STATEFULNESS AND TANGIBLE INTERACTION IN INDUSTRIAL DESIGN EDUCATION

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1. INTRODUCTION

Industrial design is continuously changing and evolving. In recent years, this change has included the integration of methods from adjacent and complementary disciplines, resulting in the expansion of knowledge and skillset. A traditional approach to industrial design focused on developing mass-produced products is no longer enough to satisfy the needs of the profession. While physical interaction remains as a key component of the process, many products out in the market also include intangible digital interfaces. This tendency is obvious in Information and Communication Technologies (ICT's) products such as computers, tablets and mobile devices but it is also prevalent in products not considered hi-tech. From lightbulbs to measuring spoons and wastebaskets, and everything in between, more and more consumer products contain circuit boards and electronic components that improve their productivity and connectivity. This dramatic change in the marketplace urges industrial design to adapt itself and to address needs for systems that address user experience at multiple levels, involving tangible and intangible components. These systems need to provide the user with multiple layers of products, services and environments that work together to address complex needs and wants for individuals, communities and society.

An area where design boundaries are being blurred is tangible interaction. Industrial designers are trained for enabling physical interaction between users and their products, which requires strong focus in understanding how attributes such as shape, materials, texture, color, and relative position communicate functionality. Interaction designers, on the other hand, look at how intangible components such as digital interfaces provide logical sequences and behaviors that allow users to perform tasks and successfully navigate through complex workflows. The concept of 'statefulness' is key in interaction design, where the dynamic changes of complex systems are broken down into states that can be defined and manipulated in order to achieve a desired user experience. By combining the attention to physical and digital interactions with a strong focus on their multiple states and overall objectives, designers can achieve new and exciting systems that benefit from logical organization and multiple layers of interaction.

This paper discusses the framework in which interaction design provides a fresh and innovative way of thinking to traditional industrial design. This framework goes beyond having physical components of a product control digital interfaces and develops systems that identify states, relationships and experiences that jump between physical and virtual realms. The integration of interaction and industrial design is put into practice in a graduate level studio course at Rochester Institute of Technology, in which students are directed by instructors with expertise in both disciplines, all working together in exploratory assignments. The result is a series of projects that elevate user interaction by integrating methods from both design perspectives. An added benefit is a model for multidisciplinary collaboration that helps students to understand their role in design's ever-evolving practice.

2. THE INTANGIBLE SIDE OF INDUSTRIAL DESIGN

There has been a natural evolution on the role of design in society. Initially, design served to identify and organize symbols and forms that served user needs in a direct way. The relationship between users and designed solutions was direct and straightforward. As the complexity of user needs has evolved, design has gone beyond linear relationships with products and focuses now on understanding how humans relate to each other and to their environment (Buchanan, 2001). This open relationship along with the evolution of digital tools is one of the critical areas being examined by interaction design. It is here where designs are not the goal of design efforts but rather used as means to influence relationships in communities and societies.

Industrial designers are effective at assigning behaviors to tangible components of a product, but this skill does not always transfer to digital interfaces. While users rely on haptic and visual inputs to interact with a product, the dynamics involved in using electronic products include additional layers of complexity that are not covered by traditional industrial design training. Making linear conversions between physical inputs and their digital representations results in products that have electronic interfaces merely stuck on them (Djajadiningrat, et al., 2004). A good interface needs to understand the flow of the information and functions that are being controlled and how physical and digital experiences should be combined when interacting with products. Donald Norman (1990) suggested in that when designing electronic controls, it is necessary to connect their morphology and behavior to analog controls that would perform similar tasks. This approach is effective for direct correlations between physical and digital controls and was valid when electronic products began to be popular in the marketplace. As products and systems have evolved, this linear approach becomes less effective since many products in today's marketplace are no longer tied to analog equivalents anymore. A good example are mobile phones (Figures 1 and 2). In the 1980's these devices were a close version of landline telephones and hence had interfaces that made those connections. Today's mobile phones have little connection to telephones, offering a wide array of other capabilities and functionalities, leaving making calls as an infrequent activity. These devices are too many degrees separated from their analog precursors and therefore need a different type of morphologies to ground their behavior and functionality. These morphologies are in many cases abstract and are no longer based on spatial relationships (Djajadiningrat, et al., 2004).

