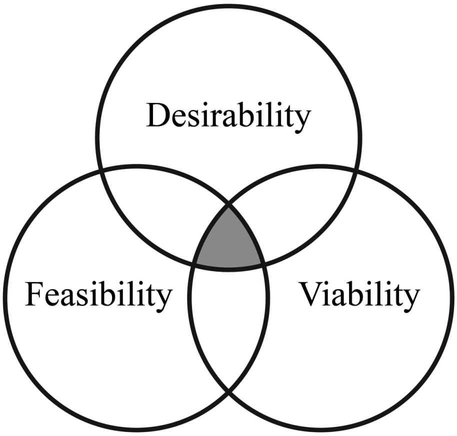

Fig. 1. IDEO's representation of design thinking as a *venn diagram*. Design thinking considers the *desirability*, *feasibility*, and *viability* of potential outcomes.

IDEO, a respected design firm based in Palo Alto, California, visualizes design thinking as a venn diagram, consisting of three sets: desirability, feasibility, and viability [3]. In academic disciplines, desirability, or the ability to create objects that are aesthetically pleasing and resonate emotionally with the customer, is traditionally the responsibility of the industrial designer. Feasibility, or the consideration of technological and manufacturing constraints, is often the responsibility of the engineer. Viability, or the economic capacity for a product or service to persevere, is the job of the business manager or entrepreneur. Therefore, design thinking can be understood as the intersection of business, engineering, and design.

IDEO describes ideal employees as "T-shaped people," [4] a term originally coined by McKinsey and Company. A T-shaped person is somebody who has a breadth of knowledge in many subjects, but also has expert knowledge in at least one. This broad knowledge base is what allows these people to more easily collaborate across disciplines, since they speak the language of their colleagues. In academic terms, IDEO seeks *transdisciplinary* employees to perform *interdisciplinary* tasks.

2 The Flaws of Traditional Academic Structure

If respected and innovative companies seek "T-shaped" employees who collaborate well with others, traditional design curricula must adapt to reflect these new qualifications. To receive a breadth of knowledge, students should take complementary engineering and business courses in addition to other general education requirements. They also need access to project-based courses that facilitate cross-disciplinary collaboration.

Unfortunately, there are many barriers to these types of interactions within the traditional university structure. These issues stem from the "necessary evil" of university divisions, such as schools, colleges, and departments. These divisions typically have different mission statements, learning outcomes, funding models, and standards for tenure and promotion. This leads to silo mentality, and can make it difficult for faculty to team teach, hold co-appointments, teach cross-college courses, or collaborate across disciplines. Silo structure also prevents students from taking courses outside of their own discipline. Many courses are closed to non-majors, making it difficult for students to diversify their experience.

Rigid curricula can also be a problem, leaving little room for electives. Even the most open-minded design programs are guilty of this as well. Portfolio development is crucial for finding an entry-level job, so faculty often overemphasize technical skills as part of portfolio development. It is important to leave room in the curriculum for students to diversify their skill set. For example, while all product designers would benefit from courses in sustainability, engineering, and business, a student who wants to work in developing nations would also benefit from courses in gender and poverty studies.

Each design program has its own identity, and this a positive rather than a negative. Some programs will emphasize technical skills. Some will emphasize design research. Most will be a blend of the two. Some universities, however, have realized that exposure to design thinking can benefit students from across the university, not just the ones in the art department.

3 Examples of Transdisciplinary Design Thinking Programs

Several national and international universities have successful transdisciplinary and interdisciplinary design thinking programs. The following is a list and description of notable examples, sorted by their location within the university structure.

3.1 Located with Business

The Rotman School of Management at the University of Toronto offers a dual-degree program where students receive both a Bachelor of Science in Engineering (BASc) and a Master of Business Administration (MBA) degree. It also offers an executive education program titled, *Design Thinking: Connecting Innovation and Strategy.*

The Department of Design & Innovation, part of the Weatherhead School of Management at Case Western University, offers a PhD in Management with an emphasis