Binary Games: Using a Short, Casual Game Format to Teach Computational Concepts

Emilia F. Gan
Paul G. Allen School
University of Washington
Seattle, USA
efgan@cs.washington.edu

Laura Vonesssen
Paul G. Allen School
University of Washington
Seattle, USA
laurav4@cs.washington.edu

ABSTRACT

UPDATED—June 6, 2017. Most people rely on internet-connected devices for their work and leisure activities, but very few progress beyond being passive users of technology. However, activities that encourage the development of computational thinking skills have obvious benefits, despite their cost in time and effort. In this project, we take a new approach to mobile learning with micro-content by integrating deliberate practice into the structure of two games to teach binary numbers. While the games we describe share features with other mobile games and with other mobile learning applications, they present a unique combination of features from both types of applications. They provide the repeated execution of a task required for deliberate practice, automatically adjusting to the user's learning needs as assessed by real-time analysis of the user's performance, while still remaining engaging and entertaining, in their own right, as games.

ACM Classification Keywords

K.3.1 Computer-assisted instruction (CAI)
K.3.2 Computer and Information Science Education

Author Keywords

education; mobile learning; m-learning; microlearning; wait-learning; learning objects; educational games; educational technology

INTRODUCTION

Technology is becoming increasingly interwoven into our daily lives. Mobile devices have become ubiquitous, with 95% of Americans owning some type of mobile phone and 77% owning smartphones [13]. Mobile devices provide users with the ability to engage in many kinds of activities anywhere, at anytime. While not everyone needs to become a professional programmer, jobs are increasingly requiring that people be able to engage in some level of end user programming [14]. Activities that encourage the development of computational thinking skills have obvious benefits, but the effort and time commitment required to engage in such activities are significant barriers, and mobile learning applications have not proven to be particularly popular [1]. The ideal solution would be to have activities that promote computational thinking or that teach a basic computer science concept close to seamlessly integrated with activities people are already engaging in on their mobile phones. In this way, learning could occur with minimal extra effort on the part of the learner.

We started with the idea of incorporating some form of micro-learning into a captcha, an idea inspired by Andy Ko, Associate Professor at the University of Washington Information School and an Adjunct Associate Professor in Computer Science and Engineering. Professor Ko's research covers the specializations of human computer interaction, computer science education, and software engineering. However, over time the project evolved into an initial exploration of the computer science micro-learning design space, and then finally focused in on the design of two games to allow people with little to no knowledge of the binary number system to gain familiarity with binary numbers. In carrying out this project, our research question was whether and how short, informal game applications could be leveraged to teach players specific computational concepts. Our contribution is thus:

- An exploration of the design space of educational micro-games through two case studies
- A preliminary evaluation of the games

RELATED WORK

Over the course of the quarter, our project evolved away from the initially proposed concept of computer science learning incorporated into activities commonly encountered online (dubbed "Guerilla Computer Science Education"). We discuss this evolution in the following subsections. At each stage, we integrated what we had learned in the context of our personal educational goals and discussed possible future directions. This review process guided the decisions we made regarding the direction taken by our project. As our project evolved, its development was informed by related work in a number of areas. In the following sections, we discuss our work in the context of the existing literature.

Original Captcha Proposal

Our initial idea was to investigate the potential of using the captcha model to impart a single computational concept. Captchas are short interactive security features intended to prove that the user is human. Use of captchas is pervasive, with Google reporting that 200 million captchas were solved daily in 2012 [2]. Traditional captchas are designed with the intent that they will be easy for humans to solve but difficult for a machine to solve [3]. Perceptual tasks are commonly used for this purpose – the three main types being 1) text-based schemes, relying on recognition of distorted text, 2) sound-based schemes, requiring the user to solve a speech recognition task, and 3) image-based schemes, involving image recognition tasks [15]. However, computers are getting better and better at completing such tasks [7]. We were intrigued by the idea that these could be replaced by cognitive or learning tasks instead (hereafter referred to as "cognitive captchas"). Since most users are familiar with the concept of a captcha task, introducing a new task in what is a familiar context seemed to be a promising approach to the style of "guerilla CS education" we envisioned.

We conducted brainstorming sessions to generate ideas for suitable concepts and formats for used in cognitive captchas. Since we were proposing something that a user might not be able to "opt out" of, we needed to be certain that the educational task did not interfere with the activity the subject was attempting to perform. This meant that we had to make sure either that the concept was something that could effectively be learned by the general population of internet users or that there was some way to easily recover from a failed attempt at the task, such as reverting to a traditional captcha task. Formats considered during our brainstorming sessions included puzzles, short videos followed by questions, cartoons, and short stories.

