ELK: An Online, Role-Playing Game to Better Elicit Learner Knowledge

by

Tiffany Chi Man Wong

Submitted to the Department of Electrical Engineering and Computer Science
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Abstract

Teachers that elicit learner knowledge at the beginning of new units are more aware of student preconceptions and reasoning. Teachers who understand student preconceptions are able better to anticipate misconceptions and help students assimilate new knowledge. However, many pre-service and in-service teachers neither collect student ideas nor know how to do so. For my thesis, I have designed and implemented Eliciting Learner Knowledge (ELK), an online, role-playing game for pre-service teachers. While playing ELK, users experiment and learn skills and strategies for gathering students ideas. The game has been iteratively user tested during Teaching System Lab’s Dine and Play sessions and implemented in MIT’s 11.125 Introduction to Education class.

Thesis Supervisor: Justin Reich
Title: Executive Director, MIT Teaching Systems Lab
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Chapter 1

Introduction

Students enter the classroom with preconceptions of the world formed by their unique experiences, interactions and cultures. If properly understood, these previous understandings can act as building blocks for learning and instruction in the classroom.[6] Thus, teachers that have a grasp of their students' preconceptions are better equipped to anticipate points of confusion, create a culturally responsive and engaging classroom, and help students assimilate new knowledge.[7, 8] Despite the potential benefits of more effective teaching, few teachers regularly gather student ideas and many lack the strategies to do so.[18] In fact, many believe that misconceptions are merely barriers to instruction.[16]

The goal of my research was to develop a practice space to help teachers (1) understand the importance of uncovering student preconceptions, (2) practice drawing preconceptions out of students (question asking techniques) and (3) better empathize with the student experience. I achieved these goals through the design and implementation of an online, role-playing game for pre-service teachers to practice eliciting learner knowledge, abbreviated as ELK.

Through the research process, I utilized the Design-Based Research (DBR) framework to design and study the game mechanics, and employed the Software Development Life Cycle (SDLC) when creating the game product. Both frameworks emphasized an iterative process, therefore I playtested the game at various points throughout the DBR and SDLC process. Playtests got incrementally more resource-heavy, start-
ing with lab internal playtests, then TSL’s bi-monthly Dine and Play, and lastly, 11.125 MIT’s Introduction to Education class. After playtesting two games of ELK in both student and teacher roles, majority of users reported that they felt that ELK helped them better understand the importance of uncovering student preconceptions and helped them practice drawing preconceptions out of students.

In the rest of this chapter, I further explain the motivation behind ELK, practice spaces, learning games, and our target users.

1.1 Motivation for Engaging Preconceptions

Eliciting learner knowledge should be the first step when starting a unit or topic in class, however, few pre-service or in-service teachers think to do it.[18] It is an important first step because it reveals students’ unique personal experiences and preconceptions that they bring into the classroom, which in turn allows teachers to build on learner thinking.[17] The premise of ELK relies on two major ideas about preconceptions. Firstly, preconceptions should be treated as stepping stones towards correct and complete understandings. Secondly, students have different preconceptions due to experiential learning.

Learning is an iterative process; while learning new information, a learner continually makes connections between ideas and concepts from their prior knowledge. Thus preconceptions should be viewed as stepping stones, linking old knowledge to new. Sometimes these new information align with prior information, other times they do not align and learners are challenged to resolve that conflict on their own. When faced with conflicts, many students will opt to compartmentalise conflicting preconceptions and learning concepts. If this conflict is not reasoned through, students may create two separate mental models; one to navigate the real world, and one while in the classroom and on tests. Consequently, some teachers will respond by pointing out misconceptions to expel. However, instead of stamping out misconceptions, it is important for teachers to encourage students to reason through the differences, to compare ideas, and test them.[6] Teachers can aid students by probing into their
preconceptions, re-voicing ideas and asking for clarifications to build accurate mental models that align with scientific or mathematical ideas.

It is important for teachers to be able to gather each student’s preconceptions instead of only learning about the most common preconceptions because students enter the classroom with unique backgrounds and understandings. Kolb’s Theory of Experiential Learning describes how children gain knowledge of the world through making sense of their everyday experiences.[15] Each student comes into the classroom with their own experiences and cultures that act as a unique lens through which new information is received and interpreted.[8] Thus, there is no “one size fits all” method of teaching. Instead, it is imperative for teachers to understand student preconceptions in order to effectively introduce new topics.

1.2 Motivation for Practice Spaces

Teacher practice spaces are necessary because (1) pre-service teachers should practice their teaching skills before attending to a high-stake classroom filled with students and (2) approximations of the classroom abstract away complexities and allow teachers to focus on specific teaching features and experiment with different methodologies.

Many pre-service teachers currently go from learning about education theory to teaching students in a live classroom. Some teachers even start teaching directly while retroactively getting their teaching certification. At Teach for America, a national organisation that employs over 50,000 educators, most teachers are considered “non-traditional” teachers and complete their coursework while teaching.[2] More comprehensive programmes, such as the Scheller Teacher Education Programme at MIT, match pre-service teachers up with mentor teachers for observation and practicum hours. However, even when paired with a mentor teacher, pre-service teachers do not get the opportunity to practice teaching skills in a low stakes environment. They are either observing the classroom, or teaching it. Thus, practice spaces are necessary in order for pre-service teachers to have the low stake opportunities to practice teaching skills.
Practice spaces are also necessary for teachers to experiment with specific teaching features. Grossman identifies approximation of practice as one of the three key concepts in professional practice of teaching.[12] Approximation is the opportunity for teachers to enact in practices and skills that are similar to those in the classroom. Its purpose is to go beyond reflection, and provide a platform for teachers to experiment with. Often times, approximations limit the scope and difficulty of a task so that certain dimensions of practice can be honed in and focused on.

Approximations provide novices with guidance in their teaching practice by consciously focusing on specific aspects of teaching. They allow greater freedom to experiment without the high stakes of a classroom. And when failure happens, approximations give novice teachers the space and time to work through their disappointment and learn how to address it professionally. Classrooms filled with students are a poor place for approximation due to the experimental nature of approximations. Thus, separate teacher practice spaces are required in order to improve teaching.

1.3 Motivation for Learning Games

Like practice spaces, games often abstract away complexity to focus on a set of skills. Thus, playing games is a great way to explore and learn new skills and strategies. Games are often designed so that its challenges are within the player’s Zone of Proximal Development (ZPD). The ZPD, proposed by Vygotsky, is the difference between what a student can do on their own without help, and what they cannot do at all.[21] Thus, things that fall within the ZPD is what the student could do with assistance using scaffolding, and ZPD is where all learning takes place.

Gee argues video games, specifically those that involve simulations, promote learning and good learning habits.[11] Firstly, video game simulations are good for learning because players are encouraged to take on new identities, through the use of surrogates, and explore with them. When players take on identities, they as human beings are not fully responsible for the winning and losing that occurs, and thus are more likely to explore, learn and persist when they lose. Players are also more likely
to set aside their own preconceptions about a topic when engaging in role-play, adding to their exploration. Additionally, the experiences that occur while in that identity promotes additional empathy for that role.

Secondly, video games promote not only verbal knowledge but also tacit knowledge – knowledge that is embedded into unconscious ways of thinking. This knowledge is typically acquired when working with others in “community of practice” and most useful when dealing with impromptu scenarios.

