
Tango Cards: A Card-Based Design Tool for Designing Tangible Learning Games

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Abstract

In this paper we present the prototype design and evaluation of Tango cards, a card-based design tool for designing tangible learning games. Tangibles and games both have been suggested to have good potential to support learning due to their unique affordance or mechanism. Tango cards is the first attempt to summarize the latest design knowledge in these two areas and transform the knowledge into a card-based design tool with the goal of making the design knowledge accessible throughout design process.

Keywords

Tangible user interface, tangibles for learning, educational games, tangible learning games, design tool, design cards

ACM Classification Keywords

H5.m. Information interfaces and presentation (e.g., HCI): Miscellaneous.

Introduction

Research has suggested various reasons why Tangible User Interfaces (TUIs) have great potential to support learning, with the arguments derived from both theoretically based assumptions and exploratory

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empirical studies. For example, the everyday, concrete physical form of TUIs is natural and enables learners to leverage their real-world knowledge to help understanding [15]. The physical manipulation involved in tangible interaction supports offloading thinking to actions on physical objects and thus facilitates problem solving [2]. The properties and/or interaction with the physical manipulative may provide metaphorical linking to help understand abstract concepts [12]. TUIs also have been claimed to have unique benefits in supporting collaboration with a design of shared space and controls [2,15].

Meanwhile, there has been increasing interest in investigating how to design effective educational games to make learning intrinsically motivating and engaging. For examples, Gee analyzed the learning principles behind good video games that make them motivating [7,8]. Fisch put forward design considerations about how to effectively integrate educational content into game play from his experience designing learning games [6]. Castell and Jenson explored how to enact ludic epistemology to design “content-free” educational games with learning information distributed among the multiple modalities afforded by digital media [5].

We propose that *tangible learning games*, which harness the unique affordance and learning opportunities provided by TUIs and the good learning principles inherent in good games, should be a promising approach to support learning. Tangible learning games are still a new concept and find themselves mostly as research prototypes, as exemplified by Kurio [14], an interactive hybrid system (TUIs and GUIs) that utilizes tangible objects and game mechanism to support the social interaction and

learning of families visiting a museum. There are more existing tangible learning prototypes, which may not meet the strict definition of games, by do enact playful learning [5], as exemplified by Flowblocks [15]. Although it seems that a majority of current tangible learning games/systems are designed for children, there is no reason why adult learners cannot benefit from them in formal and informal learning settings. The learning domains that tangible learning games fit in are not limited either, e.g., math, science, music, and general abstract concepts (such as sustainability), to name just a few.

Design frameworks and loose design principles have been developed to structure thinking and practice of tangible learning design (e.g., [1]) and learning game design (e.g., [6,7,8]). However, such knowledge is abstract and dense, which make it difficult to use in design practice. Rogers suggests that to enable design theory to best inform design, a focus on the design process is important [13]. Therefore, what is needed is a design tool that bridges this gap and makes design knowledge accessible to design process.

This paper presents the design and evaluation of Tango cards, a card-based design tool for designing tangible learning games, as an initial effort to bridge this gap. Tango cards have the potential to encourage the application of the design knowledge to the design practice of tangible learning games, which in turn can foster the validation and refinement of the design theories.

The research questions we want to investigate through our research instrument of Tango cards are:

- Are cards an effective design tool in making design knowledge about TUI for learning and learning games more accessible to designers during their design practice?
- How do designers use Tango cards in different design activities? For what purpose and in which situations are the cards most useful?
- How do the specific design features of the Tango cards (e.g., presentation, form, content) enable or limit such use?

Cards as a Design Tool

Design cards are small paper cards with text and pictures on them that concisely present a knowledge domain as sources of inspiration and/or information during design process. Our approach of using cards as a design tool was informed and inspired by previous work that transformed design frameworks or conceptual information into design cards to make the source knowledge accessible in design process [3,10,11]. According to the findings of previous work [3,9,10], small physical cards enable designers to freely move and arrange the cards to externalize their ideas and to orient team members to their ideas, thus making arguments tangible during a design discussion (see figure 6). Cards can help structure design discussions, ensuring the “design space is viewed from different perspectives and informed by a framework.” When a discussion becomes unproductive, cards can foster the shift of focus to unstuck the discussion. Cards can also be used to evaluate design.

