April 2017

Improving User Interface and User Experience of MathSpring Intelligent Tutoring System for Students

Hoang Minh Ngo
Worcester Polytechnic Institute

Huy Quoc Tran
Worcester Polytechnic Institute

Improving User Interface and User Experience of MathSpring Intelligent Tutoring System for Students

An Interactive Qualifying Project Report
Submitted to the faculty of
WORCESTER POLYTECHNIC INSTITUTE

by

_____
Hoang Ngo

_____
Huy Tran

Approved: _____
Professor Ivon Arroyo, Project Advisor

_____
Professor Jeanine Skorinko, Project Co-Advisor

Table of Contents

Abstract

MathSpring is an intelligent tutoring system that assists students in studying mathematics. Given the complex interactions between students and MathSpring system together with suggestions from students, we believe that its user interface and user experience have room for improvements. To learn the students' experience and determine our improvement strategy, we quantitatively analyze the students' suggestions and interview a teacher who uses the system for his class. We then use the results of our analysis and design principles to devise a new design for MathSpring. Lastly, we conduct a user study to evaluate the new design. The results of this study demonstrate that our new design has succeeded at improving the user experience to some extent.

1. Introduction

MathSpring is an intelligent tutoring system that assists students in studying mathematics. Students obtain proficiency in different mathematical topics by practicing on various problems and benefiting from several features such as virtual character tutoring, receiving helpful hints, and question difficulty adjustment. While students are using MathSpring's various features, they need to interact frequently with the system. Nevertheless, the more features and possible user interactions a complex product can have, the more likely the user experience can fall short (Garrett 2011). This current research, therefore, attempts to seek answers to the following questions: "What are user's reactions to the user interface (UI) and user experience (UX)?" and "Are there feasible improvements that can increase ease of use, interest in the materials, and user engagement with the system?" In order to find improvements for MathSpring's UI and UX, understanding MathSpring itself and several concepts of UI and UX is extremely necessary. Thoroughly comprehending those fundamentals can provide new insights into how to improve MathSpring.

2. Background Research

2.1. MathSpring Software

Fundamentally, MathSpring is a web application that can assist middle and high school students studying math and preparing for standardized math tests, such as the SAT, Massachusetts Comprehensive Assessment System (MCAS) or the California Standardized Testing and Reporting (CA-Star). MathSpring is able to pose questions for students to solve, offer hints, and provide custom feedback to students. As students progress through the math problems, the system can estimate their most likely state of mind (cognitive, metacognitive, and motivational) through several metrics such as mastery without effort, hint avoidance, and high effort, interpret reasons for specific behaviors towards the system, and adjust its own teaching behaviors in real time for individuals by MathSpring's namely "effort-based tutoring" approach (Arroyo et al., 2014). The flexible, fast, and personalized responses of MathSpring to students assist math teachers in overcoming the challenges that they face related to supporting the varied skill and motivation levels in their classroom, where some students excel while others lack abilities for their corresponding grade level (e.g., in literacy or numeracy). For example, the application has records of students' progress in each math topic, their numbers of correct and wrong answers, and frequency of using hints. It can then statistically estimate the student's degree of understanding of the concepts and skills that underlie the math exercises. Based on student's mastery, MathSpring provides the student with math problems that have appropriate level of difficulty and generate customized feedback to them. Through MathSpring, teachers will have a better understanding of each student's mastery in different math topics.

2.2. UX/UI Concepts

Since MathSpring is essentially a web application, the interaction with MathSpring occurs through a user interface (UI) on the web and creates a user experience (UX) through the web. In order to identify any potential improvements for the UI/UX of MathSpring, understanding some elements of the UI/UX, especially for the web, is essential. These UX/UI elements act as guidelines so designers and developers can reason around them in order to inspect the website's user interface and find UI/UX improvements. We define all the concepts below in a very brief manner in order for the reader who might never have heard of UX/UI to have a general idea about different aspects of the UX/UI study field. For each concept, there are many further elements UX/UI developers have to tackle that we cannot fully cover in this section. We will later address some of these concepts in more details and in the context of MathSpring's specific improvement plans.

The first UX/UI element to analyze is **user needs**, or the objectives that people want to achieve by going and using the website (Garrett 2011). We need to understand the user's needs and the goals the user has when interacting with MathSpring. With this knowledge in hand, we can recognize crucial content, functionality, and aesthetic requirements to improve and less important set of ones to refine in the future.

The next concept is **functional specification** (Garrett 2011), regarding the decision to improve crucial functionalities and to remove rarely used ones that already exist in the system. Part of improving a computer system is filtering out rarely used functionalities, keeping the system lean,

neat, and uncluttered. Hence, identifying critical functionalities leads to spending enough time and effort to improve their user experience and clean up the system.

Another important concept is **content requirement**. Content requirement is a description of the various materials such as text, image, audio, or video that will be required (Garrett 2011). Designers and Front-end developers discuss with the client (or content stakeholder) whether some particular pieces of content are useful and valuable to users, how users will find these contents, and how we will display them. Understanding the content requirements of a system leads to properly evaluating the impact of the presentations of its content to users.

To analyze the importance of next concepts, we assume the website has all the important features for users and work perfectly well. The only difference between it and other websites is the user interface. If this website lacks a well-designed user interface, the user will be less likely to discover the website and come back to use it again (Garrett 2011). This is because a well-designed user interface will encourage the users to discover and go beyond the first page and use the system. The look of the website will decide whether it succeeds or fails to make its first impression to the users. Therefore, we explain next four important but very closely related concepts regarding of the visual look of the website, which are interaction design, interface design, visual design and navigation design.

Interaction design focuses on the behaviors of the system in response to the users' inputs (Garret 2011). For example, interaction design defines where the system navigates the users after they tap a button or submit a text field or how the system supports the users and handles the

errors when users incorrectly use some of its functionalities.

Interface design is the arrangement of the interface elements, which enable the user to interact with the system (Garrett 2011). The examples of interface elements are buttons, text-fields, lists, tables, etc. A well-designed UI appropriately puts all these elements in place to ensure that they are accessible, understandable, and fulfilling general user needs and our own business objectives. A poorly designed UI fails to satisfy those goals.

Visual design regards the website's appearance of the website (Garrett 2011). The visual elements, such as color-scheme, appearance of the logo and brand labels, need to be audience targeted and visually compelling. There are many visual elements such as color, form design, logo, animations, some of which we will discuss later.

The last aspect of UI/UX is **navigation design**. It is the roadmap to all parts of the website. Navigation system must not only connect all the elements in the roadmap but also clearly communicate the relationship between the current page and the roadmap elements (Garrett 2011). The navigation system of every website needs to be straightforward with meaningful labels for the users to know its structure in order to locate desired information. This is a very important aspect of designing a website, especially for a tutoring system for middle and high school students like MathSpring where students need to quickly navigate to the system in order to avoid wasting time and confusion.

3. Research Plan

Having many features, a system could hardly deliver perfectly pleasant user experience to users (Garrett 2011). The current research, therefore, analyzed different interactions between users and the MathSpring system based on the UI/UX aspects mentioned previously. During this process, the researchers devised plans to improve the user experience created from those interactions. Particularly, the analysis started with the responses of students and teachers who have used MathSpring in their class. Any feedback that suggested improvements or identify shortcomings of the MathSpring's UI/UX were collected. Ultimately, this analysis will provide answers to our first research question: What are user's reactions to the user interface (UI) and user experience (UX)?

Once collecting feedback was complete, we spent a major part of our research on devising improvements for these problems. Because we did not have time to implement all improvements, we only attempt to make feasible improvements for students as the target users. We then verified the effectiveness of the improvements by conducting a user study with a number of participants. The results of the research study answered our second research question, are there feasible improvements that can increase ease of use, interest in the materials, and user engagement with the system?

4. Study 1

This study intended to discover features that worked well and features that worked less well on MathSpring by analyzing feedback from students and teachers who had used the system previously. In Study 1a, we analyzed students' feedback to MathSpring. In Study 1b, we interviewed a teacher who had used MathSpring with middle school students. By learning the insights of both students and teachers, we expected to find diverse perspectives on the system to collect as many insights into system as possible, eventually helping us to develop ideas to improve the system.

4.1. Study 1a: Analyzing Student Responses

Since end-user feedback was essential in user-centered design (Norman & Draper 1986), in this study, we analyzed feedback of students who used MathSpring. We obtained this feedback from the responses of students to questions on a survey given to them after using MathSpring. Among several questions that were available as part of the survey, we analyzed answers to the following ones: "What did you like about the software?" and "What suggestion do you have for improving the program?" This was an attempt to find out what people believed that they needed, as answers to those questions were of most relevance to our study and possibly gave us the common perspective of student users.

4.1.1. Methodology

Participants

We analyzed the responses of 202 middle school students who used the MathSpring software in

their math classes. In particular, there was data available from 44 sixth grade students from California, 91 seventh grade students in New England, 54 eighth grade students in California, and 13 seventh to eighth grade students participating in New England. No information about gender, math skills, and knowledge was included in the dataset.

Procedure

In this study, responses from students who had used MathSpring system for their classes were analyzed. Specifically, this study extracted data from answers to two questions: “What did you like about the software?” and “What suggestion do you have for improving the program?”

Our first step was to perform data reduction, which is a process of transforming raw data from the surveys into ordered and simplified form (Miles & Huberman, 1994). We only considered the feedback that mentioned any UI/UX aspects of MathSpring including its functionality, appearance, or performance. We excluded feedback such as suggestions to improve quantity, quality, and content of math questions, or requests for pure content-based features such as music or games. We also discarded feedback that did not answer the two questions above or was incomprehensible. Then, we paraphrased the students’ responses to keep them concise and pertinent to the UI and UX of the system. More specifically, we corrected the grammatical error or wording error without changing the main idea of the feedback.

Once we had the data reduced, we continued onto a thematic analysis, grouping the data into our themes (Miles & Huberman 1994). The themes we chose involved different aspects of UI and UX, including user needs, functional specification, content requirements, interaction design,

interface design, navigation system, visual design, and performance (Garrett 2011). We defined those themes after doing data reduction because reading through the responses made us realized that they corresponded to particular UI/UX aspects. The intention of the thematic analysis was to perform data reduction systematically and more thoroughly by compressing UI/UX feedback on each of the categories. After defining the themes, we went through each paraphrased feedback and classify it into a category. Once we finished categorizing the feedback, again, we merged identical or similar responses together, on each of the predefined categories. Eventually, we counted the number of responses and calculated percentage for each theme.

4.1.2. Results

Visual Design

Fourteen (14%) percent of students suggested the website should have more appealing visual design. Particularly, they wanted the website to have a more friendly color scheme. In addition, they also thought that we should update the assets such as icons, logos and background images needed updating to make the website look better. We decided to improve the visual design of the website because of the number of suggestions and the feasibility of the solution.

Functionality

Nine (9%) percent of students thought that MathSpring should have calculator. Adding a calculator was a feasible task as there were many calculator plugins available in web platform that we could use. However, we needed to discuss further with the people in MathSpring team whether it was necessary to include a calculator in the system.

Around 11% of students wanted MathSpring to not ask them about their experience and feelings. Students might find this annoying or distract them from practicing problems because the survey popped up at short interval. Other students suggested we improve the quality of auditory instructions, or have an option to hide the virtual character. Since the MathSpring team was already working on those suggestions, we did not address these issues.

Small fraction of students wanted a reward system or to be able to add profile pictures (around 2%) and choose different kinds of trees (around 2%). MathSpring actually had a reward system, which was the growth of the plants and the big tree. However, not all students understood that the growing plant was a reward system. Therefore, we attempted to make the existing reward system more visible to the students. While adding profile pictures and different kinds of tree is feasible, it was not the most important feature so we decided to not address those suggestions unless we had time after addressing the more important redesign aspects.

Lastly, around 4% of students suggested the system allow users to choose math level. Not allowing the users to choose the math level was an intended behavior because MathSpring automatically adjusted the problem difficulty based on students' performance and effort (Arroyo et al., 2014). Therefore, we had no plan to implement this.

Content

Around 16.2% of students asked for more hints and help for math problems. Since there were other members in the MathSpring team working on improving the quality of hints and help in the system, we would not tackle this problem. However, we would attempt to redesign the user

interface of MathSpring so that students could easily and conveniently see hints and access the help in the system.

Performance

Nine (9%) percent of students asked for a faster loading time and smoother interaction. Improve the loading time and the overall performance of the systems required a lot of work, such as rewriting and reconfiguring MathSpring server's implementation, optimizing database, testing and fixing performance bugs and so on. Therefore, we neither had time or resources to do such a difficult task like this. However, we still took website performance into consideration by writing clean and bug-free frontend code, optimizing the images and other assets to minimize the loading time. The new design should not perform slower than the original.

4.2. Study 1b: Interview with a teacher who uses MathSpring system

4.2.1. Methodology

To collect additional user perspectives on MathSpring, we conducted an interview with a teacher who regularly uses MathSpring for their mathematics class (Appendix A). Since our research is investigating the quality of the UI and UX of MathSpring, our interview questions were very UI or UX-oriented. We asked the teacher about the students' ability to navigate from mathspring.org to the MathSpring system, the appearance of the website, the need for assisting tools such as calculator or scrap paper, any desire from the teacher or students for a reward system, the reaction to the current method of collecting user experience data, opinions of the website's performance, and, lastly, whether future versions should provide different language options.

4.2.2. Results

We summarized the interview by presenting the teacher's thoughts, which belonged to different categories below.

