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A GAME-BASED LEARNING APPROACH TO ENHANCE UNDERSTANDING OF INTERFACE DESIGN PRINCIPLES IN DESIGN EDUCATION (PRACTICE)

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ABSTRACT

The design of user interface is an important and challenging topic for student designers to understand and master. The eight principles of good User Interface (UI) design are often taught using primarily cognitive approaches, which can leave room for improvement in students' ability to apply the principles in a variety of contexts. Game-based learning tools are recognised to be beneficial in university classrooms across a variety of discipline areas and topics due to their capacity to increase engagement. This project presents a first prototype for an instructional tool that leverages constructionism and embodied learning to enhance students' understanding and application of these principles. This tool takes the form of a board game, thus encouraging peer learning. To test the prototype, three usability tests were carried out. Each user group was unique, the first being internal to the design team, the second having some prior exposure of the subject, and the third, having no prior experience at all. In each sessions, the participants were presented with a series of UI challenges, for which they were asked to construct suitable design solutions. Following the sessions, and where possible, the quality of these solutions were evaluated against a scoring system. This initial study suggests that instructional board games may be flexible enough to support learning outcomes at various stages of knowledge and skills acquisition among different learner groups.

1 INTRODUCTION

1.1 Background & Rationale

A User Interface (UI) is a device that yields the capacity for a user and a system to interact or collaborate. This device is most often a graphical user interface (GUI), but more and more, a UI can also take the form of a voice-controlled interface (a VCI) or a gesture-based interface (GBA). UI design is the process of designing these devices. There are eight principles of good User Interface design (Schneiderman, et al. 2016). These principles, along with a description and examples, are listed in Table 1. In this upcoming collaboration project between The Technical University of Denmark (KT.DTU) and Technological University Dublin (TU), we are designing a gamified framework to develop an integrated approach to teach the principles of good User Interface design. For our first design iteration, we have selected principles 1 & 2, Strive for Consistency and Seek Universal Usability, as our primary focus. With respect to principle 2, Seek Universal Usability, it can be challenging for early designers to ignore their own instincts, perceptions and intuitions whilst establishing product needs. Developing an objective or empathetic approach can assist in overcoming this challenge (Leonard and Rayport 1997).

Game-based learning tools can be beneficial in university classrooms, not least because of their capacity to increase engagement (Justo, et al. 2022). Indeed, this study also serves as an exemplar of how student engagement increases with such activities. Our proposed instructional game aims to leverage the advantages of embodied learning to enhance students' understanding and application of the eight principles of UI design. More precisely, it proposes to augment a constructionist-inspired game with multisensory interactive learning mechanics using mixed reality technologies.

1.2 Literature

Our proposed product concept draws on two education discourses; constructionism and multi-sensory learning.

Constructionism is a pedagogy where learning occurs as a process of constructing an intelligible entity (Griffin 2019) (Papert 1987). De-constructionism is a pedagogy that is inspired by and related to constructionism, however in this case, a backward-engineering technique is utilised for learning (Griffin 2019). Constructionism is a common approach for teaching User Interface design (Khoo 2011) and it is our intention to use it to underpin the gameplay of our intended product.

From birth and throughout human development, cognitive, motor and social abilities emerge together. They are connected and complementary and exert influence on one another in a variety of different ways and contexts (Thelen 1992) (Adolph and Joh 2007) (H. C. Leonard 2016). In several studies in the field of cognitive science, it has been shown that the brain weighs individual external sensory cues according to their relative precision, and constructs a reliability model for sensorimotor control (Limanowski and Friston 2020) (Körding and Wolpert 2004) (Ma, et al. 2006) (Bestmann, et al. 2008). Cognizant of this nature, multisensory learning encourages

teaching methods that utilise diverse motor and sensory interactions (Davis and Francis 2023). An example of where this has been exploited in teaching is in a technique known as enrichment, where acquiring vocabulary for a foreign language can be enhanced by coupling physical gesturing with traditional verbal activities (Mayer, et al. 2015). Guided by the concept of 'walking in someone else's shoes', multi-sensory learning approaches will be used to inform the game mechanics of our intended product.

