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# Enhance Creative Thinking by Collaborating with Designers

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## Abstract

This paper reports a case study of training technology graduate students to think more creatively in a visual analytics system-design competition by collaborating with designers. In the summer of 2013, two faculty members led a team organized by technology and design graduate students to work on a visual analytics system design and won the only two awards of "Outstanding Creative Design." To investigate and learn from this interdisciplinary collaboration experience, we purposely tracked and collected the design process information such as meeting minutes, white-board discussion photos, and development files at different stages from the very beginning of the collaboration for analysis and review. The paper reviews this 7-week design process and specifically focuses on observing how the technology students were influenced by their design peers, started to learn and adopt design methods, then accepted and generated "wild" design ideas by themselves. Furthermore, we also discuss and report faculty's roles in this process and the types of strategies that drove the collaboration and fostered the creativity.

## Introduction

In the book of "a whole new mind why right-brainers will rule the future," Daniel Pink [1] claims that just as information workers surpassed physical laborers in economic importance, the workplace terrain is again changing, and power will inevitably shift to people who possess different kinds of minds, such as artists, inventors, and storytellers – creative and holistic "right-brain" thinkers. This argument sounds a little overbearing; however, it is very true that humanity's future relies on the creative mind. As educators, we look forward to inspiring, motivating, and fostering students' creativity. Most technology and engineering students tend to quickly focus on the technical aspects of a project, and design students tend to focus on usability, quality, innovation, and the aesthetics of products [2]. In this paper, we discuss our collaborative practice to integrate these two tendency directions and inspire creativity in the practice.

As a category of the IEEE VIS conferences, the VAST (Visual Analytics Science and Technology) challenges aim to push the forefront of visual analytics tools using benchmark data sets and establish a forum to advance visual analytics evaluation methods [3]. By participating in the VAST challenges, researchers are expected to gain understanding of how their system would be used in dealing with real data analytic tasks. The 2013 VAST challenge presented three typical challenges problems [4]. The mini-challenge 2 (MC2) was a design-focused problem that asked participants to design an innovative large display to support situation awareness in a large computer network control center [5] . Participants of this task are expected to act not only as problem-solvers, but also as innovative designers who can change the boring work environment in the network control room. In the summer of 2013, we led an interdisciplinary team of technology and design graduate students in the Purdue University to work on this competition. The technology students are from the department of Computer Graphics Technology (CGT). The design students are from Interaction Design (IXD) of the department of Art and Design (A&D). Overall, the collaborations were very successful: the two totally different designs created by the same group won the only two awards. A variety of interesting moments occurred in the process. To understand and evaluate the collaboration, and improve the strategies for future education, we collected the process information from meeting minutes, white-board photos, and design sketches, and we interviewed students during the design process. This paper reviews and analyzes the collected data, reports this interdisciplinary collaboration process, and suggests a pedagogical approach to enhance the creativity development of technology students.

## Theoretical Foundations of the Study

### Creativity and Creative Thinking

Among the varied definitions of creativity [6]–[8], there is a common agreement on what creativity involves: "bringing something into being that is original (new, unusual, novel, unexpected) and also valuable (useful, good, adaptive, appropriate) [9]." Researchers have all agreed that to be creative, creative thinking must take place. To be of value, that thinking needs to be critical. Creative thinking should integrate fundamental aspects associated with thinking in general, which combines recalling and imaging; classifying and generalizing; comparing and evaluating; and analyzing and synthesizing, deducting, and inferring [10]. The role of design and creativity is well established in art and design domains. However, in computing technology disciplines, specifically in the development of software systems and information technology, the computing educational community is struggling to include creativity and design in its teaching and research [11].

### Adopt Creative Thinking from Designers

Today's design strongly seeks ways to change itself into a more competitive and innovative discipline, taking advantage of the emerging advanced technologies as well as their profound effects on emerging design theories, methods, and technologies. Several reform programs have been initiated by research institutes, universities, and design practices. The Interaction Design program at Purdue University, which focuses on developing new approaches to explore the interaction possibilities in the context of industrial design, is one of them [12].

