Teaching Interdisciplinary Tangible Interaction Design Practice: A Framework with Material Imagination

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Abstract
This paper argues that intentionally developing students' epistemological awareness as well as materializing common imagination will facilitate interdisciplinary collaboration. Drawing on Itten's Basic Design Course [9] and providing a framework based on Bachelard's material imagination [4], a tangible interaction curriculum was designed to guide students through a process of building epistemic artifacts for discourse and dialogically criticizing the texture of a tangible interaction design. A set of shared design language, encompassing material, expression, function, and form, enables imaginative while focused communication fluently. Students' term projects illustrate their articulation for a preferred future through collaborative tangible interaction design.

Author Keywords
Tangible interaction design; interdisciplinary collaboration; basic design course; Laban Movement Analysis; material imagination

ACM Classification Keywords
H.5.m. Information interfaces and presentation (e.g., HCI): Miscellaneous.

General Terms

Human Factors; Design; Measurement.

Introduction

The last few years have seen a great deal of work on tangible interaction. Tangible interaction is a very interdisciplinary area influenced by a set of related research and design approaches in several disciplines, including HCI, computer science, industrial design, and interactive arts [6], which include different epistemologies, approaches, and outputs. Two major disciplines are HCI/computer science and product design/industrial design with different emphases and thus various curricula are designed in terms of tangible interaction respectively. It appears that learners very often use their own paradigms to learn and understand approaches from other paradigms in collaboration. However, relatively little research attention so far seems to have been devoted to a concern of building a basic course for tangible interaction design to encourage constructive dialogue between disciplines by understanding 'language' of each other, to frame a problem space with shared perspectives, to collaboratively articulate through interaction design, and to contribute understanding and knowledge to the community of HCI as well as design practice.

Researchers in HCI use the term 'tangible interfaces' to denote interfaces that utilize physical manipulation and representation of digital information, characterizing a data-centered view, which provides mediated digital data and computation with interactive physical artifacts [5, 6]. Students in HCI discipline are encouraged to explore various types of coupling and representations between the digital and the physical, highlighting human cognition and understanding through applying appropriate metaphors and embodiment to interactive tangible objects. In contrast, the perspectives from design community differ from those in HCI, emphasizing bodily interaction with physical objects, as well as the sensory richness and meaning created in interaction. Learners in this discipline are guided to consider formgiving and meaning-making wtih a perceptual-motor-centered view on tangible interaction [3].

Teaching students majorly from these two backgrounds such an interdisciplinary field together appears to be very challenging not only because of the diversity in definition of tangible interaction, but also the different ways of knowing, learning, and communicating in two disciplines. However, regarding tangible interaction as a design practice, this work addresses the issue of how students follow the course to construct their own skills and understanding of tangible interaction design in a more 'designerly way' [2]. Namely, how designers are educated is investigated first to draw implications for guiding the curriculum.

Related work

Basic Course of Design has been developed for a long time, within which exercises have formed the designerly ways of learning and understanding. For instance, Itten [9] introduced design skills of using "contrasts" and "opposite adjectives" of all kinds of forms, textures, and colors to inspire students in the very beginning of his basic course. Itten argues that students must have basic knowledge of materials before they can be truly creative. In contrast, regarding interaction design in terms of material properties has just emerged from design disciplines [16]. However, recent years have seen increased attention being given to methods and frameworks of teaching in tangible interaction design (TID), both in HCI/computer science and material design traditions. Djajadiningrat et al. from an industrial design perspective, focus on formgiving of tangible products to create a rich experience of interaction based on perceptual-motor skills [3]. In order to craft a meaningful relationship between appearance and action, the expressive properties were explored through an exercise of making pairs of sculptures showing opposite poles in a certain dimension. Baskinger and Gross [1] define tangible interaction as "form + computing" and see these two elements as equally important in making interactive products understandable.

