Exploring Serious Mini-Games for Enhancing Computing Students' Colour Selection Skills

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Abstract: Game-based learning can be used to engage students and impart content that students otherwise find difficult to grasp. We have developed a framework for mapping learning outcomes to mini-game activities. We seek to explore the effectiveness of using mini-games for teaching undergraduate computing students about colour as a part of visual aesthetics in a Human-Computer Interaction course. This explorative study investigates computing students' perception of using mini-games in a classroom setting and looks for evidence of learning gains. We found an indication that game-based learning may trivialize the importance of the content. Although an expert evaluation comparing students' pre- and post-test performance was inconclusive, students report enjoying the experience and learning from it.

Introduction

It is common for Computer Science (CS) students and professionals to have to make aesthetic design decisions – such as choosing appropriate colours – for a system's graphical user interface (GUI). Whether or not they put much thought into this, their decisions will have an influence in user perception of a GUI's appeal (e.g. Hartmann, Sutcliffe & Angeli, 2008; Lindgaard et al. 2011; Tractinsky, Katz & Ikar, 2000). Developing CS students' skills and basic design knowledge under the Human-Computer Interaction (HCI) domain helps them make better judgments and informed design decisions when in such situations. The design skills are a necessity when working on smaller projects where the developer has full responsibility for the interface, or on larger projects when communicating with designers. However, the limited duration of HCI courses (often only one semester), paired with students' lack of background in visual design presents a challenge for ensuring that students develop a sufficient understanding of aesthetics. A means of rapidly bridging this gulf of understanding is desired.

Games are often promoted to enhance learning and reduce instructional time across multiple disciplines (Susi, Johannesson & Backlund 2007). Some researchers (e.g. Ibrahim et al. 2011) promote the use of games for course content that is difficult to understand, since games have been shown to help novices engage and master fundamental concepts. Games are also frequently suggested in current educational literature as an alternative teaching method for subjects associated with poorly motivated students (e.g. Jong et al. 2013). When compared to non-game-based or traditional learning methods, Kang & Liu (2013) reported that many studies demonstrated more positive results with game-based learning. Still, some concerns have been expressed about the overall benefits of games, such as learners being more motivated to just play with the computer instead of to learn (see Okan, 2003). Thus, the aim of this study is to investigate the effectiveness of our game-based learning approach in supporting student learning. Although the use of games have been explored in CS education – such as for teaching basic CS concepts (Gouws, Bradshaw & Wentworth, 2013) – we have yet to find studies concerning its use for teaching inter-disciplinary material, such as design to CS students. This paper describes our initial exploration of games as an instructional strategy in teaching CS students about colour within the context of GUI design. We seek to specifically address the following research questions:

- RQ1. Do students enjoy game-based learning activities?
- RQ2. Do games change students' perception of visual aesthetics?
- RQ3. Do students report any learning gains from their experience?
- RQ4. Do students demonstrate actual learning gains from using the games?

We report our pedagogic considerations when bringing games into the classroom, along with the framework that we have devised for the game design. Two new purpose-built mini-games are prototyped as a proof-of-concept and trialed with students undertaking our undergraduate HCI course. To address the research questions above, the students were surveyed, and we evaluated their pre- and post-test work (from tasks they completed as part of the class exercise). The results and discussion sections are organized according to these four aspects: students' enjoyment, change in students' perceptions, their self-reported learning and experts' evaluation of their actual performance.

Background

The term *serious game* is commonly used to refer to a *digital* game designed for a purpose that is beyond mere entertainment (Susi, Johannesson & Backlund 2007); e.g. for training, healthcare or marketing purposes. The word *digital* denotes that these games can range from computer games played on PCs, to video games on game consoles, to mobile games on smartphones or tablets. Usage of the term *serious game* also encompasses digital game-based learning; an emerging learning paradigm that concerns the use of digital games specifically for educational purposes. In this paper, we use the word 'game' as a blanket term to refer to serious games – specifically digital game-based learning. Games have certain features which set them apart from other software applications. One of the key differences between games and an interactive e-learning application is the emphasis on content. Squire (2006) contends that experience is valued higher than content when it comes to games. Most importantly, games are argued to have several desirable attributes, such as challenge and representation (Kang & Liu 2013) that are advantageous to learning.