Figure 1: Motorola's 1983 DynaTAC 8000x. Photo by Rosenfeld Media [CC BY 2.0]. <https://flic.kr/p/bUAN4o>

Figure 2: Samsung's 2014 Galaxy S5. Photo by Karlis Dambrans [CC BY 2.0]. <https://flic.kr/p/mw55a8>

3. A MODEL COURSE THAT INTEGRATES PRODUCTS AND INTERACTION

A graduate course at Rochester Institute of Technology, a U.S. top-ranked industrial design program, uses a series of projects around tangible interaction in order to make students aware of the possibilities that physical elements of design have to drive interaction to more complex levels. The explorations in this course focus primarily on three-dimensional design assignments, where students can develop physical forms at more open-ended levels without having to worry about concrete limitations that would exist in the realm of traditional industrial design. When combining these approaches with traditional knowledge in industrial and product design, students are able to effectively define simple, basic and fundamental levels of interaction between humans and objects that then can be used as foundation for meaningful interactions between users and products or systems.

In order to set up a good balance between both approaches, the course is co-taught by instructors with backgrounds in industrial and interaction design. This format helps in making sure that there is guidance and expertise in both design disciplines while also modeling how the disciplines collaborate together. This interdisciplinary approach resonates with current trends in academia and industry where having multiple disciplines working together on a project provides better results and highlights benefits and gaps of each discipline involved (Eppinger and Kressy, 2002). This appreciation for benefits and gaps would be hard to happen in a single-discipline environment where no comparison between methods, processes and philosophies is possible. Additionally, while interdisciplinarity is common in most fields, design tends to be an ideal environment for working with other disciplines, given its collaborative nature and array of visualization and fabrication skills (McDermott, et al., 2014).

A number of key learning outcomes are set for this course, based on current trends in design practice, interdisciplinary collaboration, and unique skillsets that product designers don't necessarily acquire with traditional curriculum in industrial design. The goals include:

- Develop awareness on dynamic and static states or objects and systems.
- Establish a common language between industrial and interaction design, primarily based on visual mapping.
- Maximize the use of physical attributes of objects in order to communicate function and state.

These goals serve as overarching frameworks that influence the direction of all projects and discussions in the course. Their success is measured in how students are able to bring together individual actions or interactions with particular components of their solution into a cohesive and enjoyable experience. These goals also encourage students to be more comfortable with broad contexts that cannot belong to a single discipline or mindset. Just as in today's world most products combine analog and digital components and behaviors, designers need to be able to transition between these two levels. The goal is not just to be versed in either analog or digital environments but most important, to integrate them in an effective way that results in the best solutions and user experiences possible. In order to achieve these learning goals, a series of exercises and projects are defined so that students explore how to integrate new design approaches to their process. Project fall primarily into two topics: object statefulness and tangible interaction.

3.1 UNDERSTANDING THE STATES ON AN OBJECT

The concept of 'statefulness' is essential to all forms of interaction, whether that interaction is physical, digital and all combinations thereof. While 'state' is originally a concept central to computer science, the course explores how the idea of 'state' applies to our understanding of physical objects and our interactions with them. Some of the questions that students are expected to answer with their projects include: what is the nature of user interactions with everyday objects? In what ways can people understand and improve their function through an examination of their states of interaction?

The use of statefulness in user-centered design for complex systems has a unique benefit in which designers can move away from linear needs leading to solutions, and instead looking at them as different states of an integrated system (Findeli, 2002). This means that instead of developing solutions that overcome problems, it is more effective to conceive systems states in conflict that become states in harmony. This approach is more inclusive and also avoids having unresolved tension that would impact user experience in a negative way.

The exploration of states in the course involves a series of in-class exercises and short projects that help students to understand how everyday products have particular states whenever being used, many of which are overseen by users as well as designers. An example is the creation of a 'flexagon', a flat model made out of folding strips of paper that can be flexed or folded in certain ways to reveal faces besides the two that were originally on the back and front (Figure 3). The flexagon is developed in the course to transition from identifying states in existing products to develop a new object with a clear set of visual states, not to mention to challenge the level of craftsmanship of each student.

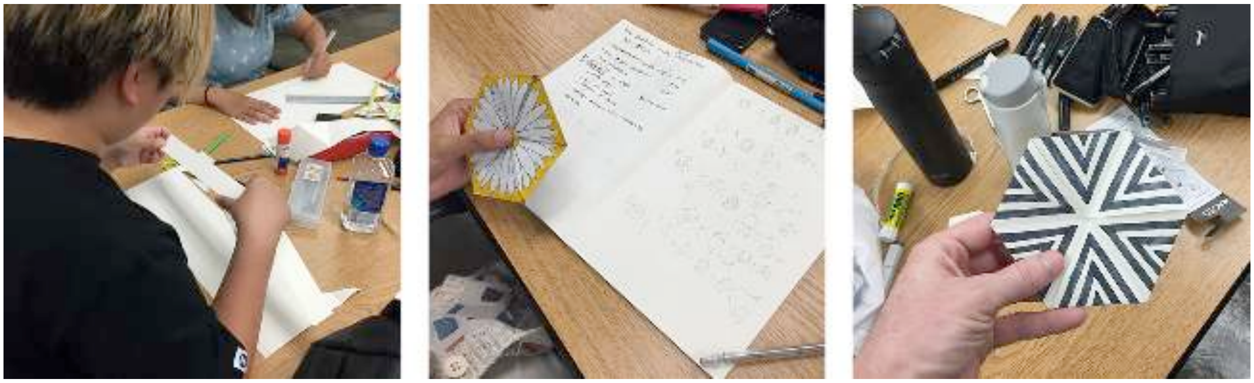

Figure 3. A series of flexagons created by students in the course.