Table 1. The eight principles of user interface design

#	Principle	Description	Example(s)
1	Strive for Consistency	Employ consistent layouts colours and fonts throughout.	The location of the menu should be the same on every page.
2	Seek Universal Usability	Design for diverse user groups	Cater for Novice and Experienced, International, visual or dexterous impairments.
3	Offer informative feedback	For every action, there should be interface feedback	
4	Design Dialogue to Yield Closure	Design for events that involve several steps (a group of actions)	E-commerce websites move users from selecting products to the checkout, ending with a clear confirmation page that completes the transaction
5	Prevent Errors		Users should not have to retype an entire name-address form if they enter an invalid postcode.
6	Permit Easy Reversal of Actions	As much as possible, actions should be reversible	Press a back button to delete data from a data entry box
7	Keep Users in Control	Users should be able to achieve their desired results	
8	Reduce Short Term Memory Load		Avoid interfaces in which users must remember information from one display and then use that information on another display

2 METHODOLOGY

2.1 Framework

The overall aim of this project is to develop an instructional design tool that is both useful, attractive and either superior or complementary to the current state of the art. User Centred Design (UCD) is an established iterative process that can be employed to support product development. Here, UCD lends itself to secondary and generative research methods, which are useful for concept development. Further, UCD is also compatible with investigative and analysis-based research methods, which are useful for product testing at various stages of design development. Our method is informed by the UCD process and is illustrated in fig. 1. Stage 1 of our method serves to deliver a design concept and will be illustrated in section 3 of this paper. Stage 2 is concerned with usability testing and will be presented in section 4. Stage 3 addresses design iterations and involves cycling through stage 1 & 2, until the design has been refined.

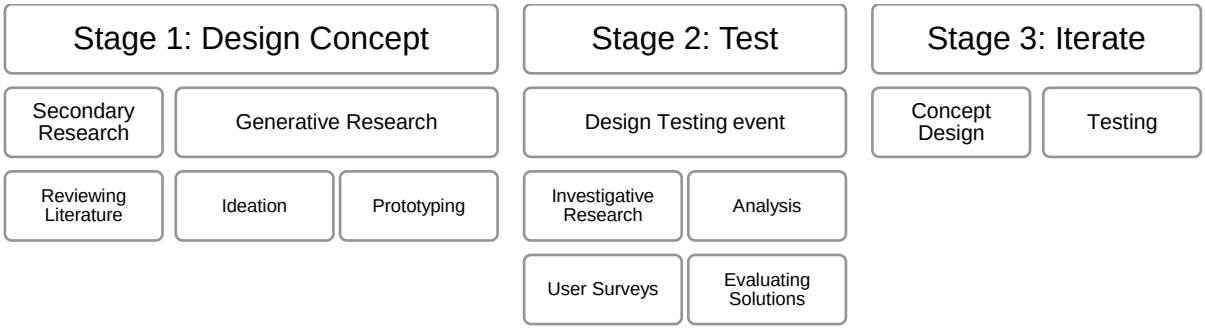

Fig. 1. Methods Diagram

3 CONCEPT DESIGN

3.1 Game Assets

A carbon tracker was selected as the subject for our game-based tool. There is no particular reason why. The tool would be just as effective had we chosen any other subject. In a brainstorm session, 7 unique features were identified that appeared to reasonably constitute a complete application (Table 2). For our initial product mock-up, and to speed up the design phase, we limited our focus to just three of these features, namely, Navigation, Calendar and Tracker.