In commercial digital games intended for entertainment, mini-games are smaller games embedded within a main game. They typically allow players to gain experience or collect bonus items, such as virtual goods, to boost their position in the game. The common characteristics of a mini-game are that it is short, lightweight and easy to learn due to its simplicity. Players usually have only one specific objective to meet. Due to their single-goal and simplistic nature, we argue that mini-games are well-suited to emphasizing basic concepts to students. In our case, such concepts relate to the visual aesthetics aspect of user interface design. To better express the pedagogy of a particular subject and to help the assimilation of new knowledge, it is suggested to string serious mini-games together (Frazer, Argles & Wills 2007). The next section provides an overview of our broader pedagogical approach to teaching visual aesthetics, followed by our current focus on mini-games and integrating the two to form a new instructional strategy.

Pedagogical Approach

In earlier work we presented how we successfully adapted the Structure of Observed Learning Outcome (SOLO) taxonomy (Biggs & Collis 1982) in structuring the visual aesthetics learning module for our HCI course (Abdul Jalil, Plimmer & Warren, 2012). Using this structure, we initially take an element-by-element approach by deconstructing the GUI into basic elements that are approximately equivalent to those of interface design languages; i.e. text, colour, images, lines and borders. These elements are further broken down into their controllable attributes – such as font size and line spacing for text. In line with the SOLO taxonomy, part of building students' competency in visual aesthetics is the understanding of each of these elements and their controllable attributes in isolation (the unistructural level), before progressing towards fusing them together to achieve visual harmony (the relational level). We found the approach suitable for our CS students since they are well drilled in decomposing problems into smaller parts and then combining these parts to make a whole when coding. We have developed a Web-based learning environment to demonstrate how learning at the unistructural level of our SOLO-based approach can be supported within an interactive system (Abdul Jalil et al. 2013). Our online learning environment presents guidelines and principles governing use of colour, and engages users through GUI colouring exercises. Our results show that students enjoy using the colouring tools in our learning environment and that the activities encouraged them to experiment more with their colour choices. Our present work extends the interactive learning tool by leveraging the use of games. Our hypothesis is that mini-games are a good match to supporting learning at the unistructural level, as mini-games enable the focus to be directed at one aspect at a time. As a proof of concept, colour is used as an exemplar of teaching one of the GUI elements in isolation. The text-based colour usage guidelines presented in our earlier environment are replaced with mini-games that illustrate particular aspects of colour. It is important to keep in mind, that while this study focuses particularly on the use of mini-games, it is part of a bigger pedagogical approach to learning visual aesthetics (as shown in Figure 1). We have also updated our GUI colouring tool based on students' feedback from the previous study and have incorporated it as part of the learning activity. The updates include a new colour picker and an unrestricted user-defined colour palette.

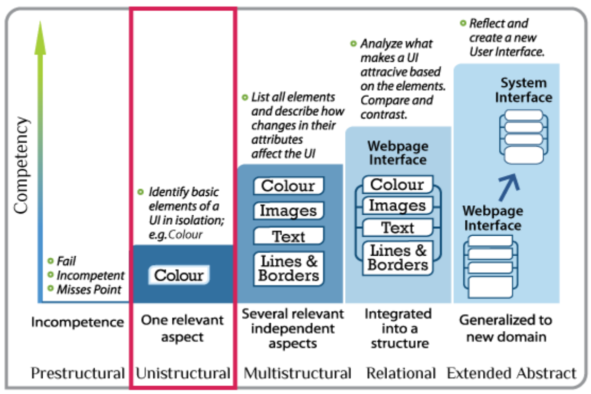


Figure 1**:** The structure of our SOLO-based approach.
The present work focuses on the unistructural level (in red box), with colour as example.

