Tango Cards: A Card-Based Design Tool for Informing the Design of Tangible Learning Games

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ABSTRACT

For over thirty years researchers have suggested that both tangible user interfaces and digital games have potential to support learning. Each domain now has a well-developed body of literature about how to design them to enable learning benefits. What is needed is a way to bring this knowledge, which is often lengthy, dense, and jargon laden to design practice. To address this need, we designed Tango Cards—a card-based design tool. In this paper we report on the design and evaluation of the cards. We found that Tango Cards enabled a variety of uses that made design knowledge about tangible learning games accessible to designers. We identify and discuss how specific card features support or limit use by designers. We draw on our findings to set forth design considerations that may support others to create design tools (card-based or alike) that make academic design knowledge accessible to designers.

Author Keywords

Design tools; design cards; design practice; tangible user interfaces; educational games; tangible learning games;

ACM Classification Keywords

H.5.2 Information interfaces and presentation (e.g., HCI): User interfaces—Theory and methods;

INTRODUCTION

Interactive technology is rapidly transforming the ways in which people work, play, communicate, and learn. For over forty years, researchers have worked to understand how to harness the motivation power of games to create effective games for learning. There now exists a robust body of knowledge about what makes good educational digital games. For example, Gee analyzed the learning principles behind good video games in order to determine what makes them motivating [7]. Fisch put forward design

considerations about how to integrate educational content into game play effectively [6]. Castell and Jenson proposed that effective games embed learning material into a broad range of game elements including character selection, art, narrative, programming, goals, game structures and play [5].

In parallel, researchers investigated how tangible user interfaces (TUIs) may be designed to support learning. For example, they found that the physical manipulation involved in tangible interaction may enable learners to offload elements of mental processes to actions on physical objects, which may make problem solving simpler [1]. The physical properties of tangible objects may be used to represent metaphorically related concepts to help learners understand abstract concepts [16,20]. TUIs also may be designed to support collaboration because they may provide multiple objects with which to interact in larger spaces than traditional desktop screen-based systems provide [11]. In particular, Antle and Wise's Tangible Learning Design Framework [2] represents a culmination of a range of findings about designing effective TUIs for learning.

Recently, researchers have brought these two research fields together, proposing that *tangible learning games* may be a promising approach that can be designed to support many kinds of learning. Design knowledge about educational games (such as [6,7]), and tangibles for learning (such as [2]) provide rich academic knowledge to draw on. However, these academically oriented design guidelines and frameworks are lengthy, dense, and jargon-laden, which make them hard to use in design practice [12]. Rogers calls for mechanisms of knowledge transfer between design theory and practice that are "more lightweight and accessible" than design guidelines and frameworks [17].

We designed a card-based design tool, called Tango Cards, to bridge the gap between scholarly design research about tangible learning games, and the practice of designing such games. Design tools and methods are a well-established form of intermediate-level knowledge, with their abstraction level spanning a broad range [9,13]. Together with other examples of intermediate-level knowledge, such as patterns, strong concepts, and heuristics, they serve as alternative ways to construct knowledge and bring theory to

practice [9]. In particular, card-based design tools have been used by a number of researchers to bridge the gap between scholarly knowledge and design practice [3,8,12,14]. They are hand-sized and typically contain both text and pictures. Researchers have found design cards to be effective as knowledge "transfer vehicles" between theory and practice [17].

In this paper, we present the design and evaluation of Tango Cards. The goal of Tango Cards is to make scholarly knowledge accessible in order to inform the design of tangible learning games. We designed a set of cards, conducted expert reviews, and then revised the cards. We conducted a user study on the revised set to investigate how designers used the cards, how card characteristics supported or limited card use, and to better understand in what situations and for whom the cards were effective. Through a process of synthesis, reflection, articulation, and abstraction [9], we present general design considerations that can be used to create design cards (or other tools) to bridge theory and practice in other design spaces.

BACKGROUND

Cards as Design Tools
Design researchers have created card-based design tools to make knowledge produced by design-based research as well as other domain knowledge accessible to designers. Hornecker transformed her Tangible Interaction Framework into Tangible Interaction Cards [12] to make the concepts better fit into the ideation flow. Lucero and Arrasvuori created PLEX Cards [14,15] to communicate the Playful Experiences (PLEX) framework to designers in a form that is more accessible in design discussions. Bekker and Antle designed DSD Cards [3] to make information about children's cognitive, physical, social, and emotional abilities at different ages accessible to designers of children's products. Halskov and Dalsgård developed Inspiration Cards [8] to bring both existing technology and application (communicated by the Technology Cards) as well as knowledge about the specific project under design (communicated by the Domain Cards) closer to designers as sources of inspiration. They aimed to facilitate designers' "reflective conversation" between the repertoire and the situation [18]. IDEO created Methods Cards[1] to expose designers to a variety of methods that they can use to understand the people they are designing for.

In studies of design cards design researchers have found that cards can help structure design discussions, ensuring a design space is viewed from different perspectives. Cards can help speed up the refinement and iteration of ideas [3,14]. Cards can also help kick off design discussion and foster focus shift when the discussion becomes unproductive [8,12]. The information on the cards provides designers with a common vocabulary to use in design discussion [8,14]. Cards can also be used to plan and guide evaluation [12,14,15].