While we were researching captchas, we realized that there were two parts to the problem, namely 1) designing a task that would be effective at teaching some concept in a very short period of time and 2) designing a new category of cognitive task that would be effective at distinguishing humans from computers. We decided to focus our efforts on the first of these considerations, micro-learning.

Micro-learning Design Space

Micro-learning refers to short-term activities that promote "repetitive learning through embedding the learning process into daily routines by making use of communication devices" [8]. We were also inspired by Cai's work on wait-learning, which looked at ways to unobtrusively incorporate tiny amounts of learning into the frequent tiny moments of waiting embedded everywhere in our daily lives [4]. In discussing the design space of small computational task, we realized we needed to consider issues of engagement and motivation. We came up with a preliminary table (see Figure 1) to help us visualize this design space along the dimensions of computing concept types and motivation.

			Motivation				
			Intrinsic			Extrinsic	
		Examples	Desire to learn	Boredom	Captcha	Payment	Badges
Concept types	Computing concepts	Abstraction					
		Data & Information					
		Algorithms					
		Automation					
		Parallelization					
	Coding concepts	Logic					
		Data structures					
		Debugging					
		Programming languages					
	Problem-solving	Strategies					
		Puzzles					
	General knowledge	Misconceptions					
		Security/privacy					
		Statistics/polls					
		Unexpected forms					
		Time-savers					

Figure 1. This table shows a proposed organization of the design space of CS micro-learning, based on concept types and motivation.

Deliberate Practice

It is well known that people learn best when they are engaged with and invested in the material they are learning – motivation matters [5]. Relying on the external motivation provided by needing to get past the captcha task is not sufficient. Since we would be asking subjects to learn in situations where they had not consciously decided to engage in learning activities, the burden would be on us, as the designers of the educational materials, to ensure that the subjects seeing the educational tasks would be receptive to them. In thinking about how we might accomplish this, we reviewed formats that would potentially provide either extrinsic or intrinsic motivation.

Many people assume that exceptional achievement is due to innate talent [5]. This belief is often associated with the related assumption that the exceptional performance is relatively effortless [5]. Research shows, however, that excellence is achieved only after a long, extended period of focused effort. Mere repetition is not sufficient to attain the highest level of accomplishment [5]. The term "deliberate practice" is used to refer to practices that have been proven most effective at improving performance [5]. The most important factor influencing successful learning is the subject's motivation, which in turn is influenced in the learner's self=perception of his or her abilities [5]. Other factors include whether the task is designed to take the learner's prior knowledge into account, whether the subject is provided with immediate feedback sufficient to asses their performance, and repetition of the same or similar tasks. [5].

Deliberate practice is not inherently enjoyable. This distinguishes deliberate practice from other activities in the same domain, namely, playful interaction and work. Playful interaction is purely intrinsically motivated. The activity is done for its inherent enjoyment. Work, on the other hand, is motivated by external rewards (salary, social recognition) [5]. Our project we is trying to bridge the gap between playful interaction and deliberate practice. Our intent is to combine some elements of deliberate practice that have been shown to be effective for learning with the inherent enjoyment typically associated with games.

We hypothesize that reducing the effort of deliberate practice will do much to overcome the motivation barrier described by Ericsson et al. [5]. In addition, by focusing on micro-learning tasks, we will avoid the risk of excessive practice, which can lead to "burnout" and subsequent loss of motivation [5]. Additionally, by "hiding" the educational component in an inherently enjoyable game, we hope to avoid the issue of user's self-perceptions of their abilities affecting their decision on whether or not to engage in deliberate practice.

Educational Games

Many guidelines have been established for making sure educational games are actually educational [6]. One of the core such recommendations is that "the educational content must be at the heart of game play." Educational games in the context of micro-learning is an area that hasn't been thoroughly explored. While games are included as a version of micro-learning in Hug's mindmap of the micro-learning problem space[8], the games described are multiple choice, quiz-type exercises, and the IEEE Standard on Learning Objects Metadata doesn't even include "game" as one of the allowed terms to describe "Learning Resource Type" in the base schema they propose [9]. In presenting these games, we hope to provide examples of how games can be designed to be more than just automated quizzes with attention-grabbing animations tacked on.