In the literature of Engineering Education, employing Industrial Design (ID) collaborators to enhance design thinking and creation has been studied for more than three decades [13], [14]. Studies have been conducted on the educational perspective [15], [16] and design methodology [17]. Esko Kurvinen [18] outlined critical settings and situations that should be taken into account when industrial design is introduced to engineering-oriented product development. In biomedical engineering, Jay Goldberg [19] argued that although engineers and designers tend to emphasize different aspects of design, both disciplines place heavy emphases on identification of customer needs, manufacturing methods, and prototyping. Several recent research efforts [15], [16], [20] focused on analyzing the collaboration between Industrial Design students and Engineering students in various projects. In recent years, researchers interested in studying problems involving complex interactions on human-machine systems have risen. Numerous researchers highlighted the importance of user interface features in design because the design will help users to predict what will happen toward the system [21] [22]. Although many studies have been made on Interaction Design and complex technology products, few studies highlight emerging themes in Interaction Design, such as the role of methods and theories, interaction design processes, and design criteria [23].

**Design Collaboration Models**

Many design process models show a cycle that repeats itself and is populated by several design strategies [24]. The illustration in Fig.1 shows the most typical design strategy. A standard starting point is to read and understand the specifications and constraints of the design challenge, followed by researching the idea and brainstorming for possible solutions. Ideas then get prioritized, and the best are selected to be built. The prototype then undergoes an evaluation based on the product specification checklist. Designers experience the cyclical nature of their work when their designs cycle through many iterations before the final version is completed. First they develop one idea, build it to try it out, notice changes that need to be made, make those changes, and evaluate the new product. The cycle then repeats itself. The act of repeating these steps is an iteration in the product design cycles.

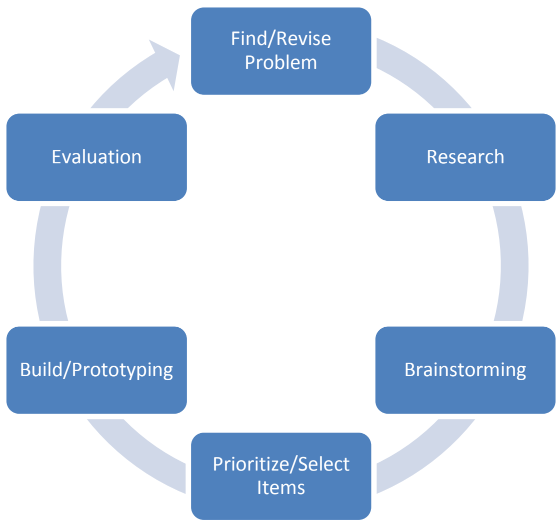

Fig.1. Cyclic Design Model

Based on this typical design process model, we want to explore how technology students can effectively learn from and collaborate with design students. Mattessich and Monsey's survey in collaboration literature [25] has drawn a clear distinction among cooperation, coordination, and collaboration. *Cooperation* is the informal relationship without a clearly defined common mission, structure, or effort. *Coordination* shares the understanding of compatible missions, but authority still rests within the individual organization. *Collaboration* suggests a more durable and pervasive relationship, and the authority is determined by the collaborative structure. We aim to establish a true collaborative relationship in this design competition task. To judge the collaboration type of design, identifying its mission, authority, and relationship is important. Kvan [26] suggested that collaboration is also episodic and cyclical. Collaborators interact periodically, but they work independently and parallel during portions of the design. Kvan's model is demonstrated by Fig. 2. There are generally four stages in an iterative cycle: meta-planning, negotiation, expert work, and evaluation.