Verplank [17] proposes four phases (categorized as motivation, meanings, modes, and mappings) to explore interaction design as well as to trace the progressive development of an interactive project. With this four-column interaction design framework, Klemmer et al. shared their teaching experience emphasizing the process of problem-finding/solving, methods, and evaluation of student-created designs [11]. This framework presents an analytic model as well as a practical agenda to translate the concerns and concepts in emerging interaction domains into a realistic design process. However, Verplank's framework regards interaction design as a problem-solving process, rather than a meaning-making one.

Hummels et al. [8] advocate the principle "interaction creates meaning" in movement-based interaction design and emphasize that an interaction designer has to be an expert in movement. In this perspective, movement is at the center of formgiving of interaction design. In order to design interactive products with aesthetic experience and intrinsic value, Ross and Wensveen propose an interaction quality framework, drawing on choreography to build a dynamic form language [Ross 2010]. Dynamic quality of movement in interaction is described according to a set of LMA (Laban Movement Analysis) qualities, providing opposite adjectives in each quality. This framework intends to elicit understanding of movement as material in interaction design and a familiarity with expressivity of dynamic formgiving in Itten's sense. In regard to emerging type of digital materiality, Jung and Stolterman [10] advocate form-driven interaction design research with its epistemological and methodological implications. Different perspectives and types of forms in interaction design are examined to inform form-making practices and provide an analytical framework to explore new qualities of interaction.

No matter which framework or method is adapted, Wiberg and Robles [18] advocate thinking interaction design as *composition* of materials ranging from digital to physical, of which the term *texture* denotes the relation and guides the quality of composition. Of notice is that critically evaluating textures is not intended to be objective. Rather than objective assessment in a positivism paradigm, the analysis of interaction design practice operates through critical dialogue. Therefore, an emerging challenge of interdisciplinary TID curriculum is how to encourage students to change epistemological perspective and consider critical and constructive dialogue to be a source of knowledge.

Problem

Challenge

Some questions are posed here to help clarify the purpose of this paper. What is the basic course of tangible interaction design (TID)? What are the contrasts in TID as Itten [9] designed hands-on based on practicing contrasts to understand the expression of a medium, followed by a series of exercises to study texture, collage, and composition. How do we teach TID? How can we inspire students to analogically learn TID in terms of texture, collage, and above all, the aesthetics. What is the common language of TID when conducting a collaborative project? What do interdisciplinary students have to learn? Is it possible to explicitly define TID and to clearly convey the concepts when teaching students with different disciplines and diverse backgrounds?

Above all, the primary challenge comes from an epistemological concern when regarding TID as a new discipline. What are the characteristics of knowledge in terms of TID? How is such knowledge obtained, accumulated, and conveyed?

Solution

Rather than searching for a theoretical, explicit, and precise definition of each term in TID in a single discipline, this paper aims at framing each term in relation to another. Drawing on Laozi's notions, that "big" can only be understood in relation to "small" [12], we argue that interdisciplinary design practice will greatly benefit from adopting ambiguous, open, and relative definitions to convey notions across disciplines in a fluent way. For example, students are encouraged to discriminate between "form" and "expression" whenever they encounter these notions in practice, instead of theoretically defining "form" in advance to inform design practice later. We propose a tangible interaction design framework encompassing four aspects (Material, Expression, Function, and Form), which form a set of design language by re-interpreting the four phases of the interaction design framework by Verplank [17]. To facilitate interdisciplinary collaboration upon a common design language in a short term, a feasible approach could be based on ambiguous and common notions of design terms according to what Gaston Bachelard [4] called "material imagination." We related material, expression, function, and form respectively to air, water, fire, and earth, which help students from different disciplines form the latent meaning of each term by creatively associating with existing experience and images of the four elements. Our framework will be detailed in the following section.

Acknowledging the practices of Ross and Wensveen [15] and Hornecker [7], we emphasize the aesthetic experience in the purpose of the course and use card game to assist students to develop concepts. Simultaneously, we also highlight the importance of collaboration and the beauty of craft and material [16]. On the other hand, to help students master contrasts in TID, we apply "Laban Movement Analysis" (LMA) [13, 15] and investigate the relation between form and movement. Interaction efforts such as time, weight, flow, and space provide a framework of dualities when regarding movement quality of tangible interaction. We investigated by constructing and administering an interdisciplinary curriculum, called Tangible Interaction Design [19], which included 42 students (12 design graduate students from National Taiwan University of Science and Technology and 30 engineering graduate students from National Taiwan University), forming 12 groups with one designer in each group.