1.4 Motivation for ELK

ELK is an online, role-playing game for teachers to improve their ability to engage with student preconceptions.

1.4.1 Practice Space for Teachers to Engage with Student Preconceptions

ELK is designed as a practice space to approximate eliciting learner knowledge at the beginning of a new topic, which many pre-service and in-service teachers neither believe is important, nor have the tools to do.

In order to effectively elicit learner knowledge, teachers should be able to:

- Collect informal-qualitative data[10]
- Anticipate and look for misconceptions
- Facilitate academic discussion
- Collect assessment data aligned with the learning goal

A lot of the skills listed above can be challenging for a pre-service teacher to do with a large classroom full of students without any prior practice. Thus, ELK provides a platform in which teachers can focus on specific subject topics, experiment with different question-asking techniques, and practice drawing conclusions about students’ mental models.
1.4.2 ELK Use Cases and Target Audiences

11.125 Introduction to Education

11.125 is an introduction to education class offered at MIT. Participants of the class include both students that are pre-service teachers and those that are interested in learning more about education. All students are required to spend 20 hours of observation in the classroom, and a few go on to complete 320 practicum hours towards their teaching certificate. Students learn about concepts in teacher education, observe them in a real classroom, and employ lesson ideas. They are given a 30 minute slot during the entire semester to teach a mini-lesson to their peers in 11.125. The students in 11.125 have a few opportunities to develop their ability to gather students’ ideas. Thus, 11.125 is the perfect candidate for implementation of ELK.

Woodrow Wilson Academy of Teaching and Learning

The Woodrow Wilson Academy of Teaching and Learning is a new graduate school of education with its first cohort starting in Fall 2017. WWA is a unique programme as its content will be delivered mainly online. It will have only 3 hours per week of in-person classes and 9 hours per week of online coursework. Thus, ELK will be designed for online use to maximize its impact and usability.

Pre-service teachers

Our definition of pre-service teachers are teachers that have not yet taught full-time in a classroom as the main instructor. Many pre-service teachers go from graduate education seminars to observing a classroom to teaching in one. However, few teachers are given the opportunity to practice their teaching skills before implementing them in front of students. ELK gives teachers the opportunity to hone their skills in eliciting learner knowledge and engaging with student preconceptions before entering the high-stakes classroom.
**In-service teachers**

Another potential group of users are in-service teachers. While not initially considered, during our first round of playtests, I discovered that even some experienced teachers neither elicit learner knowledge at beginning of units, nor think that it is helpful to do. Thus, ELK can be used as a professional development tool for in-service teachers to both emphasize and practice the importance of engaging student preconceptions in the classroom.

We managed to incorporate all of the target users into our game design and software development process using playtests, later detailed in this thesis. Chapter two gives an overview of previous solutions of practice spaces and ELK. Chapter three presents a couple iterations of ELK that were playtested and the respective lessons learnt. Chapter four describes ELK’s implementation and chapter five evaluates ELK’s efficacy using research questions and playtests. Chapter six makes suggestions for further works and chapter seven concludes with contributions.
Chapter 2

Previous Solutions

All but one previous attempt at ELK were offline, card-based iterations. This chapter details some of the prototypes and lessons learnt from them. In addition, there are a number of other practices spaces currently being developed at MIT’s Teaching Systems Lab, including but not limited to, Teacher Moments, Baldermath, and Committee of N.

2.1 Offline ELK

One of the first iterations of ELK was an in-person role-playing where one teacher interacted with three or four students. Each student was given paper cards with information about their role-playing student personalities, preconceptions, and teaching techniques written on them. All users had the same role, a hybrid of both student and student, and the game was played out round-robin style with no scoring. Games differed in topic and could have anywhere between 2-6 players. To play, each player received a card at the beginning of the round and uses their assigned techniques to learn about others’ preconceptions, all the while role-playing with their assigned preconception and personality. Another similar iteration of ELK had one teacher and four students, with personalities and preconceptions, per game.

Playtests of these ELK iterations led to two major conclusions. Firstly, while the inclusion of personalities added to the engaging improvisational nature of the game,
the personalities diverted attention away from the primary goal of understanding students’ ideas. Players who were assigned attributes such as “shy” or “stubborn” interpreted those attributes to mean they did not have to engage in the conversation, thus circumventing the entire purpose of the game. Secondly, the open-ended nature of discussion made it difficult for pre-service teachers to recall or analyze aspects of the discussion, such as which questioning techniques worked and which one did not.

To this end, we removed personalities and traits from student profiles in the next iterations in hopes of removing complexity from ELK. Additionally, we explored the use of written transcripts in the online version.

2.2 Practice Spaces at MIT’s Teaching Systems Lab

There are a number of practice spaces being developed at MIT’s Teaching Systems Lab.[3] Most of these practice spaces are designed as games or simulations and are a combination of online and offline material.

- **Committee of N** is a card game that allows pre-service teachers to investigate and discuss the history of schooling in America. Players draw cards with information about learning philosophies, assessment practices, and school structure and use those ideas to design a school.

- **Teacher Moments** is a simulation where teachers are presented different ethical situations both in a classroom and between teachers and administrators or teachers and parents. Participants are asked to respond as if they were the teacher in charge using voice recordings. It is built as an web application.

- **Motivation Station** is a card game that helps teachers practice applying principles of cognitive science to motivate students. It follows similar game mechanics to Apples to Apples.
• **Baldermath** works on a game mechanic similar to Balderdash, but instead of divining which definition is the correct one for an obtuse word, players review a math problem and identify the actual versus bluffed student response. Three student players respond to a math problem, an additional player copies actual student work into his/her own handwriting. Then, a fifth player acting as a judge, reviews all of the problems and tries to determine the “real” student answer example.
Chapter 3

Game Design

Due to the different affordances of online and offline gameplay, there was a large game design component when translating ELK into a web-based game. This section first outlines the design constraints and questions we had coming into brainstorming, then details two of ELK’s many iterations, data from their playtests, and lessons learnt.

3.1 Design Constraints and Open Decisions

ELK brainstorming started with two overarching design constraints:

1. ELK should help teachers provide better instruction

2. ELK should be a game

From the literature review, we were further able to break down the first design constraint into specific requirements so that ELK could help teachers provide better instruction: ELK should allow players to practice gathering student ideas about a topic, it should increase player’s understanding of the importance of student preconceptions when teaching, and increase player’s empathy with student misconception.

ELK’s second constraint was not goal oriented, but delivery – it had to be designed as a game. The reason is twofold: first, well-designed games place learners in their Zone of Proximal Development; second, games promote acquisition of tacit knowledge
and encourage experimentation. While not a requirement, we also aimed to design ELK as a role-playing game due to role-playing games’ abilities to increase empathy and risk-taking. In order for ELK to be a compelling game, there were an additional set of constraints. ELK needed to give users feedback on how they were doing, which in turn required a scoring mechanism. There had to be drama in order for ELK to be fun and exciting. And lastly, ELK should have minimal rules and restrictions in what players could do.

Along with the role-playing capabilities, ELK also needed a chat application. In previous iterations of ELK, chat transcripts helped users reflect on the conversation that took place during the game, what went right and wrong. Such a tool would help users maximize use of the practice space.

On the other hand, there were a few large decisions that had to be made for the brainstorming to be reasonably scoped. Major decisions including whether the game should be played by a single player or multiple players, synchronously or asynchronously, and collaboratively or competitively.

