Parson Programming Puzzles and Pilot Field Study Final Report

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0.1 INTRODUCTION

SAGE is stands for Social Addictive Gameful Engineering. The prominent goal of the SAGE environment is to provide teachers a space to design puzzles for students and teach them about computational thinking in an gameful and self-motivated manner. Computational thinking(CT) is the ability to express problems and provide solutions in a way computers execute problems. This useful in the current culture because there is a higher demand for jobs and social roles that require computational thinking skills outside of the field of engineering. Therefore, there is a need for an accessible and effective platform like SAGE that help students develop their CT skills in a gameful manner. Our platform not only facilitate teacher's experience of teaching CT, it also make the learning experience inclusive, adaptable and engaging for students.

Our platform teaches different concept of CT, such as sequences, loops, conditionals, etc, through the exploration and construction of Parson's Puzzles. Different topics imply a different skill within CT and help student build up different component of their CT skill. In order to evaluate the clarity and effectiveness of the platform, and to continually improve by getting meaningful feedback, we continue to conduct field studies middle schools in NYC and also online through Mechanical Turk. We gain insight from the experience of teacher and student, who are the two-main target user of this platform. In addition, we are also preparing to get feedback from adult participants on MTurk through their direct feedback and performance on the field study material. In this way, we are able to get a wholesome view and a range of feedback for the platform.

0.2 RELATED WORK

0.2.1 Tutorials

Learning Programming from Tutorials and Code Puzzles: Children's Perceptions of Value
(Harms, Balzuweit, Chen, Kelleher)
The paper by Harms, Balzuweit, Chen and Kelleher surveyed children's preference of learning style. They found that while 17 percent of the students would choose Puzzles for challenging concepts, 41 percent of the students prefered to start with a tutorial and then move on to puzzles. A comment from a student during an interview seems rather insightful. He said that he preferred tutorials because puzzles are novel to him and he worried he wouldn't understand what the puzzles are trying to teach him. Such worry explains the current popularity of instructional learning, which the students are

being taught a specific concept. In my opinion, SAGE has the opportunity to address such problem by making every step of the learning experience as transparent and clear as possible. This includes unambiguous puzzles instructions, design, progress report, feedback and scoring system. In this way, students can gain a wealth of information in turns of their goal, performance and understanding of current concept. Thus, this address the problem brought up in the paper regarding possible confusion and unclear goals associated with Parson's Problem learning style.

0.2.2 Survey

Challenging Stereotypes and Changing Attitudes: The Effect of a Brief Programming Encounter on Adults' Attitudes toward Programming (Charters, Lee, Ko, Loksa)
Even though programming is widely used in many jobs nowadays, there is a negative stereotype associated with programming. In the paper by Charters, Lee, Ko and Loksa, they researched on adult's attitudes towards programming. More importantly, they investigate whether there is a change toward programming after a brief gameful online programming experience. They have found that it is true that most people have a rather negative attitude toward programming initially. However, their attitude often changes dramatically after the brief interaction with the online programming game. This positive change happens across all demographic groups, including gender, population density and education level. In the paper, they have also categorized the main groups of attitude both before and after the positive programming exposure. These categories are helpful in our own research especially with the adult study. By including these categories as scaled-Reponse questions in our own surveys, we are able to compare our results with theirs, while taking even more factors into account, such as the type of online programming that the participants experience.

Intrinsic Motivation Inventory (IMI)
This document provides a standard for the types of Intrinsic Motivation questions researchers can include in their surveys to evaluate participants' subjective experience of the target task they are doing. Questions within the IMI include questions that evaluate Interest/Enjoyment, Perceived Competence, Effort/Importance, Pressure/Tension, Perceived Choice, Value/Usefulness and Relatedness. This paper gives out possible questions researchers can ask related to IMI, and also provides example of how it is used in previous research. It is crucial to have such a standard regarding the types of questions asked and

how each question is asked. This makes comparison between different researches easier and more translatable. In our research, we include questions from each category above to access participant's subjective experience related to our SAGE puzzles.