Following the flexagon, a two-week project focuses on developing an object whose form can reflect at least five distinct physical states. Each state must be clearly and uniquely identifiable while sharing formal attributes that make them part of a shared system. Physical models allow to configure the objects into each one of their five distinct states. Objects may be traditional products with a clear function, or may also be abstract in their function. In either case, they need to provide good interaction and distinct, user configurable states.

Jiamei Huang developed a stackable structure with modular shapes that can be repositioned in countless ways (Figure 4). This is a good example of the use of materiality since the shapes are all the same but come in two colors. The contrasting colors along with their position and orientation provide innumerable possible combinations. In fact, the student calculated that the blocks can be configured to over 24,000 different combinations.

Figure 4. Wooden block set. Photo by Jiamei Huang.

Fangyi Lin took inspiration from nature and developed a flexible flower that can be repositioned in multiple ways (Figure 5). The pedals move individually but because of their pattern structure the user tends to position them in interesting patterns. As the form takes different states it is easy to imagine different roles of functions that could be assigned to a product with these physical characteristics.

Figure 5. Reconfigurable flower. Photo by Fangyi Lin.

3.2 FROM SEQUENTIAL STATES TO TANGIBLE INTERACTIONS

The final portion of the course is the core component of the sequence, which focuses on tangible interaction via dynamic objects. The concept of statefulness is essential to all forms of interaction, whether that interaction is physical, digital and all combinations thereof. While ‘state’ is originally a concept central to computer science, students are asked to explore how the idea of state applies to our understanding of interactive systems.

When industrial designers first look at tangibility within electronic products they tend to think of physical objects that will manipulate the digital/virtual space (Jensen, et. al, 2005), similar to how an ATM or a gas pump has buttons around the screen that allow to select options. This approach is valid but also very limited as tangibility can have a broader impact on how a product performs and the type of experiences that happen within it. This part of the course looks at how to discover those possibilities by using tangible interactions to perceive digital/intangible relationships. Students are charged with developing objects that combine elements of control, display and feedback as a screenless, physically embodied system. The objects should be a physical representation of computational systems that may or may not currently exist. The goal is to develop a tangible system that explores how interaction may be driven through the manipulation of stateful objects. When exploring these objects, students are looking at multiple elements of their materiality. A key component for tangible interactions is to move away from looking at objects simply as controls but rather as multidimensional systems that use form, color, texture, relative movements, sounds and other physical expressions as channels of communication. This utilization of these elements provides more opportunities for clever interactions with objects while also closing the gap between physical and digital worlds (Robles and Wiberg, 2010).

Xavier Arvelo designed a platform that controls a music streaming service such as Spotify (Figure 6). The interface has a round platform where three spheres can be placed. The spheres hover over the platform with the help of magnets, adding an interesting visual appeal. But the use of this feature goes beyond just aesthetics. The spheres can be moved in any three-dimensional direction. Moving them sideways along X-Y axis helps to select the songs and playlists that want to be played, while moving them up and down along Z axis controls the volume. Different spheres are used for particular playlists and if multiple ones are placed near the center of the platform, Spotify will combine them.

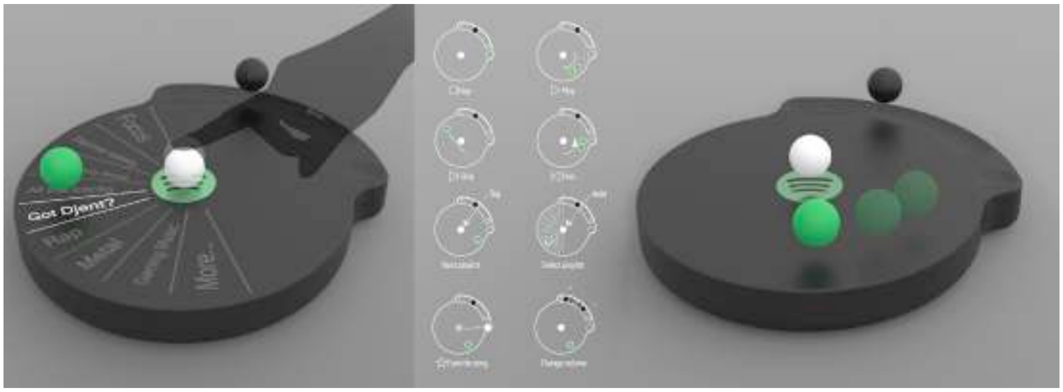

Figure 6: Digital music controls. Rendering by Xavier Arvelo.