Game Design

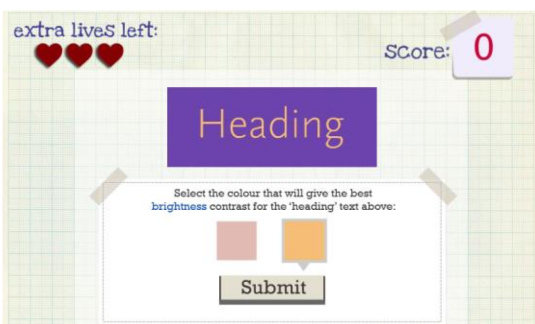
The first step in game design is to devise a framework that forms a meaningful connection between a mini-game and a desired learning outcome. The desired or intended learning outcome is an explicit statement of what we expect students to be able to do to demonstrate their understanding or competence upon completing the mini-game. This should be aligned with the learning outcomes of the course curriculum. The design must also balance conformance to fundamental mini-game characteristics (being short, lightweight and easy to play) with the need to deliver necessary conceptual knowledge.

Figure 2: The mini-game design framework.

The 'series of steps for constructing an activity' provided in the *CS Unplugged Design Pattern* (Nishida et al. 2009) serve as a general solution for us to adapt when devising our framework. This design pattern is intended to be used for guidance in revising or developing a new *CS Unplugged* activity. In our case, as each activity is also based around a game or a challenge, repurposing the general solution for the mini-games design framework (Figure 2) is relatively straightforward. We extend the solution by adding 'gamify' to the design process. This consists of incorporating three game elements derived from the literature (Heintz & Law 2012): challenge, victory condition and reward. Table 1 below presents how the design process is applied to yield two mini-games, each with a distinct learning outcome. Prototypes of the games are shown in Figure 3.

	Mini-game A: Colour Contrast	**Mini-game B:** Colour Scheme
Learning Outcome	Students will be able to select colours with appropriate contrast for their GUI design.	Students will be able to select harmonious colours for their GUI design.
Concept/ Principle	Contrast via the brightness attribute of colour.	Colour schemes; e.g. analogous and complementary.
Key feature	Comparison between two contiguous colours; e.g. foreground and background	Relationships between colours in the colour wheel.
Mapping	Coloured cards	Rotating wheel.
Activity	Player selects colour for the foreground text to create contrast with its background via mouse clicks.	Player rotates the cream dispenser using left/right arrow keys on their keyboard to change the cream colour and presses spacebar to dispense the cream.
Gamify	Player is given three chances (in the form of 'lives') to correctly guess between two coloured cards. The colour for each card is generated randomly every time, and the challenge increases when colours that are close together in hue are generated. Player gains a score by selecting the colour with the higher brightness difference to the background.	Player dispenses the correct cream colour onto a coloured cupcake that is moving on a conveyer belt before it passes the cream dispenser at the end. Level increases with each 5 correct answers in a row. As level increases, the cupcakes move faster and faster towards the cream dispenser. If the player gets more than five wrong answers, the game ends.

Table 1: Application of the design framework.



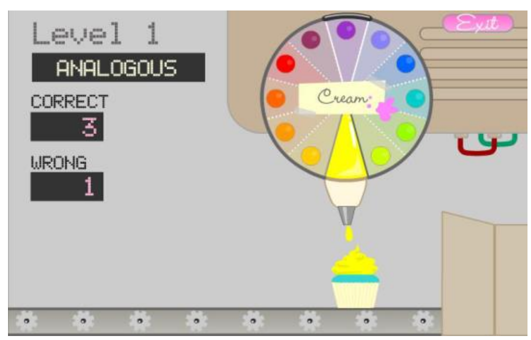


Figure 3: Colour contrast mini-game (left) and colour scheme mini-game (right).

The individual steps comprising the design process are elaborated below.

Select the related concept or principle: The fundamental concept or principle that is essential for students to understand to achieve the learning outcome is considered and selected. As with the focused learning outcome, it is recommended to keep to just one key concept introduced per mini-game. If several concepts are required to achieve the learning outcome, they should be introduced in separate mini-games.

Extract key feature: The distinctive feature of the concept is then identified. Borrowing from the example given in the *CS Unplugged Design Pattern*, the concept of a 'bit' – which is inherently discrete and binary – is the key element in the concept of data representation in CS.