To do this, we designed features of our games that would adapt to the user for a personalized challenge as in deliberate practice, but in small enough doses to avoid burnout [5]. Our goal was to combine this with an appropriate level of cognitive load and provide motivation via reward from successfully completing tasks. By appropriate scaffolding, the same basic game idea would be able to lead a player from a complete novice level to a more advanced level without requiring a great deal of outside explanation.

To explore these ideas in a case study, we decided to design two games to teach the computing concept of binary numbers. This is a concept that's interesting enough to provide variety, but not, we thought, too complex for a game of only a few minutes' duration. This isn't the first time this topic has been explored in an educational game setting [10], but the context is sufficiently different (that one was designed for supervised classroom use) that we feel we can still add something to the discussion.

DESIGN PROCESS

Iterative Design

Throughout this project, including during the development of the games we created, we followed an iterative design approach similar to the one discussed by Zimmerman et al. of synthesis, analysis, and iterative modeling [16]. During our brainstorming sessions, any and all suggestions were recorded and discussed. When interpreting the feedback received by our prototypes we found we were compelled to consider the quality of the interaction users had with the came and make design decisions based on the quality of this interaction. This reinforced the importance of designing the "right" thing for the task stressed by Zimmerman et al. [16].

Collaboration/Brainstorming

As described in earlier sections, this project was a collaborative effort. The authors met weekly with Andy Ko throughout the quarter and had additional collaborative sessions on their own. Team members also communicated and shared materials online. The face-to-face team interaction was invaluable, as we generally did most of our idea-generation at these sessions, and found online communications more useful for staying current on project milestones and for coordinating creation of project deliverables (milestone reports and presentations). We also drew on the expertise of mentors and peers. Neither author had experience in game development before starting this process. Based on a peer recommendation, coding was done in JavaScript with the codeheart.js library [11]. This was both for ease of development, since codeheart.js was designed for writing games and had many examples, and to make the resulting games as widely available as possible – JavaScript is available on any device with a browser.

Prototyping and User Testing

Our brainstorming resulted in multiple ideas that appealed to us. Once we had settled on binary numbers as our concept of interest, we had to decide how we were going to present the concept in the context of a game. We both liked the core idea of allowing players to select a sequence of tiles labeled with a 1 or 0 and translating the resulting number, since it allowed for user engagement through choice but didn't preclude the use of prompts to encourage exploration of numbers not yet seen. For simplicity, in both games the binary number is created such that the first tile selected corresponds to the highest place value digit in the final number and the last tile selected determines the ones place value digit.

User feedback was sought at several stages in the design process. The feedback obtained guided the development of the games in subsequent design and development iterations. Initially we focused on feedback from people knowledgeable in the areas of games, education, and/or binary numbers. Later, we sent out links to the game and asked for feedback either by a Google form (Emilia) or by directly talking to the player (Laura). None of the participants in our user testing rounds were compensated in any way for providing feedback on our games. No demographic data was collected on the players testing the Binary Chain game.

GAME 1: BINARY CHAIN

Description

The first game was developed primarily by Author 1 and is available at http://homes.cs.washington.edu/~efgan/binaryChain/play.html. This game presents the user with a 4x4 grid of 1s and 0s (see Figure 2 and Figure 3) and asks the user to select a connected chain of digits by dragging the cursor from tile to tile. Once a chain of digits is selected, a dialog window pops up, and the user is asked to "translate" the binary number into a base 10 value. Players are given 3 opportunities to "guess" the correct base 10 value of the binary number, but take a significant score penalty for not providing the correct base 10 value on the first attempt. As players succeed in correctly identifying lower digit numbers,

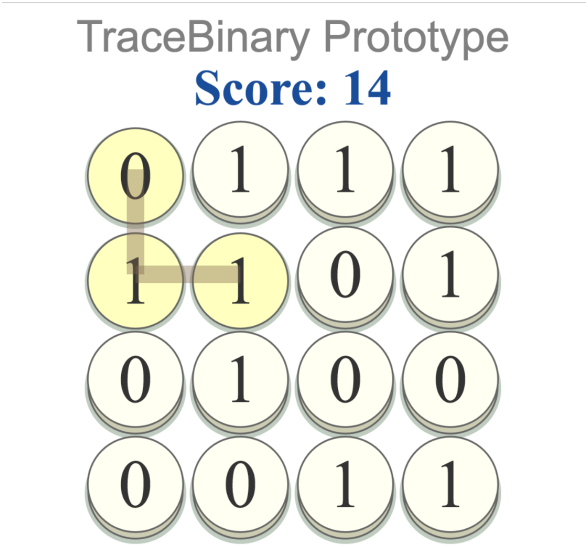

Figure 2. Prototype 1: Screen shot of the first prototype of the Binary Chain game.