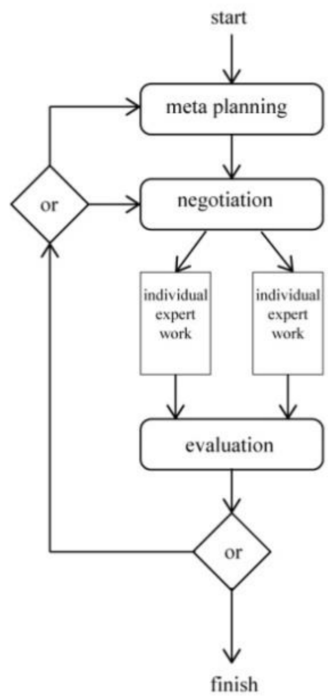


Fig. 2. Kvan's model of Design Collaboration [26]

## Conceptual Justification of the VAST Competition Project

The design problem developed by the 2013 VAST mini-challenge 2 is how to help the computer network administrators to obtain accurate knowledge about a large computer network and analyze issues in an efficient manner [5]. This challenge was looking for design talents than can task risks and envision creative solutions [4]. We sliced this problem into three layers: (1) visualize all the dimensions of the real-world security network; (2) help the analysts to quickly be aware of emerging issues; and (3) provide an effective but not disturbing environment in a control room. To meet these requirements, we look into literature in three areas: big data Visual Analytics system design, situational awareness, and ambient information display.

To represent, communicate, and analyze complex information, previous work in Visual Analytics (VA) has explored a variety of approaches to handle 'big data' [27]. As 'big data' are often complex, multidimensional, and multivariate, many VA works have discussed different methods of visualizing large datasets. Pixel-based visualization in different forms are popular to fit the huge data space into a limited screen space [28]. Another popular method of visualizing network data is to use graph-oriented visualizations where machines are mapped to nodes, and links connecting those nodes with different characteristics, such as thickness and color, represent relations among nodes [29].

Situation awareness (SA) refers to the perception of elements in the environment within a volume of time and space, the comprehension of their meaning, and the projection of their status in the near future [30]. The importance of SA as a foundation of decision making and performance spans many fields, such as emergency medical call-outs, search and rescue, forestry service, air traffic controllers, driving, power plant operations, maintenance, and military operations. In a review by Livnat et al. [31], a growing body of research aims to validate the role of visualization as a means to solve SA issues in complex data problems.

In this challenge task, the analysts should become aware of issues and their severities as soon as these issues emerge, but they still should spend most of their time on investigating and solving identified issues. Therefore the display should not be disturbing when not needed. Ambient Information Displays provide an alternate method of displaying information that does not require the constant attention of the user [32]. This method has been widely used to encourage and facilitate communication. Researchers have developed systems that use a multitude of everyday items to display information such as lights, sounds, shadows, and artificial flowers. Pousman and Stasko [33] proposed a taxonomy of ambient information systems as a new information visualization subdomain that complements the focus on analytic tasks, and also provides analytics, awareness, social, and reflective sights.

## A Collaborative Design Process

The mini-challenge of “Situation Awareness Display Design” started in the beginning of May and its submission deadline was on July 8, 2013. We organized a team with two Computer Graphics Technology (CGT) students, three Interaction Design (IXD) students and two faculties. The seven team members started to actively work on these challenges from the middle of May. The two faculties, one come from CGT, one come from IXD, served in multiple roles – supervisor, teacher, collaborator, and researcher to study the collaboration process. The whole collaborative design and development period lasted for about seven weeks. To effectively integrate design thinking into the process, we as instructors purposely introduced design methods and models to the collaborative process. Although most of the students are unfamiliar with the cybersecurity and visual analytics techniques, we encouraged them to speak out and suggest wild ideas bravely. We recorded and collected all the meeting minutes, white-board notes, brainstorming sketches, and related documents to review this collaboration. In the following text, we integrate the traditional cyclic design model (Fig.1) and Kvan’s model of design collaboration (Fig. 2) to describe and analyze this 7-week collaboration process.