Transition from the landing page to the MathSpring system. The students had to do multiple steps in order to navigate to the "Main tutoring system" page where they could start practicing. They had to:

(i) Click "To Use MathSpring" button (see Figure 1);

Figure 1: MathSpring's former landing page

(ii) Check popups, flash, sound (see Figure 2);

(iii) Click another MathSpring button to navigate to the login page (Figure 2);

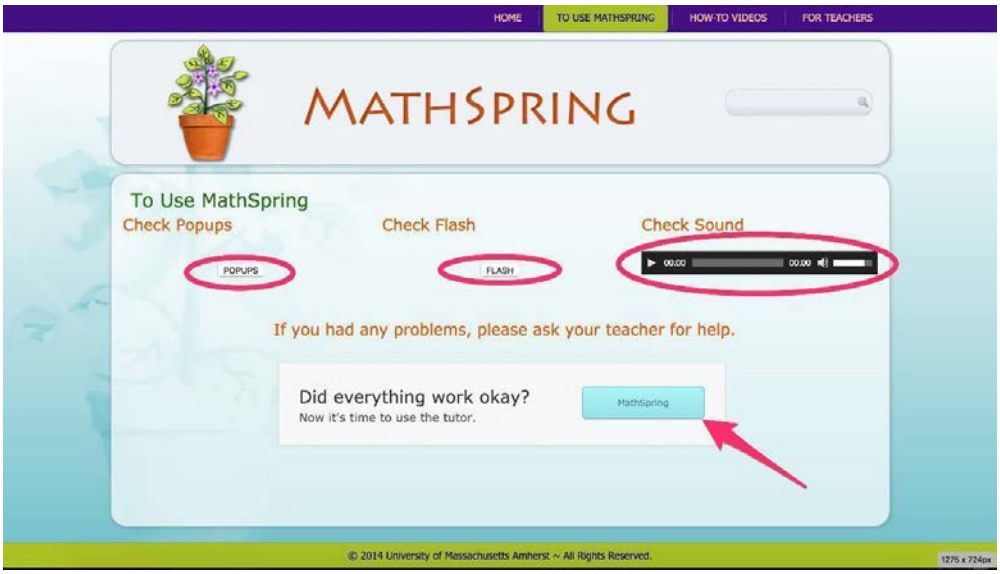


Figure 2: MathSpring's former "To Use MathSpring" page

(iv) Fill in text field for username and password to login (see Figure 3);

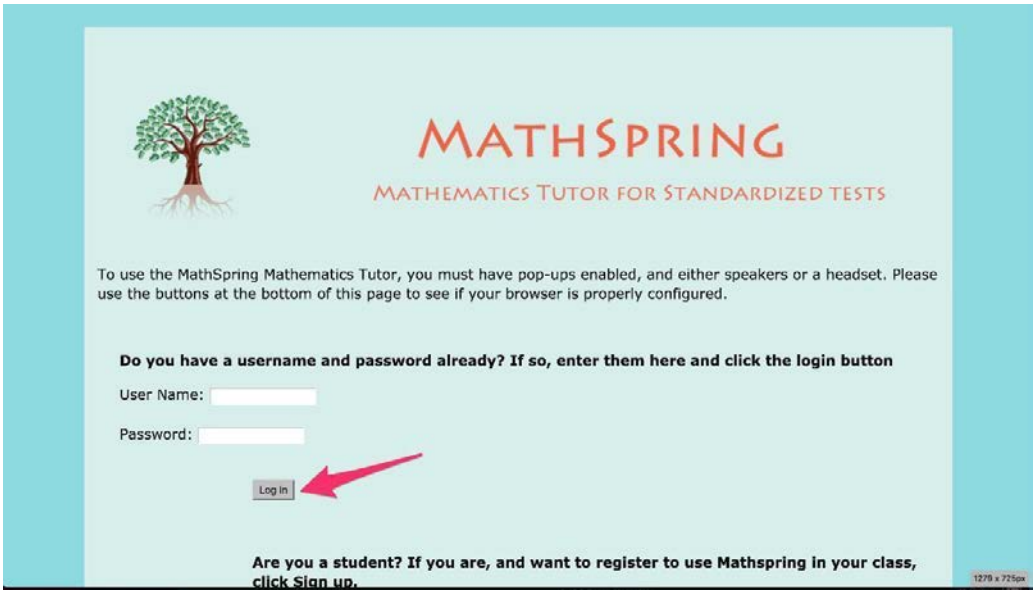


Figure 3: MathSpring's former login page

(v) When the students successfully login, they need to press another “Start Working” button (Figure 4).

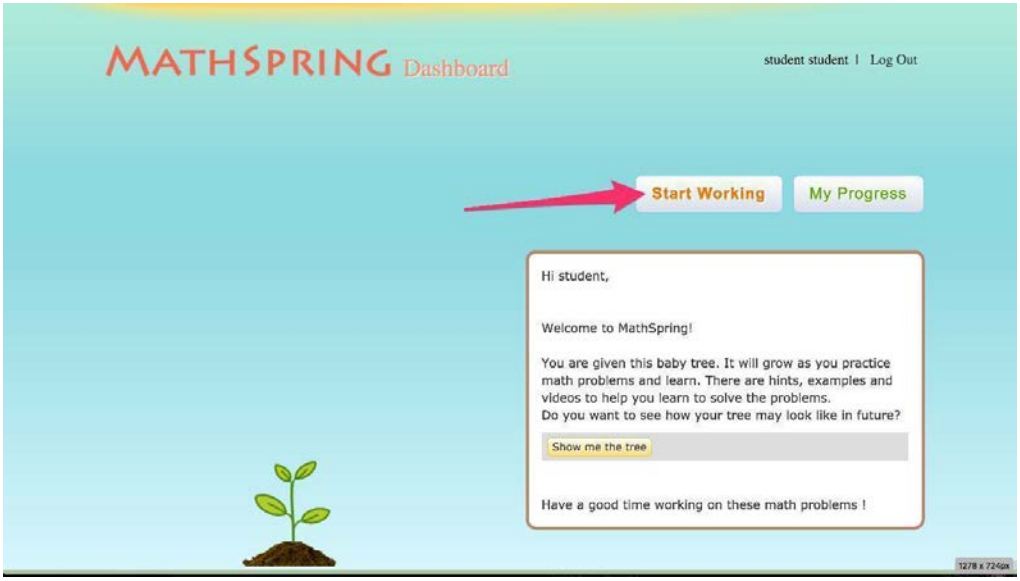


Figure 4: MathSpring’s former welcome page

Naturally, students like to play with the system. Because there are many buttons on the MathSpring landing page that navigate to different pages, the teacher reported that students would, at times, click these buttons rather than go to the practice page. Therefore, redesigning the landing page to offer a more streamlined experience will be an important improvement from the teacher’s perspective. The teacher suggested we design a click-through landing page which describes the website product briefly, well-targeted, and has one or two big centered buttons to get the students started.

Interface of the MathSpring website. The MathSpring main page has many buttons helping students to navigate to learning resources (see Figure 5), such as hints about the current problem

and auditory instruction. The teacher reported that students do not use these resources much because the students seem to believe that using hints is considered cheating. Therefore, it would be important to find a way to make asking for hints seem more natural and less like cheating within MathSpring.

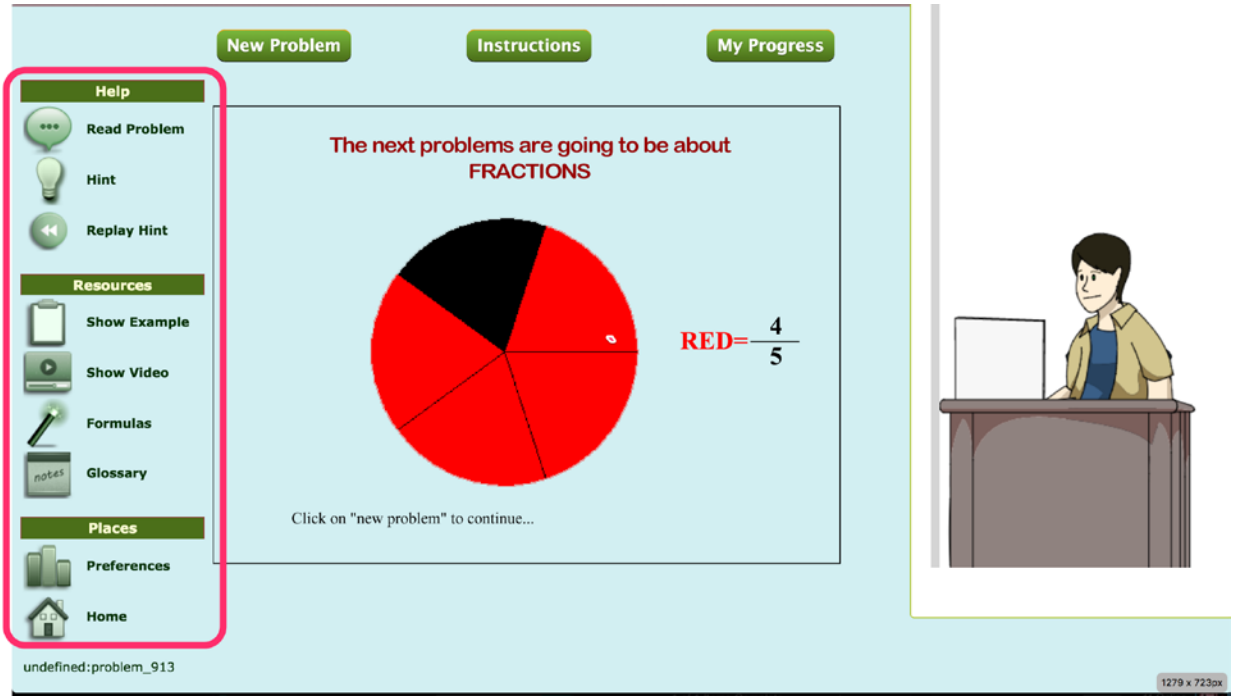


Figure 5: former UI of MathSpring tutoring system

Assisting tools. Some students suggested the MathSpring website should have a calculator, a tool for them to solve problems with big numbers. However, according to the teacher, the students mostly used paper to solve more challenging problems. Sometimes, they would use a calculator software on the computer, their phone, or tablet. Therefore, according to the teacher a calculator tool is optional.

My Progress page. The “My Progress” page on the MathSpring website displays all the math topics available to the class and allows the students to keep track of their progress and to select the topics that they want to work on. However, because this page has many buttons that can direct the students to other pages, the teacher reported that the students tend to spend their time discovering the MathSpring system instead of doing math problems. Therefore, we concluded that there is too much student agency on the “My Progress” page. We need to prevent students from accessing all topics that are available. One suggestion from the teacher was that the system will notify the students to go back to previous topic and continue practicing before they choose a new topic.

4.3 Conclusion

Based on the analysis of students’ feedback on Study 1a and the teacher’s suggestion on Study 1b, we evaluated the feasibility and importance of aspects discussed above and came up with a plan for the next studies. Particularly, we decided to improve the visual design, interface design, emphasize reward system, make hints and help instruction more visible, shorten the transition from the landing page to MathSpring system. Our implementation process of this plan is presented in the next study.

5. Study 2

Study 1a and 1b enabled us to determine different features that can be revised on MathSpring's user interface. Using the results from Study 1a and 1b, we designed a new user interface. We started by examining MathSpring's current user interface based on basic elements of user experience and results of the previous study. We gathered information and indicators that suggested possible UI/UX improvements by looking for contradictories between the current user interface and generally accepted design principles from *Universal principles of design* (Lidwell, Holden, & Butler, 2003). Then we started working on the design by defining the color scheme, typography, and logo and then creating the layouts for the webpages in the MathSpring system. We presented this process and the results such as color scheme or typography in the methodology section and the complete design of web pages in the followed results section.

5.1. Methodology

Color Palette

The core brand logo and colors of all visual components on a website usually belong to a broader color palette. Colors in this collection must be carefully selected to work in harmony (Garrett 2011). Since the core brand logo and many visual components would use the colors from the color palette, we selected the colors that represented MathSpring's ideology: growth and spring. Among the colors used in the current MathSpring system, we reused the plain yellow and android green (#81BE3B) that already represented elements of growth and spring. In addition, we picked light mahogany (#CD4747), slightly dark brown (#AD7C6A), light green (#2ECC71), and white because those colors went well with yellow and green. In our color palette, we decided

that green and yellow would be the mainly used colors.