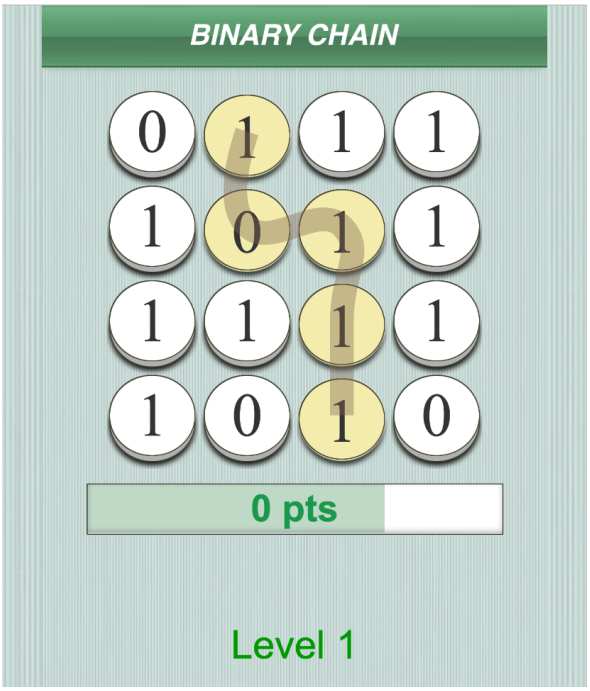

Figure 3. Prototype 2: Screen shot of the current prototype of the Binary Chain game.

the required minimum length of the binary number they can select increases, thus increasing the challenge of the game. In keeping with the motivation for this project, the game is meant to be completed quickly, and a round of play last 90 seconds. The time remaining in a given game is graphically represented on the timer bar below the game board. The current score is also displayed on the timer bar. In the space below the timer bar, the last correct conversion is shown, along with the current skill level. At present, there are no opportunities for bonuses built into the game.

Development

The initial version of the binary chain game is shown in Figure 2. The consensus from the first round of user testing was that although the concept seemed good, the lack of instructions and any easily visible game information to refer to during play made it difficult for users to engage with the game. Based on user reactions to these prototypes, the Binary Chain game was modified to provide on-screen game information, such as time remaining, score, and level. The second (current) iteration of the Binary Chain game attempted to address these complaints. This version of the game underwent a more significant user testing process, with close to thirty individuals testing the game online and providing feedback via a Google form.

During the second round of user testing, the Binary Chain game received much negative feedback about the style of the tiles being used in the game. The "button" depiction, complete with the appearance of button depression upon selection, led users to assume the tiles should be clicked, rather than dragged, in order to be selected. Additionally, the inconvenience of the pop-up dialog box for user entry, as mentioned previously, was still an issue.

The third round of prototypes for this game attempts to address these complaints. Both of these prototypes are still under development, but screen shots of their current appearance is provided in Figure 4 and in Figure 5. The design shown in Figure 4 attempts to use the shape of the number tiles and their interconnecting bridges to suggest that the path from block to block should be a continuous line, rather than a series of distinct clicks. A side effect of this change in design is that tile selection would be limited to tiles directly adjacent to each other (i.e. selection of tiles at diagonals to each other would no longer be permitted). This design does not address the issue of the sub-optimal input entry method. The design shown in Figure 5 attempts to solve the problem of the pop-up input entry window by moving the location of the user interaction to the game screen. Numbered elements in the game serve as "in-game" number keys that can be clicked on to enter the base 10 equivalent of the binary number selected on the game board. This design does not address the design flaws of the button-shaped tiles on the main game board. It is clear that the Binary Chain game will need to undergo at least one additional round of design and user evaluation, and the final design will likely incorporate elements from both Figure 4 and Figure 5.