Table 2. Features for the Carbon Tracker App concept, indicating

#	Feature	Variations	# UI Elements	Mock-up Ready for Review?
1	Navigation	1	13	Yes
2	Calendar	1	11	Yes
3	Tracker	1	13	Yes
4	Methods	2		
5	Moderators	1		
6	Options	3		
7	Metrics	2		

To facilitate the challenge we designed three distinct assets, a collection of diverse UI elements, a UI Design board, and, a set of UI Challenge cards. The UI elements are a collection of pre-designed template pieces that, like with a jigsaw, can be used to construct a complete picture for a user interface design. The UI Design Board is a poster style collaborative work tool that facilitates the organization of the UI elements. The UI challenge cards direct the goals of each round of the game. Examples of these challenges are as follows:

- Construct a suitable UI for a User who is visually impaired
- Construct a suitable UI for a User who is new to digital technology
- Construct a UI Design that conserves screen space
- Construct a UI design that minimises cognitive load
- Construct a UI Design that is consistent in its design composition
- Construct a UI that is inconsistent in its design composition

A printable version of the game is available for download on our github repository here The UI Game Board.

3.2 Game Rules

The instructions for the game were conceived as follows:

1. Populate The UI Board with the UI elements
    a. Separate the elements into two groups, Icons and Text.
    b. Separate the elements in each group by feature
    c. Organize the Icon elements by size
    d. Organise the Text elements by size and function
2. Populate the blank UI Interface with appropriate UI elements
3. Pull a challenge card
    a. Using elements from the UI Board, construct an appropriate corresponding UI design

3.3 Scoring

The initial mock-up addressed three features. For each feature there was, on average, 12 UI elements to choose from, culminating in a total of 36 pieces. With a view to establishing a method to evaluate the participant's designs, each element was categorised according to several criteria (Table 3). Using these criteria, the number of unique combinations that emerged was 22.

Table 3. UI element categories

#	Group	# Variations	Options
1	Type	2	Icon, Text
2	Size	3	Small, Medium, Large
3	Font	2	Sans, Sans serif
4	Contrast	3	Low, Medium, High
5	Interaction	3	Expand, Dropdown, Select

Subject to our current stage of development and where appropriate, each element was also given a score based on their suitable application for each challenge in the challenge card deck. Here, the assignment varied from poor to excellent across a 4 point Likert scale.

The scores for two challenges, to design a UI for (1) a user who is visually impaired and (2) to conserve space, are now complete. The main criteria for assigning these scores related to the elements size, font and contrast. For example, a UI element would have to exceed a minimum size threshold to score high on a challenge to design for a user who is visually impaired. Conversely, the same UI element may score low on a challenge to conserve screen space.

A process of developing scores for challenges that are concerned with design consistency and cognitive load are currently underway. As designing for consistency is a product of the position of and the similarity between elements, and cognitive load is impacted by levels of detail and variability, we will need to engineer a scoring matrix to evaluate these challenges reliably.

4 TESTING

4.1 Usability study

Table 4. Summary of Testing Sessions

#	Participants	Count	Participant Configuration	Date
1	Members from the Project Team	2	Individuals	15/04/23
2	Students from Y3 of the Product Design undergraduate programme at TU	6	Pairs	19/04/23
3	PhD scholars, Postdocs and faculty from the PROSYS research centre at DTU	17	Teams of 5-6	27/04/23

We conducted a usability study comprised of three sessions, a summary of which is provided in Table 4. Each of the sessions built on insights garnered from the one before. The first session was internal to our design Team where the participants were very familiar with the vision of the project. As such, we will exclude this session from further discussion. The process for session two and three is outlined below.

4.1.1 Session 2

1. A facilitator presents the 8 principles of User Interface Design
2. The concept and aims of the game are introduced.
3. Round 1, each team:
   a. Receives a randomly selected challenge card
   b. Constructs a corresponding UI design
   c. Presents their outputs and discusses the rationale with the rest of the group and tutors.
4. Round 2, each team:
   a. Receives the same challenge card – one for a user who is visually impaired
   b. Constructs a corresponding UI design
   c. Presents their proposals and the rationale for same
5. Each team fills out a feedback sheet, including observations made in the presentations.