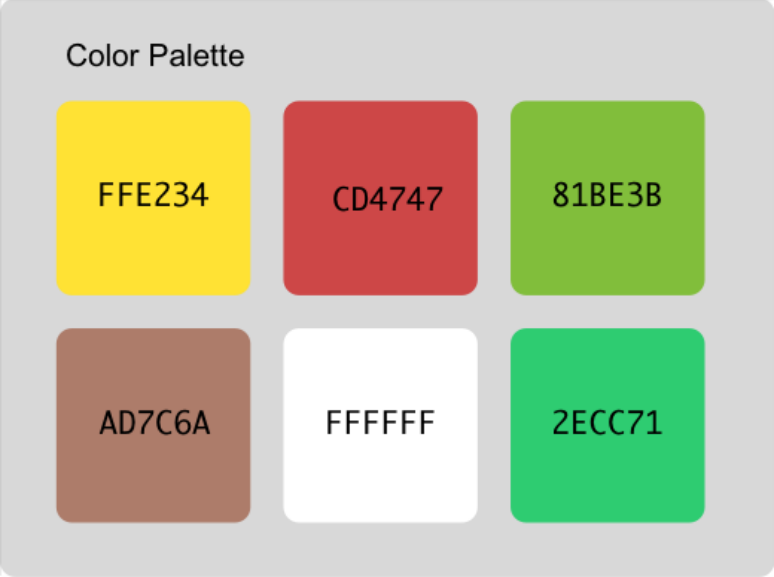


Figure 6: MathSpring Color Palette

Typography

Typography creates a particular visual style, which in turn builds brand identity (Garrett 2011). Many organizations have their typography designed specifically for them to create this impact (Garrett 2011). Since we did not have the time and resources to create a unique typography, we chose a different font, Raleway, rather than the commonly used ones such as Times, Helvetica, or Arial to distinguish MathSpring from many other websites. Although using a different font would distinguish MathSpring from other websites, using too many different fonts would overwhelm users with visual clutter (Garrett 2011). Hence, we used one font consistently throughout the system. For the web browsers that did not support this font, we used safe fonts

such as san-serif, Helvetica, or Arial to ensure typography consistency.

Figure 6: Raleway Font

Logo

Once we had our color palette and typography, we designed a new logo representing MathSpring. We wanted a simple minimalistic logo that showed users the growth, spring, and the system's name, MathSpring. This logo would appear on every webpage of the MathSpring system. Using the yellow background to represent sunlight and warmth, we put a red bird flying upward to symbolize the growth and youth. The green leaf underneath the bird illustrated the spring's regrowth. Next to the logo is the name of the system, MathSpring.

Figure 7: MathSpring logos

User Needs and Functional Specifications

At the same time, we learned the user needs and functional specifications of MathSpring. We learned about the intelligent tutoring system in MathSpring (Arroyo et al., 2014), investigated the system's implementation, and talked with people on the MathSpring team. For the landing page, we understood that it provided information that convinced visitors to use MathSpring and an entry point for them to go into the tutoring system. On the other hand, for the tutoring system, we learned that the user needs were to evaluate and to enhance students' proficiency in mathematics. Therefore, all our improvement plans must result in a design that met the user needs. Furthermore, the functional specifications assisted us in making decisions and plans for improvement. For example, the functional specifications stated that the system must allow users to sign in as guest, student, or teacher. Since authentication process was similar among different kinds of users, we thought that grouping these functionalities into one page would simplify our design and create convenience for users. The detailed functional specifications of MathSpring are summarized in Table 3. We discuss our design decisions based on these specifications along

with some web design principles in the next subsections.

Forms Improvement and Alignment

Login and registration process were important because MathSpring users could only use the system once they were authenticated. Based on the functional specifications (Table 3), we knew that user could register as teacher or student and sign in as teacher, student, or guest. Therefore, we need to design these forms so that they are easy to be filled, leading to faster and more comfortable registration process. Alignment is one design principles that could help solve this issue because it provides visual cues to how items are grouped and can reduce layout complexity (Lidwell, Holden, & Butler, 2003). As seen in Figure 8, we placed all elements such as texts, text fields, buttons so that their edges lined up. The layout of the form in the middle of Figure 8 were clearer and simpler than that of the form on the left as we could see the relationship between the labels and the corresponding text fields. More interestingly, by using edge alignment, we could organize personal information such as first name, last name, age, and gender into one group and account information such as email, username, and password into another group as shown in the form on the right of Figure 8. Filling forms that had intentionally arranged and intuitively organized fields would take shorter time than filling out an unorganized form. Furthermore, we also applied alignment on components such as buttons, images on other pages of MathSpring.

Figure 8: Lining up elements

Interface Components

Components such as logo, buttons, navigation bar, or footer should have an identical design across different pages to improve system usability (Lidwell, Holden, & Butler, 2003). We can merge some less frequently used buttons on the tutoring page such as “Preferences”, “Show Formulas”, or “Glossary”, into a menu because according to Hick’s Law (Lidwell, Holden, & Butler, 2003), the more buttons on a page, then the longer users would need to make a decision about which button to click. Also on the tutoring page, we wanted to emphasize the new problem, hint, replay hint, instruction, and read problem buttons over the other buttons because those were core functionalities of the system. These buttons and their corresponding functionalities reminded us of the 80/20 law, which stated that users use a small number of core interface components to do most of their work (Lidwell, Holden, & Butler, 2003). Thus, the interface containing the core functionalities had to be clear, fast, and easily accessed. In other words, we would improve the interface of the tutoring page by redesigning buttons and layout so that users could access the above mentioned functionalities easily.

Conceptual Model

We organized our ideas by developing a conceptual model, a high-level description of a system’s

organization and operations. A major advantage of explicitly designing a conceptual model is to ensure a better chance of having users use the tutoring system the way we intended (Johnson & Henderson, 2002). One possible conceptual model of the current MathSpring system was that it consisted of two layers: personal data layer and problem practicing layer (Figure 9). The personal data layer consisted of pages that contained students' information and their learning progress. The problem practicing layer consisted of the page that allowed students to practice math problems. This conceptual model was simple and task-focused as the model's two layers nicely mapped into the user needs, evaluating mathematical proficiency and practicing problems in mathematics.

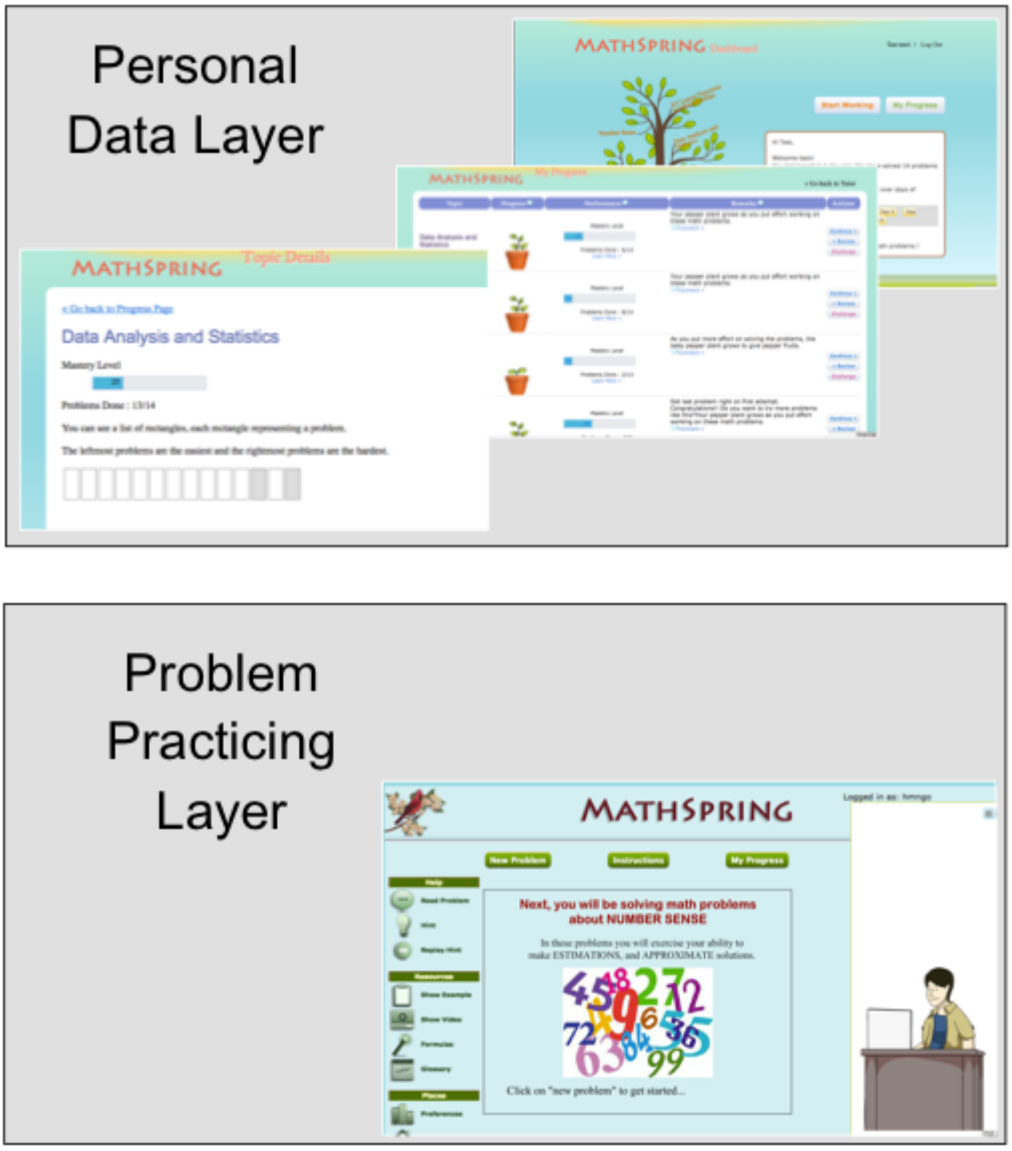


Figure 9: Conceptual Model of MathSpring

With this conceptual model, we attempted to draw a clear boundary between the two layers by putting all buttons that linked to personal data layer's webpages, such as the dashboard or topic details, next to each other in wireframes. We reasoned that by applying the alignment design pattern, arranging visual components close and lined up to each other (Lidwell, Holden, &

Butler, 2003), users would be likely to see the webpages in the personal data layer as a group (Johnson & Henderson, 2002). The process of drawing wireframes was purely iterative until we reached a design that achieved consensus among us and project leader of the MathSpring team.