Literature Sources of Tango Cards

The literature source of Tango cards covers two categories: TUIs for learning and games for learning.

Tangible Learning Design Framework

The considerations about designing tangibles for learning were transformed from the Tangible Learning Design Framework by Antle and Wise [1]. This framework is the first attempt of an explanatory tangible learning design framework, and represents the most current effort to provide design guidelines for tangibles for learning. It aims to fill the knowledge gap by providing specific, testable mechanisms by which the unique affordances of TUIs might facilitate learning. In this framework, the authors identify five important elements for TUI learning design (physical objects, digital objects, actions on objects, informational relations, and learning activities). The authors then propose 13 design guidelines from cognition and learning theories to inform the design of these elements. Empirical examples are provided to support guidelines when available. This framework can help designers make predictable design decisions and evaluate design analytically.

Design principles/considerations for learning games

Currently there is no design framework for learning games. Instead we extracted learning game design principles/considerations from mainly two sources: the principles of learning that Gee found by analyzing good video games through cognitive scientist lenses [7,8], and design considerations that Fisch summarized from his research and design experience about educational games [6].

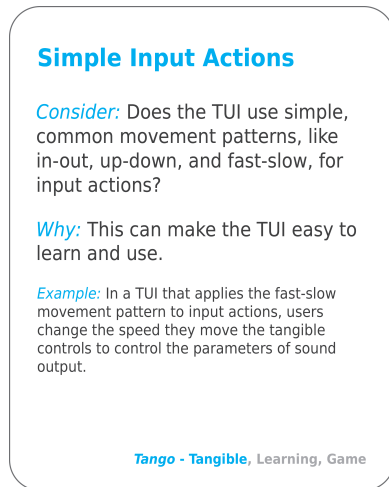


Figure 1. Example Tango card: Tangible category, text side



Figure 2. Example Tango card: Tangible category, image side

Designing the Tango Cards

The design goal of Tango cards is to make knowledge about designing tangible learning games accessible and usable to designers during their design process. Unlike Hornecker's card brainstorming game that she transformed from her Tangible Learning Framework [10], which focuses on inspiring the design discussion in early design phase and allows free interpretation, we want our Tango cards to both inform and inspire design in a variety of design activities throughout design process. We care about the cards' ability to effectively communicate the original design knowledge more than the cards' innovation power. We assume that most of the users of Tango cards, i.e., design researchers and students (and future users of design practitioners), have experience and knowledge with some aspects of the design domain of tangible learning games, but not all. We want to make sure that the information presented by both the tangible and game categories of Tango cards makes sense to all users. We made the design decisions described below with these goals and requirements in mind.

Design Process

Based on our design goal and the design knowledge contributed by other researchers who designed cards as a design tool or design research tool [3,10,11,16], we designed Tango cards through an iterative design process. We then conducted an expert review to gather feedback on card content and design. Four researchers, including three PhD students and one senior researcher with expertise in TUIs, game design, or learning science participated in the review. We revised our cards based on their feedback. The final design is a set of 25 cards (a PDF copy of the cards can be downloaded from <http://www.sfu.ca/~yingd/tangocards.zip>).

Developing Card Content

We distilled considerations, explanations, and examples from the literature described earlier and transformed them into more concrete and pragmatic information in simpler language. Such transformation aims to make the information more accessible and usable to designers. For example, for the "Simple input actions" card of the tangible category, the original design guideline in the Tangible Learning Design Framework is "*Leveraging image schemas in input actions can improve usability and system learnability*". We rephrased it to "*Does the TUI use simple, common movement patterns, like in-out, up-down, and fast-slow, for input actions?*"

Tango Cards Design

Tango cards consist of two categories: tangible cards and game cards. The design considerations for both TUIs and games are learning-oriented. The cards are color-coded by categories: blue color for the 11 tangible learning cards (figure 1 and 2), and orange color for the 14 game cards (figure 3 and 4).

Each Tango card has two sides: the front text side and the back image side. The front side (figure 1 and 3) contains five parts: title, design consideration, rationale, textual example, and a label "Tango Cards – Tangible, Learning, Games" in the order from top to bottom of a card. The design considerations are phased in a provocative question format as inspired by [10]. The rationale part explains what benefits such consideration can bring, mostly from the learning perspective. The text example briefly describes a practice or technique that reflects this consideration.