4.1.2 Session 3

1. A speaker presents a talk on Cognitive Load Theory, Embodiment, and, this UI design Project
2. Game packs are distributed
3. Working as a group, each table:
   a. Organises the UI elements according to the UI Design board format
   b. Selects a challenge card from the challenge card deck
   c. Constructs a corresponding UI design
   d. Repeats, if time permits

3. Each table collectively fills out a feedback sheet

For clarity, the key differences between session two and three are illustrated in Table 5.

Table 5. Variability between Testing session two and Testing session 3.

#	Variable	Level 1 Learners	Level 0 learners
1	Lecture / Talk (Primer)	The Principles of User Interface Design	Cognitive Load Theory & Embodiment
2	UI Design Board Activity	No	Yes
3	Present & discuss results	Yes	No

4.2 Investigative Research

A survey for the testing sessions was designed to establish the following:

- The base competency of the participants
- Which variables (e.g. activity, tool, instructor, peer) are perceived as having value for teaching
- Participant sentiment in relation to -
    - The suitability of the teaching approach
    - The pleasure of learning this way
- The quality of the instructional tools in relation to:
    - Ease of use
    - Perceived purpose
- The existence or otherwise of any unexpected use cases

5 RESULTS

It is important to bear in mind that the testing sessions were subject to high variability. Further, the level of subject exposure differed between the undergraduate students who participated in session two and the PhD scholars, postdocs and faculty who participated in session three. Therefore, and hereafter, we will distinguish the participants from session two and session three as level 1 learners and level 0 learners respectively, where level 1 denotes prior subject exposure consistent with an introduction and level 0 denotes no prior exposure at all.

Due to the limited extent of the scoring feature of the current prototype, we will also limit the quantitative analysis of the participant's designs to round 2 of session two. The main reason for doing so is that only the Level 1 learners integrated all of the available features into each of their solutions. Whilst the Level 0 learners did not produce designs that were substantial enough to evaluate, at the same time, the session facilitators were able to garner some insights through dialogue. For example, one Team who were challenged to design a UI for 'users new to technology' deliberately selected Text elements instead of Icons to increase familiarity. In another example, a different Team who were challenged to design a UI to 'reduce cognitive load' constructed a fuss free UI using large elements for a single feature.

5.1 Solution Evaluation

In round 2 of session two, three teams of two participants were challenged to design a UI for a user with a visual impairment. All three teams performed well and the solutions are illustrated in fig. 2. Scores for each design are set out in Table 6 whilst a short interpretation regarding the quality of each design is discussed forthwith.

Fig. 2. Testing session 2, Round 2, Results for the challenge to design a UI for a visually impaired user

Table 6. Scores for the challenge to design a UI for a visually impaired user

Element ref	Score	Team			Element ref	Score	Team			Element ref	Score	Team		
		1	2	3			1	2	3			1	2	3
f1	*1*				*t1*	*4*	**4**			*c1*	*1*			
f2	*1*		**1**		*t2*	*1*				*c2*	*4*	**4**		
f3	*4*				*t3*	*4*				*c3*	*1*			
f4	*4*				*t4*					*c4*	*1*			
f5	*1*				*t5*	*2*				*c5*	*2*		**2**	
f6	*2*			**2**	*t6*	*-*				*c6*	*4*	**4**	**4**	
f7	*4*			**4**	*t7*	*2*				*c7*				
f8	*1*				*t8*	*2*				*c8*	*2*			
f9	*1*				*t9*	*1*				*c9*	*1*			
f10	*1*				*t10*	*2*			**2**	*c10*	*1*			
f11	*2*				*t11*	*4*	**4**	**4**	**4**	*c11*	*4*	**4**		**4**
f12	*4*	**4**	**4**		*t12*	*4*	**4**							
f13	*-*													

Team 1 took an approach to provide users with the flexibility to work with minimal or maximal content at any given time using ‘show and hide’ functionality. Whilst the elements were a mix of icons and texts, the size, contrast and font options were a good choice for their intended user.

Team 2 took a creative approach and extended the UI design features using drop down functionality. Coupled with the medium sized calendar option, the image suggests that a design choice to conserve space may have been in operation.