### Week 1. Meta-planning Stage: Design Research to Identify Problem

The goal of the design project is to create a large display in an operation control room that can monitor an enterprise network consisting of several hundred thousand computers. To motivate the creativity, the organizers listed no particular requirement. The description specifies only three network features (health, security, and performance) and four types of conditions (normal activity, routine issues, non-routine issues, and crises). It is hard to find descriptions of the setup and workflow of a computer network control room. The problem described is close to the cybersecurity dataset provided in VAST 2012 MC1 [34]. The two faculties have accumulated some successful experience while competing in that challenge [35]. But to avoid influencing students’ creative thinking, the faculties only introduces the VAST 2012 data and solutions briefly, and encourages the students to explore the possibilities by themselves. Design students were used to conducting ethnography studies to inspect the context and investigate the problem. During the very first week while everybody was still puzzled by the challenge description, one IXD student self-initiated to interview a network security analyst.

The interviewee described their main responsibilities, expertise, and the work flow in the control room. Two students coded this interview audio recording. Based on the interview coding, team members started to understand how control rooms function to monitor a network for certain conditions and how to avoid degraded service by controlling it in real time. Generally, the functions analysts are monitoring status boards, route information, internal networks, external networks, and social media in real time. Given the urgent nature of work, the organizational structure tends to be very hierarchical. This hierarchical nature applies to both the personnel and the procedure. Employees usually have been distinguished and utilized based on their types and levels of expertise. One level of analysts will be assigned to solve a certain type of problem. At the same time, management is strongly centralized and directive via formal lines of communication. As a result, a central information display should be comprehensive and easily legible, which should facilitate connectivity across organizational connectivity.

Based on these interview outcomes, our design problem has been defined more clearly. We aimed to develop a large and multidimensional network display that monitors the four types of conditions of three features in real time and will help the managers to be aware of urgent conditions and assign tasks to suitable personnel immediately.

**Weeks 1 ~ 2. Meta-planning Stage: Brainstorm with Sketching**

Based on the identified problems, we encourage students (both IXD and CGT) to sketch their ideas freely without constraints. Designers think visually. Visual thinking involves the interaction between mental (imaging), graphical (drawing), and perceptual (seeing) images [36]. Although cognitive psychologists have mixed views of relations between mental imagery's nature and representation, it has been examined and confirmed that drawing is valuable for creating new problem-solving ideas [37].

For CGT students, they are not used to representing ideas through sketching. In Fig. 3, they either drew ideas carefully on the grid paper or made annotations on existing images. They tended to limit everything into a reasonable organized arrangements and start the brainstorming from a constrained perspective of designing system interface. In the middle sketch, the student tried to sketch the steps of interaction with a couple of smaller windows and directional arrows.