GAME 2: FALLING TILES BINARY GAME

Description

The second game was developed primarily by Author 2 and is available at `http://homes.cs.washington.edu/~laurav4/play.html`. It presents the user with a grid into which tiles labeled with a 1 or 0 fall from the top (see Figure 6 and Figure 7) and asks the user to select a connected string of digits by dragging the cursor from tile to tile. Once a string of digits is selected, a dialog window pops up, and the user is asked to "translate" the binary number into a base 10 value. Originally, players could only guess once and the dialog disappeared either way, but

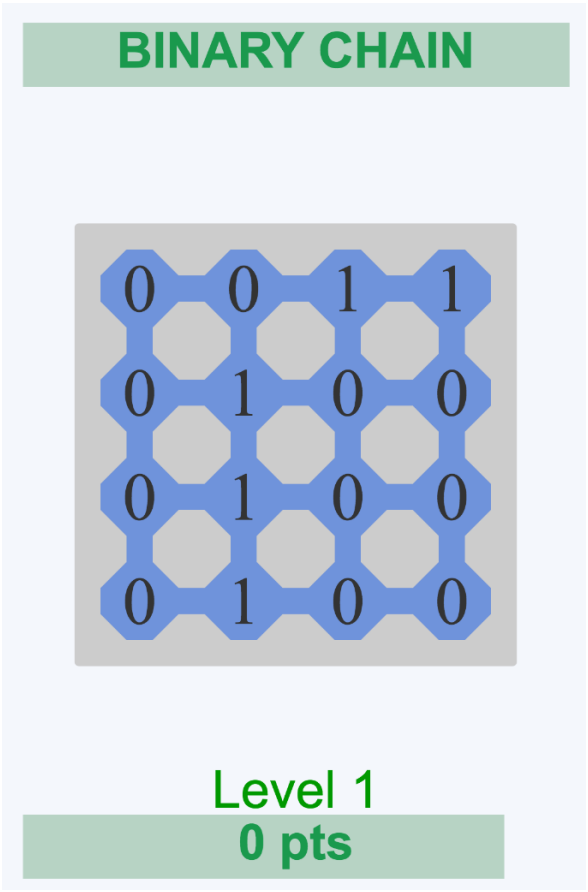

Figure 4. Prototype 3a: Game board with octagonal, connected tiles.

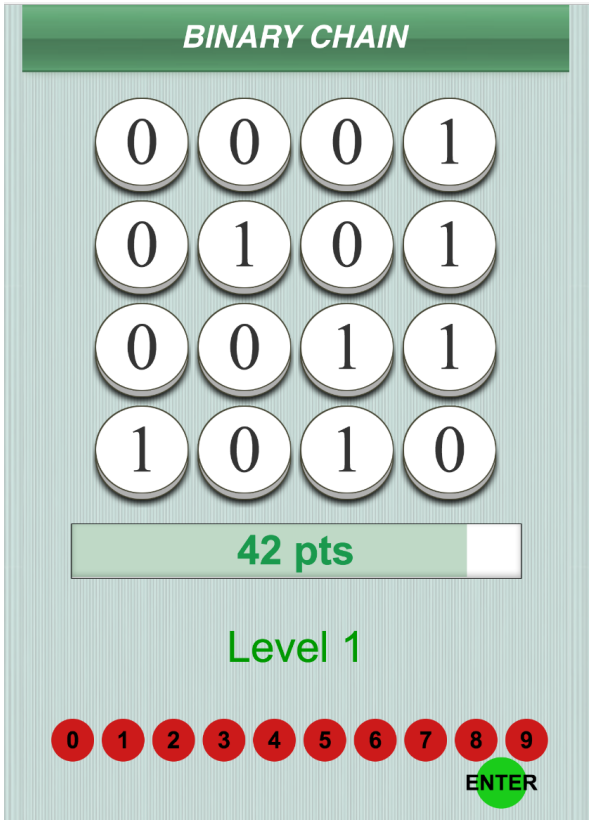

Figure 5. Prototype 3b: Game board with associated number buttons for base 10 number entry.

Figure 6. Prototype 1: Screen shot of the first prototype of the falling tiles binary game.