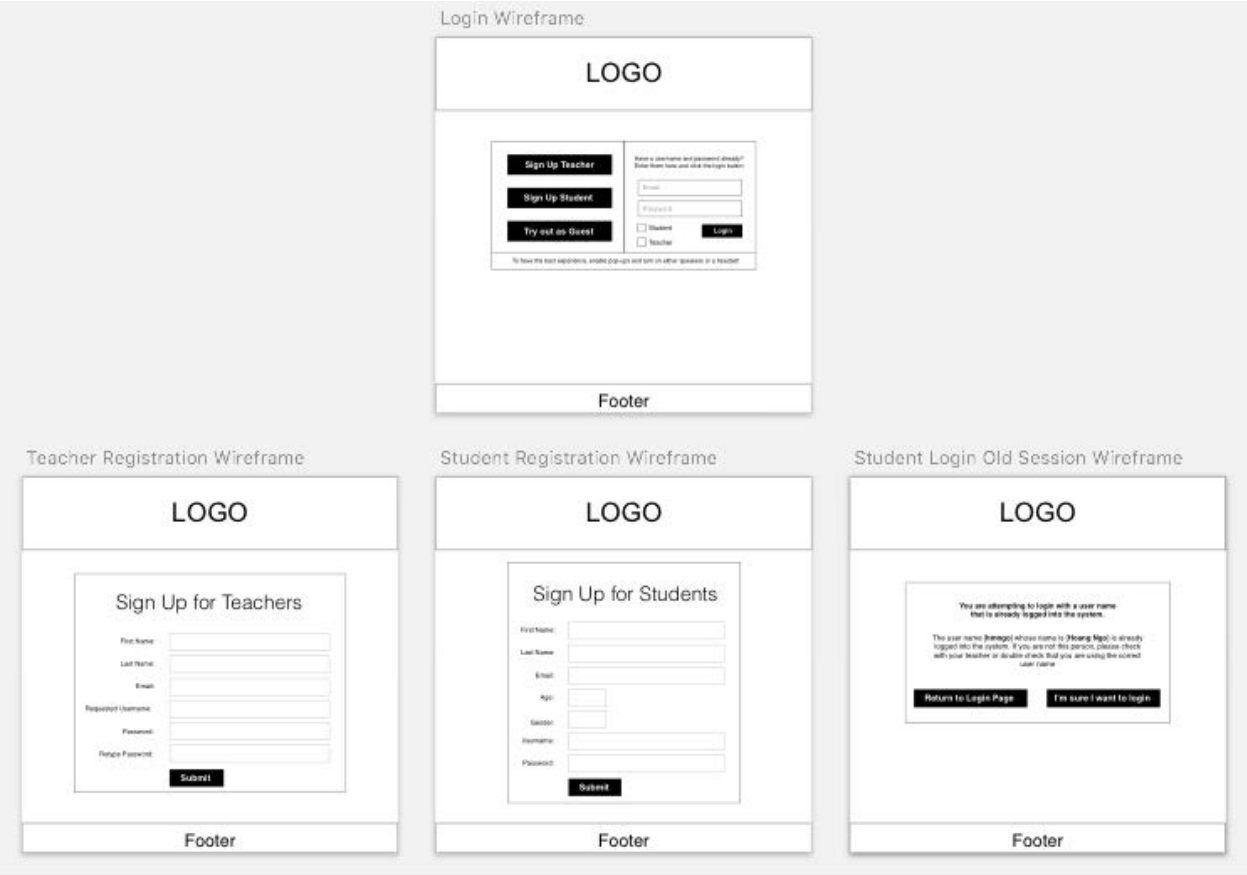


Figure 10: Wireframe of Registration and Login Processes

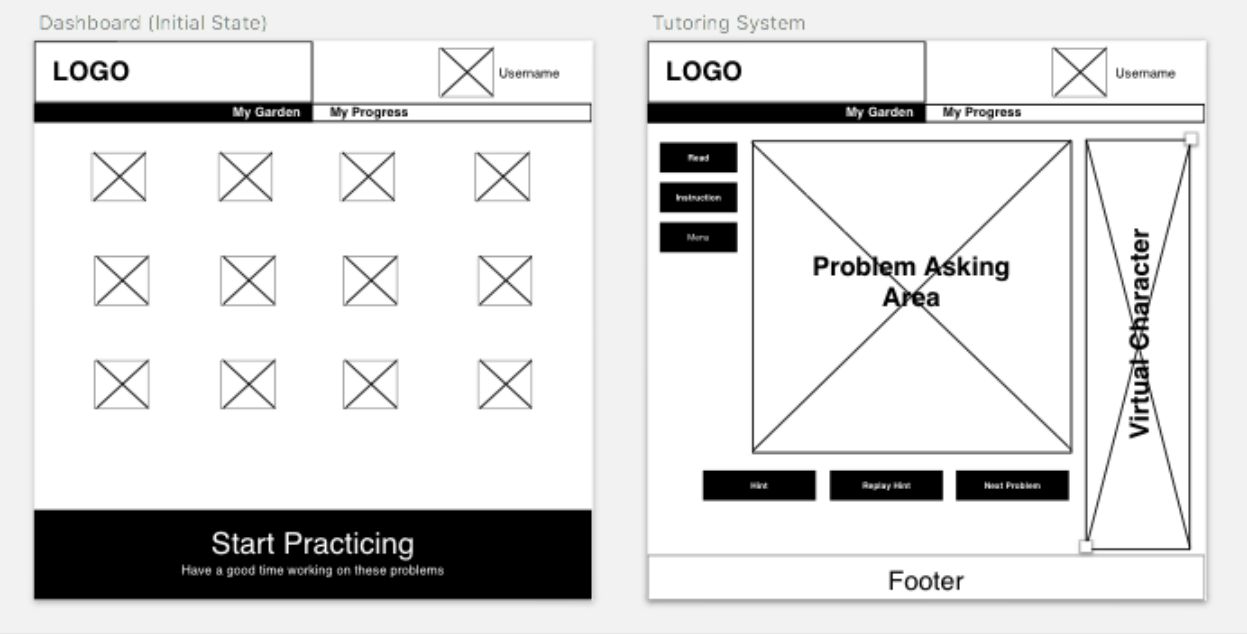


Figure 11: Wireframe Dashboard and Tutoring System

5.2. Results

Landing Page

We chose the landing page, mathspring.org, as the starting point for the redesign. This page was the entry point for users where they could access the tutoring system. Since there were many different ways in which users could access the login or sign up forms in the old user interface, to abridge the steps of access the system from the landing page, we created a single entry point that allowed every target user to go further and authenticate into the system. As in Figure 12, that entry point was the big, colorful “GET STARTED” button on the main section of the landing page. This button led target users to a webpage which contained all login and signup forms.

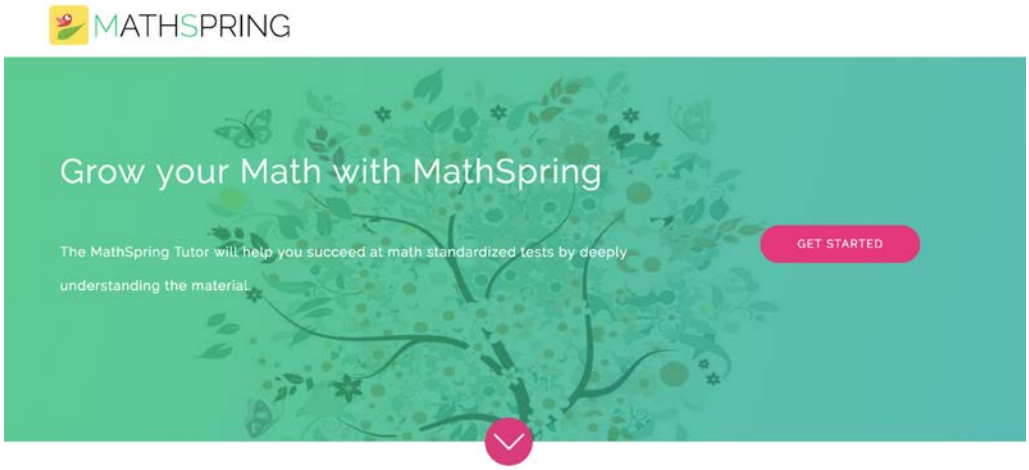


Figure 12: Top of the new MathSpring landing page.

Next, we worked on producing the information on the landing page that convinced students and teachers to use MathSpring. Since designers should focus on the purpose and size of contents before its format (Garrett 2011), we worked with the creators of MathSpring to select and revise the form (text, images, videos, numbers…) and size of the information. Our objective was to condense the introduction and description text about MathSpring while still keeping the most important information. On the main section of the landing page, we placed a slogan for the website. Although the slogan "Grow your Math with MathSpring" contained only five words, it provided the name of the product, the main functionality (to practice math), and the meaningful theme, spring (a symbolism of growth). Below the slogan, we provided a sentence that described how users would benefit from using the product and included statistics and quotes regarding MathSpring's materials, effectiveness, and popularity (Figures 13 and 14).

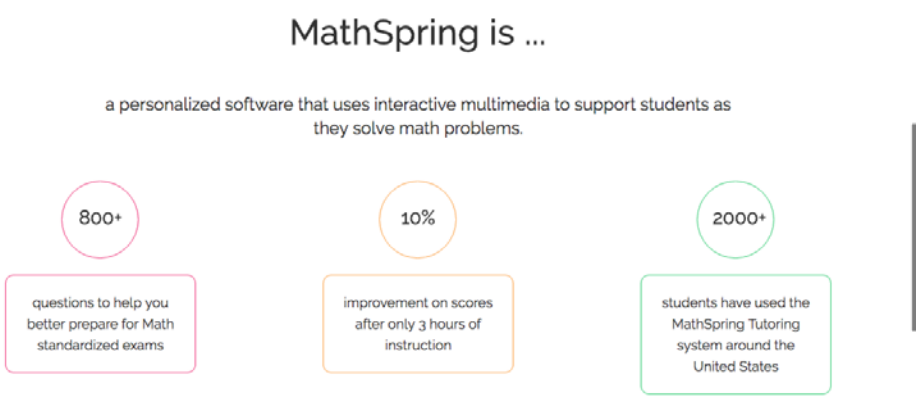


Figure 13: Middle of the new MathSpring landing page.

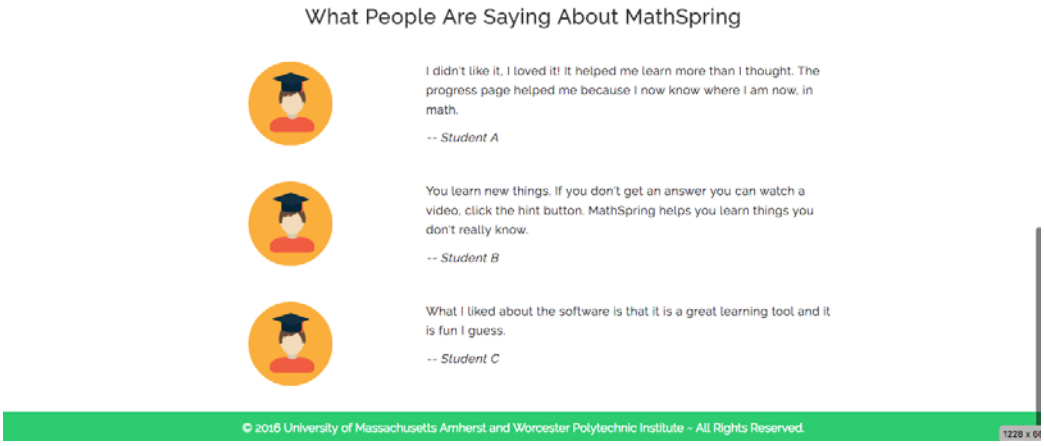


Figure 14: Bottom of the new MathSpring landing page.

Login and Registration Pages

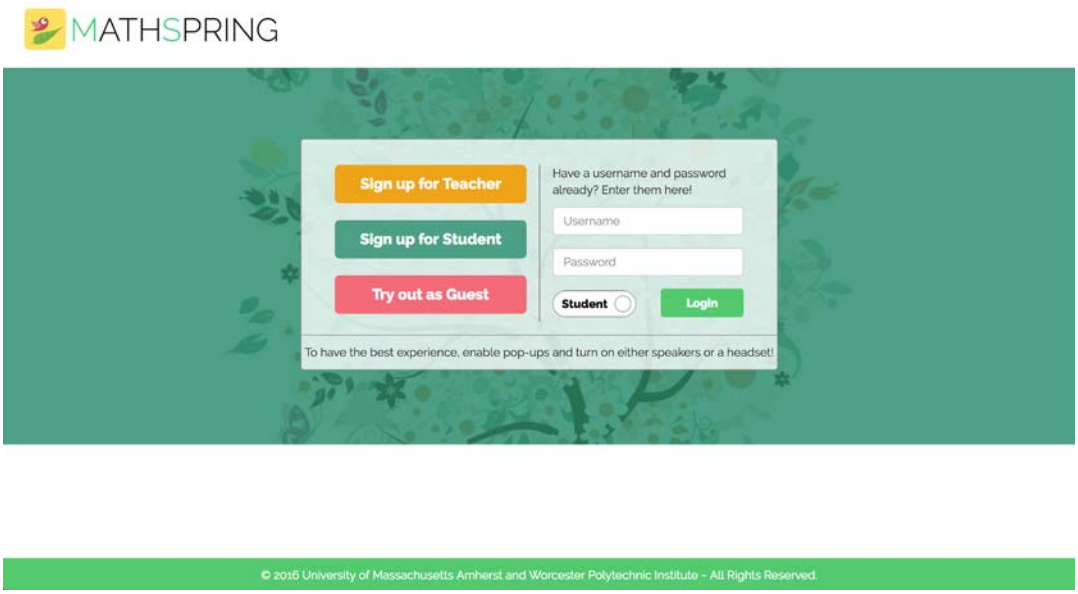


Figure 15: New MathSpring page for login and registration.

To design this page, we took into account two factors: reusability and simplicity. We intended to reuse basic components such as the header, page background, or footer on other web pages as to make the user experience across different pages consistent and seamless. In addition, we wanted to create a simple design so that the users could intuitively understand the functionalities. In order to do that, the appearance of the visual components that initiated different functionalities must be straightforward. All the visual components on this page that users could interact with had concise text explaining the purpose written on them. For example, the sign up button for teachers contained the text “Sign up for Teacher” while the one for students had “Sign up for Student”. In the end, by putting together the login forms and registration links for students and teachers, we avoided having separate pages for each of the functionalities. In the former MathSpring website, there were two links leading to two identical login form for teachers and for students.

For the pages that the login page could lead users to, such as the registration pages for students and teachers and the existing session warning page, we reused the header, background, and footer while adding different contents on top of them. By using the same visual components, we tried to create a fluid transition between the login page and the other pages. Because the structures of the newly designed pages were identical, the browsers usually cached the assets and reused them among the pages. Loading the subsequent pages would be faster than loading individual pages from scratch. As the result, users would feel that only a small set of visual components instead of the entire page was reloaded while navigating through different pages.

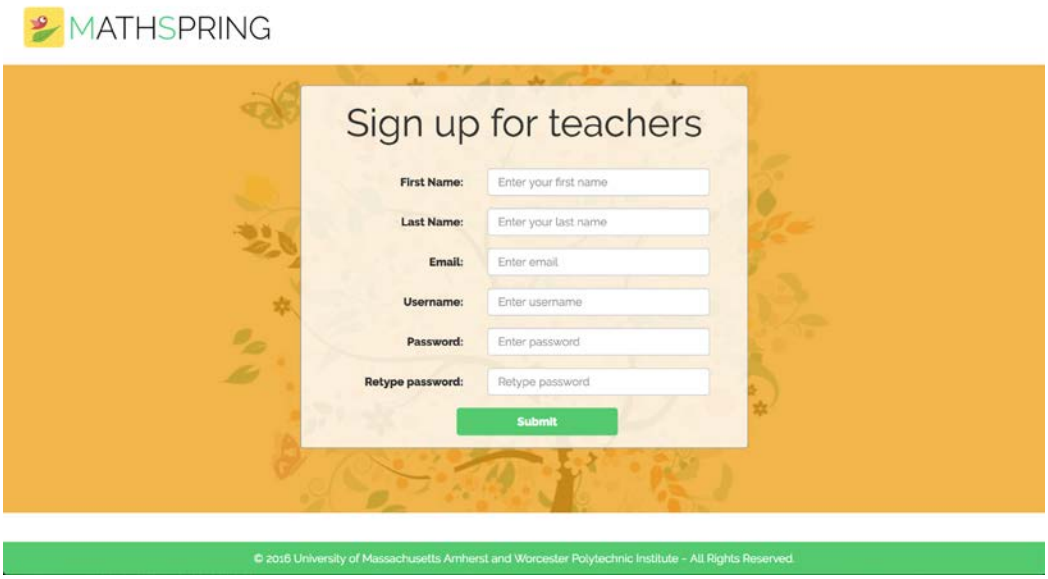


Figure 16: New registration page for teacher.