Fangyi Lin designed a set that helps to cook by keeping track of portions of key ingredients in a recipe. A shallow bowl is used to place pieces that represent ingredients of a recipe (Figure 7). The more pieces of a particular kind that go in, the more of that ingredient that will go in the actual recipe. This helps to visualize in a clearer way the makeup of a dish and can help users to understand which ingredients are more or less abundant in their diet. The bowl could potentially send out this information to shopping lists or calculate nutritional content and portions.

Figure 7: Kitchen ingredients' interface. Rendering by Fangyi Lin.

4. BENEFITS OF COMBINING PRODUCT AND INTERACTION DESIGN

There is a frequent misconception that product design focuses on physical products and that interaction design addresses digital interfaces (Buchanan, 2001). The difference on the medium is hardly relevant and a key distinction is that industrial design focuses more on how to develop design solutions to be fabricated in large quantities, while interaction design focuses on how designed systems improve human to human and human to environment interactions. This distinction drives the goals of the course to develop systems that combine physical and virtual components in order to elevate experience and emotion. Industrial design tends to overlook many states of a product. For example, industrial design tends to focus on active use of a product, thinking about how the product solves a need or fits with the user while interaction design is more careful in analyzing what each state of a product communicates. Part of this awareness comes from the attention that interaction design gives at all the steps needed in order to create a fluid flow or animation. This is similar to how people working on live-action videos take movement for granted whether as sequential animators or stop-motion artists have to pay extra attention to all the intricacies involved in communicating movement and gestures.

Tangible interaction is a natural space where industrial design and interaction design connect. This space goes beyond creating buttons, slides, or other types of control that will give inputs to an electronic module inside a product. Hordecker and Bluur (2006) propose a multi-layered framework that looks at tangible interaction from four interconnected angles, including how product components are directly manipulation, the way that they are move in physical spaces, the user behaviors that they produce, and their innate expressiveness that reflects user experience. This overarching view of product interaction, typical in industrial design, helps in being more critical and focused about the benefits or applications of experience for solving user needs. It is common for interaction designers to focus on a cool feature or interaction but industrial designers question more what is the goal of a given interaction or how it serves a larger function that benefits everyday life.

The knowledge that industrial design has on materials, processes, manufacturing and industry, also helps in making sure that whatever experiences are conceived can be successfully executed. A topic commonly discussed in class is the avoidance of “black box concepts”, referring to concepts that sound engaging in terms of interaction or experience but that are not back up by a clear idea of how they can be executed. Limitations for the execution of concepts include access to specific technologies, form-factors that are two small to fit internal components, to name a few. Some examples of black-box concepts in the course have included dancing objects with small shapes that wouldn’t fit a battery or beautiful lighting effects that can only be seen in total darkness.

5. CONCLUSIONS

Design is evolving into an inclusive discipline with blurred lines between specialties such as product, interface, visual communication and new media. This integration of disciplines aligns with more complex systems that need multidimensional solutions that transcend physical and virtual, analog and digital, and spatial and experiential realms. The implications for design education do not imply that curriculum needs to be vague but rather to have a clear foundation of discrete skills in a core specialty with ample opportunities to collaborate with other areas both within and outside of design. It is in this collaboration that strong solutions emerge and that complex needs and wants are adressed in engaging ways.

The model course described in this paper makes it evident that design students benefit from navigating through different approaches such as industrial and interaction. During this process they understand subtleties such as materiality, physical and virtual states, and cohesive user experiences. Allowing them to explore how design enables interaction between humans and their relationship to their environment leads to richer experiences and more effective ways of integrating emerging digital technologies with traditional physical objects. A point of caution is not to overlook the need for core skills that each discipline brings to the table. Even if students understand the higher meaning of their design concepts, they will be frustrated if they don’t know how to execute them in a feasible, effective and efficient way. A good way of approaching this issue is to allow for basic explorations of interactions that eventually grow into more complex systems.

As students develop technical competencies and experiential sensitivity, they will be able to move beyond basic relationships of problems-solutions. The goal is for them to define concepts as interconnected systems with states that might initially cause conflicts but eventually are resolved in an elegant and engaging way. This is the core of successful collaboration and interdisciplinary frameworks that drives education and practice for generations to come.

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