It is neither intended nor possible to unify different paradigms into a definite one in this curriculum. Rather, we see student projects as 'epistemic artifacts' [14], which can be seen as tools or means to develop discourse and reflection. These epistemic artifacts also play roles of common ground to elicit critical dialogue between disciplines. Instead of superimposing a single epistemological perspective on students, their constructive making of epistemic artifacts is expected to lead to new knowledge.

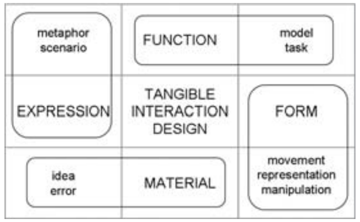

Figure 1. Tangible interaction design framework.

TID Framework and Toolkit

To address methodological issues, we propose a TID framework. Drawing on Verplank's interaction design framework that basically consists of four sequential columns, we provide students with a modified version of framework based on design language. This reframing adopts all detail concerns proposed by Verplank, which also represent respective methods and techniques for addressing these concerns. In addition, we add 'movement' in the aspects of form to highlight the relationship between body gestures and epistemic artifacts. This framework not only provides an analytic model but also a guiding map for collaborative construction of tangible interaction. The spatial layout in Figure 1 indicates a perspective that equalizes these four aspects in their roles and the sequential orders. Our TID framework is based on what phenomenologist Bachelard [4] calls "the material imagination." He distinguishes between two types of imagination: formal imagination and material imagination. Rather than being conceived intellectually in formal imagination, material imagination is an idea that comes from contact with nature. The reason why we employ Bachelard's work in tangible interaction design is that design process is not only a process of rationality but also of imagination, creativity, and dream. Therefore, how imagination works as a design resource becomes significant in our framework. Bachelard conceptualizes the dynamics of imagination in line with the experimental laws and he proposes the term "material imagination" to indicate a way to "materialize" the imaginary, which may be thought of by a creative imagination.

Four fundamental elements: earth, water, fire, and air, are mostly concerned and each of them will shape a certain type of "material imagination." Bachelard also points out that we usually have a combination of these types of imagination, such as fire vs. water, fire vs. earth, water vs. earth. Seeing tangible interaction design as an imaginative process, as well as a scientific and rational one, we relate the whole design process to the four elements which materialize the imagination of tangible interaction design as well as provide mutual interpretation in pairs. The benefit of materializing imagination is to invite students of different backgrounds to creatively associate an abstract aspect of a tangible artifact to the image of a concrete nature element. This method makes communication across perspectives from different paradigms very fluent while keeping discussion ambiguous and flexible but concentrated.

Form is conceptualized as the earth element of a tangible interaction. Association between creative imagination of the earth element and the aspect of form will generate understanding and semantic meaning such as shape, appearance, tangibility, affordance, etc.

Function on the other hand indicates enabled tasks by a certain model. Fire element is associated to a set of meanings such as innovative function, enabling, and advance technology. The discrimination of Function vs. Form can be literally discussed or related to the discussion of fire vs. earth. Nevertheless, the subtle understanding will emerge in this way, beyond definite definition of each term. Similarly, expression, associated to water element, denotes metaphor and scenario in tangible interaction. Material, both literally and metaphorically, indicates physical matter and conceptual idea to inform tangible interaction design, and is associated to the air element.

Figure 2. Card deck of tangible interaction design issues.

Followed by the methodological structure, four elements in our framework, are necessary toolkits or methods to address concerns in every element, such as movement in form, or metaphor in expression. Figure 2 shows a set of cards to help students brainstorm on the idea concern in ‘material’ element. The front face of a card is an inspiring drawing with issue title, and the back is the issue with its associated annotations for further ideation. Although this card deck is introduced to students as an initial toolkit, students are welcome to insert a new issue by themselves, or create another toolkit. Moreover, tentative and impromptu rules by students are also welcome. In fact, this card deck is a result from a workshop where interaction designers were invited to make creative imagination and annotation upon 22 typical Tarot cards of Major Arcana. The symbol, meaning, and image of each Tarot card are listed and used as stimuli to ask question such as what this card could be in terms of a framework of tangible interaction design. In this way, issues related to 22 images became very diverse and rich.