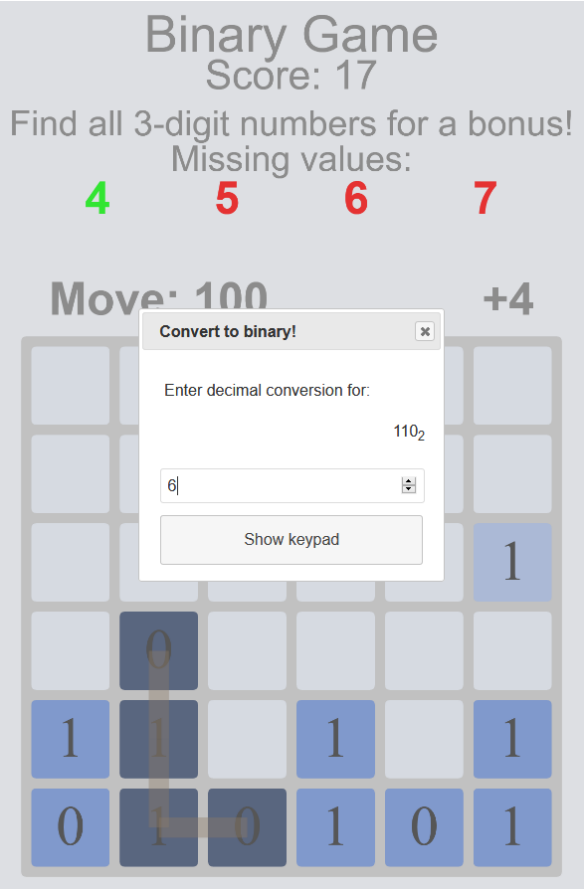

Figure 7. Prototype 2: Screen shot of the current prototype of the falling tiles binary game.

the current prototype allows an arbitrary number of guesses while tiles continue to fall in the background. There is no minimum "length" of a binary number that can be selected, but each correctly translated binary number adds its value to the score, so there is incentive to select longer numbers. Additionally, to encourage exploration over merely choosing a few binary numbers to memorize and sticking with them, the second prototype of the game provides a bonus each time all binary numbers of a given length have been successfully entered. The game ends when no more tiles can fall into the grid.

Development

The initial version of the falling tile game is shown in Figure 6. Anecdotal evidence suggests that even the first falling tiles prototype was engaging–one player said she "couldn't possibly need to play more than that" and sent a screen cap showing a score of more than 500 million. Others liked the game but found the falling tile animation too fast (or near the beginning of the game too slow). Most commented on a bug that caused the game to never end, and on the lack of an instructions screen.

This feedback led directly to the implementation of an end-of-game when the screen filled up with tiles. Columns were weighted so that emptier columns were more likely to receive a new tile than columns that were close to being completely full. The lack of instructions, however, seemed to hurt in two ways. One was a lack of clarity in game play, and one was a lack of experience with binary numbers. When combined with the ideas of deliberate practice and scaffolding, this suggested several further improvements for the binary tiles game. First, while the bonuses already provide some scaffolding in the encouragement to start with smaller binary numbers and work toward larger ones, and encourage exploration over stagnation, there is still more that could be done in this area. For example, instead of free entry, a dialog might be multiple choice, or provide more or easier hints at the beginning (see Figure 8). The game could also generate specific prompts based on board status and player history instead of "all x-length binary numbers" for a more personalized experience.

RESULTS

Results from our user studies are preliminary and have not been extensively analyzed, as our focus was more on gaining design feedback than on evaluating the game prototypes as they are now.

Informal User Surveys: Game 1 (Binary Chain)

After developing the current (second) prototype of the game, we solicited feedback from a number of individuals. These testers were either personal friends of the author's college-aged son, or members of CSESOC, the computer science and engineering social group at the University of New South Wales (Sydney, Australia) or members of the general chat Slack channel of StudentRND, a national non-profit organization based out of Seattle, WA, that promotes STEM and programming. Both of these groups are groups that restrict access to registered members. This feedback was primarily qualitative, and was intended to guide development of the games, rather than