To maximize ELK’s accessibility, the ideal goal was for ELK to be both single and multiplayer compatible and have the flexibility to be played both synchronously and asynchronously. However, we decided to design ELK for multiplayer and synchronous play for the first end-to-end implementation. The reason is twofold: firstly, traditional role-playing is both multiplayer and synchronous; secondly, single player mode would require some artificial intelligence and existing data to model a two-sided conversation.

### 3.2 TSL’s Bi-Monthly External Playtests

The Design-Based Research (DBR) framework emphasizes an iterative process, thus ELK was frequently playtested throughout the design stage. At the peak of its design stage, ELK was being playtested twice a week internally at the lab. These were highly useful for testing small changes and receiving rapid feedback, but results were always slightly tainted due to bias. TSL’s bimonthly playtests were a lot more effective as educators including pre-service teachers, in-service teachers, administrators and more,
would come to TSL to playtest teaching games and simulations with little or no prior knowledge of our work.

During each playtest, we would use some or all of the following research questions to guide our evaluation:

1. Is ELK an effective teaching space? Does it provide opportunities for approximations?

   (a) Does it simplify a task by limiting complexity?

   (b) Does using ELK provide opportunity for enactment of the important skill of understanding and eliciting student ideas (not just reflection)?

   (c) Does using ELK allow participants to experiment with its features (question asking techniques)?

2. Did ELK achieve its goals to help teachers provide more effective instruction by

   (a) practicing drawing preconceptions out of students

   (b) understanding the importance of uncovering student preconceptions

   (c) developing empathy for the student experience

ELK was playtested externally during TSL’s Dine and Play in October 2016 and December 2016. During each Dine and Play, ELK was playtested with two groups of users and each playtesting session lasted 40 minutes. Both playtests focused on testing ELK’s game mechanics. ELK was playtested using Google Sheets and/or Google Docs to minimize time investment when prototyping. Feedback was collected through surveys, observations and group discussions, then incorporated into future prototypes.
3.3 October Playtest

3.3.1 Game Mechanics: Multiplayer, Equal Roles and Competitive

The first version of ELK was very different from the version of ELK playtested in 11.125. In October 2016, ELK was a 4 to 5 player game and played competitively.

Players had the same neutral role that resembled both students and teachers in the classroom. The role was student-like because players were assigned a unique student profile in the form of true/false questions and answers at the beginning of the game. All players had the same set of questions but with different answers. They had to piece together their profile from the answers as part of the role-playing. At the same time, the role was teacher-like because players had to question each other to uncover preconceptions. The game goal was to be the first player to correctly guess for all players what their respective true/false answers were.

During the game, players took turns asking each other questions to elicit preconceptions. To encourage group discussion and probing, during each turn, players could either ask a new question or ask the entire group to follow-up to a previous question. They could also ask to have their answers checked by the game facilitator. Figure 3-1 is a screenshot of the game rules players were given and Figure 3-2 is an example the answer sheet players had to fill out.

3.3.2 Gameplay Observations: A Logic Game

During the game, players copy and pasted true/false questions from the profile directly and did not attempt to understand others’ mental models. Follow up questions were used to repeat the same true/false question to a bigger audience. Figure 3-3 is a snippet of the first session’s transcript and highlights the players’ techniques. During the game, we observed a few eureka moments on gameplay techniques. When asked about it, the players explained that they used logic to figure out how to get the maximum number of players to reveal their true/false answers, while minimizing
Eliciting Learner Knowledge

Objective
Correctly guess what answers all players have put down for their T/F questions before other players.

How to Play
At the start of the game, every player is randomly assigned to an order. Players will take turns playing in this order until the game is over.

During each "turn", a player can
1. ask a new question to any single player
2. have the rest of the group reply to the most recent answer e.g. if player 1 asked player 3 a question, player 2 can ask player 1, 4, 5 to respond to player 3
3. validate all answers recorded in player’s score card so far. responses: "All Guesses Correct" or "One or More Guesses Incorrect."

Validating when all answers are filled in and correct wins.
Once a player has all of the correct answers to all question, they will be the winner!

Answer Sheet
In the next tab, there is an answer sheet to keep track of player answers. Use the scratch space around to keep track of misconceptions, quotes and other notes.

Figure 3-1: Game rules from ELK’s October playtest

<table>
<thead>
<tr>
<th>T/F Question</th>
<th>Your Answer</th>
<th>Player 1</th>
<th>Player 2</th>
<th>Player 4</th>
<th>Player 5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Animals can change their genes to help them survive</td>
<td>T</td>
<td>F</td>
<td>F</td>
<td>F</td>
<td>F</td>
</tr>
<tr>
<td>All mutations are random</td>
<td>F</td>
<td>T</td>
<td>F</td>
<td>F</td>
<td>F</td>
</tr>
<tr>
<td>Organisms evolve to become better and more complex</td>
<td>F</td>
<td>F</td>
<td>F</td>
<td>F</td>
<td>F</td>
</tr>
<tr>
<td>Evolution can happen over a single lifespan</td>
<td>T</td>
<td>T</td>
<td>F</td>
<td>F</td>
<td>F</td>
</tr>
</tbody>
</table>

Figure 3-2: Answer sheet from ELK’s October playtest
information they had to share about their own profile. They treated ELK as a numbers games and limited themselves to asking only the questions given to them in the student profiles. While ELK manages to be a thought provoking game, it is not achieving its goals of having teachers experiment with techniques to understand student preconceptions.

Once during the first session, a player tried to experiment with a technique and asked “M, what are your thoughts on evolution?” M replied, “It’s a pretty useful thing” and did not reveal any information that the player could use to fill in their answer sheet. This again shows that ELK is not achieving its goals because the player asked the type of question we wanted the users to be practicing, however, this interaction shows that the competitive game model discourages players from sharing information and asking open-ended questions.
3.3.3 Adjustments Required: Different Profiles, Collaborative and 1-on-1 GamePlay

Profiles Should be Distinct from Scoring Method and Should Emphasize Thought Process

Feedback from the survey data shows that 70% of users found the game an interesting way to learn about preconceptions. However, they learned only what the preconceptions were, and not the reasoning or mental models behind them. While some users did not like contradictions in student preconception, others did not mind them, but “would have loved to see real or simulated student journal entries that fleshed out their answers more”. Student profiles needed more than just T/F question answers.

From the transcript in Figure 3-3, it is clear that users are not internalising their profile of true/false questions and communicating preconceptions, but instead directly revealing their answers. Similarly, instead of asking thoughtful questions, players were copy-pasting survey questions. To counter these techniques, assigned profiles needed to be distinctly different from the scoring mechanism. That way, even if users continue to copy-paste the content from their student profile, it would not directly translate into the right solution for the answers for other players’ profile. We chose to modify profiles because they also needed more details. In the next iteration, profiles are written out in 1-2 paragraphs as the student voice and true/false questions continue to be used for scoring. However, these questions are not available until after the game, so profiles must still be internalised.

Collaborative Models and 1-on-1 Conversations

A large barrier to engaging conversations was the competitive nature of the game. Players did not want to reveal much about their profile and would answer as succinctly as possible. This tactic in turn forced players to ask very specific questions. Additionally, the game was treated as a logic game instead of a role-playing one, and users aimed to maximize the number of answers they could acquire using single questions. This gameplay falls far from the ELK goal of increasing players’ understanding.
of student preconceptions. In response, the next iteration of ELK uses a collaborative model and decreases the number of players per game to increase interaction and engagement.