Intrinsic Rewards

Consider: Are rewards intrinsic to game play? Can rewards enhance users' game play experience?

Why: Intrinsic rewards are more motivating and interesting than extrinsic rewards such as high scores or more points.

Example: Giving access to locked content, functions, or more powerful items is a good intrinsic reward.

Tango - Tangible, Learning, Game

Figure 3. Example Tango card: Game category, text side



Figure 4. Example Tango card: Game category, image side

The spatial order as well as the font hierarchy of the elements on the front side of a card corresponds with their order of importance to card use. We want users to catch the core information; that is, title and consideration on their first sight on a card; and they can choose to continue reading the card if they need further information. This feature supports users of different levels of familiarity with the design knowledge. After users get familiar with the concepts, they might need to look at only the title and consideration question (or only the title) to remind themselves of the concept. Large title font size also enables users to read and refer to a card from a distance. The examples can facilitate understanding the concept as well as provide users with design ideas.

The back of a card (figure 2 and 4) contains the card title and images examples. Similar to the text examples on the front side, we anticipated users to use the image example to gain a more concrete understanding of the design concept as well as for inspiration. In addition, the image example can serve as a visual shortcut for a specific card, especially after users become familiar with the cards. We also wanted to add a QR code linking to detailed information about the prototype (e.g., publications and videos), but this was not implemented and the QR code image on each card is just a placeholder. (In our user studies, we asked participants to ask us for access to further information if they wanted to.)

Choosing Image Examples

We decided to use images of existing prototypes (learning games or systems with tangible interfaces or on other platforms, such as multi-touch tabletop, interactive environment, and computer) to illustrate the

design considerations if any is available. We did use examples of human activities (e.g., building a tree house for the "Relating skills to goals" card) or diagrams (e.g., the "Feedback as scaffold" card) occasionally when we decided they were a better fit for the specific cards than any prototype examples we were able to find. We preferred examples of specific prototypes to more general examples because we felt that such prototype pictures would inform and inspire designers more directly regarding how to apply a design consideration about tangible learning games [9]. We thought such direct, specific examples were especially important for the design domain of tangible learning games, as it is still a new concept to many target users. We also felt that such prototype examples would serve a quick learning and research tool for designers when they work on their own.

However, we do admit that such specific prototype examples may require more contextual information and explanation to make sense. Moreover, the relatively short conceptual distance between the source of inspiration (i.e., prototype examples) and the design domain may weaken the innovation power of the cards [9]. There is a trade-off here between making the usefulness of the examples easy to recognize and making the examples powerful in triggering innovative ideas.

We anticipated that the use of Tango cards would be similar to the use of the design cards serving similar purpose, as described in the "Cards as a Design Tool" section. We also anticipate new use of Tango cards attributed to their unique knowledge domain and card design.

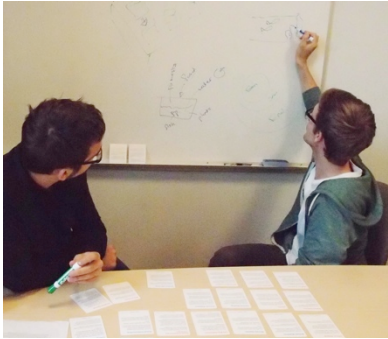


Figure 5. Switching back and forth between cards and whiteboard; going back to cards for inspiration when stuck.

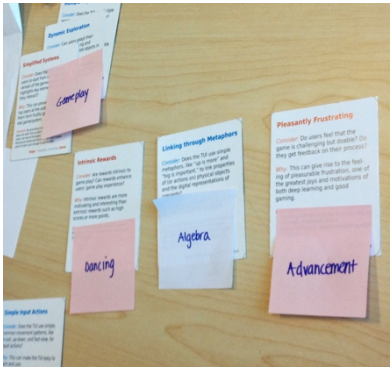


Figure 6. Using cards (with sticky notes) to externalize and bookmark ideas

Design-in-Use Study

Twelve sessions of design-in-use studies have been conducted to explore the utility and limitation of Tango cards. Twenty-four graduate students and undergraduate students from School of Interactive Arts and Technology at Simon Fraser University participated in the study, with a pair of them for each session. Each pair of participants has knowledge and experience in at least one of the following fields: game design, tangible interaction design, and learning science. In a design-in-use session, the pair of participants was asked to work together to complete two design cases using Tango cards. Each study session lasted 2.5-3 hours. After the design activities, the participants were asked to fill a Likert-Scale questionnaire and interviewed to gather their feedback on card design and usage. All the sessions were video recorded (for the user study part) and audio recorded (for the interview part). We also took observation notes and interview notes. The triangulation of data from observation, questionnaire, and interviews enhances the validity of our research.