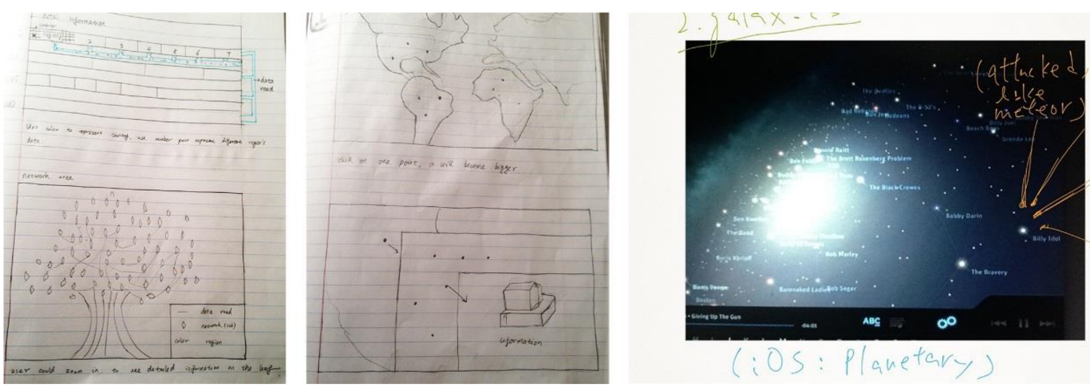


Fig. 3. Idea Sketches by Computer Graphics Technology Students

IXD students are accustomed to communicating ideas with sketches, but they are unfamiliar with system design and visual analytics concepts. They felt free to draw their ideas on any type of paper (the middle image of Fig. 4 was on a kind of cream-colored cardboard), flexibly occupying the paper corners. They also inserted notes and small figures freely to explain their ideas of how analysts interact with the visualizations (right sketch in Fig. 4). There are usually several components of one idea's representation. Any useful piece would be added if necessary.

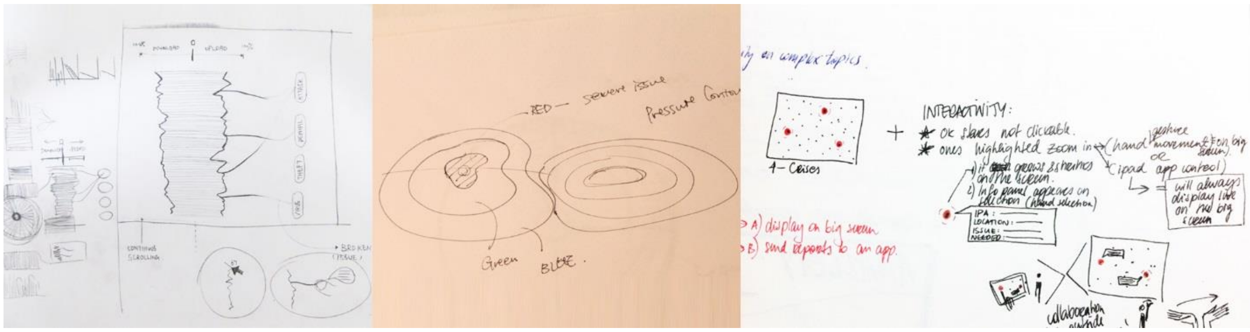


Fig. 4. Design Sketches by Interaction Design Students

**Weeks 3 ~ 4. Negotiation Stage: Prioritization and Brainstorm**

After the first round of idea sketching, the students quickly generated more than thirty sketches. In week 3, we began to review, compare, discuss, and filter ideas. The challenge task is to design a large visualization that would grant analysts awareness of the current condition and help them to understand its effects in light of their pertinent goals. Ambient displays seek to convey a continuous feed of live information subtly in the background, without alerts to unnecessary effects. In our search for delicately complex designs we looked into the nature and wanted to bring some scenes that can be soothing for those who have to face the monotonous and detailed data on a daily basis.

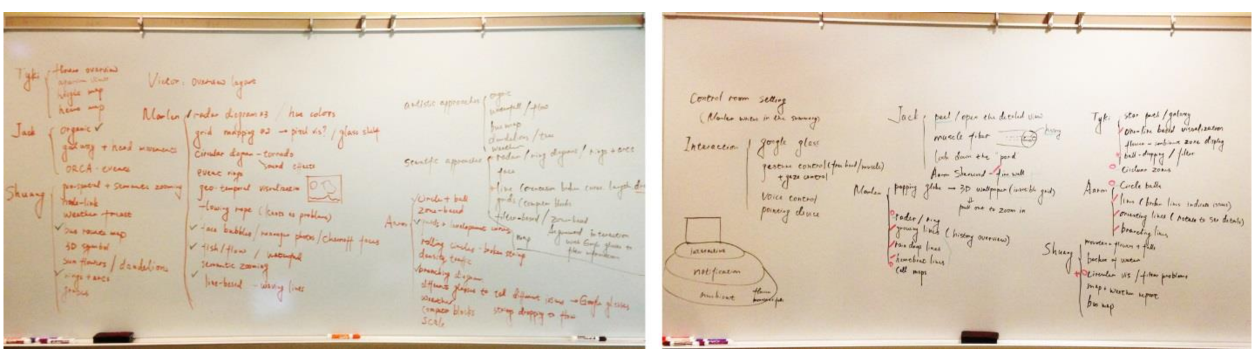

Fig. 5. Discuss, Filter, and Integrate Ideas (photos of white boards)