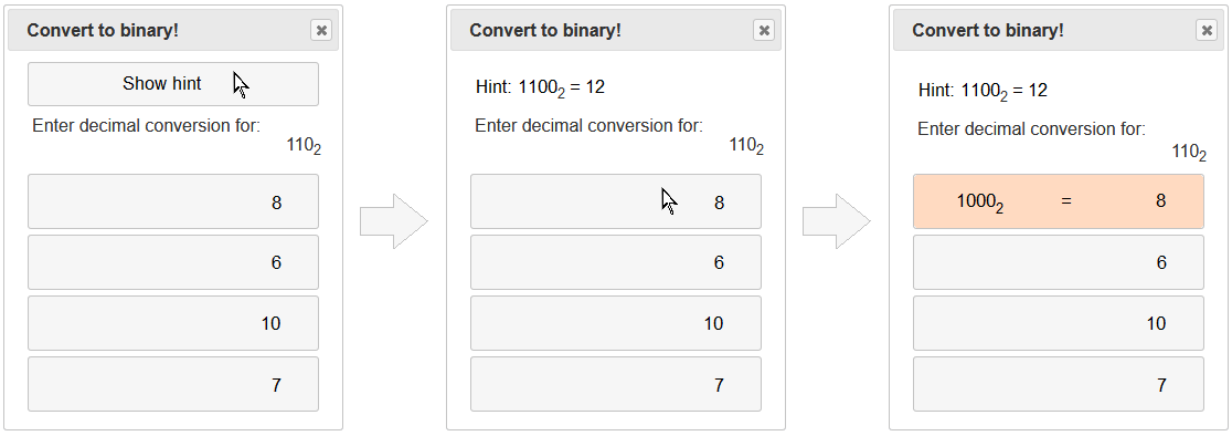

Figure 8. Prototype 3: A potential new dialog for the falling tiles binary game to provide hints. Initially, some hints might show by default, or there would be no penalty for revealing them, while later in the game penalties would increase. This prototype has not yet been implemented.

test their effectiveness at teaching the concept of binary counting. The informal survey created to collect feedback on the Binary Chain game was returned by more users than anticipated, and will be summarized in this section. The survey questions are provided below. Summary data from half the questions are provided in Table 1 (key word identifiers used in the table are provided in parentheses in the survey question listing of the relevant questions).

1. How many times did you play the game (Game Rounds)?
2. Were you already familiar with binary numbers?
3. If you didn't know binary numbers, do you think you understand them now (Understanding)?
4. If you did know binary numbers, do you think you are more skilled in counting in binary now?
5. On a scale of 1 to 5, how educational would you say the game is (Educational)?
6. On a scale of 1 to 5, how entertaining would you say the game is (Entertaining)?
7. What suggestions would you have to improve the game?
8. What is the most enjoyable feature of the game?

While the survey is still open (https://goo.gl/forms/viQzv6LYnPkRu1dk1), to date 29 people have tested the game and provided feedback. The majority of testers (17/29) rated the game a 4 out of 5 on entertainment value, yet most people only played 2 or 3 rounds of the game.

Even though the respondents to the survey were drawn from a large target of potential testers, they were all connected to programming or computer science. Not surprisingly, they uniformly reported already being familiar with binary numbers. Question 3 was intended to be answered only by people who had previously not been exposed to the concept of binary counting. Regardless, 18 people responded to this question, with two-thirds stating the games contributed to their understanding. Almost everyone answered Question 4 (28/29), with

Question	*Result*
Game Rounds (#)	2.64
Understanding (percent)	66.7
Educational (Likert)	3.41
Entertaining (Likert)	3.38

Table 1. Survey results for Binary Chain game: Average number of rounds played, percent of users who feel they understand binary numbers after playing the game, average Likert scale rating for educational value, average Likert scale rating for entertainment value.

43% reporting that playing the game increased their skill in reading binary numbers.

The qualitative data provided in response to Questions 7 and 8 were helpful in detecting strengths and weaknesses of the game. The following comments suggested concrete ways to improve the game that related to actual game play:

- More sounds, and maybe multiplayer?
- ... record every try so I can get on a roll.
- Maybe something that tells you what the number is when you guess wrong.
- ... maybe a rule where you can't just guess the same number multiple times.
- ... force them to find a decimal number in the binary digits

In addition, there were comments on the mechanics of the game related to instructions and on how non-intuitive dragging was with the current board. Suggestions for improvement were provided by three-quarters of the respondents (22/29).

When asked about the features of the game that made a more positive impression, the users comments included such feedback as:

- I like that I was able to choose and make it a just right challenge.
- The "levelling system"

- trying to choose a path that's easy to count!
- finding the best way to select as many 0s as possible
- boggle like
- It's... fun? *shrug*

Positive comments were provided by more than half the respondents (17/29).

Informal User Surveys: Game 2 (Falling Tiles)

The falling tiles binary game was not evaluated with the same form, but with informal back-and-forth conversation with a few players at different stages of the game. Initial comments (see below) focused mainly on shallow fixes rather than game play.