Map key feature to similar object: The next step is to map the feature to common objects that share the feature so that it can be used as a metaphor or vivid comparison. Continuing from the 'bits' example earlier, objects with two states or sides such as a coin are a good mapping. An advantage of it being a virtual game object is that the feature can be emphasized via exaggeration that may not be possible in the real-world.

Turn it into an activity: This step creates a (virtual) action that a student can perform on the object. This is of course platform dependent; e.g. since our games are web-based, any action is limited to what can be expressed via mouse and keyboard interactions. Mini-game actions should not be overly complicated.

Gamify: To finally transform a learning outcome into a mini-game, we overlay the activity with a challenge, set the win/lose condition and develop a reward system. A challenge can be created by e.g. adding a time limit or injecting some form of 'guessing'. A feedback mechanism is also needed so that the students are informed of what effects their action has on the game and whether they are moving towards winning or losing, such as by displaying points that are awarded when they are correct, or deducting 'lives' when they are wrong. Rewards can be in the form bonus points or a level up e.g. for maintaining a streak of correct answers.

Evaluation

Participants

Participants were students enrolled in our third year Human Computer Interaction course during semester 1 (2013). This is an elective course offered to third year undergraduate Computing students consisting largely of Computer Science and Software Engineering majors. The study was conducted during a 1-hour tutorial session on visual aesthetics. At the end of the tutorial session, we collected 52 voluntary survey responses, 12 of which were from female students and 40 from male students. Of these students, only 10 stated they had formal training related to graphic design (e.g. art subjects taken during high school) prior to taking the course. Thus, while we expect our third year students to be proficient in computer programming, the majority are novices in visual aesthetics and design. The week before the tutorial, three 1-hour lectures were given under the topic of visual aesthetics within the context of GUIs. The lectures covered a wide range of sub-topics for each visual element (*text*, *colour*, *images*, *lines* and *borders)*. These include the attributes of the element and also how those attributes affect the aesthetics, information model and usability. Lecture notes are also made available online. It is therefore assumed that students are exposed to basic colour theory prior to this study.

Tasks

During the tutorial, we gave students four tasks to do as their class learning activity. The first task was a GUI colouring task where we instructed the students to colour a given GUI using our GUI colouring tool (Figure 5).

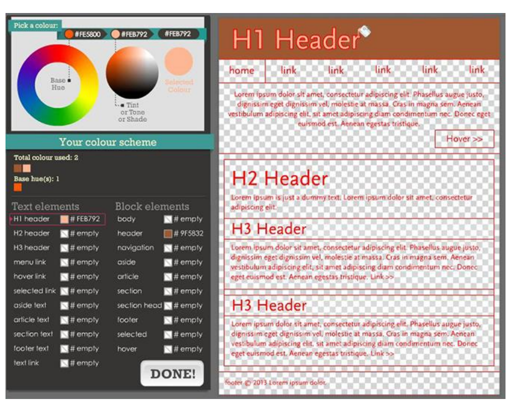


Figure 5: Our GUI colouring tool.
Colour is picked from the colour picker (top left) and dropped onto the given web interface (right).

This was followed by playing the two mini-games on colour contrast and colour schemes. For the final task, they repeated the GUI colouring exercise using the same tool based on what they had learned through exposure to the mini-games. Students were encouraged to compare and discuss their completed GUI exercises with the person sitting next to them or with their tutor.

Methodology

To answer our research questions (RQ1-RQ4), we used a within-subjects design where all participating students go through the same 'treatments' (which are the four tasks described earlier). This includes the administration of pre- and post-test surveys. The pre- and post-test survey instruments both contained the same 12 questions. They asked students to rate their own design skills, their knowledge on the subject (*colour)* and their perceptions of GUI aesthetics. These items are either a five-point Likert item (6 items in total) or use a ten-point scale (6 items in total). We then analyzed the pre- and post-test survey data using Wilcoxon signed-rank test (unless otherwise stated) for evidence of any statistically significant change.