0.2.3   Puzzles

Distractors in Parsons Problems Decrease Learning Efficiency for Young Novice Programmers (Harms, Chen & Kelleher)
Another paper by Harms, Chen and Kelleher address the usage of distractors in Parson's problems. A distractor is described as a way to address common misconception, like the distractors in a multiple choice question. However, a distractor in this context has many implications. They claim that while distractors increase cognitive load, it decrease learning efficiency and effectiveness. During their studies, they used three kind of distractors: 1)add unrelated random noise, 2)add tangentially related noise, 3) add unrelated control flow constructs. While the first two kind of distractors are easily being identified, the third kind was reported to be harder to spot. Thus, it allowed students to think about the necessity of each block and the logic flow of the puzzles. In our case, I think creating distractors of such kind could potentially encourage students think more deeply about the computational logic within each puzzle. Besides, the necessity of a sub-optimal path is also being discussed. While this idea is might not apply to sequences, I think this the an interesting idea for future lessons. It is found that providing a sub-optimal solution sometimes prevents students from discovering the optimal path. However, when there there are incomplete sub-optimal path distractors, it eventually push students toward the optimal path solution.

0.2.4   Feedback

The Effect of Providing Motivational Support in Parsons Puzzle Tutors (Kumar)
In this paper by Kumar, he studies the effects of feedback on student's programming experience. He finds that the feedback did't change the amount of learning that happened, but it does increase the time students spend on each puzzle. The kind of feedback Kumar provides in the study is simply the correctness of the puzzle. Therefore, the tutor would warm students is the puzzle is incorrect. In addition, the tutor also helps students to keep track of moves they have already taken and moves that are left to complete the puzzle. During the student study, the correct solution of the puzzles are not shown during the pre-test. Therefore, students only learn through their own interaction with the puzzles

and the feedback the get from the tutor. The kind of feedback given in this paper is the same kind of feedback we give to our participants in the Parson's Puzzle condition. However, the different is we do provide them with solutions during the warm-up phase and there are only four puzzles in total to complete. It would be interesting to see whether these two difference changes the effectiveness and the meaning of feedback for students.

0.3 PLANNING

Preparation

I built upon materials that Rebecca, Emily, Juvaria and I finished last semester. The surveys I have used include the Background Survey, the Pre and Post test survey, Cognitive Load Survey on Puzzles, Cognitive Load Survey on Test and Intrinsic Motivation Survey. In addition, I have also used the sequence puzzles we designed as the basis of my continued work. The puzzles included three conditions: Parsons, Parsons with distractors and the Scratch condition. I was also reconnecting with Elissa, who is a teacher at Life Sciences Secondary School that has been partnering with SAGE for field studies in her classrooms. In addition, I was preparing materials to publish our study on MTurk to get adult participants. This include reorganizing the surveys and puzzles to adapt for our adult audience and also new materials and guidance to accommodate for the non-interactive nature of online field studies.

Parson's Puzzle Design

To evaluate the difficulty level of the puzzles and the clarity of the instructions, I conducted a preliminary research around with undergraduate students at Columbia. The questions I was trying to investigate are:
1) Are the instructions clear enough to guide them through the puzzles?
2) What are the dominant challenges when building the puzzles?
3) What are some confusing or distracting component of the overall experience?

This round of research included 6 students, 3 are CS majors and 3 are non-CS majors, all undergraduates at Columbia University. Through their collective feedback, I was able to gain much insight on the above three questions. The instruction created confusion due to its ambiguity. Therefore, I have added more signal word like "then", "after", "finally" to separate information for each block. I have also added the "number of blocked required"

as a hint for the participants. This is especially beneficial for the Scratch condition because it gives them a clue regarding the general complexity and structure of the puzzle. A predominant challenge for students is the interface. They could click on a functionality they don't need and spend a lot of time exploring it. Since this is not the intention of our puzzle, and some functionalities are not designed to create distractions, we have disabled these functionalities in the student mode. This have been proved effective in helping them focus on the solving the puzzles. Finally, a confusing factor is the auto submission function. When students find the correct solution, the system auto-submits their answer immediately. This could be confusing because it does't give students enough time to fill in attribute in the last block. To ensure a more fluent and complete experience for the students, we have decided to postpone the auto-submit popup by 5 seconds, giving students enough time to complete filling in the attributes. Other minor changes, like the set-up of the progress bar, have also been made based on the undergraduates' feedback.