It is not intended to make a definite and complete set of tangible interaction design issues with the association of images of Tarot cards. Drawing on the imaginative process as well as a ritual of evocation and explanation of Tarot cards, our method materializes imagination, in Bachelard’s sense, in an improvisational way. Moreover, the contents of the original images of Tarot cards encompass 4 elements, 12 Zodiac signs, and 9 planets in the Solar System, with 3 overlapping elements, to form 22 characteristics to describe and explain all aspects of our everyday life. This composition also illustrates what system ancient people considered holistic enough to interpret every issue in our life.

Practice

Based on the above framework, we devised two basic exercises, and one project. Basic exercises are intended to help students constructively gain their own understanding about the design space of form, function, and movement. Conceptual design and paper prototypes were presented for critical dialogue in the classroom. Final project is an interdisciplinary, collaborative one, focused on the issue of “reminiscence”. Functional prototypes and posters of collaborative projects were demonstrated in an exhibition with invited reviewers from HCI community and design disciplines.

Exercise: Simple form

To understand the design space of form and function, students were assigned with an exercise to build a simple form to support function of adjusting a continuous value. This exercise focused on a very simple type of function to explore the rich possibility of formgiving.

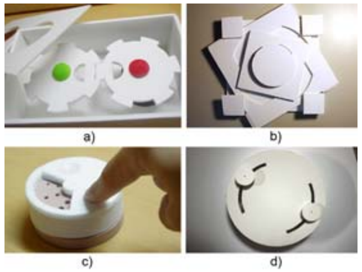

Figure 3. Formgiving exercise: simple form to support function of adjusting a continuous value.

Students were guided first to think in a specific scenario, adjusting a value by increasing or decreasing a corresponding degree of something. Then, abstraction and imagination of a form to support the above function were required. Typical materials are card boards and foam boards (Figure 3). With or without intended purpose of function in mind, these artifacts provide a common ground for discussion and mutual inspiration among students of different mind-sets.

Artifacts with clear and explicit semantics are easier to understand the intended functions (Fig. 3a, 3c). On the other hand, more abstract forms (Fig. 3b, 3d) demonstrate ambiguity and openness for more possible mappings and interpretation between form and function. Contrasts such as increasing/decreasing in a specific type of function, and concrete/abstract in formgiving are learned.

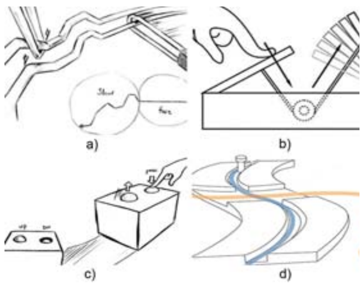

Figure 4. Movement sketches: form and movement studies using contrasts in dynamic qualities.

Exercise: Movement sketch

In order to study movement and form, an analytic framework is necessary for designers to investigate movement. Rather than improvisation in body gestures to get inspired in most body-storming session, we apply Laban Movement Analysis (LMA) [13, 15] to frame possible gestures supported by a specific form. The dynamic quality of movement in interacting with a form can be analyzed in four dimensions: Time, Weight, Flow, and Space. Each dimension can be further analyzed with opposite poles. For example, Time dimension includes quick vs. sustained qualities; Weight dimension includes strong vs. light qualities; Flow dimension includes free vs. bound qualities; Space includes indirect (multi-focused) vs. direct (single-focused) qualities.

This exercise asked students to follow LMA contrasts first and apply them to arbitrary forms. In addition to the function of analysis provided by LMA, this framework concretely brought perspectives of movement quality that most students did not have. As Hummels et al. argue [8], a tangible interaction designer must master in body gestures and movement. Since most students were not professionally trained in body gestures and movement before, contrasts in LMA could efficiently help them understand and frame movement very quickly.