### 3.4 December Playtest

#### 3.4.1 Game Mechanics: Assigned Roles and GameBundles

The ELK iteration for the December playtest had many adjustments from the October one and was a lot closer to the final version. The game was collaborative and consisted of two rounds. Each game required exactly two players, one student and one teacher. This 1-on-1 interaction allowed teachers to hone in on a single student’s preconceptions and uncover the mental models behind them. The goal of playing two rounds was so that players could receive feedback on their process and make adjustments if necessary.

At each round of gameplay, the student received a *student profile* detailing their preconceptions in paragraph form (Figure 3-4) and the teacher received a *teaching objective* with hints on topics to cover (Figure 3-5). Both the student profile and teaching objective had a short background to provide greater classroom context to the game. The teacher had seven minutes to question the student on their preconceptions before both of them had to fill out a *challenge*.

Similar to last playtest, the challenge was composed of three true/false questions (see Figure 3-6). Both players had to individually complete the challenge, answering the questions as the student would have according to their profile at the start of gameplay. The score was calculated by counting and summing the number of matching answers (1) between the student’s and the “pre-designed” answer and (2) between the student’s and teacher’s answers. The two aspects of scoring rewarded the students’ comprehension of their profile, their ability to effectively communicate the student profile, and the teacher’s ability to draw preconceptions out of the student.

During the second round, players remained in their same role and repeated round
Background
You are a ninth grade student in an introductory biology class. This is the first lesson on evolution. No readings have been assigned yet; all students answer based on their profiles.

Student Profile
I think all mutations occur by chance. Mutations are changes in the DNA and when cell reproduction occurs, mutations happen because there are accidents and mistakes made in the copies. Mistakes happen randomly and thus mutations are also random. Evolution can be thought of as changes over time due to lots of compounded mutations. This means that evolution can be very random. However, only good mutations get passed on so while mutations can be random, evolution always leads to better things in a population. Evolution can happen to a single organism if they have enough mutations.

Animals can adapt to their environment because only good mutations get passed on. Good being that it is complementary to the environment so that it helps the animal survive. I've heard about the moths that turned black over a few generations because there was a factory smoke turned trees black. And so black moths can camouflage on black trees (whereas both were white previously). Due to "natural selection" (not exactly sure what that is but I know its application here), moths that can camouflage don't die so their genes get passed on. So while the mutation could have created red, orange, gold moths, only the black ones were passed on. And that is how adaptation works.
Round 1

Determine to what extent students are able to achieve the following:

Students will be able to explain the evolution of populations

Hints:
Topics may include:
- The time frame of evolution
- The subject and process of evolution
- Mutations (physical and on a cellular level)

Example questions:
- What is a mutation?
- Do single animals evolve or populations?
- Why do animals evolve?
- Can you give me an example of when an organism evolved?

Figure 3-5: Teacher objective from ELK’s December playtest.

Round 1 Challenge

Please put down what you think you would have answered to the following True/False questions according to your student profile.

A "?" can be used for statements you would not know how to solve e.g. if you do not know vocabulary in the word.

<table>
<thead>
<tr>
<th>Statement</th>
<th>Your guess</th>
<th>Answer</th>
</tr>
</thead>
<tbody>
<tr>
<td>Animals can pass on all of their mutations</td>
<td>F</td>
<td>F</td>
</tr>
<tr>
<td>Mutations happen because of a breakdown in how DNA gets copied</td>
<td>T</td>
<td>T</td>
</tr>
<tr>
<td>Organisms start simple and get more complex with evolution</td>
<td>T</td>
<td>?</td>
</tr>
</tbody>
</table>

Figure 3-6: Teacher objective from ELK’s December playtest.
1, with different but related profiles and objectives. The conversation was supposed to be a continuation of the previous one and student preconceptions from the first round still held.

In order for the game to be repeatable even within the same topic, for each teacher objective there were multiple possible student profiles and set of three or more challenge questions and answers. All of these combined make up a GameBundle for that specific topic.

3.4.2 GamePlay Observations: Gameplay Mechanics were Appropriate

The two sessions provided very different feedback. All four users from the first session did not find ELK an interesting way to learn about preconceptions while all six users from the second session did.

Users from the first session had trouble buying into the online interaction. They found it “silly to use Google docs when we were face-to-face and could just talk to each other” and wanted “more time and personal, not computer interactions”. Their conversations were also significantly shorter than those previous playtests as many of them had difficulty typing as seen in Figure 3-7. Users from the second session had longer conversations (Appendix A), but still found seven minutes too short of an interaction. Five of six users indicated on their surveys that they wanted additional time for the conversation. These response were consistent with feedback received during both sessions’ discussion: users did not have enough time during the game to have a comprehensive discussion and that questions were not reflective of their conversation.

One complaint we received from both playtesting sessions was that Most game design work after this iteration was focused on calibrating the GameBundle scopes and not the game mechanics. Thus, it was appropriate for implementation to start. These GameBundles were developed independently of the remaining portion of this research but later integrated into the application using a GameBundle template that
Figure 3-7: Sample full transcript from session 1 of ELK’s December playtest.

could be filled in. The implementation of ELK described in the next chapter assumes that GameBundles will be perfected as a separate project.

Looking at the transcripts and survey, it is clear that the December iteration of ELK encouraged thoughtful questions and an engaging discussion. Under “What did you learn from this game?” on the survey, 8 of 10 users mentioned lessons learnt that were consistent with ELK’s goals such as “good reminder of student’s potential preconceived notions”, “practiced connecting and asking questions to get a full understanding of what student thinks”, and “helped me think about interaction from students’ perspective”. Thus, moving forward few changes were made to the gameplay mechanism of ELK.
Chapter 4

Software Design and Implementation

The most updated implementation of ELK at the time of this writing is hosted at www.tsl-elk.herokuapp.com. This section will first describe the user interface design, then detail implementation decisions including using React for frontend, Socket.IO for server-client communication and PostgreSQL for the back end. It will also describe the GameBundle data models.

4.1 User Interface Design

The main goal of this user interface design was to maximize learnability. ELK’s main audience will be playing the game as part of a larger professional development curriculum, hence it was important to decrease the overhead for using ELK. The UI design process consisted of storyboarding ELK’s main use cases, then determining the required components from there. Lastly, a preliminary UI was sketched-up to inform software implementation.
4.1.1 Storyboard

Storyboards were created for two of ELK’s specific audiences: 11.125 and Woodrow Wilson Academy.

<table>
<thead>
<tr>
<th>Instructors introduces the importance of preconception in class. Then assigns ELK to be played in class.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Students spend 20 minutes playing two games of ELK in class; one as the teacher and one as the student</td>
</tr>
<tr>
<td>The class comes together for a discussion on initial findings. What worked? What didn’t? Were there difficulties? Surprises?</td>
</tr>
<tr>
<td>Students coordinates with others to play ELK in their own time between the last and next lecture. They can do so from anywhere as long as they have a laptop.</td>
</tr>
<tr>
<td>During the next lecture, a second discussion happens. How has the repetition and practice helped? How have they changed as teachers and students?</td>
</tr>
</tbody>
</table>

Figure 4-1: Storyboard detailing the 11.125 use case[1, 13, 9, 20]
4.1.2 Required Components for Minimum Viable Product

The implementation goal for this thesis was to build a minimum viable product for the use cases described. Required components for such an MVP were informed by the storyboards in section 4.1.1 and final game design in section 3.4.1.