Field Study Implementation

In addition to the traditional classroom student study, we have also added a field study on adults through a online platform called Mechanical Turk. For both studies, we ask the participants to finish the Background Survey, the Pre Test survey before doing the puzzles. The SAGE puzzles include a warm up phase with one puzzle and a learning phase with three puzzles. Participants are able to get help during the warm up phase. In the student study, the warm up phase is guided by their teacher. In the adult study, the solution and a step-by-step explanation is provided in a document for the participants. After the completing the SAGE puzzles, they then fill out the Post Test survey, the Cognitive Load survey on Puzzles, Cognitive Load Survey on Test and Intrinsic Motivation Survey. The content of the surveys varies based on the target group, and some changes to the adult surveys will be explained in the Implementation Section.

0.4   IMPLEMENTATION

0.4.1   Overview

Here, I summarize the important materials that I have worked on. Some I have modified based on previous works, others I have created. While there are some modifications for the student field study materials, the focus is on the Adult field study materials, since that is our main goal for the upcoming summer.

Material	Platform	Notes
Adult Background Survey	Qualtrics	Modified to add demographic and attitude questions
Adult Intrinsic Motivation Survey	Qualtrics	Changed wording of IM questions and added attitude questions
SAGE Adult Conditionals Puzzles	SAGE	Created
SAGE Adult Sequences Puzzles	SAGE	Created based on student Sequences Puzzles
SAGE Student Conditionals Puzzles	SAGE	Have one puzzle, need three more
Adult Puzzle Instructions	GoogleDoc	Created, not tested yet
Student Puzzle Instructions	GoogleDoc	Created, tested
Warm up phase explanations and solutions (for sequence and conditionals)	GoogleDoc	Created, not tested yet
SAGE Sequence Tutorial Slides + Recording	Panopto	Created, not tested yet

0.4.2 Surveys and Tests Modifications

To adapt to the adult participants in the online research, there are modifications to both the Intrinsic Motivation Survey and the Background Survey. In the Background Survey, we have added more demographic questions asking about Age and occupation to better understand our pool of participants. In the Intrinsic Motivation Survey, we modified the intrinsic motivation question into its original question, since we have simplified some questions to facilitate middle student's understanding previously. These questions include:

Old Questions	New Questions
I think this activity was useful to me	I believe this activity could be of some value to me
I'd prefer not to do this activity again	I would be willing to do this again because it has some value to me
I would like to do this type of activity again	I believe I had some choice about doing this activity

The reason we have made these changes is because we want to use the exact questions from Intrinsic Motivation Inventory paper to ensure consistency of the metrics we are using. This could also provide us an opportunity to directly compare our result with other works in the field.

Additionally, we have also added another set of questions to both the Background Survey and the Intrinsic Motivation Survey. In the Charters, Lee, Ko and Loksa paper, they summarized categories of people's attitude towards programming. We want to use these categories and evaluate our participant's attitude toward programming both before and after the puzzles through scaled-Response questions. Therefore, by having identical questions in both surveys, we can directly compare the results. To also gather our subject's real thoughts towards programming, we have provided a short answer question that is also asked in the Charters, Lee, Ko and Loksa paper to gauge the general attitude about programming in addition to the scaled-Response questions.