- [I] need instructions (P1)
- How does the game limit the Player? Time? Repeated tries? (P1)
- On my cell [the keypad doesn't work properly] (P1)
- There should be a time limit (P2)
- Why even bother with the falling animation? If it signaled the end of the game, like in tetris, it would make sense, but [the tiles] would have to fall much more slowly (P3)

There were some positive comments, too, though:

- [I] couldn't possibly need to play any more (P2) (regarding a score over 500 million)
- [The] pop-up system is pretty good (P3)
- I like the keypad (P4)
- The game is cool (P4)

These comments showed that while free play was engaging, it was not particularly intuitive. After providing instructions and adding basic features like end-of-game functionality, feedback became more helpful. Summarized, comments indicated that switching between selecting tiles and entering text in the pop-up was disruptive to game flow and that more scaffolding and personalization of prompts was required. This led to the prototype in Figure 8.

DISCUSSION

Although both of the games we presented are still "works in progress," we did gain important knowledge from the process so far. Our games, though still imperfect, have been successfully used by members of the general public. The underlying premise of making short games that can serve as opportunities for micro-learning that incorporates elements of personalized, deliberate practice has thus been shown to be practicable. This opens up new areas of opportunity for mobile education. Comments received demonstrated that users generally felt the level of challenge presented by the games was appropriate and actually commented on how they appreciated the increases in challenge level as the game progressed and their skill at counting in binary increased. This suggests that our games were able to manage the intrinsic cognitive load associated with learning binary numbers without adding excessive extraneous cognitive load [12].

Although it is not always given the respect it deserves [16], the design process is an essential part of any HCI research project. At least one author (Emilia) was surprised to discover unconscious biases in her thinking about design, which were consistent with attitudes described by Zimmerman et al. Without intending to, she found that in the process of trying to produce a working prototype, she'd relegated design considerations to an afterthought, rather than treating them as integral to the development of her game. This led to increased effort in later iterations that might have been avoidable.

Both authors found that simple open-ended requests for design suggestions were not particularly effective when a prototype had a simple but obvious flaw, since game players were often too distracted by it to share meaningful feedback. Emilia found that specifically asking for one suggestion for improvement and one enjoyable feature led to more helpful, descriptive feedback. The design and preparation of future user surveys, therefore, will likely require as much attention as the design of the games, themselves. After receiving feedback, Emilia realized that certain questions on the survey were producing unexpected results. In particular, it is difficult to determine how effective users found the game to be due to conflicting responses to the "Understanding" and "Skill" questions (Questions 3 and 4). The 18 individuals who responded to the question intended for people encountering binary numbers for the first time could represent their views of how effective the game would be in teaching someone who was completely new to the topic. Similarly, Question 4 could be interpreted as indicating that playing the game resulted in worsening skill levels (not just unchanged skill levels).

If the authors were to do this again, they would pay greater attention to choosing a minimum set of features to implement. However, given that any design project is, of necessity, a journey of exploration, perhaps this is more aspirational than realistic. When eliciting feedback, the authors would also thus prefer asking a few "experts" for more extended insights over asking many people a few formulaic questions, at least in the early stages of design.

Future Work

Having shown that the basic premise of a game incorporating deliberate practice is feasible, future work will focus on improving the personalized nature of that practice. Both games currently contain methods by which to track user performance and to adjust the challenge level in response to changes in user knowledge. However, the direction the games are able to provide is limited at present, in part due to constraints imposed by the design of the games and in part due to the nature of the current game data collection and analysis performed within the program. At present, it is still too easy for the user to latch onto certain patterns in selecting binary numbers to convert. Design changes integrated into future iterations of the game, similar to the bonus strategy added to the falling tiles game, could give bonuses for translating specific binary numbers. Methods to control user behavior that are under

consideration include highlighting specific numbers on the board as having higher value if selected, changing the ratio of 1s to 0s appearing on a given game board, and removing specific tiles from play (e.g. by leaving them blank such that they act as obstacles to the formation of binary numbers and restrict the user's choice of subsequent digits).

In the less immediate future, these games show the feasibility of incorporating deliberate practice into micro-learning games and could lead to better stealth-learning applications, where education is present and central but not, from a player perspective, the single defining feature.

CONCLUSION

We have demonstrated that deliberate practice can effectively be incorporated into educational games in the context of micro-learning. In doing so, some of the "effort" of deliberate practice can be reduced by adding an element of inherent enjoyment. This can be beneficial even for novices, who often believe they lack the innate talent to achieve a high level of performance in a given domain. This could help counteract some of the negative, self-defeating beliefs people commonly hold about their own abilities (or lack thereof).

By making computing concepts more accessible, we hope to enable people to progress beyond being passive users of technology. Although the pace of technological advancement can be overwhelming, people should be able to bootstrap computer science skills without being intimidated by the time or effort required.

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