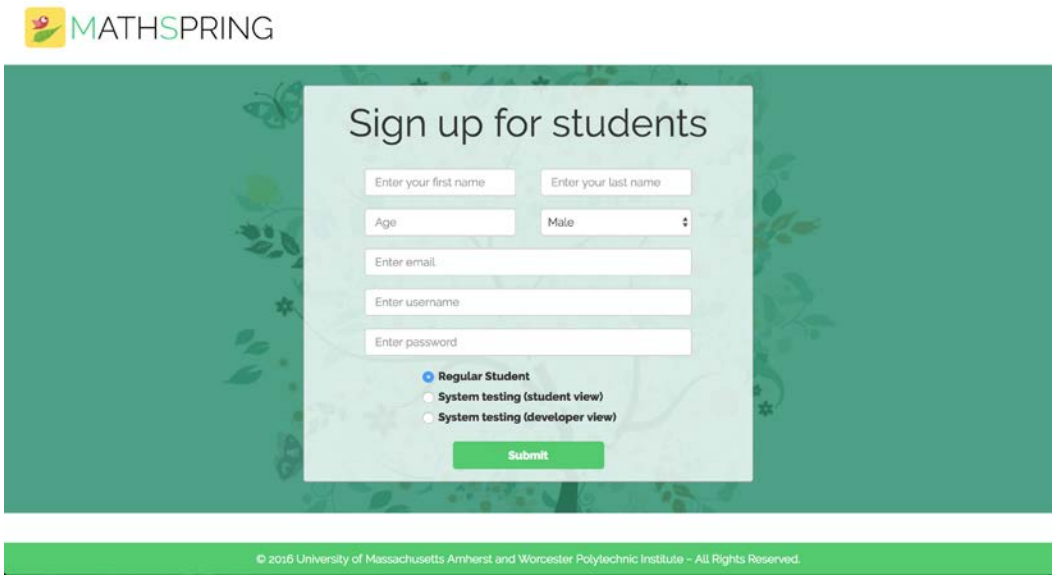


Figure 17: New registration page for students.

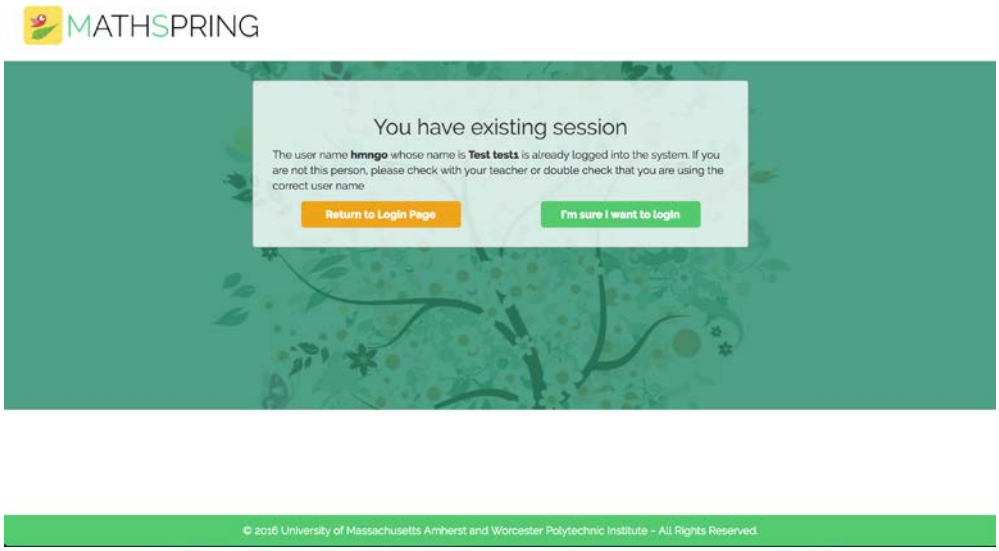


Figure 18: New page to warn users about existing sessions.

The Dashboard Page

In this page, we have two tabs, “My Garden” and “My Progress”, which students could go back

and forth to track their current learning progress. We used green color to indicate the active tab and yellow color for the inactive one. In “My Garden” tab, every student had a garden of plants, which represented all of the topics that the student tried. The growth of each plant represented the effort the students put into the practice problems of the corresponding mathematical topic. When users hover over a plant, a bubble pops up and provides the topic name corresponding to that plant. As students click into a plant, a dialog box appears and displays the topic name, mastery level, number of problems done, and the buttons that let them continue practicing. By letting students see the dialog box after clicking into a plant, we made the purpose of the plant as a reward clearer as the dialog box associates different size plants to different learning progresses (Figure 20). In addition, “My Garden” page also has a big button that allows students to quickly resume their progress and continue working on problems. “My Garden” page gives students quick access to topics in progress while still managing to provide basic information about that topic.

On the other hand, the “My Progress” page includes all of the topics that students can access on the system. “My Progress” page shows the detailed information about all the topics, such as topic names, comments, mastery level, and numbers of problems done. In addition, from this page, students can use the “Learn more” button to learn more about the status of a specific problem in that topic, whether they answered that problem correctly, gave up, used hints or some other states (Figure 22). By using “My Progress” page, students could compare the progress of different topics and decide which topic to practice next.

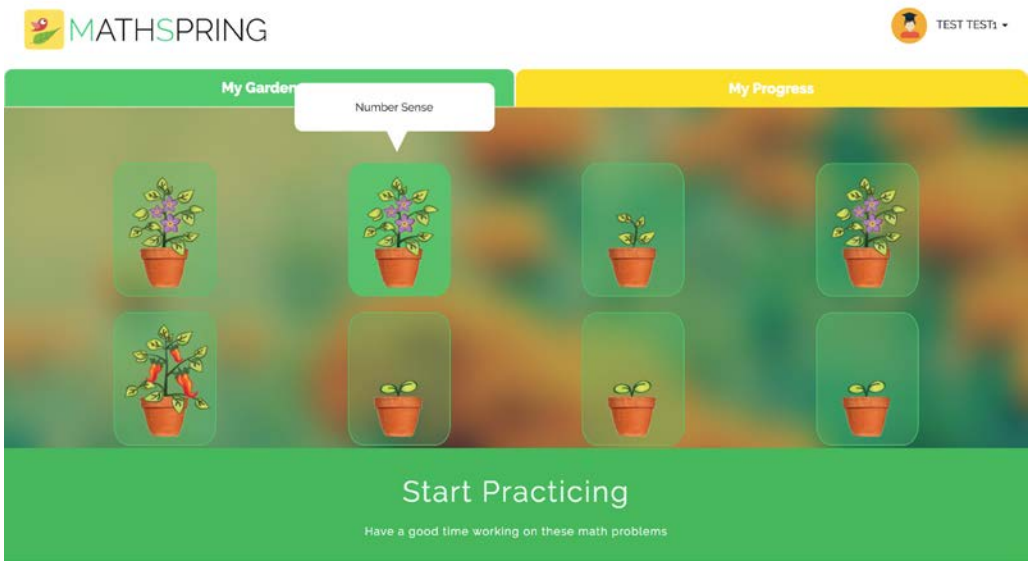


Figure 19: New Welcome Page/Dashboard.

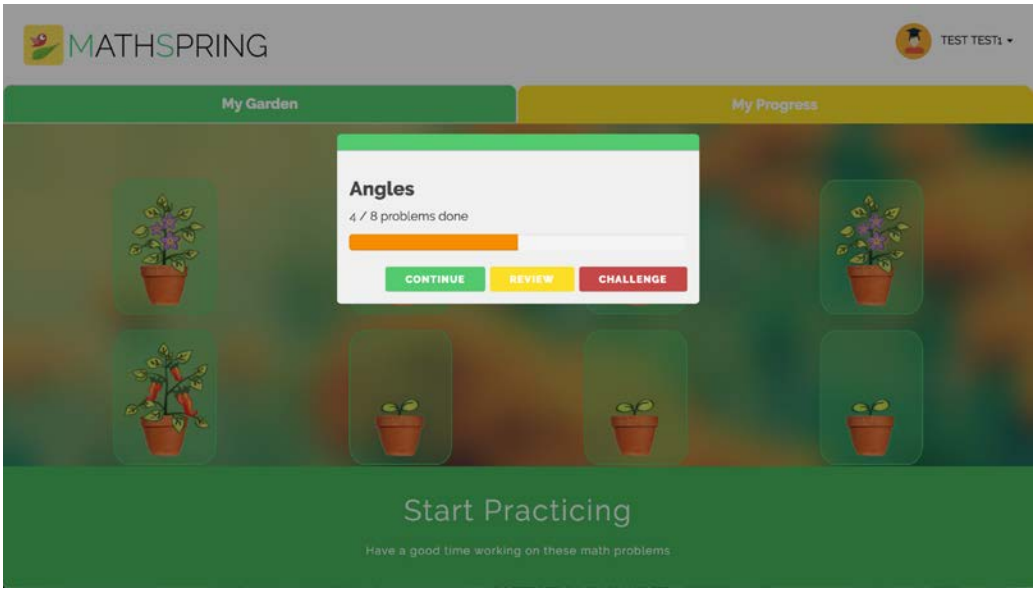


Figure 20: Dialog box for each topic

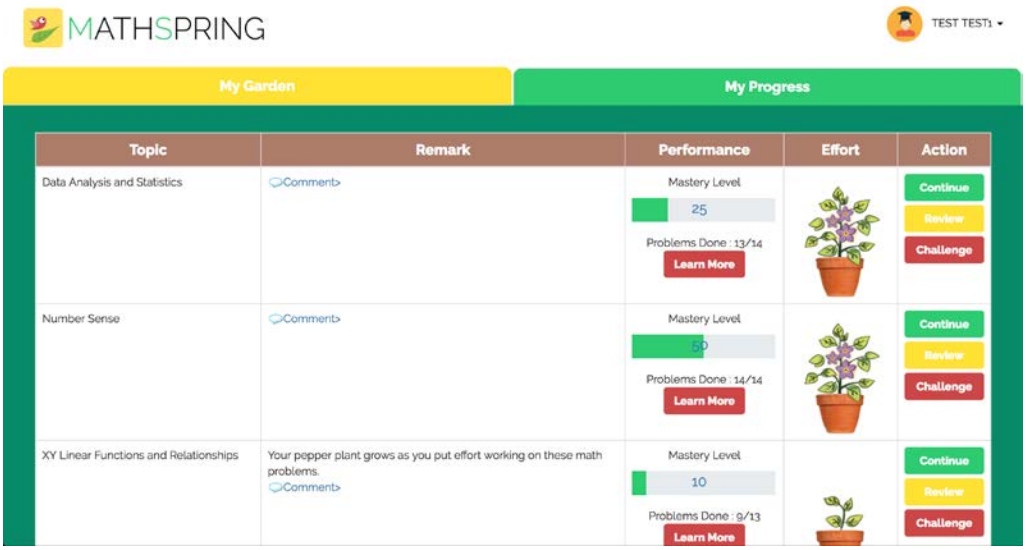


Figure 21. My Progress page

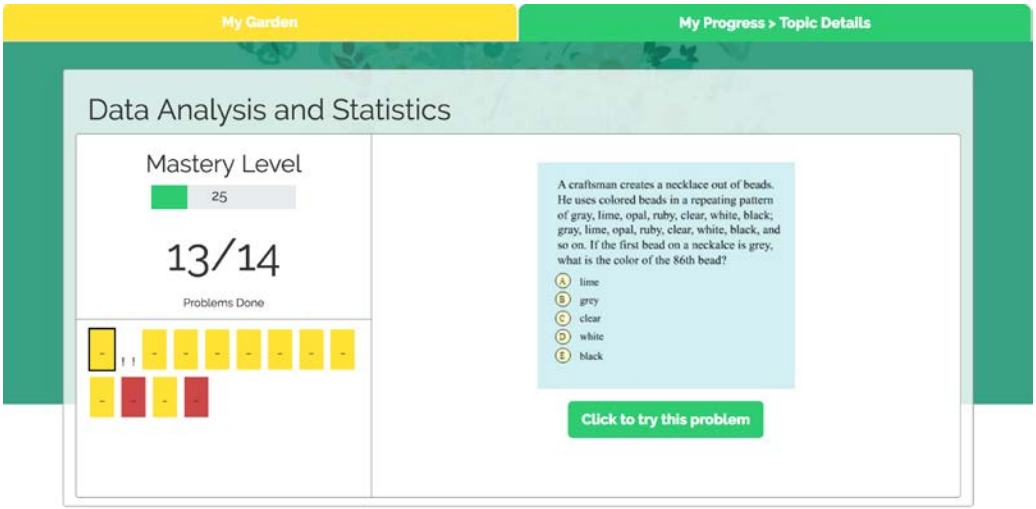


Figure 22. Topic Details page

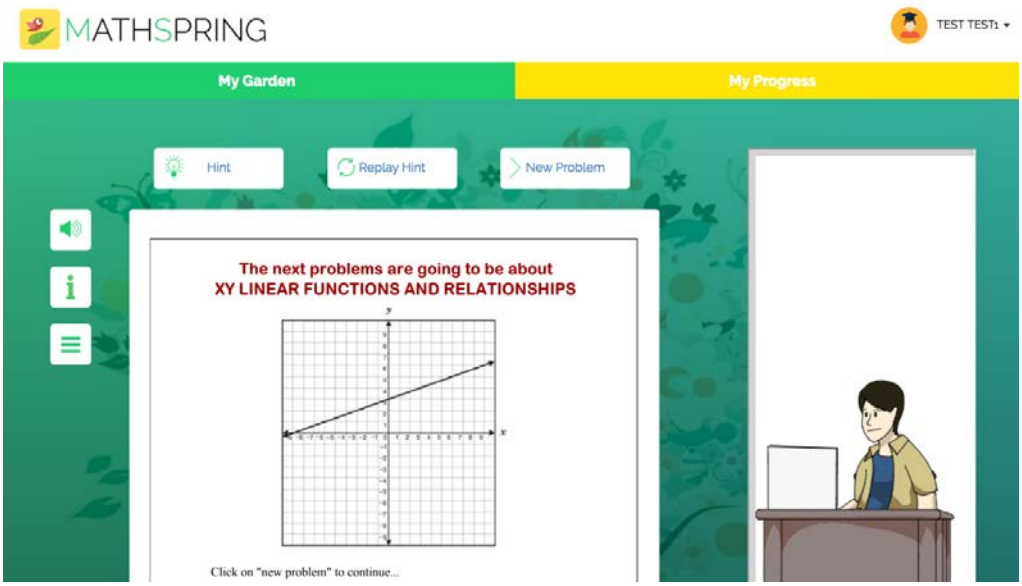


Figure 23. Main tutoring system page

The Tutoring System Page

We also redesigned the “Main tutoring system” page where the students can practice problems. First, in order to have a uniform look across all web pages on the system, we applied the same background image, color scheme and the navigation bar on this page. The only difference was that we set the background image darker than that of the landing page and register/login page so that the students could focus on the main content and work on problem without getting distracted by other elements on the page. Second, we also changed the arrangement of the buttons to make the page have a cleaner and less cluttered look than the original page. “Hint”, “Replay Hint” and “New Problem” were the three most used and most important buttons, so we designed these buttons to be bigger and arranged them on the top. Moreover, we triggered an animation effect for the “Hint” button whenever the students answered a problem incorrectly to make it more visible. “Read Problem” and “Instruction” and other less frequently used buttons were arranged