In particular, the form of cards is important in terms of how the cards support designers. The small physical form of cards affords physical manipulation [12]. Cards can serve as a physical reference during design discussion, facilitating communication and shared understanding [3,12]. Cards can be used to bookmark discussion ideas [12,14]. Indeed, as Hornecker claims, using cards is tangible interaction [12].

Each set of cards serves as a useful design tool for its specific design space, often enabling the transfer of knowledge from academe to design practice. However, card research to date has not been generalized to other design situations. Nor have researchers always articulated what design knowledge was embedded in their card artifacts. Another limit of previous work is that most card sets were designed to provide inspiration in the early stage of a design process (e.g. [8,12,14]). Less is known about how to design cards that can inform designers and can be used at various stages of design.

Design Space of Tangible Learning Games
The design space that Tango Cards were designed to support—tangible learning games, actually consists of three dimensions: tangibles, games, and learning, with the learning dimension embedded in the first two; that is, the tangible and game dimensions are learning-focused. It is a complex design space in terms of its multiple dimensions, and the complex design knowledge involved with each dimension.

We translated the knowledge about designing tangibles for learning from the *Tangible Learning Design Framework* (TLD) by Antle and Wise [2]. We extracted learning game design principles mainly from the learning principles that Gee derived by analyzing examples of good video games through cognitive science lenses [7], and design considerations that Fisch summarized by drawing upon his experience designing educational games [6].

DESIGNING TANGO CARDS
Our design goal for Tango Cards was to make knowledge about designing tangible learning games, which researchers have produced through design-based research, accessible to designers in different activities throughout the design process. Our first priority was to create cards that could be used to accurately and easily inform designers during their work. Our second priority was to create cards that provided inspiration.

Considering that tangible learning games are still in their infancy and mostly exist in laboratories as research prototypes, the target audience of Tango Cards for now and the immediate future would mostly be design researchers and students. However, in the long term (hopefully in the
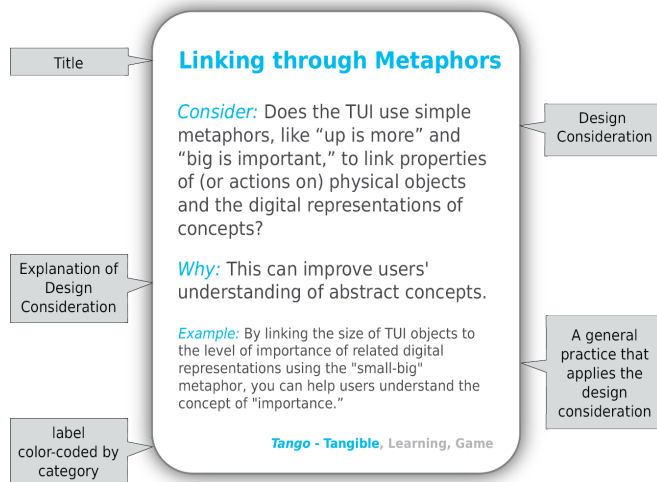
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[1] http://www.ideo.com/work/method-cards

Linking through Metaphors

Consider: Does the TUI use simple metaphors, like "up is more" and "big is important," to link properties of (or actions on) physical objects and the digital representations of concepts?

Why: This can improve users' understanding of abstract concepts.

Example: By linking the size of TUI objects to the level of importance of related digital representations using the "small-big" metaphor, you can help users understand the concept of "importance."

Tango - Tangible, Learning, Game

Title

Design Consideration

Explanation of Design Consideration

A general practice that applies the design consideration

label color-coded by category

Figure 1. A Tangible Card, front/text side.

Information "On Demand" and "Just in Time"

In *Kurio*, the interactive museum guide is distributed among several tangibles (e.g., pointer, listener, and reader), a tabletop display, and a PDA. Users learn knowledge about museum artifacts through using the tangible guide to complete their missions to fix a time map.

Title

A short description of the picture example

A picture about a specific application of the design consideration

QR code linking to papers and websites about the principle and example

Figure 2. A Game Card, back/picture side.

near future) design practitioners in industry will also get involved in designing tangible learning games. We designed Tango Cards with both the current and future target users in mind.

Tango Cards Design

We first did a literature review of research about design cards including [3,8,12,14]. We then designed our cards based on this review and our goals. The final design was a set of 25 cards, approximately 3.8" by 4.4" in size. A PDF copy can be downloaded from

http://antle.iat.sfu.ca/tangocards

Tango Cards consist of two categories: cards about tangibles and cards about games. The learning aspect is embedded in all cards. The cards are colour-coded by category: blue colour for the 11 tangible learning cards (Figure 1), and orange colour for the 14 game cards (Figure 2). These colours are very distinct, which enables designers to sort the cards by category when needed. For example, when they are unfamiliar with only one category of knowledge.

Our review reveal that cards intended for inspirational use (such as [12,14]), tend to include only a few words related to a concept on each card. Our priority for Tango Cards was to inform designers. Therefore we needed to include more information about each concept on our cards to avoid vagueness. Based on the design of IDEO and DSD cards [3] (which cover more information), we decided to include five types of information in the cards. The front side (Figure 1) has five elements: title, design consideration ("Consider"), rationale ("Why"), textual example ("Example"), and a label "Tango Cards – Tangible, Learning, Games" in the order from top to bottom. Titles are short, punchy phrases capturing the gist of each concept. The design consideration is framed as a question as inspired by [12]. The rationale

part explains what learning benefits such a design principle can bring. The text example briefly describes one or a couple of general ways to apply the design consideration.