From the design, the MVP needed a 2 player chat during rounds, and a challenge
and scoring mechanic. There should be multiple, well-scoped GameBundles for users to choose from. For playtesting purposes, there should be a functional UI. For research purposes, there should be a database storing pertinent information from each game.

Additionally, the 11.125 storyboard has students playing ELK at the same time in class, thus there was a need for multiple instances of ELK. In the WWA storyboard, players scheduled to play ELK with specific classmates, which requires a mechanism for users to intentionally enter the same game. The game also needed a way for the round to begin and a timer so that the game could be ended automatically and at the same time for both users. All students were expected to have their own laptop, so ELK only had to be developed as a web application and not cross-platform. Additionally, players are unlikely to stop in the middle of the game and with each game being so short, a pause mechanism was not required. Similarly, it was not necessary for users to be able to exit and reenter an existing game. Table 4.1 outlines the required components of ELK’s minimum viable product.

### 4.1.3 User Interface to Maximize Learnability and Usability

ELK’s UI was designed to maximize learnability and usability. ELK should be learnable so that there is minimum overhead for first time users. Instructors should be able to introduce ELK in class and have students play it immediately with few instructions. ELK should also be usable so that players can efficient conversations to maximize game goals.

We aimed to maximize learnability using external consistency and explicit instructions. For example, in ELK’s chat application, pressing the Enter key sends the written message and Shift-Enter adds a new line to the same message. These keyboard commands are similar to those of other chat applications’ such as Facebook messenger. The UI also has very explicit instructions. Figure 4-3 is a screenshot of ELK’s home page. Upon landing there, users are instructed to “create a new game by selecting a new topic using the buttons below”. Similar styled instructions help users navigate the rest of ELK.

A wireframe for the initial UI design can be found in Appendix B.
Welcome to MIT Teaching System Lab's ELK Game

Create a new game by selecting a new topic using the buttons below

- Rational
- Evolution2
- Chromosomes
- Cell1
- Circles
- Negative
- Algebra

Or join an existing game using the game ID

| gameID | Join Game |

Figure 4-3: Screenshot of ELK’s homepage

<table>
<thead>
<tr>
<th>Game mechanics</th>
<th>Pre-round screen with student profiles or teacher objectives</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2 player chat during rounds</td>
</tr>
<tr>
<td></td>
<td>Quiz and scoring mechanism</td>
</tr>
<tr>
<td></td>
<td>Timer</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Game navigation</th>
<th>Multiple game bundle options for players to choose from</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Single game creating mechanism</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Misc</th>
<th>Database</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Functional UI</td>
</tr>
</tbody>
</table>

Table 4.1: Required components of ELK’s minimum viable product
4.2 Software Implementation

This section outlines some of the decisions behind the technology stack employed when building this project. It also discusses how GameBundles were designed with the goal of rapid development and extensibility.

4.2.1 Front-End: React for Reusable Components

React was selected for the reusability of its user interface (UI) components. React uniquely renders only the diff between the existing DOM and the updated one. This makes ELK a lot faster to render given that ELK has a chat app as part of the application. React also makes it easy to combine and reuse user interface elements. Other libraries considered included AngularJS and JQuery. JQuery allows for direct interaction with DOM elements, which makes it great for animations and elaborate user interactions. Angular separates its controller from HTML and has 2 way binding. While both of these frameworks build powerful websites, React has the simplicity and reusability that benefits ELK.

4.2.2 Server-Client Communication: Socket.IO for Rooms

Socket.IO was a suitable choice of web communication for ELK because the game has a lot of player-player interaction, which in turn translates into a lot of server-client communication on the application. Socket.IO boasts a synchronized, bilateral exchange using a persistent channel. This synchronisation allows the chat application to be easily updated with messages, and it also allows synchronization between clients. This synchronization is vital to ELK’s gameplay. For example, a feature of ELK is that users can individually indicate when they are ready to start the round, when both users are ready, the message form appears at the same time on their respective screens for seven minutes until the end of the round, then disappears and is replaced by the challenge. Because the server can send messages to the clients, it is able to store a single timer and update the clients appropriately. If ELK was developed using asynchronized exchange, the clients would have had to poll the server constantly.
for time remaining, or they would have had to keep individual timers, opening the
door to all sorts of problems. One drawback is that persistent connections can reach
a maximum depending on server side resources, luckily, scalability is not a current
concern of ELK.

In addition, Socket.IO has a notion of rooms that clients can subscribe to in order
to receive broadcasts. These rooms make it very simple to implement multiple games.

### 4.2.3 Back-end: PostgreSQL

The back-end was built using PostgreSQL mostly due to its compatibility with Heroku.
SQL was used over noSQL due to its simplicity. While the back-end will be modified in the future to fit research and data needs, its immediate purpose is to simply
log messages. A new message is sent to the server every time it is posted with the
following details: timestamp, gameID, user and message.

### 4.2.4 GameBundle Object: Data Model

The main goal when designing the data model for the GameBundle object was (1)
rapid development and (2) extensibility, two often conflicting goals.

The GameBundle template was written in JSON to increase accessibility for non-
technical persons. To encourage rapid GameBundle development, the ideal workflow
for adding, modifying or removing a GameBundle from the ELK’s web application
should not require a software engineer. While this stage has not yet been reached yet,
the GameBundle template is designed to make it easy for non-technical researchers
to create software-ready GameBundles. The GameBundle object template uses a lot
of dictionaries where lists would be similarly appropriate. For example, in Figure 4-4
line 6, the student profile’s id is “0” and additional profiles added will have sequential
id numbers. However, using a dictionary makes it easy for a student profile to get
removed quickly and it decreases the chance for development bugs, such as fetching
the corresponding challenge answers.
Figure 4-4: Snippet of code from the GameBundle data object
Chapter 5

Evaluation

In my thesis proposal, I determined two major success factors for my thesis: (1) if ELK is built as a standalone application with all components that make it an MVP and (2) if students of 11.125 and volunteers from playtests are shown to be engaged and learning from ELK.

My original plan for ELK’s minimum viable product is detailed in Table 4.1. Each component of the game mechanics, game navigation, and miscellaneous section have been implemented in the current version of ELK. Additionally, ELK is hosted as a web application on Heroku. Thus, ELK is successfully built as a standalone application with all the components that make it an MVP.

To test whether 11.125 students and other pre-service teachers were engaged and learning from ELK, I designed and performed a playtest to evaluate ELK’s efficacy as a practice space for understanding student preconceptions.

5.1 Study Design

I performed a study to evaluate the effectiveness of ELK as a practice space for participants to acquire the skills and understandings necessary to elicit learner knowledge. The study was designed to evaluate ELK’s research questions:

1. Is ELK an effective teaching space? Does it provide opportunities for approximations?
(a) Does it simplify a task by limiting complexity?

(b) Does using ELK provide opportunity for enactment of the important skill of understanding and eliciting student ideas (not just reflection)?

(c) Does using ELK allow participants to experiment with its features (question asking techniques)?