on the left side of the main problem-solving pane (Figure 24). We omitted the text part of these buttons and only kept the icon part to make the interface cleaner. However, to make sure that everyone understood the functionalities of these buttons and did not get confused, we provided the text part through a bubble talk panel when the users hovered the buttons. In addition, we placed all rarely used buttons by the users into a drop-down menu, which could be accessed by clicking the "3-line hamburger" button. Third, we kept the main problem solving pane at the center of the page and the virtual character pane on the right, just like the original page. We saw that the original layout and position for these panes were good and did not need further changes.

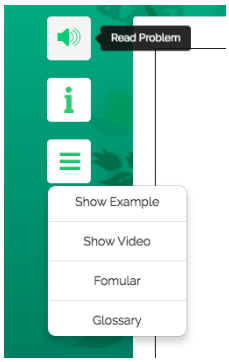


Figure 24. Sidebar buttons

Another useful part of the "Main tutoring system" page that we implemented was the developer tool for testers and developers of MathSpring (Figure 25). This small footer only appeared in the developer accounts on MathSpring. It showed essential information for developers to debug the behaviors of the system and fix potential problems.

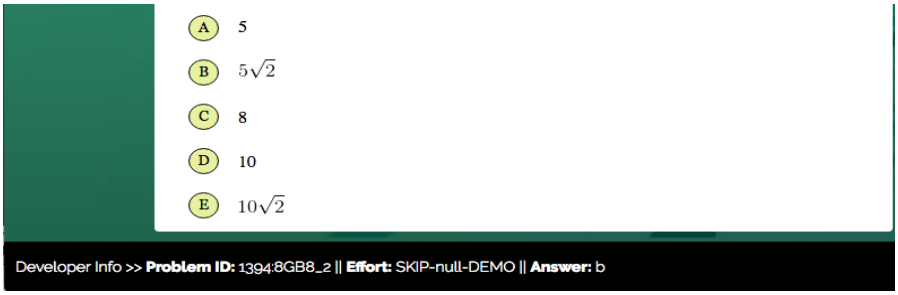


Figure 25. Developer tools for tester and developer of MathSpring

6. Study 3: Experiment on Evaluation of Improvement

After completing the new design for MathSpring, we assessed its quality and effectiveness. Specifically, we wanted to understand whether our design outperformed the former design in ease of use, attracting user interest in the learning materials, and user engagement. To do so, we conducted an experiment where half of the participants used the MathSpring with the former user interface and the other half used our new user interface. The participants were then asked to provide their opinions on both of the old and new user interfaces by answering our survey. After that, we performed formal statistical tests on the collected answers to quantitatively gauge the improvement of the redesigned website as compared to the original one.

6.1. Methodology

Participants

Thirty (30) college students (16 male; 14 female) at a small private institution in the northeast of the United States participated in this study. Around 57% of the participants were Caucasians (not Hispanic or Latino), 27% were Asians (not Hispanic or Latino), 10% were Hispanic or Latinos, and 6% were African-Americans.

Procedure

We recruited participants through a participant pool at the institution and by personally asking students at the institution to complete the study. After arriving at the lab, participants first read

through and gave informed consent. We then randomly assigned each participant to one of two conditions: experimental or control. Participants in the control group accessed the current MathSpring system on mathspring.org while the ones in the experimental group accessed a MathSpring system with redesigned user interface on a private server. Each group had 15 students.

Each participant then spent a total of 30 minutes completing three tasks. First, participants read through the landing page to learn about MathSpring and created a new account. Once the account was created, each participant logged into the system and practiced at least three different mathematical topics for 15 minutes. This 15 minute task corresponded to the first part of the experiment, letting participants use MathSpring for the first time. After playing with MathSpring for 15 minutes, we asked participants to log out of their MathSpring account and play a mini game (jigsaw puzzle on http://blocks.ovh/) for 5 minutes. The main purpose of playing a mini game was to have participants focus on something other than the MathSpring website. After this task, participants logged back into MathSpring and reviewed their previously completed or new mathematical topics for 10 minutes. This 10-minute section corresponded to the second part of the experiment, evaluating how the participants logged into MathSpring for the second time and continued their practice. After interacting with MathSpring for the second time, participants completed a short survey (Appendices B and C).

The questions in the survey focused on the landing page, the registration and login process, the overall appearance of the tutoring system, and the user experiences associated with the functionalities. For example, to learn the user experience associated with the logging in and

registration processes, we asked the participants their opinions on the statements: “Registering an account on MathSpring is easy, fast, and intuitive” and “Logging into the system is time-consuming.” The questions were measured using a 6-point Likert-Type scale (1 = Strongly Disagree; 6 = Strongly Agree). To learn more about user perspectives, we had some open-ended questions such as “What do you like about the software?” and allowed participants to type answers without limiting number of characters. The participants answered the survey through Google Form software, which automatically counted the frequencies for different answers to the interval scale questions while organizing the different answers to open-ended questions in the same table.

6.2. Results

To determine the difference between our design and the former MathSpring design, we performed one-tailed independent-sample T-test to compare outcomes for the two groups (experimental and control) to understand whether the redesigned site increased ease of use, interest in the materials, and user engagement with MathSpring, compared to the original site. We presented the results of the statistical tests and their interpretation below. More details could be found in tables 4 and 5.

Ease of Login and Registration

To investigate whether there was a difference in the ease of logging in to existing accounts and registering new accounts on the redesigned or original MathSpring website, we conducted an independent-samples t-test regarding convenience of the logging in and registration process.

Participants reported that logging into the redesigned website was not easier than to the original website, $p = 0.16$. On the other hand, they reported that registering new accounts on the redesigned web design ($M = 5.6$, $SD = .74$) was easier than on the original website ($M = 3.93$, $SD = 2.02$), $t(14) = 3.01$, $p < 0.05$. We also investigated whether participants' prior experience with math learning software was related to how they viewed the login and registration processes. The results of a Pearson product-moment correlation test suggested that participants' prior experience with math learning software had weak correlation with their perception of ease of logging in, $r = -0.07$, $n = 30$, $p = 0.70$, or the registration process, $r = 0.32$, $n = 30$, $p = 0.08$.

User Engagement with the Learning Progress Page

We also investigated whether there was a difference in the user engagement with the "My Progress" page on the redesigned or original MathSpring website. We conducted an independent-samples t-test on the survey question regarding students' decision to check their learning progress through the My Progress Page. Participants reported that they were tracking their learning progress through the My Progress Page more often on the redesigned website ($M = 3.47$, $SD = 1.69$) than the original website ($M = 4.73$, $SD = 0.96$), $t(14) = 2.53$, $p < 0.05$. The Pearson product-moment correlation test suggested that participants' prior experience with math learning software had no correlation with the decision to use My Progress Page, $r = -0.03$, $n = 30$, $p = 0.90$.

The Landing Page

The results suggested that there was no significant difference between our design of the landing page (Figures 12, 13, and 14) and the original design (Figure 1). Our redesigned website did not provide more convincing information than the original design to persuade visitors to use MathSpring in their classes, $p = 0.15$. Also, there was moderate correlation between participants' prior experience with math learning software and their perspective on the landing page, $r = 0.39$, $n = 30$, $p = 0.03$.

General User Engagement with MathSpring

We also analyzed the relevance of our changes to the website on student engagement with MathSpring. The results suggested mixed results on whether our redesigned website was better than the original design in encouraging users to engage more with MathSpring, as explained next.

Some results were marginally in favor of our redesigned website. For instance, participants tended to use hints marginally more often, when using the redesigned website ($M = 3.07$, $SD = 1.49$) compared to the original website ($M = 2.33$, $SD = 1.18$) $p = 0.07$. Not significant, but close to significant, participants reported that MathSpring had more features and tools available to help them on the redesigned website than on the original one, $p = 0.13$. Lastly, they reported that the user interface of the redesigned website ($M = 2.53$, $SD = 1.25$) marginally distracted them from practicing problems less than that of original website ($M = 1.93$, $SD = 0.96$), $p = 0.08$.

Some results were not in favor of our redesigned website. Participants did not see the tree or plants as incentive to practice more problems in the redesigned website, $p = 0.41$; nor utilize help and instruction more in the redesigned website, $p = 0.15$. Finally, participants reported that navigating through different pages was not easier on the redesigned website, $p = 0.31$. The Pearson product-moment correlation test results suggested that participants' prior experience with math learning software not likely had an influence on their perception on the number of features, $r = 0.17$, $n = 30$, $p = 0.36$; marginally influenced their perception on hints, $r = -0.35$, $n = 30$, $p = 0.06$; not likely had an influence on their perception of the growing trees representation, $r = 0.10$, $n = 30$, $p = 0.59$; not likely had an influence on help and instructions, $r = 0.18$, $n = 30$, $p = 0.34$, nor on ease of navigation, $r = 0.18$, $n = 30$, $p = 0.33$.

We conclude that some aspects of our redesigned website made a difference in student registration, availability of the student progress page as well as student engagement, especially related to making helpful tools available to them, and not distract them from problem solving. The reader might want to refer to Tables 4 and 5, to examine these results further.

7. Discussion

In conclusion, this research found a variety of features whose user experience could be improved with the MathSpring software. For instance, redesigning its layout and interface were suggested by those using MathSpring. The login and registration process for new users could be shortened. The reward system should be emphasized, appealing, and more visible to students. Existing functionalities such as hints, help, instructions, topic review, or step-by-step examples should be easily accessible and conveniently used by students. The number of improvements and their challenges in design, implementation, and testing were remarkably exciting and demonstrating that MathSpring system would be getting better and better at assisting students in learning and teachers in teaching mathematics.

Given the numerous possibilities to improve the user experience with the MathSpring system, we worked on its overall visual and interface designs, registration process for new students, reward system, and representation of the core functionalities such as hints, help, and instruction. We redefined the color palette, typography, and logos for MathSpring. We simplified the layout, login and registration processes, and navigation system, giving a clean, consistent looks throughout MathSpring's webpages. Regarding the core functionalities, we redesigned the behavior of hints button, grouped less frequently used features such as glossary, formula, videos, and examples into a single visible dropdown menu on the tutoring page.

The results of our study investigating user experiences with the original MathSpring system and the redesigned MathSpring system showed that the redesigned system succeeded, to some extent,

at improving aspects of the user experience. Our effort and attempt to simplify the registration process received positive feedback from the participants. Our design encouraged students to use the My Progress page to keep track of their learning progress more frequently and hints to answer question slightly more often. On the other hand, the landing page, login process, and tutoring page of the redesigned MathSpring system still had room for improvements.

Even though the results were mixed, we next give our perspective and reasoning on the outcome of our study to show its limitations and to give guidelines to future studies. We believed that many improvements on our design could be made to make the MathSpring system better.

Landing Page

Our design for the landing page, though introducing visitors quickly to the tutoring system, did not successfully convince them to see MathSpring as a supplementary resource for their classes. There could be many possible explanations. The visitors might not have scrolled down the landing page to read the statistics and student recommendations. Another possibility is that the visitors did scroll down, but the information was not persuasive enough. Also, our survey question could not collect user experience for the landing page correctly due to its phrasing, so we could not verify whether the information on the landing page was convincing to the participants. Further research should check which of the above mentioned possibilities happened to determine the improvements for our landing page.

Login and Registration Processes

Although our attempt to shorten the registration process in the new design was effective, as predicted, we did not expect our login process was not as convenient as the old website's. In hindsight, we discovered that after signing out of MathSpring during the study participants were directed to the login page rather than the landing page—making logging in very simple and consequently hard to measure. Future research will need to examine whether the login process on the redesigned MathSpring is more efficient and effective than the original MathSpring.

More interestingly, even if we had correctly assessed the new login process, the participants would have thought the login process of our design was no different than that of the old design. While conducting the experiment, we observed that many participants in the control group accessed the tutoring system with one click on the old design, similar to the login process of the new design. The participants used a link without understandable label on the old MathSpring landing page leading them to the login page (Figure 26).