The back of a card (Figure 2) contains the card title, a picture example (with a short description), and a QR code (unimplemented). Most pictures are photos of tangible learning systems (games) that demonstrate the design consideration. The picture examples serve as specific, concrete examples of applying the concept.

The information architecture of the cards; that is, the spatial arrangement of different elements as well as the font hierarchy of the elements on the front side aligns with the order of importance of different elements to card use. We wanted to present the title and design considerations, which communicate the core idea of the concept, at a glance. Designers can choose to continue reading the other elements if they need to.

Developing Card Content

When we developed the content, we used the card structure (i.e., the different card elements as described above) as the "template" to guide us in extracting information from the source literature [3,6,7]. We aimed to make the title tantalizing and memorable as well as descriptive. We focused on replacing academic jargon with simpler words to make the information easier to understand and apply. We thought that this rewriting would be important to both design practitioners and design researchers and students. For example, we didn't use the term of *image schema* used in the source [2]. Instead, we adapted it to *Simple Input Actions* (as the card title). We phrased the corresponding guideline as "Does the TUI use simple, common movement patterns, like in-out, up-down, and fast-slow, for input actions?"

Choosing Picture Examples

We chose to use pictures of tangible learning systems (games) for most cards (e.g., *FlowBlocks* [20], *Kurio* [19], *Tern* [10], *Bifocal Models* [4]). For previous cards that focus on inspiring, their picture choice concentrated on inspiration and innovation. Researchers of these cards suggested that picture examples should be familiar to end users and easy to relate to [12,14]. They argued that the examples should not be too specific to constrain the ideation space; nor should they be too general so that designers find it difficult to relate to the examples and apply them to their projects [8,12,14]. Because our focus was informing rather than inspiring, we chose prototypical examples rather than generic examples. We thought that the former would better serve as sources of information because they would provide more specific, concrete guidance on how the concept could be applied. We considered this to be especially helpful for the domain of tangible learning games, which is still new to many designers. We put the picture example on the back side because of 1) the space constraint of the front side of the cards and 2) their main anticipated use as further reference.

One major challenge that we faced when looking for picture examples was that there are not many tangible learning games. For some concepts, we could not find a suitable prototype example. In such cases, we used pictures from everyday activities/objects, commercial video games, or diagrams (e.g. Super Mario for the *Intrinsic Rewards*[2] card and a diagram for *Feedback as Scaffold*).

Pictures of prototypical examples are complex and may be unfamiliar to designers. They provide more information but also require context to make sense. However, we did not think that providing generic examples from everyday life would be an effective way to communicate the dense concepts in this domain without additional explanation either. That was why we intended to include a QR code to point users to further explanation on the prototype example and other relevant information.

Expert Review

After our initial design of the cards, we conducted expert reviews with four researchers. The researchers were three PhD students and one senior researcher with expertise in TUI design, game design, or learning science. They studied or worked in Canada, United States, and Australia.

The goal of our expert review was to identify and fix any quality issues with the cards and to ask the experts to provide feedback for our subsequent designer studies. The experts were provided with an electronic copy of the card set and our interview questions about a week before the interview on Skype or in person. The interview consisted of 12 open-ended questions, soliciting feedback on card content (e.g., whether they were easy to understand,

whether they were at the right level of detail, any inaccuracies); image examples (whether they were helpful in illustrating the guidelines); visual design; their anticipated card uses; and overall impression about the cards. The interviews took about 1.5 hours.

Based on experts' feedback, we revised some wording that they found confusing, inaccurate, or had negative connotations. For example, the title "Content on the Plotline" was changed to "Integrating Content and Play". Two of experts thought some prototypical examples, especially examples of *Bifocal Models*[3], were too complex and required much context to make sense. We changed several of these examples accordingly. For example, for the *Intrinsic Rewards* card, we replaced the *Bifocal Model* picture with a picture of Mario turning into Super Mario after eating a mushroom as a reward. Actually the experts suggested using pictures of video games or everyday life in general instead of prototypical examples. However, we continued to use tangible learning game pictures for most cards because our priority was *informing* and we wanted to explore the effectiveness of prototypical examples for informing design.

USER STUDY

After we revised the card set, we conducted a user study to evaluate if the cards were effective in informing the design of tangible learning games. We also examined how the cards' features supported or limited the usage of the cards. We used a combination of observation, interview, and survey methods.

Participants

We conducted 12 sessions with 12 pairs of graduate and undergraduate design students at Simon Fraser University (Canada). The 24 participants (seven female and 17 male) comprised nine graduate students and 15 undergraduate students. All but one were from the interaction design program at our university. Seven of them were members of an undergraduate student game developers' club.

We wanted to recruit participants with experience with designing for at least one of tangibles, games, or learning applications. However, we were unable to find enough participants with tangible or learning experience, which speaks to the need for Tango Cards! As a result, we decided to recruit designers with general interaction design experience and exempted the requirement for learning design experience. We paired the final 24 participants so that the experience of each pair covered both tangible design (or general interaction design) and game design. Five pairs had tangible experience while the other seven pairs did not. For convenience of reference and discussion,

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[2] We refer to cards by their title in italics.