Design Cases

We developed two design cases with the goal of exploring the utility of Tango cards in different design activities and application areas. The first design case was a redesign of a web-based interactive game that helps children learn to solve algebra problems and the importance of healthy eating to a tangible game. The redesign should also make the game more effective in educating balanced meals and nutrition knowledge. This case focused on late-stage design activity (redesign) and school subject (algebra). The second design case was an initial concept development of a multi-player tangible game that helps children understand the complexity involved in building a

sustainable environment. This case focused on early-stage design activity (initial idea development) and more general, abstract concept (sustainability). Due to the time constraint, we did not include a design case of evaluating an existing design, although the redesign case actually required participants to evaluate the old design in order to decide how to approach their new design.

Preliminary Results

We are in the process of analyzing the data. We present some preliminary results here.

We observed all the card uses identified by earlier work as described in the “Cards as a Design Tool” section. Participants generally recognized the cards’ value in developing concrete ideas and refining ideas. They thought the cards helped guide their design and reminded them of all the important perspectives they need to consider. Some participants also remarked that the cards served as jump-off points for their concept development (figure 6). It was repetitively observed in the design sessions that participants returned to cards iteratively for new inspiration when their design discussion became unproductive (figure 5). We also observed in many sessions that participants used cards to evaluate and critique the original design that they were asked to redesign and their own design ideas. On the other hand, participants did not find the cards very useful for brainstorming when the design space was still to be defined. This echoes Hornecker’s finding [10].

Regarding card design, the biggest theme noticed so far is that many participants thought unfavorably about the image examples about complex research prototypes, especially those about *Bifocal Model* [4] (e.g., the

"Smart tools" card and "Simplified systems" card). They found it difficult to grasp the idea about the prototype with only a prototype picture and short description. Although they were provided with the option of QR code, none of the participants used it. (As the QR code was not implemented, they were told to ask us for access to further information about the prototype if they want.) When asked about whether they prefer prototype image examples or images of general human activities (e.g., the image of building a tree house for the "Relating skills to goals" card) or diagrams (e.g., the "Feedback as scaffold" card), most of them preferred images of human activities or diagrams. The image side of the cards was generally much less used than the text side. Regarding the text side, many participants expressed their appreciation for the information hierarchy of different elements, as *"they are just the right order."* Some participants felt that the text on the card was a bit wordy and dense.

A few participants stated that they found it difficult to locate a card they read earlier from a piles of cards (although they mentioned that the color coding and/or the images on the back side facilitated their searching to some degree). They wanted the cards to be more "searchable". One suggestion was to have a thumbnail view of the image example on the front side.

Discussion

While it is still too early to make any strong claim about our findings, we think our study results, might reflect the challenge of designing the cards to serve different uses and roles throughout the design process, especially the conflict between designing to communicate the source design knowledge accurately and informatively and designing to support quick

ideation discussion. The former role requires including sufficient, in-depth information, while the latter role appreciates cards' at-a-glance value and the support of free interpretation. At this point, we feel tentative as to whether cards as a design tool can stand on their own to serve these multiple roles at the same time.

Contribution and Future Work

We contributed a card-based design tool - Tango cards, with the goal of making the design knowledge of the nascent domain of tangible learning games accessible to designers throughout their design process. We hope Tango cards can promote the dialogue between researchers and designers of tangibles and games for learning. This reciprocating process would be especially beneficial for this fledging research/design area. In addition, as another practice of transforming design knowledge into a card-based design tool with the goal of serving multiple design activities and phases, our work will contribute new design insights about the potential and limitation of cards as a design knowledge transformation tool.

We are in the process of analyzing the design-in-use study data to address our research questions. We will revise the cards incorporating the insights and feedback gained from the study data to make the card set better meet its design goal. As future work we might extend the investigation to field projects by design practitioners to explore the cards' utility in real life situations and in a variety of settings and learning domains.

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