Figure 4 shows movement sketches by students, applying LMA contrasts to create and analyze form with movement. Figure 4a is a sketch based on the contrast in Time dimension, and Figure 4d illustrates another case based on the contrast in Flow dimension in LMA. In addition, students were encouraged to extend LMA and define contrasts in movement on their own (Fig. 4b, 4c).

Project: Reminiscence

Interdisciplinary collaboration is always challenging and demanding in our everyday life and in the future. Seeing tangible interaction design as a practice-led design and research activity, located at the core of this course is the concern of how designers and engineers can co-work to articulate through a novel design output for a preferred future. Namely, how creative imagination and rational feasibility are integrated and balanced to make substantial articulation and further discourse is expected. Four aspects in our framework, material, expression, function, and form, provide a clear guiding map of both analytic and generative processes. These four aspects also form a set of design language and play roles of conveying and

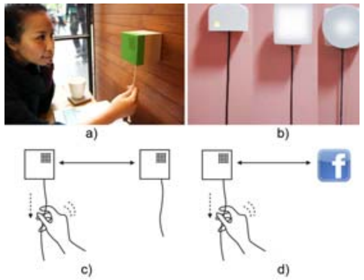

Figure 5. KITID.

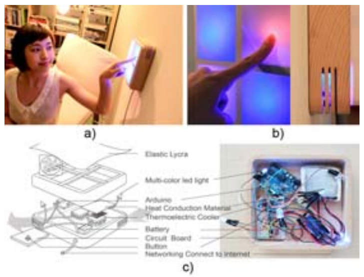

Figure 6. InTouch.

communicating ideas across different disciplines. Once the issue, reminiscence, was given, students in each team were encouraged to plan a specific design process for their own team based on shared agreement. Therefore, some teams directly started from form-making and body-storming, while others might first embark on functions and respective enabling technologies. Here we found different preferences from different disciplines, and the difference was highlighted and intentionally made aware for students. For example, design students were often eager to make physical forms but might ignore the technologies possibilities and limitation. In contrast, engineering students were more often fascinated with function enabled by novel and cutting-edge technologies.

Among 12 projects in total, here we highlight three projects, KITID (Keep in Touch ID), InTouch, and Hi!Me!, which were voted and discussed as most impressive ones, and present another two, which demonstrated strong tangibility concern and expressive body gestures. Of notice is that the issue of reminiscence works as inspiration to initiate design processes, rather than a limited goal to achieve.

KITID is a device to evoke friendship by unexpectedly calling on friends through the simple movement of drawing a rope, which would send messages to friends (Fig. 5a). Making interaction on social web tangible while crafting simple and elegant things to live with, KITID demonstrates beauty of materials after deliberately studying various kinds of forms and materials (Fig. 5b). This sociable artifact provides two modes of functions. Mode A will send a signal to a friend, expressing one’s consideration to friends with wireless communication module (Fig. 5c). Mode B transmits a random greeting message to a randomly selected Facebook friend through a connection between KITID and Facebook (Fig. 5d). In both mode, if a KITID gets a signal or message from the other one (mode A) or Facebook (mode B), it will sound a ringtone and blink LED. An Arduino board is embedded in the device to sense the movement, send signals or connect to Facebook, and produce output. The composite of physical/virtual materials shows unique texture of interaction experienced.

InTouch aims to explore how alternative sensory output can enrich the experience of mediated social interaction (Fig. 6a). InTouch consists of four sections in a wooden box surfaced with elastic Lycra. Each section stands for a communication link with a friend. By pressing a link, an individual can express her consideration for a friend. When pressed, the color changes from blue to red, while raising the temperature on a friends’ device. The temperature of each link is provided from a thermoelectric cooler (TEC), turning hot or cold based on the input electrical current (Fig. 6c). One movement triggers two senses, namely touch and vision, forming perceptual crossings as perceiving while being perceived. InTouch intends to stimulate participant's curiosity to explore the meaning of such a functional mapping of input and output. During the process of making design choices, a poetic expression that definitely made students go toward a clear destination came up: Can you imagine a red link feeling cold (Fig. 6b)? Besides the simplicity of movement, gesture, and function, students investigated materials ranging from physical form to digital material. Making an alternative usage beyond its intended function hidden behind the computer, they employed a thermoelectric cooler as a technical implementation choice.