[3] Bifocal Models comprise a computer model connecting to a sensor-based physical model. Bifocal Models aim to support students in developing and/or investigating scientific inquires. See [4] for more information.

the first five pairs will be referred to as the *expert group*, while the other seven pairs will be referred to as *novice group*. This compromise in recruitment criteria can be seen as a limitation of this study. However, in such a new and complex design space, it would be rare that designers had adequate knowledge about two or more dimensions of the design space. Again, this speaks to the need for Tango Cards.

Tasks: Two Design Cases

We developed two design cases to cover a variation in design activities and application areas. The first design case was a redesign of a web-based game that used concepts in algebra to teach children about healthy eating (e.g. how to eat balanced meals, nutritional knowledge). The task involved redesigning from web to tangible form, and making the game more effective in educating healthy eating. This case was a later-stage design activity (redesign) and school subject (algebra). The second design case was concept development for a tangible learning game that helped children understand the complexity involved in building a sustainable environment. This case focused on early-stage design activity (initial idea development) and a more general concept (sustainability). Due to time constraints 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.

Procedure

We evaluated Tango Cards by observing participants using the cards in the two design cases, followed by a semi-structured interview and questionnaire. Before participants started working on the design cases, they were given a 10-minute introduction to TUIs. Participants were then introduced to Tango Cards and were asked to explore the deck for five minutes. After that, they were provided with an explanation about the specifics of the first design case (redesign). They worked on this activity for 40 minutes and then presented their design concept and rationale for five minutes. After a five-minute break, participants started working on the second design case (new concept design), which was structured in the same way as the first case. Participants then filled out a questionnaire to rate the value of the cards in different design activities, how much they liked different sections of the cards, and the overall design and value of the cards on a 5-point Likert scale. The session ended with a semi-structured group interview. Questions included asking participants about their overall impression of the cards, what they liked and disliked about the cards, and whether they would used the cards in future design activities and how. Sessions lasted between 2.5 and 3 hours.

Data Collection and Analysis

We captured video and audio of the sessions. We also took handwritten or typed notes during the design activities and the interviews. The triangulation of data from observation, questionnaire, and interviews provides rigor and supports the validity of our methods.

We analyzed the qualitative observation and interview data inductively following a standard qualitative coding process to search for common and atypical but interesting themes. We also used findings from previous card work (e.g. how designers used cards and values of cards) as an analytical lens to search for evidence of themes reported in previous research. We used descriptive statistics (mean and standard deviation) to analyze questionnaire data.

RESULTS

Usage Scenario

We first present a comprehensive scenario extracted from session 10 to demonstrate a variety of card uses and how cards fit within the study's larger design process.

As P19 and P20 started working on design case two, P19 proposed using fruit-shaped control for the tangible interface as inspired by the 'Coherent Mapping' card (she soon realized her idea was actually about 'Linking through Metaphor'). P19 also generated an idea from the 'Intrinsic Rewards' card. From there, they moved their ideation to the white board and generated further ideas without cards. After developing a few ideas, P20 suggested they return to the cards on the table to evaluate their ideas using the cards. They asked themselves whether their ideas incorporated any rewards after checking the 'Intrinsic Rewards' card, and said, "Yes." The 'Feedback as Scaffold' card reminded them they had not developed feedback mechanics. They went on to develop feedback ideas, and then returned to cards to check other aspects of their design.

"Pleasantly Frustrating?" "I think we got it."

"Pause for Reflection?" "For sure!" They both said.

"Thinking with Hand?" "Yes."

"Multiple Representations?" "Yes."

"Dynamic Exploration" "Yes."

When they saw the 'Simplified System' card, after some initial hesitation and thinking, they realized their game could have multiple levels with the entry level as a simplified system. They went on to develop the game
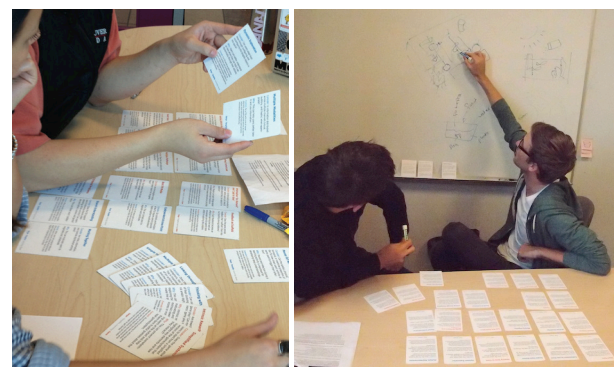

Figure 3. Working with Tango Cards.

mechanics for advanced levels. Finally, the 'Work Together' card reminded P19 that they could make a multi-player game. "They can play together!" claimed P19 excitedly.

As shown in the scenario, participants used cards to kick off their discussion. Cards enabled them to formatively evaluate their ideas. Cards guided them in developing and/or fleshing out ideas, reminding them of perspectives they would otherwise neglect. The cards also served as physical reference and common vocabulary to help them reach shared understanding.

Card Uses

In this section, we describe in detail two new card uses identified in the user study. We also briefly mention three other card uses that previous works have identified.