2. Did ELK achieve its goals to help teachers provide more effective instruction by

(a) practicing drawing preconceptions out of students

(b) understanding the importance of uncovering student preconceptions

(c) developing empathy for the student experience

In keeping with spirit of design-based research, I aimed to implement and evaluate ELK as similarly as I pictured it being used in practice. ELK was designed to be used in the classroom alongside an introduction to formative evaluation and with discussion time for debriefing ELK, thus the implementation of ELK used for this study was crafted as a comprehensive 60 minute class. More specifically, I chose to collaborate with the professor of an education course that is part of MIT’s Scheller Teacher Education Program (STEP) to present ELK in a course for students who are seriously considering or actively preparing for teaching as a future career.

Pre-service teachers playing ELK would likely be practicing topics that they would have experience with. I controlled for the variable of background knowledge of users for the GameBundles by selecting the Rational and the Circles GameBundles. This decision was made under the assumption that majority of MIT students have a confident grasp of middle school mathematics.

5.2 Survey Design

The post survey was designed to answer the research questions as directly as possible using user self-reports. Table 5.1 connects the survey questions to the research questions that they were written to answer. Note that in the evaluation, research questions
<table>
<thead>
<tr>
<th>Research Question</th>
<th>Survey Question</th>
</tr>
</thead>
<tbody>
<tr>
<td>1a</td>
<td>This game is an interesting way to learn about student preconceptions?</td>
</tr>
<tr>
<td></td>
<td>What did you learn from this game as a teacher? As a student?</td>
</tr>
<tr>
<td>1b</td>
<td>What did you learn from this game as a teacher? As a student?</td>
</tr>
<tr>
<td></td>
<td>Teacher role: What tactics did you use throughout the game?</td>
</tr>
<tr>
<td>1c</td>
<td>Teacher role: What tactics did you use throughout the game?</td>
</tr>
<tr>
<td></td>
<td>Teacher role: Did you change the way you asked questions during the game?</td>
</tr>
<tr>
<td></td>
<td>What would you do differently if you played this game again as teacher? as a student?</td>
</tr>
<tr>
<td>2a</td>
<td>T/F Goal has been achieved: to increase players’ empathy with students with misconceptions</td>
</tr>
<tr>
<td>2b</td>
<td>T/F Goal has been achieved: to increase players’ understanding of the importance of student preconceptions when teaching</td>
</tr>
<tr>
<td>2c</td>
<td>T/F Goal has been achieved: to allow players to practice gathering students’ ideas about a topic</td>
</tr>
</tbody>
</table>

Table 5.1: Mapping survey questions on to research questions

may answered using data from other parts of the survey. The data structures and types of data gathered are described in Table 5.2. I aimed to collect quantitative data from users supplemented with qualitative explanations.

The pre- and post-survey were designed to capture all the necessary data required to answer the research questions. The effectiveness of ELK as a practice space was evaluated mostly using qualitative answers and both the pre- and post-survey. To analyze all users’ answers for each question, I extracted repeated themes seen in the questions and tallied up each time they were mentioned. Direct percentages were taken from the quantitative data for how users self-reported to believe ELK achieved its goals to help teachers provide more effective instruction. Where conclusions can not be made with statistical significance, I highlighted surprising outcomes.

5.3 Study Procedure

A total of 24 users, of all genders, took part of this study. They were all undergraduate students enrolled MIT’s 11.125 Introduction to Education: Evaluating Education
class. Before class, the student participants were asked to bring in their own laptop and used the web browser of their choice. They were given the same pre-reading, pre-survey, user briefing and introduction, ELK GameBundles, and post-survey. The 60-minute class study consisted of 6 segments: pre-survey, ELK introduction, 2 rounds of ELK gameplay, post-survey, and a debrief. While the debrief is part of the ELK experience, I chose to collect the post-survey data before the discussion to allow me to understand each individual’s reflection on the game and its goals as well as the reflection of the entire group. Table 5.3 shows the breakdown of time spent on each segment.

The participants first took the pre-survey to report hours spent on classroom observations and their current stance on the importance of acquiring student preconceptions. The professor gave a short introduction to ELK and its rules to the entire class. The professor also showed screenshots of the game to, as well as pointed out features such as the countdown timer, chat mechanism, challenge, and collaborative scoring. The professor had already integrated two other related but distinct practice spaces into the class, and the class had touched upon the importance of understanding

<table>
<thead>
<tr>
<th>Data</th>
<th>Structure</th>
<th>Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>Participants’ Classroom Observation Experience</td>
<td>Buckets for 0 hours, 1-3 hours, 6-10 hours, 11-20 hours, 20+ hours</td>
<td>Quantitative</td>
</tr>
<tr>
<td>Participants’ Beliefs of the Importance of Understanding Students’ Preconceptions</td>
<td>Scale of 1 (strongly disagree) to 4 (strongly agree) and free response explanation</td>
<td>Quantitative Qualitative</td>
</tr>
<tr>
<td>Preconception Acquisition Strategy before gameplay</td>
<td>Free response</td>
<td>Qualitative</td>
</tr>
<tr>
<td>Goal 1 relevance</td>
<td>True/False and free response explanation</td>
<td>Quantitative Qualitative</td>
</tr>
<tr>
<td>Goal 2 relevance</td>
<td>True/False and free response explanation</td>
<td>Quantitative Qualitative</td>
</tr>
<tr>
<td>Goal 3 relevance</td>
<td>True/False and free response explanation</td>
<td>Quantitative Qualitative</td>
</tr>
<tr>
<td>Reflection on tactics used during gameplay</td>
<td>Free response</td>
<td>Qualitative</td>
</tr>
<tr>
<td>Change in Tactics</td>
<td>Free response</td>
<td>Qualitative</td>
</tr>
</tbody>
</table>

Table 5.2: The structure of self-reported data from the survey
what students know through readings such as *How People Learn*.\[7\]

After the introduction, the professor divided the students into pre-assigned pairs and initial game roles. The students played two GameBundles: first, they played the Rational game bundle, then the Circle game bundle. Students had an opportunity to ask questions about gameplay rules and mechanics such as scoring. Additionally, the professor clarified the goals of the game with the students, reminding them that the primary goal was to understand the student ideas, and not to teach the student about the concept. Reinforcing the goal of the game was essential to ensure that participants were using the tool for the purpose for which it was designed.

### 5.4 Discussion

ELK is an effective practice space because it simplifies student-teacher interactions by focusing activity on what students’ know. This focus allows teachers to really understand students’ ideas, so that they may plan next step strategies for teaching. It also provides opportunities for pre-service teachers to actively practice asking student questions and making conclusions about students’ existing understanding. Lastly, ELK succeeds as a practice space by encouraging pre-service teachers to experiment with different question-asking techniques. ELK is also successful its learning goals: to allow players to practice drawing preconceptions out of students, to increase player’s understanding of the importance of uncovering student preconceptions, and to increase players’ empathy for the student experience.
The pre-survey data showed that all users have spent 1 to 20 hours in the classroom doing observations during the spring semester. As these students have been in classrooms, they have witnessed how teachers elicit and act upon learner knowledge. Additionally, reflection about teaching is an important aspect of the course so the students are primed to reflect on this experience.

This remainder of this section will discuss the how the pre- and post-survey results collected support the conclusion that ELK is both an effective practice space and a helpful tool for teachers to improve on understanding student conceptions.

5.4.1 ELK as a Practice Space

Does Using ELK Simplify a Task by Limiting Complexity?