Based on this overall goal, the team listed all the ideas on the white boards to discuss and filter them. The left image of Fig. 5 shows the results of the first round of negotiation. Some of the ideas were ticked and grouped into either the artistic approach or the scientific approach. Students did another round of sketching after the 3rd week's group meeting. After looking at the design student sketches, CGT students were obviously relaxed and started to sketch in a more flexible way in the second round. In week 4, we compared and selected a couple of ideas as shown by right image of Fig. 5. Generally, there were two main directions of these visual design ideas: circular-based visualizations that can show the hierarchical structure of network, and line-based visualizations that display most of the network properties. The team members were also excited by the waterfall scene idea of artistic approach and the galaxy scene idea of scientific approach. We found it difficult to give up either of these directions or ideas. So we decided to make two submissions to the challenge: integrate the circular visualization with the galaxy idea and the line visualization with the waterfall idea. The group of five students split into two teams and each team has at least one CGT student and one IXD student. Two faculties were participating in the design and development of both teams.

**Weeks 5 ~ 6. Expert Work Stage: Detailed Design and Prototyping**

During the expert work stage, both teams focused on the visualization design details and building interactive prototypes to demonstrate the design. For example, the circular visualization SolarWheels was inspired by the Solar System and the wheels commonly seen in our daily life. We applied the metaphors of orbiting planets, solar coronas, planetary hierarchies, along with the circular shape and spoke element of wheels. Together the display, as a collection of modified form of Solar Systems, is able to interactively visualize a global computer network. In the detailed design, the team members discussed how different dimensions of data can be visualized by properties in the circular graph (right image in Fig. 6). The designers illustrated the decisions in the figures (left image in Fig. 6) and the technology students created interactive prototypes to demonstrate how circles split, connect, scale, and integrate. The two components were under construction in parallel. We used different kinds of communication tools (e.g. Dropbox, Skype, and WeChat) to discuss and update progresses on a daily basis.

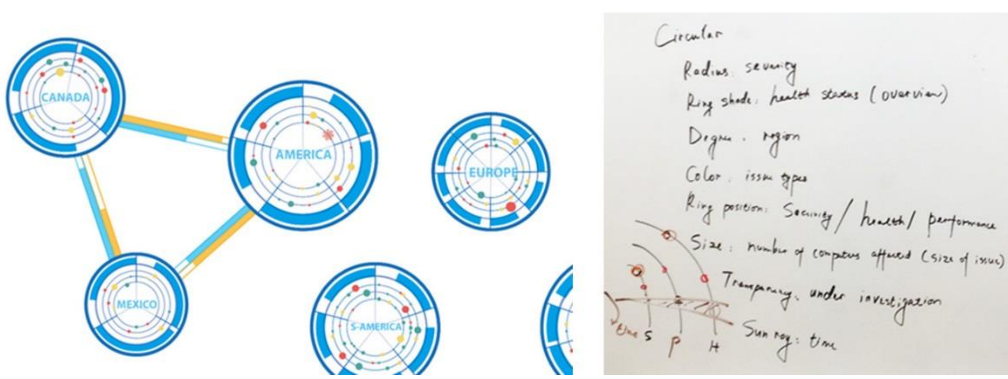


Fig. 6. Process of Designing the Display of SolarWheels.