Formative evaluation

Formative evaluation— evaluating design ideas along the way as they were being developed*,* is a new use and the most prominent card use that we found. We observed participants checking the information on the cards from time to time to formatively evaluate the concepts that they had developed. The guidelines on the cards either confirmed that they were on the right track, or pointed them to the right direction, or reminded them of something else missing from their ideas. Sometimes participants went to the cards for formative evaluation after they had developed some game ideas without the cards, as described in the previous usage scenario. Sometimes they reached for cards right after they generated an idea, possibly with specific cards on mind as illustrated below.

In design case 1, P21 and P22 were discussing the game mechanics of where the (food) items should be placed when a new level of the game started. The idea they had at that point was to have the food items stay where they were left in the last round. However, they were not sure whether this was good. "*You know what,*" said P21, "*I was just looking at this one here,*" as he picked up the *Dynamic Exploration* card and read the design consideration part, '*Can users adapt their ideas through configuring and reconfiguring the tangible objects in the space?*' *Is there another card about taking a pause for reflection or something*?" He looked for the *Pause for Reflection* card. P22 helped him find it. P21 checked the card and commented, "*It might be a good idea to force players to rearrange the starting positions... the game won't get started until you put everything to where it is supposed to be… set up the table…like setting up a chess board...*" So they approved their idea, as it was good for players to explore their idea and reflect on it according to the *Pause for Reflection* and *Dynamic Exploration* cards. In the mini impromptu interview right after the first design activity, P21 explicitly mentioned how the *Pause for Reflection* card assured them that they were on the right track.

Indeed, as P24 spontaneously remarked during design case 2 when he looked for cards to confirm his ideas: "*This is when I get to these (cards)… so that all these weird floating ideas can be grounded in some kind of context…*"

Advanced leverage of card form

As expected, we observed many instances where participants did simple sorting and grouping of cards as a way to decide which cards were relevant to their design problem, and to bookmark discussion ideas [3,14,12]. Moreover, we observed more "advanced" arrangement and manipulation of cards in two sessions, as a way to *outline their design rationale or analysis*.

In design case 1, P17 and P18 used cards together with sticky notes to externalize their analysis of the old design (Figure 4, left). For example, they put a sticky note with "algebra" on it onto the *Linking through Metaphor* card, meaning that they believed the way the old game taught algebra incorporated the "linking through metaphor" idea. They put another sticky note with "dancing" on it on the *Intrinsic Reward* card because they considered the robot dancing at the end of each round when kids successfully balanced the meals of robots an intrinsic reward.

In design case 2, P11 and P12 picked out and grouped the cards into three piles, with each pile showing the concepts that they incorporated into one of the three game modes they designed (Figure 4, right). Each pile of the cards consisted of tangible blue cards on the left and game orange cards on the right. They meant to incorporate the game concepts by applying the tangible mechanisms.

Other uses

We also found the following card uses that previous card works have reported: to get inspiration when ideation gets unproductive [3,14,12], to jump off ideation [8,12], and using the content on the cards (mostly the title) as a common vocabulary and communication shorthand [8,14].

Card Features that Supported Card Use

An analysis of observational, interview, and questionnaire data revealed that the following card features supported
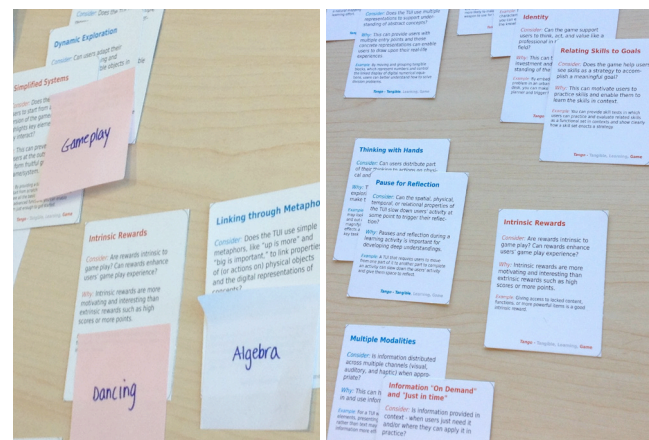

**Figure 4. Use cards to outline design rationale and analysis.**

card uses: clear information hierarchy; short, punchy titles; design considerations in a question format; and physicality and mobility of the card form. In this section, we describe the first two features in detail because they are unique to Tango Cards and/or are not explicitly identified by previous card works. The last two features have been described in previous research (e.g. [3,12,14]). (We have also described advanced uses of physical forms above.)

Clear information hierarchy
We received very positive feedback about the information hierarchy design of Tango Cards. P24 said: "*like the hierarchy...the title is big...I recognize it the best...'Consider', 'Why', and 'Example' are ordered the way I want them to be*." P19 similarly remarked: "*I think it is the right order. I would read in this order…*"

The information hierarchy let participants skim and scan the information as they liked and needed, supporting participants with varying levels of domain knowledge and familiarity with the concepts. Expert group participant P23 stated: "*I didn't read any example text, ever. I really like the title, "Consider" and even the "Why" field… I didn't need to go that far to have an idea about how to change the design we had...*" He later corrected himself and commented that for some cards that he did not have a clear idea about, he would use the examples. Another expert group participant P11, a senior game researcher, said that he only needed the title.