ELK strips away the other elements of a classroom so that players can focus on gathering preconceptions from a single student. ELK achieves limited complexity by rewarding users who focus on the primary objective of the game – collecting student preconceptions. While this was received both positively and negatively, users agree that ELK does limit exchanges between players in narrowing the goal to uncover students’ ideas to encourage eliciting learner knowledge. In the post-survey, users stated ELK removed elements of conversation and discouraged teaching, thus allowing players to focus on gathering students’ ideas about a topic. One user pointed out that by scoring based on whether the teacher and student role submitted matching answers, the game emphasized the importance of being on the same page as opposed to having the “right answer”. Some users even criticized ELK for being too oversimplified and limited in complexity, thus resulting in conversations that were “too direct” or conversation where the teacher was “quizzing [the student] instead of having a real conversation”.
Teacher role: Did you change the way you asked questions during the game? |
| I made significant changes | 3 |
| I made some changes to the type of questions asked | 20 |
| Not at all | 1 |

Table 5.4: All users made changes to questions asked

Does Using ELK Provide Opportunity for Enactment of the Eliciting and Understanding Student Ideas?

We can see that ELK provided users with opportunities for enactment of eliciting student ideas from the lessons learnt, percentage of users that changed tactics, and what users plan on doing differently the next time they play the game. Table 5.6 lists the top four lessons users learnt from playing ELK. Seven of 24 users learnt that teachers need to be more careful about their assumptions of student preconceptions and 5 users realised some effective strategies for asking questions. Both of these lessons learnt require enactment of eliciting and understanding student ideas. Additionally, table 5.4 shows 23 of 24 users reported to have changed the way they asked questions during the game, and the same number of users believe ELK ”[allows] players to practice gathering students ideas about a topic. Lastly, in response to ”what would you do differently if you played this game again as teacher?” , replies were either to make changes in question asking techniques, changes in methods of interpreting student preconceptions, or no changes at all. These responses highlight the opportunities ELK provides for users to ask questions to collect student ideas and understand student responses.

True or False: ELK achieved the following goals | % True
---|---
To allow players to practice gathering students’ ideas about a topic | 96
To increase players’ understanding of the importance of student preconceptions when teaching | 83
To increase players’ empathy with students with misconceptions | 67

Table 5.5: Users found ELK to have achieved its goals
Does Using ELK Allow Participants to Experiment with Question Asking Techniques?

All participants responded in the survey that they were able to experiment with question asking techniques. Firstly, 23 of 24 users either made some or significant changes to the way they asked questions during the game. Additionally, when asked what changes they would make if they were to play the game again, 50% of the users mentioned specific changes to question asking techniques, and 21 of 24 users mentioned general changes in the teacher role. The combination of both sets of data shows that ELK encourages experimentation both within a single game and amongst multiple games.

5.4.2 ELK to Provide More Effective Instruction

From the self-reported survey data in Figure 5.5, we can also see that users believe ELK achieves all three of its goals to help teachers better teach. Twenty-three users (96%) users reported they were able to practice drawing preconceptions out of students, 67% reported they increased understanding of the importance of uncovering student preconceptions, and 83% of players reported they increased empathy for the student experience.

<table>
<thead>
<tr>
<th>What Users Learnt from ELK</th>
<th># users</th>
</tr>
</thead>
<tbody>
<tr>
<td>Teachers need to be careful about their assumptions of students’ preconceptions</td>
<td>7</td>
</tr>
<tr>
<td>Eliciting preconceptions without teaching can be difficult</td>
<td>6</td>
</tr>
<tr>
<td>There are more effective question asking techniques than others</td>
<td>5</td>
</tr>
<tr>
<td>Students may have gaps or contradictions in their knowledge</td>
<td>4</td>
</tr>
</tbody>
</table>

Table 5.6: Top lessons users learnt from playing ELK.

To Allow Players to Practice Gathering Students’ Ideas about a Topic

This ELK goal goes hand-in-hand the requirements that make ELK a viable practice space for teachers. Our analysis of the first research question shows that ELK em-
bodies the requirements to make it a successful practice space, which itself requires ELK to allow players to practice gathering students’ ideas. As mentioned previously, all but one user tester reported that ELK gives opportunities for players to gather students’ ideas. In their explanations, users pointed out that the game design requires understanding and focus on preconceptions and thus also gathering them, but without trying to teach anything.

To Increase Players’ Understanding of the Importance of Student Preconceptions When Teaching

While the pre-survey shows that all user testers believed student preconceptions are critical to instruction, only 20 of them self-reported “true” to believing that ELK achieves the goal to increase players’ understanding of the importance of student preconceptions. Those that did not explained that since the ELK did not have teachers follow through to teach the students, they were unable to see the effect of preconceptions on (attempted) concept change. One user said, “I still think that if the content was broken down properly and explained step-by-step it wouldn’t matter what the student believed coming into the classroom”.

In their explanation of how goal 2 has been met by ELK, users pointed to being about to see preconceptions in action during ELK and their effect on how students answer quiz questions. Even though all of them had already found preconceptions at least somewhat important prior to ELK, playing the game highlighted “how subtle but powerful [misconceptions can] be”. Table 5.7 show that prior to ELK, users listed (1) anticipating misconceptions and receptiveness, and (2) gauging competency level to adjust lesson as the top two reasons preconceptions are critical. In the post-survey, participants mentioned preconceptions as a lens for viewing knowledge.
Why are student preconceptions critical to effective instruction?

<table>
<thead>
<tr>
<th>Reason</th>
<th>% Users</th>
</tr>
</thead>
<tbody>
<tr>
<td>To anticipate misconceptions and receptiveness</td>
<td>38</td>
</tr>
<tr>
<td>To gauge competency level to adjust lesson</td>
<td>25</td>
</tr>
<tr>
<td>To use as a lens for viewing new knowledge</td>
<td>25</td>
</tr>
<tr>
<td>To anticipate student interest or boredom</td>
<td>17</td>
</tr>
</tbody>
</table>

Table 5.7: Pre-Survey: Top reasons user think engaging preconceptions are necessary

**To Increase Players’ Empathy with Student Misconceptions**

There was the greatest amount of mixed feedback in response to the success of goal 2. While majority of users agreed that their empathy with student misconceptions had increased after the game, 33% of the users did not. Those that agreed mostly sourced playing in the teacher role as having increased their empathy. They mentioned that taking the same quiz as the student, accepting student misconceptions instead of stamping them out immediately, and building 1-on-1 conversations helped increase their empathy. Users that did not increase in empathy wanted more background and details on misconceptions, and did not like the distance created from using a text-based interaction.
Chapter 6

Future Work

From the evaluation above, it is clear that the current implementation of ELK is successful in meeting the stated goals to an extent. However, there are many limitations to ELK’s current gameplay. Firstly, there must always be an even number of players that are online at the same time in order for everyone to participate. Future iterations of ELK could include single player and asynchronous modes. From intermediate playtests, it is also clear that each GameBundle is unique and takes a lot of fine tuning, and the general formula to building a GameBundle has yet to be perfected. UI/UX changes should be made for the playing process to go more smoothly. Beyond ELK, additional practice spaces should be designed and implemented to ensure teachers have a all-rounded teaching skills.