Team 3 appear to have prioritised consistency, demonstrated in their commitment to using icons for all features in both designs. Only one of their designs includes an element for the calendar function. The sizing of this calendar block is more consistent with the medium sized icons, and is located accrodingly.

5.2 Participant Survey

A survey was designed to elicit qualitative responses from participants at our testing sessions. For the questions that correspond to 1, 2, 3, 4 and 5 in figure 4, participants were given the options Nothing, Something and A lot to choose from. For the questions that correspond to 6, 7 and 8 in figure 4, participants were given the options Not at all, Somewhat, Mostly and Completely. These options were converted to a numerical system (to 0, 2 and 4 in the first instance, and 0, 2, 4 & 6 in the second) for the purpose of graphing and comparing general sentiment across the two testing sessions.

In both events, participants (on average) scored the instructor and their peers higher than the activities themselves as a support for learning. The Level 1 Learners rated the teaching instruments, instructions, activity and 'point of the exercise' somewhat higher than the Level 0 Learners. Conversely, the Level 0 Learners rated the appropriateness and enjoyment of the learning method somewhat higher than the Level 1's did.

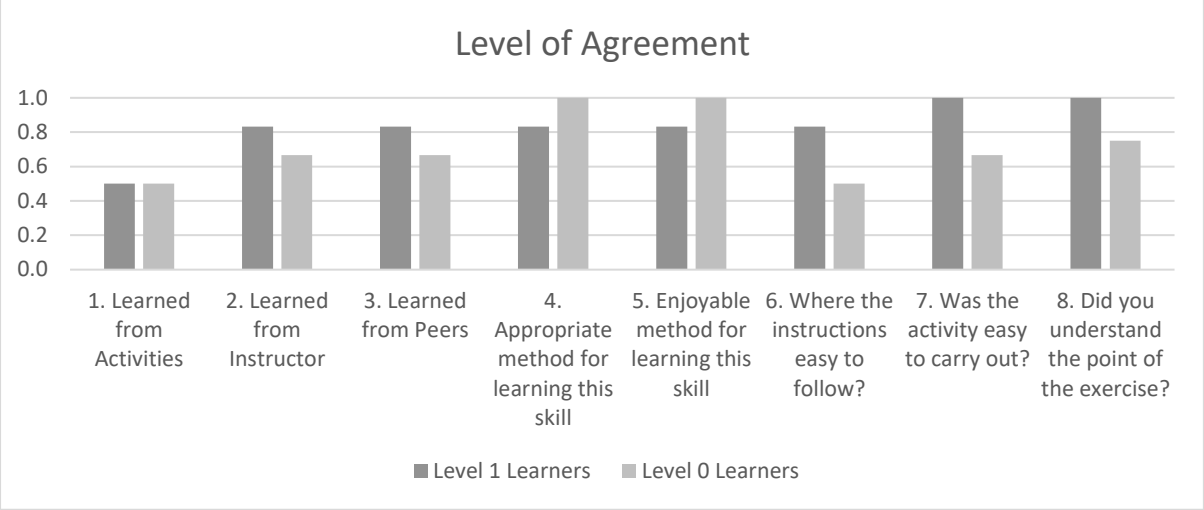

Fig. 4. Comparison of survey responses for user testing session

6 DISCUSSION & FUTURE WORK

Bearing in mind that we are discussing a handful of results across two early product testing sessions, still, there is a suggestion that these tools have different value propositions for learners at different levels of skill and knowledge acquisition.

As a teaching instrument, activities were valued less than the Instructor and Peers by both groups, indicating that learning was a social process. Further, the more experienced learners perceived the social process as being more valuable. These results are consistent with a recent case study that leveraged board games as instructional tools where the authors suggested that peer instruction may have more value among novice groups with some prior exposure (Carberry, et al. 2022).

In the next phase of this project, the team will look to explore the value of instructional board games as both an introductory tool for learners with no prior experience, and, as a revision tools for those with an elementary understanding.

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