Another piece of evidence comes from an interesting finding from the survey data. In the post-questionnaire, participants were asked to rate how they liked different elements of the cards on a 5-point Likert scale, with 5 being liked most. The mean rating and standard deviation for each element by both *expert group* and *notice group* is shown in Figure 5. Due to the small sample size and uneven group size, we were unable to run inferential statistics to see whether the difference was statistically significant. However, simple observation of the chart shows that the expert group participants preferred the title and design consideration ("Consider") to the other elements, while the novice group participants rated rationale ("Why") slightly above other elements. Their mean ratings of other elements
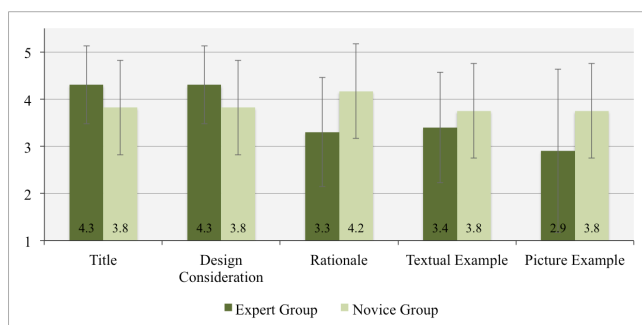
Figure 5. Expert vs. novice group participants' average ratings on different card elements.

were quite close. One interpretation of this difference between the two groups is that the information provided by the title and design consideration was sufficient for expert group participants with a relatively good understanding of the domain knowledge to understand and apply the concept. The novice group participants with less domain knowledge needed access to more information on the cards to aid their understanding.

Short, punchy titles
Using short, punchy phrases as titles, reinforced with large font size and colour, has supported the use of titles as a quick visual reference and a communication shorthand during discussions. According to our observation and interview data, the title was the most heavily used card element. P19 commented that the titles "*are well chosen.*" Moreover, title was rated high in post-questionnaire (Figure 5).

Card Features that Limited Card Use

Complex prototype (picture) examples
Picture examples on the back side were much less used than the text side. Many participants responded with negative feedback on the picture examples or simply did not use them. Several participants said some pictures examples of tangible learning systems (games) were difficult to understand. For example, P18 said that he found the cards using the *Bifocal Models* "intimidating". P11 said prototypes from the university's research projects (such as *Kurio*) were not accessible to general users outside the school. On the other hand, picture examples with more universal meanings generally received positive feedback, such as from well-known commercial games (Super Mario Bros.), everyday life (game controller), or diagrams.

Such feedback indicates that participants perceived pictures more as something to be taken at face value and used quickly, rather than a visual pointer to further information that required additional reading to understand. However, we would argue that the unfavorable feedback could also be attributed to a mismatch between the designated use of the picture examples as pointers to specific examples for further study, and the short duration of the design activities in which the cards were evaluated. (Several participants commented explicitly that they would check the prototype examples if they had more time and during later iterations with their design ideas.)

"Too much" information on the cards
Three pairs of participants (session 4, 6, and 7) commented the cards were "a bit wordy" and/or there was too much information on the card. P11 said: "*...diving into information-gathering mode of each card strongly kicked me out of the brainstorming in my domain area*". He suggested the information should "go minimum", with only a phrase such as the title. P13 also commented: "*It seems it is easier to get the message from just looking at the title and then looking at the picture ... we can almost not read the writing ...*"

Such comments made sense when participants already knew the concepts well, such as the game cards for participants with game design experience. Yet they were confusing when participants knew little about the concepts, as was the case for novice group participants with the cards about tangibles. Further investigation revealed that contrary to our assumption, unfamiliarity with the tangible concepts made novice group participants of session 4 and 7 use the cards less or even ignore them, rather than read "abundant information" to pick up the concepts. For example, P8 of session 4 admitted that he used the tangible cards less than game cards. P8 said he found tangible cards not that helpful because he was not familiar with them. He remarked: "*[saw] TUI cards like introduction to these ideas; while seeing game cards like reminder to these ideas…*"

Expert group participants P11 and P12 of session 6 (two PhD students with game research background) did examine the tangible cards that they knew less more closely (as we hoped). P12 said: "*…never dealt with tangible cards, have to read them more carefully… because not that familiar with the concepts…*" Despite this, P11 and P12 still disliked that reading information got in the way of their ideation (as P11 stated above). From these data, we see a *clash* between these participants' preference for not being distracted from fast-paced ideation on one hand, and their need for the information on the cards on the other. P11 insightfully commented: "*…the card is just this big. You can only do so much about them…constrained by space strongly. If your impulse is to put as much as possible on them, then you are going in the wrong direction…*"

Lacking in distinguishing visual elements
We observed in many sessions instances where participants tried to retrieve a card they had discussed before from a pile of cards, but did not succeed. P11 criticized: *"(The cards) didn't support me to differentiate the concepts and remember them… if I have two cards side by side, I would have to sit there and read them a bunch of times."*

Next, we present *how* cards made design knowledge about tangible learning games accessible to designers, *who* would benefit most from such a design tool, and *when* during design process Tango Cards should be useful.

Accessible: How
We examine the *accessibility* of the cards from the following facets: *Did designers find the knowledge easy to understand? Did designers find the knowledge useful and usable? How well did the cards fit into the design process?* We analyze how the content, presentation, and form of the cards make cards accessible [3], in terms of both individual use and group use.