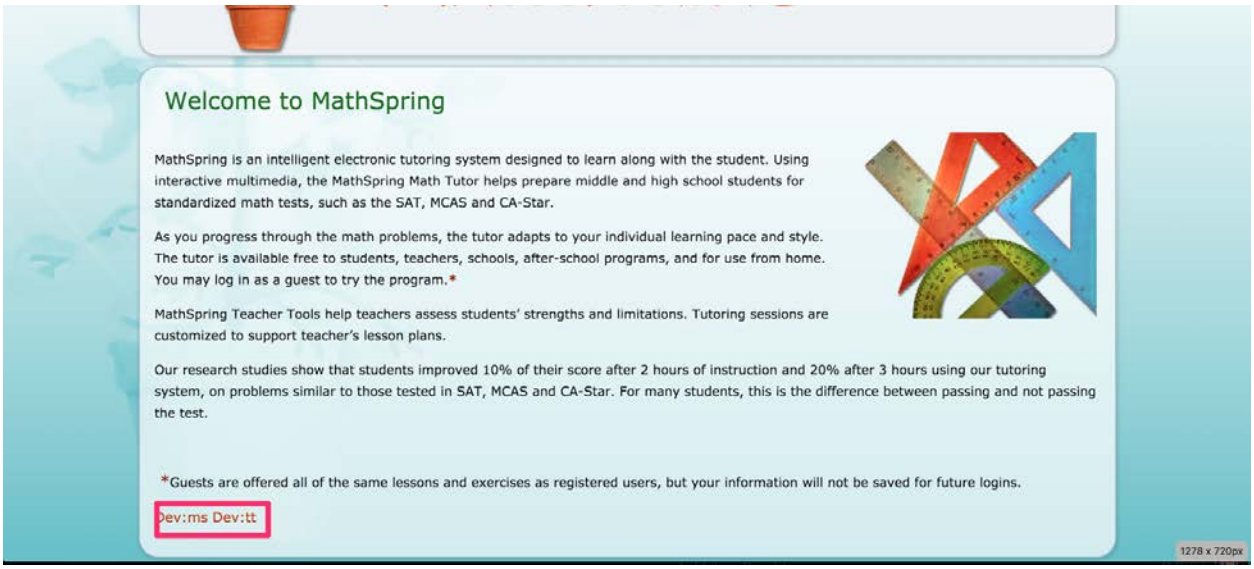


Figure 26: Links to tutoring system without meaningful labels

While trying to access the tutoring system, many participants in the control group accidentally found this link and probably remembered it as a means of getting into the login/registration page. Hence, even if they had started to log into their account from the landing page, the participants would probably have reused this link. Still, this is our conjecture from observation, so more careful experiment is needed to confirm this.

Tutoring System Design

While the new tutoring system's pages had consistent and clean layout design, it contained an imperfection that was conspicuous to the participants: the navigation tab bar. We originally chose green to highlight the active tab on the navigation bar and yellow to highlight the inactive one. The navigation bar differentiated the "Garden" tab and the "My progress" tab very well. However, this choice of color confused users when they were on the problem practicing page because on this page the garden tab was highlighted, indicating the garden tab is being active.

Users no longer understood which page they were on, garden page or problem practicing page. Furthermore, choosing yellow to highlight inactive tab was not a good choice since the white textual content of the inactive tab is harder to be read. Future work should address this problem. We suggest that the navigation bar remain on the page; however, the style of it needs some work.

Core Functionality Design

According to the results of our user study, the redesigned MathSpring did not encourage participants to use hints or learn existing features or functionalities more than the original MathSpring site. We believe further research is needed because our participants, all in college, were familiar with middle and high school mathematical topics. Through our observation, they had little difficulty working on the problems. Thus, using hints, watching examples, or utilizing any functionality to solve problems was less necessary for our participants. Future study should recruit students in middle and high school to test the frequency of using hints or other existing features that assist students in practicing math problems.

User Suggestions

In our final study, the participants had a few suggestions to improve the redesigned site. They generally reported liking the colors, fonts, style, and layout of the redesign. Some reported that navigating through pages on the redesigned site was easy and intuitive. However, participants noticed that the area where they practiced math questions did not match the redesign. This section of the MathSpring program was not part of our initial redesign as the coding for it was more difficult to change. Participants suggested that the same design should be implemented

through.

We believed our study has explored different improvements and laid the foundation for future study to continue improving the user interface and user experience of MathSpring. Future study can explore more possibilities to improve the system and bring out more pedagogical potential from MathSpring, which is already built upon strong theoretical researches.

References

Garrett, J. J. (2011). *The elements of user experience: User-centered design for the Web and beyond*. Berkeley, CA: New Riders.

Arroyo, I., Woolf, B. P., Burelson, W., Muldner, K., Rai, D., & Tai, M. (2014). A multimedia adaptive tutoring system for mathematics that addresses cognition, metacognition and affect. *International Journal of Artificial Intelligence in Education*, 24(4), 387-426. doi:10.1007/s40593-014-0023-y

Lidwell, W., Holden, K., & Butler, J. (2003). *Universal principles of design*. Gloucester, Mass: Rockport.

Johnson, J., & Henderson, A. (2002). *Conceptual models: Begin by designing what to design*. New York: ACM. doi:10.1145/503355.503366

Norman, D. A., & Draper, S. W. (1986). *User centered system design: New perspectives on human-computer interaction*. Hillsdale, N.J: L. Erlbaum Associates.

Miles, M. B., & Huberman, A. M. (1994). *Qualitative data analysis: An expanded sourcebook* (2nd ed.). Thousand Oaks: Sage Publications.

Tables

Table 1: Answers and corresponding amounts for "What did you like about the software?"

Theme	Answers	Number of Answers
Content	That it had hints	23 (39%)
Content	The growing tree and its growth after passing a topic	9 (16%)
Content	That it showed overall learning progress	7 (12%)
Content	That it showed example	5 (8.5%)
Interaction	That it read the question out loud (Auditory instruction)	4 (6.7%)
Interaction	That it was easy to use	3 (5%)
Content	That it showed step-by-step solution	2 (3%)
Content	That it had a good range of math topics	2 (3%)
Interaction	The UX survey within the tutor + The emotion/feeling question in UX survey + The questions about feelings and process in UX survey	1 (1.7%)
Functionality	That it showed topics users need to work on	1 (1.7%)
Content	That it has videos to watch and learn	1 (1.7%)
Content	That it allowed to review questions	1 (1.7%)
	Total questions	59

Table 2: Answers and corresponding amounts for "What suggestions do you have for improving the program?"

Theme	Answers	Number of Answers
Content	More hints and help	7 (16.2%)
Visual	More appealing UI + Colors and design more friendly for kids	6 (13.8%)
Interaction	Stop asking user experience	5 (11.6%)
Content	Improve quality of auditory instruction + Make auditory instruction more appealing + Make interactive voice louder	4 (9%)
Functionality	Add calculators	4 (9%)
Functionality	Fasten loading time and smooth interaction	4 (9%)
Functionality	Remove interactive characters	3 (6.8%)
Functionality	Have a reward system	3 (6.8%)
Functionality	Allow users to choose math level	2 (4.6%)
Functionality	The ability to choose different kind of trees	1 (2.2%)
Functionality	Add profile picture	1 (2.2%)
Functionality	Show the growth of the tree at every level (more often)	1 (2.2%)
Interaction	Reduce use of auditory instruction	1 (2.2%)
Visual	Move the visual character to different place	1 (2.2%)
Visual	Need better instructions to use the software	1 (2.2%)
	Total Answers considered	44

Table 3: Functional Specifications for Student User

No.	Functional Specifications
1	The system must allow visitors to create new teacher accounts
2	The system must allow visitors to create new student accounts
3	The system must allow visitors to sign in with their teacher accounts
4	The system must allow visitors to sign in with their student accounts
5	The system must allow visitors to sign in with no account (guest account)
6	The system must allow users to sign out their teacher, student, or guest accounts
7	The system must be able to show students their general learning progress (topics done, questions done in each topic, and mastery level of each topic)
8	The system must be able to show students their proficiency in any mathematical topic
9	The system must be able to show students their effort in any mathematical topic
10	The system must be able to show students their learning progress (number of problems done and content of problems done) in any particular mathematical topic
11	The system must be able to give advice to students on how to progress in any mathematical topic
12	The system must allow students to practice different math problems
13	Students must be able to use hints during practicing problems
14	Students must be able to replay a hint when they are practicing problems
15	The system must be able to remind students the availability of the hint functionality when they are practicing problems
16	Students must be able to review any mathematical topic
17	Students must be able to continue working problems of any mathematical topic
18	Students must be able to work on challenging problems of any mathematical topic
19	Students must be able to listen the any math problem out loud
20	Students must be able to see sample problem of any mathematical topic
21	Students must be able to see an example video of any mathematical topic
22	Students must be able to see a certain number of mathematical formulas and laws of any mathematical topic during practicing problems
23	Developers must be able to see the problem id, effort id, and answer of any question during practicing problems

Table 4: Results of Two-Independent-Sample T-Test on Answers of Survey in Study 3

Statement	Group	*N*	*M*	*SD*	*t*	*p*
Convincing home page	Control	15	4	1.65	-1.08	0.15
	Experimental	15	4.53	0.99		
Easy Registration Process	Control	15	3.93	2.02	-3.01*	0.003
	Experimental	15	5.6	0.74		
Easy Login Process	Control	15	1.8	1.08	1.03	0.16
	Experimental	15	1.47	0.64		
Non-distracting UI	Control	15	1.93	0.96	-1.48	0.08
	Experimental	15	2.53	1.25		
Useful/Helpful Features Available	Control	15	5.13	0.92	1.18	0.13
	Experimental	15	4.67	1.23		
Used hints often	Control	15	2.33	1.18	-1.50	0.07
	Experimental	15	3.07	1.49		
Used My Progress to work on topic	Control	15	3	2.30	-1.35	0.09
	Experimental	15	4.07	2.02		
Used My Progress to track learning progress	Control	15	4.73	0.96	2.53*	0.01
	Experimental	15	3.47	1.69		
Allows to Learn/Review a lot	Control	15	3.73	1.27	1.02	0.16
	Experimental	15	3.27	1.22		
Big tree/plant encourages to practice more	Control	15	3.6	1.60	0.22	0.41
	Experimental	15	3.47	1.69		
Help and instruction are easily accessible	Control	15	5.07	0.80	1.06	0.15
	Experimental	15	4.6	1.50		
Navigating through pages is easy	Control	15	3.87	1.41	-0.48	0.32
	Experimental	15	4.13	1.64		

Note: * = $p \leq 0.05$

Table 5: Pearson Product-Moment Correlations of Students' Prior Knowledge with Learning Software and Their Perception on Different Aspects of MathSpring (N = 30)

		Prior knowledge with math learning software
Convincing home page	r-value p-value	0.39 0.03
Easy Registration Process	r-value p-value	-0.32 0.08
Easy Log in Process	r-value p-value	-0.07 0.70
Non-distracting UI	r-value p-value	0.09 0.61
Showing many features	r-value p-value	0.17 0.36
Use hints often	r-value p-value	-0.35 0.06
Use My Progress to work on topic	r-value p-value	0.20 0.28
Use My Progress to track learning progress	r-value p-value	-0.03 0.89
Learn/Review a lot	r-value p-value	0.10 0.59
Big tree/plant encourages to practice more	r-value p-value	0.10 0.59
Help and instruction are accessible	r-value p-value	0.18 0.34
Navigating through pages is easy	r-value p-value	0.18 0.33

Note: * = $p \leq 0.05$; ** = $p < 0.005$

Appendix

Appendix A. Interview Questions for Teacher in Study 1b

1. How do students interact with MathSpring the first time? How long does it take for students to navigate from the landing page (mathspring.com) to the learning/testing page?
2. Do majority of students have any common opinions on the look of website?
    a. What do they think about the colors?
    b. Arrangement of content (text, font). Do they have hard time seeing the questions, answers and graph because of the font size?
    c. Arrangement interface elements (button, interactive character)? Do they navigate the buttons/text fields they want easily and quickly? Do they feel excited or annoying about the interactive character window?
3. Do students use calculator while working on problems on MathSpring? What else do they use while working on the problems? (Dictionary, paper?)
4. Some students suggest a cool reward system. Right now we're thinking about some features like experience points or achievement token unlock. Do you think that idea is suitable? Is it too much game-like and making students distracted?
5. Do students ask you for hints before using the website's hints? Do students use the "my progress" button often to keep track of their learning progress?
6. Do students complain about the ask-your-feeling feature?
7. Do students listen to the interactive characters or mute the sound?
8. How do students feel about the growing tree that tracks their learning progress? Do you think they like more diverse kinds of trees?

9. Any complains about the performance?

Appendix B. Survey for Participants in Control Group

Post-Test Survey

Click the option that best matches how you feel. Please be very SINCERE in your responses. We are really interested in knowing how you feel about our system. NOBODY other than the IQP team will know what you answer.