**Weeks 5-7. Evaluation Stage: Review and Packaging**

During the final stage, the two teams evaluated each other's projects in the big group weekly meetings. This type of peer evaluations turned out to be very effective and productive. Since these two ideas are concentrated from early ideas contributed by all the team, their names should be listed in both submission entries but varies in sequence. As a result, all students were motivated to carefully inspect problems and tried to contribute innovative and practical ideas to both entries. The relationship between two teams are more like collaborators than competitors. For example, suggested by other team members, the circular team added a corona-like ring to display the network speed. The line team changed the metaphor from a pouring waterfall to a scene of calming rain (Fig. 7). Many changes like that were made, based on the peer critiques and suggestions in the big group meetings.

We submitted two entries to the 2013 VAST mini-Challenge 2: SolarWheels and SpringRain. Each of these submissions had to include a digital system prototype, a summary Web page, and a high-resolution 4-minute video to demonstrate the design. During the final two days, all students and faculties worked intensively in the same lab. Everybody was busy working on the parts in which they are most expertized. For example, the student with a good voice was responsible for all the video narrations, an experienced movie editor worked with a novice on both videos. The professors drafted the submission summaries, solved key technical problems, and inspected all the submission components.


Fig. 7. Two Challenge Entries: SolarWheels and SpringRain

## Discussions

Our two submissions won the only two awards of 2013 VAST mini-challenge 2 while competing with teams from many prestigious research centers. Both of these awards were entitled "Outstanding Creative Design" and received many compliments from the reviewers and from the conference presentations. Students were very excited and motivated by the international reviewing committee and thus built up confidence to explore more in the domain. While looking over this whole design experience, as the supervisor and educator of the team, we were interested in investigating how creative thinking was seeded, nourished, and flourished. The collaboration of technique and design was definitely a winning start. However, we have had experience with projects having such interdisciplinary collaboration that were not very successful [2]. To understand more about this process, we not only analyzed the process data collected, but also reviewed the entire process with all of our student participants after conference presentations.

Based on a discussion by Amoussou et al. about the fundamental aspects of creative thinking [10] and our team review discussion, we identified a few related design strategies to be referred by technology students:

- *Define criteria and constraints for ill-defined design problems*. For technology students, they used to solve well-defined problems with professional skills: the problem has a clearly defined given state, a finite set of operators or rules to apply on a given state, and a clear goal state. Many times only a limited number of optimistic solutions are available. Facing open-ended design problems like this challenge, they are easy to get confused and lost because of so many viable solutions, or they will focus deeply on their first idea and spend all their time to make that one perfect. Adopting some ethnographical research methods to investigate, analyze, and define the constraints are very crucial for solving the design problem in a creative way.
- *Use drawings to imagine, represent, recall, and communicate ideas*. Sketching is a tool, but not a task. A creator should allow the mind to drive the pencil and escape the limits of paper size to record emerging ideas, using free-style drawings to recall and discuss ideas. Even though the sketch may not be professional and aesthetically pleasing, the wild ideas behind it are invaluable and traceable.
- *Classify, deduct, infer, and synthesize the idea pool to elaborate*. For a design problem, the number of solutions is basically infinite. The strategy to find a good solution is not to select an idea, but to group, compare, filter, integrate, and even reconstruct several ideas. While facing a large group of choices, analyzing the pool to identify the best and creative solution requires collaborative intelligence and efforts.
- *Compare and evaluate to enhance the solution*. Based on the circular design model, evaluation is always the decisive stage to review and detect flaws. We luckily had two teams working in parallel to solve the same problem with different approaches and were able to evaluate and contribute in an effective way. Using a proper evaluation method and recruiting the suitable evaluators are very determinative for the success of this project.

As educators, participants, and observers of this interdisciplinary collaboration experience, we continuously encouraged technology students to try and learn “wild” design methods and metaphors from their design major peers. The goal of this collaboration is not to receive creative ideas from designers like many previous approaches [12] [13], but learn to be as creative as designers. At the same time, our students also taught us a great deal and motivated us to explore more in this journey of searching for creativity in education.

## Acknowledgment

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