A quick reminder
The knowledge presented in a short and concise format by cards provides designers with a quick reminder to the related knowledge and experience on their mind, which in turn elicits idea generation and refinement. As P12 neatly

stated, the cards provided "*a prod to memory*". Many participants mentioned "reminder" when they commented on cards' value (session 4, 6, 10, 11). P24 stated: "*…even if I have some background knowledge, it is nice to read one nicely formed sentence that refreshes your memory…maybe you don't know as well as you thought… I found it really useful, even it is a concept I heard before…*" In a similar vein, P23 said: "*…a sweet summary of research… things you've probably read somewhere but you didn't remember in the moment… accelerate refining…*"

A learning-in-use tool (to some extent)
Besides reminding designers of their existing knowledge, we suggest that cards support *some level of* concept learning during the design process for *some participants*. P8 and P24 made explicit positive remarks about learning from cards. P8 said although he had played a lot of games, he did not know the game theories behind and how to apply them. "*I learned a lot (from the cards) in terms of the game that played in the past and have a way to ground them, reuse and apply them in future game design*." Conversely, P11 argued that the role of the cards as a learning tool was at odds with their role as a quick reminder because being a learning tool required more information. Moreover, as shown earlier, designers' prior knowledge level of the domain also matters. Novice group participants avoided cards that they knew too little about.

Common language
The concise information on the cards (especially the titles) serves as a common language and communication shorthand. They help participants articulate their ideas and concerns and reach shared understanding during design discussions. P8 commented: "*I think it is a shorthand for what you are talking about…becomes easier to throw it around in development meetings…shared vocabulary in a meeting…instead of spending 20 minutes explaining what it means…*" This finding is consistent with that found in [8,14].

Physical anchor, making ideas tangible
Cards afford actions such as pointing, grabbing, grouping, and sorting. Cards support participants in externalizing design rationale and analysis, thus making ideas more concrete and accessible to themselves and to their partners. P11 thought the cards provided "*concrete reference to abstract ideas*". P12 said: "*...like being able to visually glance and move them about … because that is the way my mind works."* This finding echoes with and extends that found in [3,12,14].

In addition, the information hierarchy of the cards helped make the knowledge accessible to users of varying levels of domain knowledge and/or familiarity with different cards. This has good practical value because such team diversity should not be unusual in real-world projects.

Accessible: When
We directly evaluated the cards in two design cases. Both involved early concept development, although the redesign

case was more narrowly defined since the context and main idea were already determined. Some sessions also started to use the cards to iterate their ideas. Our findings confirmed the utility of the cards for generative use as design considerations in early concept development and iteration of ideas. During the design activities we observed participants' prevalent use of cards for formative evaluation of design ideas. From this we can infer that the cards may also be valuable for evaluative use as heuristics in summative evaluation.

Accessible: Who
Although information architecture has helped support users of varied level of domain knowledge, the finding that some novice group participants used less or ignored Tangible Cards suggests that a certain level of prior knowledge about tangible learning games is necessary for designers to use the cards effectively and appreciate their value. This is also supported by survey data. In the post-questionnaire, participants were asked to rate the overall usefulness of the cards on a 5-point scale, with 5 as most useful. The average rating by expert group participants was 4.4 (standard deviation 0.5), while the average rating by novice group participants was 3.4 (standard deviation 0.9). So less familiarity with the design space made novice group participants value the cards less.

DISCUSSION
We now discuss themes that have emerged from our analysis of the study results as outlined above. We also extracted and abstracted design considerations for designing card-based design tools that make academic design knowledge accessible to designers during their design process. These design considerations can be generalized to design tools (card-based or alike) as knowledge transfer vehicles for other design spaces. This would especially be the case for design spaces where dense design knowledge exists.

Streamlining, not distracting design flow
An analysis and synthesis of study findings shows that supporting rather than distract from design flow is important for the effectiveness of design cards. All the card design features that were proved to be effective all contributed to making the cards quick to use and/or fit into the design flow. For example, the information architecture design supported scanning and skimming card information. As another example, the card titles, serving as a common vocabulary and communication shorthand, helped accelerate reaching a shared understanding. On the other hand, card design features that were found unfavorable hindered the design flow in some way; for example, "too much information" could defeat its purpose. This echoes with Rogers' claim that for theory to best inform design, the ways of knowledge transfer should focus on the design process and support the ways that designer work [17].

Design Considerations
Based on our study findings and experiences, we suggest several considerations for the creation of design cards, with the dual goal of informing designers and supporting their design flow.

Include "appropriate" amount of information. As we observed in the study, there existed a tension between participants' preference for staying focused on the fast-paced ideation on one hand, and their need for card information on the other. To mitigate the tension, we argue that a delicate balance should be achieved between providing adequate information to effectively communicate the design knowledge and minimize the cards' distraction of designer's attention from design flow, with the priority given to the latter. After all, card content was "*secondary to [their] thinking*" (P13). We suggest considering these factors when deciding the amount of information to present on the cards: the knowledge level of target users with the design space; the design activities that the cards focus on (e.g., ideation, evaluation, learning and research); and the work style and preference of target users.