6.1 Joining as a Single Player

ELK currently requires players to pair up outside of the game in order to play. In 11.125, the instructor had to pair students ahead of time. During TSL Dine and Play playtests, users paired up and shared their Game IDs. This setup requires a lot of overhead to play and can deter teachers from playing ELK. Future work should allow players to either participate as a single player, either by pairing them up automatically with another player, or having them play against the computer. For both options, there must be changes to the gameplay to ensure a smooth game
experience. An asynchronous mode described in the next section would help with pairing up players. Playing against the computer may require restricting users to multiple choice conversations, as opposed to current free flow text model. It could also allow players to type freely, and use keywords to supply appropriate responses.

6.2 Asynchronous Mode

The initial motivation for creating an online game was so that users can have greater flexibility when practicing how to elicit learner knowledge. While ELK currently allows for locational flexibility, users must still be online at the same time. An asynchronous gameplay mode would allow give users temporal flexibility. This would mostly likely involved adjustments in game mechanics – just lengthening the amount of time users can converse for would not be ideal as users may lose track of their conversation and train of thought.

6.3 GameBundle Development

When ELK was playtested during the TSL’s Dine and Play December playtest, it was concluded that GameBunles had all of the right components e.g. student profile, teacher objective and challenges, but were not correctly scoped. GameBundles were then spun off into their own mini research project. While ELK currently has functional GameBundles more work still needs to be done in this area.

For 11.125, we had every user play the same two maths GameBundle due to the variety of difficulty across different topics and grades. For example, many testers found the biology GameBundles overly complicated, and challenging to play with due to a lack of prior understanding and ambiguity in the content. Some players thought that more hints for the teacher objective would be more helpful while others found them too leading. During all of our playtests, we received conflicting feedback on our game bundles and this in turn has made it difficult to make progress.

Future work should include finding a formula for building GameBundles that are
easy to interpret, and well scoped for 7-minutes of conversation. Challenges should also be designed so that they increase in difficulty the more practice a teacher has had with ELK.

### 6.4 User Interface/User Experience

There were a few user experience issues that came up during the playtest. Firstly, a lot of verbal instructions and assistance was given to the users, from how to start and join a game, to how the scoring for the challenge worked. To decrease instructor involvement and make ELK a more standalone game, changes to the user interface should be made to increase its intuitiveness. Written rules and instructions would also be helpful.

Another sustaining issue is ELK’s browser inflexibility. Currently, it’s only fully functional in Chrome on a laptop. There have been issues reported with Firefox, Safari, and Chrome on an iPad.

Another concerning feedback we received throughout our playtests even up until the 11.125 class study was that our game did not reflect what a typical classroom situation would look like. While the feedback is 100% correct (teachers rarely, if ever, spend seven minutes conversing with a single student), the fact that the user thinks that ELK is attempting to mimic a real classroom elucidates another problem: that ELK is not coming through as a practice space or an approximation. One way to correct this is by increase ELK’s gamification by making the user interface more game-like. This could be via the additional of graphics, sound, or more game-like interactions.

### 6.5 Curriculum Integration

ELK is merely one game out of a suite of practice spaces that the Woodrow Wilson Academy plans on utilizing in their graduate education classroom. ELK was a natural starting point as gathering student ideas should be the first thing a teacher does
when teaching a new topic. Once the teacher understands students’ preconceptions, instruction can be adapted to address those conceptions. Future work should focus on integrating ELK into curriculum and dissemination of the idea to potential users, including graduate schools of education.
Chapter 7

Conclusion

The vision of this thesis is to provide a practice space that stripped away the complexities of a classroom, thus allowing teachers to (1) practice and experiment with collecting student preconceptions, (2) increase their understanding of the importance of student preconceptions when teaching, and (3) increase their empathy towards the student experience. I achieve these goals by designing and implementing an online, role-playing game to help teachers better elicit student understanding. Survey data from the 11.125 playtest showed that 96%, 83% 67% of users believe ELK achieves each of its respective goals.

Over the past year, I designed ELK’s game mechanics and GameBundles, and tested them iteratively through lab internal playtests and at ELK’s bi-monthly Dine and Play sessions. I created storyboards and wireframes to illustrate the user experience with ELK, and from that defined a minimum viable product (MVP) and a user interface with high usability and learnability. Next, I implemented ELK with all of the requirement components from its MVP, and furthermore, playtested ELK in 11.125 and presented and analyzed the user testing data. Lastly, I detail future works for ELK specifically and in the larger TSL context.

The implementation of ELK at the time of writing is hosted www.tsl-elk.herokuapp.com.
Bibliography


Appendix A

Sample Transcript

Teacher: Hi, M - we’re about to talk about evolution. We should start with something that kicks the whole process off. How far back do you think evolution has been going on?
Student: I think forever, or at least since the first life, because all life has mutations sometimes.

Teacher: That’s great - can you say more about what you consider a ‘mutation’...
Student: Well dna makes us who we are, like, our dna says what we should look like and how we should grow. And DNA gets copied into each cell. But sometimes DNA doesn’t get copied right and that is a mutation, which makes life look different.

Teacher: I think that’s a good summary of that topic. Can you tell me ways/reasons why the DNA doesn’t get “copied right”?
Student: I’m not sure, I know its random though.

Teacher: OK - do you feel that it’s just a cellular thing - are there other ways life can look different?

Student: I think environment has something to do with it. Like I was taught that there was a factory that made trees look black, and moths are white, but if the trees were black the white moths couldn’t camouflage anymore. So the moths that mutated black lived and now the moths there are black.

Teacher: I see.. What do you thi

Figure A-1: Sample full transcript from session 2 of ELK’s December Playtest.
Appendix B

Wireframe

Enter a code to join an existing game: 0001

Or create new:

- Biology = Evolution
- Chemistry = Stoichiometry
- Math = Functions
- Math = Fractions

Play as:

- Student
- Teacher
Appendix C

Pre-survey

Name
Your answer

How many hours of classroom observations have you completed?
- 0
- 1-3
- 6-10
- 10-20
- 20+

Student preconceptions are critical to effective instruction *
- Strongly Agree
- Somewhat Agree
- Somewhat Disagree
- Strongly Disagree
- I don’t know

Explain your choice above
Your answer

How do you go about gathering students’ ideas before you teach a topic?
Your answer
Appendix D

Post-survey

ELK - post-survey

* Required

Name
Your answer

What was your Game ID when playing "Student"? *
Your answer

What was the score?
Your answer

What was your Game ID when playing "Teacher"? *
Your answer

What was the score?
Your answer

NEXT
ELK's Goals

There were three goals for the game. We are curious as to what extent the game met these goals for you.

Goal 1 - To allow players to practice gathering students’ ideas about a topic.*

〇 True
〇 False

Please explain your answer to Goal 1 *
Your answer

Goal 2 - To increase players' empathy with students with misconceptions *

〇 True
〇 False

Please explain your answer to Goal 2 *
Your answer

Goal 3 - To increase players' understanding of the importance of student preconceptions when teaching *

〇 True
〇 False

Please explain your answer to Goal 3 *
Your answer
ELK as a Practice Space

This game is an interesting way to learn about student misconceptions? *

1 2 3 4

Strongly Disagree Strongly Agree

What did you learn from this game as a teacher? As a student? *

Your answer

Teacher role: What tactics did you use throughout the game? *

Your answer

Teacher role: Did you change the way you asked questions during the game? *

☐ Not at all
☐ I made some changes to the type of questions asked
☐ I made significant changes

What would you do differently if you played this game again as teacher? as a student? *

Your answer

What suggestions do you have for improvements?

Your answer