Here are some sample questions:

Programming is too difficult to understand	scaled-Response questions
Programming is something I've wanted to learn	scaled-Response questions
Programming is an innate ability	short answer questions

0.4.3 Puzzle Design

Our primary focus was on creating a Conditionals Puzzles as the fourth condition in our adult research. The general structure is same as the previous Sequences Puzzles, with one familiarization puzzle and three study puzzles. This puzzle is in the Parson's Puzzle's condition. One of the challenges faced is designing the Boolean statement inside the if-statements. It is difficult to create a Boolean statement without deploying different variables. To solve this problem regarding variables, we came up with two solutions. The first one is to use the "pick random value" block. For example "pick random value from 1 to 2" block would pick either 1 or 2. This solves the need to use a fixed variable and makes the puzzles simpler to understand. Another solution we came up with is the "touching color" block. This block is inherently a Boolean statement, so it is intuitive and easy to use. For example, if the Sprite character is touching the color red, the character would enter the if statement. Otherwise, it enters the else statement.

Among the three puzzles, there is a consistent story line that connect them together. The overall theme is "Let's go sailing" and the theme for each puzzle is as the following: 1. "At the casino" 2. "Shopping for supplies" 3. "When to sail today?" 4. "Finding Gem in the Ocean" The overarching story line is about two friends winning a lot of money from the casino, who then goes on a sailing trip. When one of them lost gems in the Ocean, the other then goes scuba diving in the attempt of finding the treasure. Through a continuous

Figure 1: This puzzle uses the pick random block. It is a roulette wheel themed puzzle and the player can choose either red or black on the wheel. The number 1 corresponds to red and 2 corresponds to black. Therefore, if the random number is 1, it says "Its Red! You win!". If the random number is 2, it says "It's black, you lose!!!" This is an example of how to construct Boolean statement without the use of variables
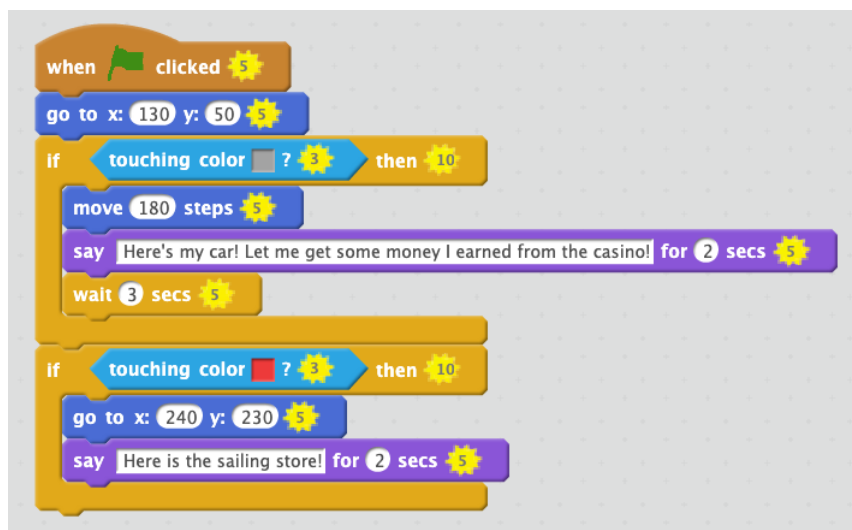

Figure 2: This puzzle uses the touching color block. The theme about the puzzle is a sailor going to the sailing store and he makes two stops before getting there. When the person touches grey, which is the color of the road, he follows instructions in the first if statement and stops at his red car. When he is then touching he car, he goes to the sailing store from there. This is another example that demonstrates how to construct Boolean statement without variables.

story, participants could have more motivation to engage in later puzzles and have more motivation to find the correct solution to reveal the correct animation. The main blocks we used are the If block and If/else block. After doing the puzzle, participants would learn to use both of these both separately and in various combinations.