The post-test survey contained additional questions, 8 Likert-type items and 4 open-ended questions. We added these items to elicit students' responses to the mini-game learning activities. 4 of the 8 Likert-type items form a scale to measure students' enjoyment and are answered using a five-point scale (1= Strongly disagree to 5= Strongly agree). The other 4 items asked students how much the learning experience contributed to their knowledge and skills in the following: understanding colour contrast, understanding colour scheme, choosing effective colours and choosing visually pleasing colour palette for their GUI design. The open-ended questions further invite students to submit their comments based on the questions below:

1) *Which parts of the learning activity do you like the most?*
2) *Which feature was most helpful for your learning?*
3) *Which parts of the learning activity do you like the least?*
4) *What improvements would you like to see?*

To assess actual learning gains (RQ4), we also collected completed GUI colouring exercises that students did for both the first task (pre-) and the final task (post-) for comparative evaluation. Students' submission of their work was voluntary. We designed a new SOLO-based scoring rubric as the instrument for assessment. This is a 5-level scoring rubric that corresponds with each SOLO taxonomy level; i.e. from the lowest level (level 1) being the *prestructural* level to the highest level (level 5) being *the extended abstract* level. In line with SOLO, our scoring rubric intends to measure how well students have achieved the intended learning outcomes by looking at the level in which their work demonstrates a coherent understanding of the whole. For example, the criterion for the work of a student operating at the *unistructural* level (level 2 in the rubric) is that it demonstrates a surface understanding of either of the concepts taught through the mini-games. A student operating at one level higher (*multistructural* level) should exhibit surface understanding of both concepts taught; i.e. colour scheme and contrast, albeit a disconnection between these two concepts. The work that demonstrates a good integration of the concepts taught and those that further this application (e.g. use these concepts to also enhance the visual hierarchy of the text from headers to body text) are considered to be at the *relational* level and *extended abstract* level respectively. We colour printed all of the collected work (both pre- and post- GUI colouring exercises) on separate sheets of paper and combined these papers in a randomized order. To help us identify the individual work during analysis, each printed copy is tagged with an ID number on its back. We then appointed two experienced graphic designers as our expert evaluators. We gave them the printed copies and asked the experts to score the students' work together using our new SOLO-based scoring rubric. Printing the work out was a quick way for us to enable the experts to spread these works on a large surface (i.e. the floor), allowing the experts a better overview as they compared submissions. It also made it easier for them to move the work around as they discussed and sorted them according to the score they agreed on. Once they had sorted all work based on the SOLO-score, they proceeded to rank each work from best (first place) to worst (last place). We then recorded the rank and score before pairing each pre- and post- work back together based on their ID number. Finally, we analyzed their paired data using Wilcoxon signed-rank test for evidence of any statistically significant change between students' pre- and post-test work.

Results

Not all students completed the entire survey, and the results reported in this section take this into account by removing the missing data. Where necessary, N is shown to indicate the number of students answering a specific item/question.

Students' enjoyment

The questionnaire items that we use to measure students' enjoyment were those included only in the post-test survey. The results in Table 2 below show the total number of negative (-ve), positive (+ve) and neutral (0) responses as well as the average rating value for the corresponding questionnaire items listed in the first column. Negative response is the number of students who rated the item as 'Strongly Disagree' (1) or 'Disagree' (2) while positive response (+ve) totals those who rated the item with 'Agree' (4) or 'Strongly Agree' (5). Q1-Q4 in Table 2 use a Likert-scale to measure how enjoyable students found the mini-games activities. The Cronbach's α (alpha) coefficient for these four items is .784, suggesting a relatively high internal consistency between them. Note that **Q2** and **Q3** are **negative questions**, thus their scores are reversed prior to measuring for consistency. The four items as a scale (with reversed scoring for Q2 and Q3) has the result of *mean* = 3.71. This shows an overall positive response in terms of students' enjoyment.