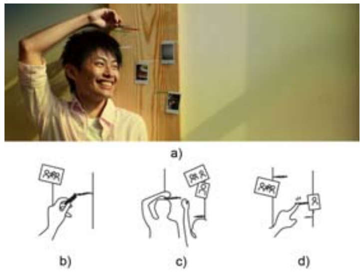

Figure 7. Hi!Me!

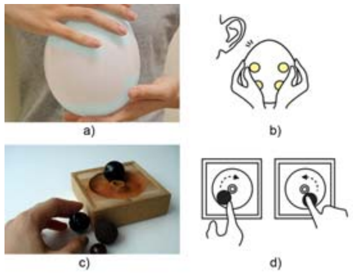

Figure 8. WishEgg (top) and Vorice (bottom)

Hi!Me! is a conceptual design to inscribe traces of a person's height from childhood to adulthood on a graffiti tree made of an upright wooden board fixed on the wall (Fig. 7). The graffiti tree is combined with an audio time capsule composed of vocal recordings and silhouette projection. Whenever parents mark the height of their children by a chalk and an attached RFID tag nearby, Hi!Me! will start to record voices and capture silhouettes. "Re-touching" an inscription with a specially made RFID reader will trigger the time capsule that was created and intended to provide dialogs and reminiscence with an older self. This design notices the gradual change of our body in height, and uses this nature measurement as an evocative feature for associated memory. Spatial inscription related to the body posture, changing without intention, matters for memory evocation with a solid indication of how high one was ever, how one's voice sounded, and what shape one's body was.

To save a wish, an individual holds the WishEgg with creative hand gesture and makes a wish (Fig. 8a, 8b). Then the saved wish can be recalled by making the associated gesture that was performed when recording on the egg. By combining the gestures into the process of wish-making, this artifact connects sound, sense of touch, and body interaction altogether. Evocation of memory should be a bodily expressive experience rather than a precise and decontextualized task. Vorice is a tangible woodwork music player (Fig. 8c, 8d). A music album (playlist) is encapsulated in a ball for expressive manipulation. Placing a ball at the center of the device indicates that a playlist is recognized and in a state of pause, while nudging the ball into the groove, the device will decide the sequence of music playing according to directions of the rolling ball, sensed through three magnetic reed switches underneath the groove. A functional prototype with excellent crafting quality has provided a unique felt experience of controlling music playing with expressive embodied movement. Such rich bodily experience includes the weight of balls, the texture and tactile feedback of the woodwork, and the whole dynamic quality of movement.

Discussion

A sensitive and mindful educator in an interdisciplinary course may notice different epistemologies of students from different disciplines, which form a major challenge in their collaboration. Graduate students in this course are from two typical paradigms: analytic and generative mind-sets, with logical inferences of inductive/deductive reasoning, and abductive reasoning respectively. Rather than bending one paradigm to fit the other, we argue that searching for a common ground to bridge different perspectives is of the first priority in teaching an interdisciplinary course such as tangible interaction design. We have demonstrated possible ways of building a common ground: a framework with material imagination and practice to make epistemic artifacts.

Conclusion

Three major findings conclude this research. First, providing a framework with ambiguity and openness, such as material imagination, can make interdisciplinary communication feasible and focused while imaginative. Imagination should not be sacrificed for rigid rationality from a tight framework. Second, we should provide necessary skills and methods for students to build their epistemic artifacts, in order to gain understanding in a designerly way. Experience from Basic Design Course, such as using contrasts in exploring material's expression, can shed some light on tangible interaction design education. Finally, we should guide students to articulate their design through delivering functional prototypes for bodily experience, as well as being dialogically criticized to build a body of knowledge based on feltness and constructive meaning-making.

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