0.4.4 Field Study with Students

With our field study with Elissa Levy at Life Sciences Secondary School, students were able to finish the pre-test survey and the background survey. However, there has been an issue with their school network which blocked our log-in functionality on the SAGE website. Since we couldn't trouble shoot to arrive at a timely solution, the study is postponed until further notice. However, after the problem have occurred, we did analyze the potential problems that could have caused this and tried to resolve the issue for our future field studies with Elissa. We suspected that the school network may not support Angular Js, or might not support HTTP. The short-term solution we thought of are 1) bring students to Columbia's campus; 2) Get portable WIFI and set it up for the classroom during the field study; 3) Have students complete puzzles at home. Each solution comes with its own challenges and the most feasible one with the current COVID-19 situation would be having students finish the puzzles at home. This would not only have us proceed with our student study under the current situation, but presents us an opportunity to recruit more students from different school districts. Nevertheless, recruitment of target student group remotely also poses a challenge to our field study at its current stage. In the long term, the website will be transferred from HTTP to HTTPS and this will be helpful with the school network blockage issue when we are able to resume in person field studies in the future.

0.4.5 Field Study with Adults

To prepare for the adult field study, we have added additional materials to accommodate for our online participants. Since it would not be possible to offer them real-time tutorials and help, I created a tutorial recording and a warmup puzzle explanation document. In the 5-minute tutorial recording, I used a PowerPoint to teach the participants about the usage of the SAGE website and also to introduce them to the concept of sequences. The SAGE website tutorial includes how to find navigate to their puzzles, how to use the blocks and use the feedback and progress bar feature, etc. I have also explained the different version of SAGE the one may encounter due to the different conditions. To make the theme consistent, I have used the Scratch cat for all sample graphics. The sequence tutorial includes a brief introduction of sequences and three sample exercises. I have also explained and demoed all of the exercise solutions either through pictures or videos. After the participants are ready to start with the puzzles, they are first shown with the warm up puzzle. To help them understand the meaning of each block and

possible confusions they may have, the warm up puzzle explanation document includes the correct solution and also a step-by-step explanation of each block. Therefore, the participants can reference the guide if they have any questions. This document simulates the in-person guidance for the warm-up phase in the student study.

0.5 LIMITATIONS AND ASSUMPTIONS

Due to the unfortunate COVID-19 situation, we have to stop study studies with Elissa's classroom since the schools began to teach remotely. This also creates a barrier for us to explore collaboration with other teachers for student study. This leads to the decision of also doing adult field studies online in addition to student studies. In order to do so, we have to adapt the materials to our adult participants. However, this also created more opportunities for us to recruit a much larger pool of participants. This will help us improve our puzzles and surveys and evaluate the effectiveness of Parson's Puzzles in our SAGE environment as a tool to learn CT. One challenge we do have with online research is the authenticity of the information we gather. For example, we are dependent on the participant to provide us with their background information. With Mechanical Turk, which is the platform we are using, we are unable to filter the target participants we want. However, the demographic information may not be the specific area of interest when analyzing our results.

0.6 FUTURE WORK

Starting next semester, we will be connecting with Elissa again to continue our field studies in her classroom. Prior to the field study, it would be beneficial to go to their computer lab and ensure all websites and links work as expected. In the future, it can still be useful to gather feedback from Columbia undergraduates if it is convenient to do so. In this way, we are able to get quick and effective suggestions for each interaction of the project. In addition to the puzzles, I think it is so important to think about modifications of the database structure in Mlab. It could be interesting to add "order of puzzles" and "number of correct puzzles" into the database. These two features would help us better understand the learning process of the students and where most errors and confusion occur. It would also be beneficial to categorize the types of incorrect moves. In this way, the feedback bar will not only provide hints on the correctness of the move but also on the type of errors made if the move is incorrect. The opportunity to connect with

Outreach Engineering over the summer can also be valuable. Therefore, we should follow up with them and inquire about the kinds of collaborations possible over the summer.

0.7 Conclusion

The main focus of the semester is to perfect existing student study and create new materials for adult study. With the material we have now, we are ready to start any kind of field study. Future work can refine the conditionals puzzles for students, and analysis of data through Qualtrics and Mlab as we start to gather results. From there, we can readjust our current works and become closer to share the SAGE platform with teachers to use in their classrooms.