Questionnaire Items on Enjoyment (1=Strongly Disagree to 5=Strongly Agree)	**Frequency**				**Mean value**
	-ve	**0**	**+ve**	**N**	
Q1. I wanted to complete the activity.	3	11	37	51	3.49
Q2. I was not interested in exploring the options available.	25	16	8	49	3.45
Q3. I found the activity boring.	32	9	9	50	3.47
Q4. Overall, I enjoyed the learning activities.	6	8	36	50	3.49

Table 2: Results of the survey on students' enjoyment

Open-ended questions

We asked students to explicitly comment about what they liked the most and the least about the overall learning experience. We also asked them what they had found useful for their learning and welcome their suggestions for improvements. The qualitative data is then analyzed quantitatively by categorizing the comments according to four recurring 'themes' that we found between them: Mini-game A (colour contrast), Mini-game B (colour scheme), both mini-games and colouring tool. Specifically, the comments were coded based on which theme it is related to; e.g. a student's comment "*contrasting the font on the block of colour*" written under the question 'Which feature was most helpful for your learning?' was coded as Mini-game B (Colour Contrast) under 'Useful for learning'. These coded findings are summarized in Figure 6.

We received a response rate of 52% to 75% for the open-ended questions, with the balance of students choosing not to comment. Those who, did largely commented on the colouring tool instead of the mini-games (approximately 44% on 'liked most', 42% on 'useful for learning', 27% on 'liked least' and 37% gave some suggestions for improvements). For Mini-game A, a student liking it the least commented that it was "*too slow*" while those who liked the game commented that they liked "*comparing the different colours*" and seeing the "*percentage of colour that was a good contrast for a given colour*". For Mini-game B there was a gender effect with 8 out of 9 of the students who liked it the least being male. While many of them did not provide a reason, a few claimed they found a bug in Mini-game B; e.g. "*The cupcake game was buggy*" and this was what they actually liked the least. One male student explicitly stated that he found the game boring. On the contrary, two male students explicitly stated Mini-game B as what they liked most – referring to it as the "*cupcake game*" and that it "*was fun*". One student commented "*The games helped a lot*" under what they liked the most and this was coded as 'both mini-games'.

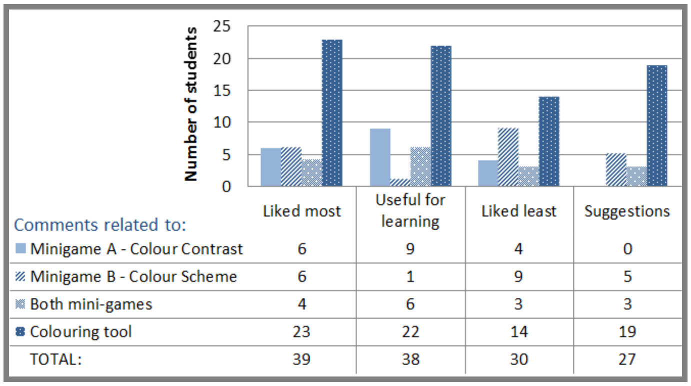


Figure 6: Qualitative summary of students' responses for the four open-ended questions.

Change in students' perceptions

Four questions were designed to explore changes in students' opinion of aesthetics. They answered these questions pre and post task. Table 3 summarizes the questions and response. The results for the Wilcoxon signed-rank test show a statistically significant decrease in students' perception of the importance of visual aesthetics for items Q5 to Q7.

Perceptions of visual aesthetics (1=Strongly Disagree to 5=Strongly Agree)	**Mean** (pre, post)	**Z**	***p***
Q5. I think it is important that a user interface is attractive.	4.37, 4.09	-2.427	.015
Q6. I think that an attractive user interface affects a user's opinion of the software/website	4.41, 4.06	-1.982	.047
Q7. I think that learning/improving on my interface design skills is important.	4.38, 3.88	-3.800	>.001
Q8. I put learning/improving on my interface design skills among my priorities.	3.77, 3.69	.923	.356

Table 3: The change in students' perceptions of visual aesthetics

Self-reported learning

Our results for pre- and post- items measuring students' self-reported learning show that both mini-games elicited a statistically significant increase between their ratings (Table 4).