Transforming scholarly design knowledge into a set of cards is a process of extraction and simplification. As a result, much context and nuances of the original knowledge is lost inevitably during this process. This entails a risk of misinterpretation [3,12]. Inspired by [3], we suggest providing links to detailed information (e.g., through a QR code) from the source literature to rectify this.

Implement effective information architecture to support skimming and scanning the information on the cards and users of different knowledge levels. In Tango Cards, the five elements are spatially arranged by their importance, from "must read" (on the front, top) to "read if necessary" (on the back, bottom). Visual characteristics are also applied to reinforce the information architecture; for example, different font sizes are used to signal the relative importance of the elements. The section headings (title, "Consider", "Why", and "Example") are highlighted using the colour of the card category (tangible and game). These features were found to work well in our study.

Apply visual design to make cards highly searchable; that is, make it easy to differentiate individual cards from each other. Previous card research has mentioned this briefly but did not delve into specifics. For example, it was suggested colour coding could make cards more searchable [3,12]. Tango Cards are colour coded by the two categories (tangible and game). In addition, the titles in a large font stand out and work effectively as a visual identifier for the cards. Participants also suggested that further colour coding, or using icons or thumbnails of picture examples would make the cards even more searchable. We could also consider introducing accessories such as clothes pegs for designers to mark cards that they consider important.

CONCLUSION

Tango Cards address the need for a design tool to bridge the gap between theory and practice for the growing design space of tangible learning games. Based on our study findings and experience, we present general considerations for the design of cards for informing design practice in any complex domain space. We hope this work will encourage further conversations on how to design tools, especially cards to make scholar design knowledge accessible to designers. As future work, we would like to revise the cards based on the findings and feedback from the user study, and then to evaluate the cards in industry-based projects, which have longer timespans and real-life constraints.

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REFERENCES

1. Antle, A.N., Droumeva, M., and Ha, D. Hands on what?: Comparing children's mouse-based and tangible-based interaction. In *Proc. IDC 2009*, ACM (2009), 80–88.

2. Antle, A.N. and Wise, A.F. Getting down to details: Using theories of cognition and learning to inform tangible user interface design. *Interacting with Computers 25*, 1 (2013), 1–20.

3. Bekker, T. and Antle, A.N. Developmentally situated design (DSD): Making theoretical knowledge accessible to designers of children's technology. In *Proc. CHI 2011*, ACM (2011), 2531–2540.

4. Blikstein, P., Fuhrmann, T., Greene, D., and Salehi, S. Bifocal modeling: Mixing real and virtual labs for advanced science learning. In *Proc. IDC 2012*, ACM (2012), 296–299.

5. De Castell, S. and Jenson, J. Digital games for education: When meanings play. *Intermédialités: Histoire et théorie des arts, des lettres et des techniques, 9* (2007), 113.

6. Fisch, S.M. Making educational computer games "educational." In *Proc. IDC 2005*, ACM (2005), 56–61.

7. Gee, J.P. *Good Video Games + Good Learning: Collected Essays on Video Games, Learning and Literacy*. Peter Lang Pub Inc, 2007.

8. Halskov, K. and Dalsgård, P. Inspiration card workshops. In *Proc. DIS 2006*, ACM (2006), 2–11.

9. Höök, K. and Löwgren, J. Strong concepts: Intermediate-level knowledge in interaction design research. *ACM Transactions on Computer-Human Interaction 19*, 3 (2012), 23:1–23:18.

10. Horn, M.S., Crouser, R.J., and Bers, M.U. Tangible interaction and learning: The case for a hybrid approach. *Personal and Ubiquitous Computing 16*, 4 (2012), 379–389.

11. Hornecker, E. A Design theme for tangible interaction: Embodied facilitation. In *Proc. ECSCW 2005*. Springer Netherlands, 2005, 23–43.

12. Hornecker, E. Creative idea exploration within the structure of a guiding framework: The card brainstorming game. In *Proc. TEI 2010*, ACM (2010), 101–108.

13. Löwgren, J. Annotated portfolios and other forms of intermediate-level knowledge. *Interactions 20*, 1 (2013), 30–34.

14. Lucero, A. and Arrasvuori, J. PLEX Cards: A source of inspiration when designing for playfulness. In *Proc. Fun and Games 2010*, ACM (2010), 28–37.

15. Lucero, A., Holopainen, J., Ollila, E., Suomela, R., and Karapanos, E. The Playful Experiences (PLEX) Framework as a guide for expert evaluation. In *Proc. DPPI 2013*, ACM (2013), 221–230.

16. Manches, A. and O'Malley, C. Tangibles for learning: A representational analysis of physical manipulation. *Personal and Ubiquitous Computing 16*, 4 (2012), 405–419.

17. Rogers, Y. New theoretical approaches for human-computer interaction. *Annual Review of Information Science and Technology 38*, 1 (2004), 87–143.

18. Schön, D.A. *Educating the Reflective Practitioner: Toward a New Design for Teaching and Learning in the Professions*. Jossey-Bass, San Francisco, 1987.

19. Wakkary, R., Hatala, M., Muise, K., et al. Kurio: A museum guide for families. In *Proc. TEI 2009*, ACM (2009), 215–222.

20. Zuckerman, O., Arida, S., and Resnick, M. Extending tangible interfaces for education: digital montessori-inspired manipulatives. In *Proc. CHI 2005*, ACM (2005), 859–868.