* Required

The home page, mathspring.org provides convincing information for you to consider logging in to use it. *

	1	2	3	4	5	6	
Strongly Disagree	◯	◯	◯	◯	◯	◯	Strongly Agree

Home page

Registering an account on MathSpring is easy, fast, and intuitive. *

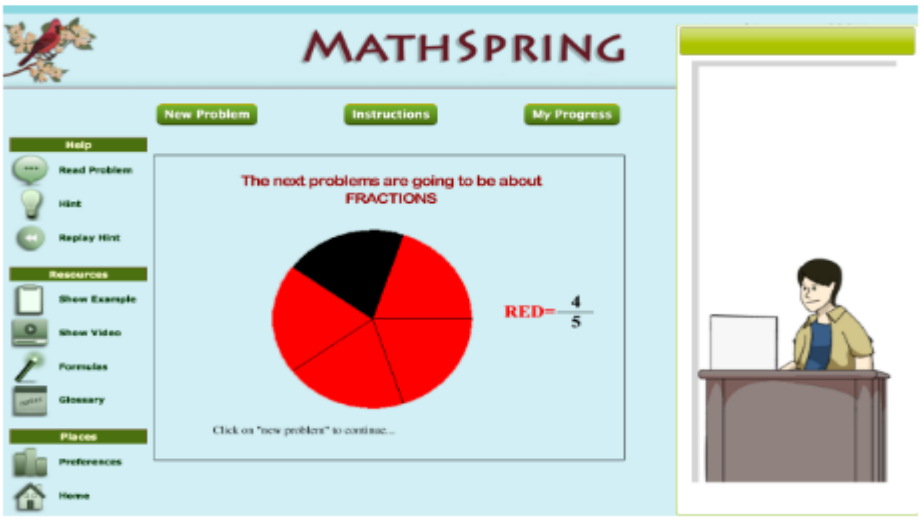
	1	2	3	4	5	6	
Strongly Disagree	◯	◯	◯	◯	◯	◯	Strongly Agree

Logging into the system is time-consuming. *

	1	2	3	4	5	6	
Strongly Disagree	◯	◯	◯	◯	◯	◯	Strongly Agree

The appearance of MathSpring distracts you from practicing problems. *

	1	2	3	4	5	6	
Strong Disagree	◯	◯	◯	◯	◯	◯	Strong Agree



There are many features/tools available to help on problems in MathSpring. *

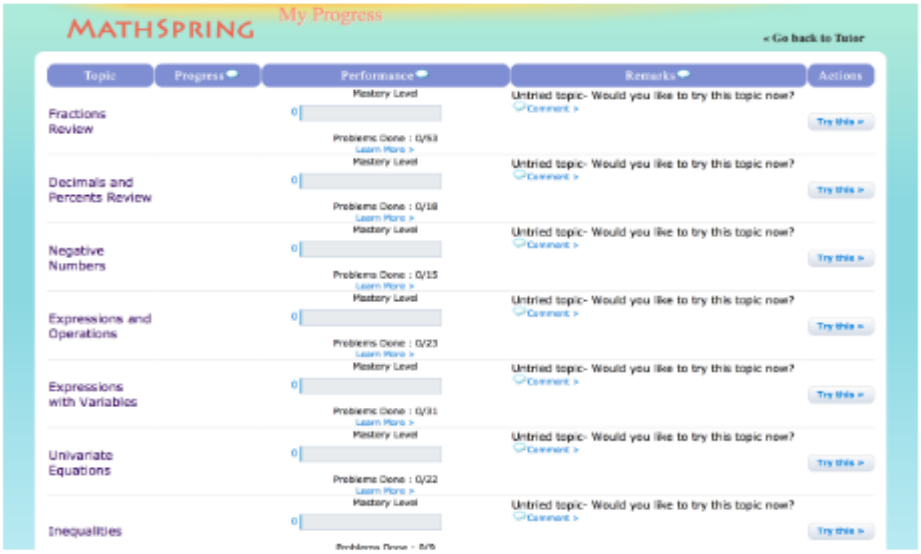
	1	2	3	4	5	6	
Strongly Disagree	◯	◯	◯	◯	◯	◯	Strongly Agree

How often have you used the hints to help you solve a math problem? *

	1	2	3	4	5	6	
Strongly Disagree	◯	◯	◯	◯	◯	◯	Strongly Agree

I have used the "My Progress" page as a way to start a new set of problems or to continue unfinished problem sets on a specific topic. *

	1	2	3	4	5	6	
Strongly Disagree	◯	◯	◯	◯	◯	◯	Strongly Agree



I would consider using "My Progress" page often to keep track of my learning progress. *

	1	2	3	4	5	6	
Strongly Disagree	○	○	○	○	○	○	Strongly Agree

I have learned/reviewed a lot on MathSpring? *

	1	2	3	4	5	6	
Strongly Disagree	○	○	○	○	○	○	Strongly Agree

The plants and big tree encourage me to keep practicing a few more problems. *

	1	2	3	4	5	6	
Strongly Disagree	○	○	○	○	○	○	Strongly Agree

The help and instruction buttons are easily accessible *

	1	2	3	4	5	6	
Strongly Disagree	○	○	○	○	○	○	Strongly Agree

Navigating through pages in MathSpring is easy *

	1	2	3	4	5	6	
Strongly Disagree	○	○	○	○	○	○	Strongly Agree

What do you like about the appearance of the website? *

Your answer

What do you dislike about the website? *

Your answer

What are your suggestions for improvement? *

Your answer

You identify your gender as... *

- ○ Male
- ○ Female
- ○ Prefer not to disclose
- ○ Other: _____

What is your ethnicity? *

- ○ Hispanic or Latino
- ○ Black or African American(Not Hispanic or Latino)
- ○ White (Not Hispanic or Latino)
- ○ Asian (Not Hispanic or Latino)
- ○ Native Hawaiian or Other Pacific Islander
- ○ Native Hawaiian or Other Pacific Islander (Not Hispanic or Latino)
- ○ American Indian or Alaska Native (Not Hispanic or Latino)
- ○ Two or More Races (Not Hispanic or Latino)
- ○ Prefer not to disclose
- ○ Other: _____

What is your class year? I am a ... *

- ○ Freshmen
- ○ Sophomore
- ○ Junior
- ○ Senior
- ○ Graduate

What is your name? *

Your answer

What is your username on MathSpring? *

Your answer

What is your experience with learning math through software or game before MathSpring? *

	1	2	3	4	5	6	
Not Much	○	○	○	○	○	○	Very Much

SUBMIT

Never submit passwords through Google Forms.

Appendix C. Survey for Participants in Experimental Group

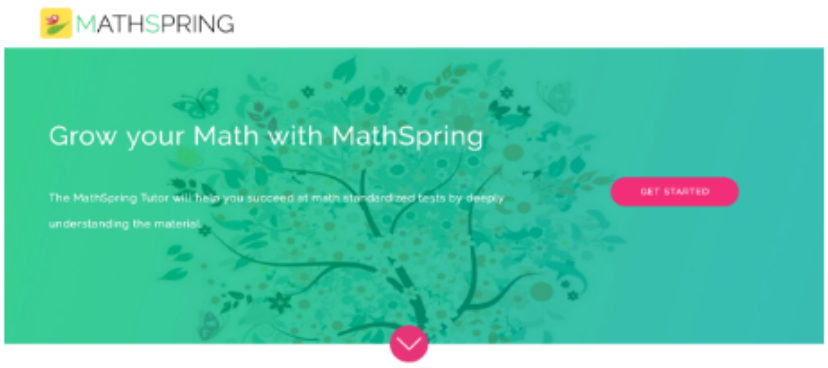
Post-Test Survey

Click the option that best matches how you feel. Please be very SINCERE in your responses. We are really interested in knowing how you feel about our system. NOBODY other than the IQP team will know what you answer.

* Required

The home page, mathseeds.wpi.edu provides convincing information for you to consider logging in to use it. *

	1	2	3	4	5	6	
Strongly Disagree	○	○	○	○	○	○	Strongly Agree



MathSpring is ...

Registering an account on MathSpring is easy, fast, and intuitive. *

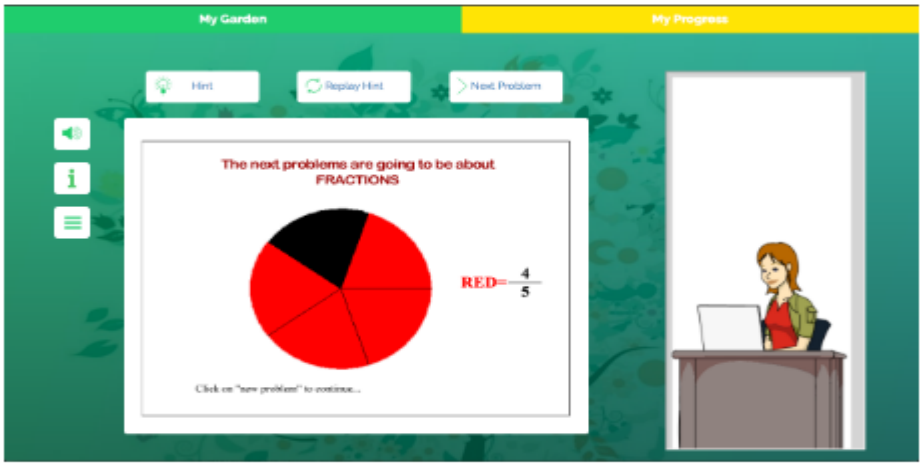
	1	2	3	4	5	6	
Strongly Disagree	○	○	○	○	○	○	Strongly Agree

Logging into the system is time-consuming. *

	1	2	3	4	5	6	
Strongly Disagree	○	○	○	○	○	○	Strongly Agree

The appearance of MathSpring distracts you from practicing problems. *

	1	2	3	4	5	6	
Strong Disagree	○	○	○	○	○	○	Strong Agree



There are many features/tools available to help on problems in MathSpring. *

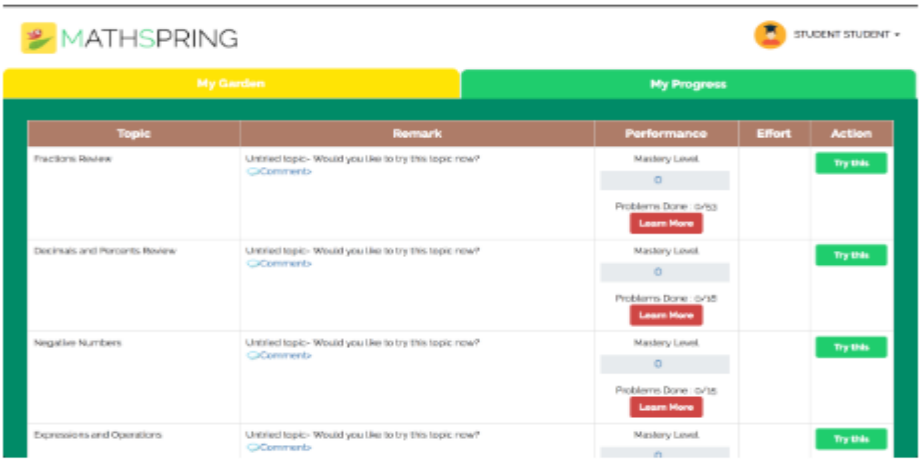
	1	2	3	4	5	6	
Strongly Disagree	○	○	○	○	○	○	Strongly Agree

How often have you used the hints to help you solve a math problem? *

	1	2	3	4	5	6	
Strongly Disagree	○	○	○	○	○	○	Strongly Agree

I have used the “My Progress” or "My Garden" page as a way to start a new set of problems or to continue unfinished problem sets on a specific topic. *

	1	2	3	4	5	6	
Strongly Disagree	○	○	○	○	○	○	Strongly Agree



I would consider using “My Progress” or "My Garden" page often to keep track of my learning progress. *

	1	2	3	4	5	6	
Strongly Disagree	◯	◯	◯	◯	◯	◯	Strongly Agree

I have learned/reviewed a lot on MathSpring? *

	1	2	3	4	5	6	
Strongly Disagree	◯	◯	◯	◯	◯	◯	Strongly Agree

The plants encourage me to keep practicing a few more problems. *

	1	2	3	4	5	6	
Strongly Disagree	◯	◯	◯	◯	◯	◯	Strongly Agree

The help and instruction buttons are easily accessible *

	1	2	3	4	5	6	
Strongly Disagree	◯	◯	◯	◯	◯	◯	Strongly Agree

Navigating through pages in MathSpring is easy *

	1	2	3	4	5	6	
Strongly Disagree	◯	◯	◯	◯	◯	◯	Strongly Agree

What do you like about the appearance of the website? *

Your answer

What do you dislike about the website? *

Your answer

What are your suggestions for improvement? *

Your answer

You identify your gender as... *

- ○ Male
- ○ Female
- ○ Prefer not to disclose
- ○ Other: _____

What is your ethnicity? *

- ○ Hispanic or Latino
- ○ Black or African American(Not Hispanic or Latino)
- ○ White (Not Hispanic or Latino)
- ○ Asian (Not Hispanic or Latino)
- ○ Native Hawaiian or Other Pacific Islander
- ○ Native Hawaiian or Other Pacific Islander (Not Hispanic or Latino)
- ○ American Indian or Alaska Native (Not Hispanic or Latino)
- ○ Two or More Races (Not Hispanic or Latino)
- ○ Prefer not to disclose
- ○ Other: _____

What is your class year? I am a ... *

- ○ Freshmen
- ○ Sophomore
- ○ Junior
- ○ Senior
- ○ Graduate

What is your name? *

Your answer

What is your username on MathSpring *

Your answer

What is your experience with learning math through software or game before MathSpring? *

	1	2	3	4	5	6	
Not Much	○	○	○	○	○	○	Very Much

SUBMIT

Never submit passwords through Google Forms.