Self-rated knowledge and skills (1=Lowest to 10=Highest)	**Mean** (pre, post)	**Z**	***p***
Q9. My current understanding of colour schemes.	5.79, 6.55	2.972	.003
Q10. My current understanding of colour contrast.	6.28, 6.92	2.988	.003
Q11. My skills in choosing good colour contrast when designing a UI	6.00, 6.76	3.125	.002
Q12. My confidence in choosing a visually pleasing colour palette	5.94, 6.61	2.854	.004

Table 4: The difference in students' perceptions relating to their current knowledge on colour

Contribution of the learning experience to… (1= None, 2=Very little, 3 = Some, 4= Quite a bit and 5= A lot)	**Frequency**						**Mean value**
	1	**2**	**3**	**4**	**5**	**N**	
Q13. Understanding of colour contrast	1	5	14	27	2	49	3.49
Q14. Understanding of colour scheme.	2	4	15	26	2	49	3.45
Q15. Choosing effective colours for my UI design.	1	5	16	24	3	49	3.47
Q16. Choosing a visually pleasing colour palette for my UI design	1	5	16	23	4	49	3.49

Table 5: Students' perceptions of how much the learning experience contributed to their knowledge and skills.

Students were also asked to rate the extent to which the learning experience contributed to their knowledge/skills for items Q13-Q16 (Table 5 above) in the post-test survey. Overall, the results show that all except 1 or 2 students felt that the activities have certain degrees of contribution to their knowledge and skills.

Students' performance

Out of the 52 students voluntarily participating, only 26 (5 female and 21 male) students submitted their completed pre and post GUI colouring exercises together. From the scores given by the experts, 10 students showed an increase in their level, 7 showed a decrease and 9 remained at the same level. In terms of ranking, 15 students went up in rank for their post-test work while 11 students went down. While the number of students who made progress exceeded those who got worse for the ranking results and the scoring results, our Wilcoxon signed-rank test (Table 6) showed that both increases are not statistically significant.

	Mean (pre, post)	**Z**	***p***	**N**
A. SOLO-based Score (1 = *prestructural* to 5 = *extended abstract*)	2.31, 2.38	0.457	.648	26
B. Ranking (1= best to 52=worst)	27.15, 25.85	-0.661	.509	26

Table 6: Results for expert evaluation on students' performance

Discussion

While these are mixed results, they indicate an overall positive response from the students. However, a statistically significant number of students showed a decline in their perceived importance of visual aesthetics and in how they prioritize learning visual design skills. Considering games are typically played for entertainment, perhaps the implicit implication is that when it is 'fun' and 'playful' it is also 'unimportant'. This flags the risk of students trivializing the content covered by mini-games. Other authors have expressed similar concerns about games in higher education, where students may not view games in a classroom as 'serious' learning or that it may trivialize the learning process (e.g. Okan, 2003). Therefore, caution is needed when adding mini-games to the learning environment. An example of a precautious step we can take is to clearly communicate the importance of the lesson via a real-world application. In our case, it could be by adding a learning activity that can demonstrate the positive impact of a GUI that is appealing to its users or the negative impact of an unappealing one. For the open-ended questions, it is interesting that a higher number of students chose to explicitly comment on the colouring tool that they used in the GUI colouring exercise. It may be that the colouring tool enabled students to immediately apply the concepts they learned from the mini-games, and that this resulted in their particular focus and appreciation of it. In a way, this confirms our previous findings that students enjoy using the colouring tool and find it helpful for their learning. It also further highlights the importance of bringing the conceptual knowledge back into context, which in turn allows students to make deeper meaning of what they have learned. Our next plan is a study with a focus group to better elicit specific aspects of mini-games that can both engage students and effectively impart the essential knowledge without trivializing it. We also intend to investigate gender implications of game preferences within this context. This can then help us in minimizing any gender marginalization while maximizing the learning potential of games.

Conclusions

We presented the development and trials of two mini-games in our undergraduate HCI course to supplement students' learning of visual aesthetics. We found an increase in students' perception of their understanding. Similarly, the results of the experts' evaluation may suggest an increase in their actual performance, although the change is not statistically significant. The majority of the literature supports the use of games in a learning delivery method. However, our result showed a significant decrease in their perception of the importance of the topic. This may suggest that mini-games as an instructional tool carries the risk of making the subject seem trivial for some students. Nevertheless, our results also provide a strong indication that mini-games are enjoyable for students. Instructors considering the use of mini-games should therefore consider the trade-off between the level of enjoyment provided by mini-games to engage students with a subject, and the potential long term impact of reducing the perceived importance of that subject.

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