Over the past two years, our research lab worked to investigate the efficacy of an augmented reality intervention on the mathematical and social problem solving skills of eight secondary students with autism spectrum disorder (ASD). The following report outlines rationale and findings from the two single-case research design studies. Finally, implications of those findings are included for future teachers, parents, or other stakeholders working with secondary students with ASD.

Rationale

Mathematics skills are crucial to postsecondary success. Secondary students with ASD need instruction that explicitly prepares them to apply the skills they learn in school to real-world settings. Simply knowing *what* to do, without *when* or *why* is insufficient. Modified schema-based instruction (MSBI) is an intervention that has been effective in building mathematical problem solving of elementary and middle school students with autism, but has not yet been evaluated for post-secondary students. With generalization and independence as the ultimate goal, students with ASD need instruction that addresses the social skills necessary to execute such tasks. Technology can facilitate generalization training and provide non-stigmatizing visual supports for individuals with autism to use across settings. The proposed study sought to evaluate a technology-based mathematical and social problem-solving intervention which directly teaches how, when, and why to apply mathematics and social skills necessary for independence and success. Researchers used a single-case research design to evaluate the effects of technology-based modified schema-based instruction (TB-MSBI), specifically using augmented reality (AR) to provide video-based instruction and visual supports on an iPad and/or iPhone. This study provides valuable information to address the everyday issues and challenges that impact the quality of life and post-school outcomes of individuals with ASD.

Intervention

In two separate studies, the students were taught to solve percent of change word problems where they checked the correctness of their receipt, calculated an appropriate tip, and used socially appropriate interactions to sign and leave their receipt. Students selected a theme from the menu below (Figure 1), and all problems for the day centered around the theme of their choice. We used an augmented reality app called HP Reveal to show the students a short video about how mathematics can be used at that community location. For example, if the student selected the Taco Restaurant, the video would have been about going to Pancho's, ordering food, checking the receipt, and leaving a tip. Students then solved two word problems each day about their selected theme. Students used a graphic organizer (Figure 2) and electronic check list (Figure 3) to calculate an appropriate tip for various receipts. Below is a copy of the theme menu with community locations and the checklist for the student to monitor their progress.

Students learned to not only check their receipt for accuracy, but also to ask for a new receipt when needed. They then used the graphic organizer to calculate the tip, and add the tip to the original amount. Finally, students signed the receipt and returned the signed receipt to the "cashier". Students also watched a video model of how to solve the problem correctly, and then had the opportunity to change their responses if they wanted to do so. During generalization sessions, students ordered items at the school's snack shop instead of solving written word problems. They had access to a calculator during generalization sessions as well as the graphic organizer, but not the checklist.

Findings from Study One

All four students improved in their ability to check their receipt, request a new receipt politely, calculate an appropriate tip, calculate the final amount, and sign/leave their receipt (see

Figure 4 for graph of student performance). Three of the four students generalized these skills to a more realistic setting, and maintained their performance two weeks after their final intervention session. Participant One consistently scored 1 point during baseline sessions. His performance immediately jumped after intervention (6), and he met mastery after 10 sessions. The star on the graph indicates when we gave Participant 1 a highlighter to help him check the accuracy of his receipt to the word problem. Participant 2 consistently scored 3 points during all baseline sessions. After intervention, participant 2 jumped to a 7, and then reached ceiling level for two sessions, before dropping slightly for the final two intervention sessions. Participant Three also demonstrated a stable pattern of behavior during baseline with a score of 1, and then immediately jumped to 11 after intervention. Intervention scores for Participant Three fluctuated somewhat, but overall followed an upward trend. Finally, Participant Four scored 1 or 2 points during all baseline sessions, and also demonstrated an upward trend over intervention sessions, reaching mastery after 10 sessions. Students also learned to use the video model to monitor their own accuracy and often self-corrected at various rates (see Figure 5 for details).

Findings from Study Two

Three of the four students improved in their ability to check their receipt, request a new receipt politely, calculate an appropriate tip, calculate the final amount, and sign/leave their receipt. Students also generalized some skills when making a purchase at a local mall food court. The results are graphed in Figure 6. The Y axis (vertical) represents each of the 12 steps the student could complete independently correct (6 steps for each of the two problems), while the X asis (horizontal) represents the sessions held across the study. Therefore, each dot represents how many independently correct steps each participant completed during each session.

Participant One consistently scored 0 points during baseline sessions. His performance gradually increased after intervention for six sessions. The star on the graph represents when we began using the more explicit task analysis with participant 1 (see Figure 7). With that task analysis his scores increased to 12 for one session, and were then variable over five sessions. Wanting to further help participant one, we then gave him the opportunity to earn a short break based on his performance (green circle on graph; Figure 8 shows what was provided to the student). After four additional sessions, participant one met mastery criteria (two sessions at 10 or above) and finished the study. Participant two also completed zero steps independently correct during baseline sessions, but immediately jumped to 9 out of 12 after intervention. Participant two completed the study in the shortest amount of time, reaching mastery criteria over only five intervention sessions. Partcipant three also demonstrated zero steps independently correct during baseline, but did not immediately improve after intervention. We tried to add to the MSBI instruction first by providing performance reinforcement (i.e., the participant could earn 10 minutes of iPhone time if he solved a set number of steps independently), which led to a small improvement for two sessions. Then we added a system of least prompts (indicated by a diamond on the graph), correcting participant three after each step of the task analsyis as needed. On the fourth day of using that system, participant three increased to his highest score of 5 steps. Participant three did not reach mastery criteria after eight intervention sessions. Participant four also completed zero steps independently correct during baseline sessions. After intervention, however, he immediately increased to 4 steps correct, and with the addition of the system of least prompts (correction at the step level), he continued to improve, reaching mastery criteria after just five sessions.

During generalization sessions, students went to the food court in the mall and ordered food. They were then given a receipt (sometimes correct and sometimes incorrect) and observed to see what they would do. Students were less successful applying their new mathematical knowledge during these sessions. For example, none of the students calculated a tip based on an appropriate percentage, and none of them added any kind of tip to their total cost. They were more successful, however, with the social aspects of purchasing. For example, several students were not able to identify a receipt prior to the study, but by the end they knew what a receipt looked like and what it was for. Two students also identified incorrect receipts from the foodcourt after intervention.

Implications/Suggestions

While the results of these two studies only contribute preliminary evidence regarding the efficacy of MSBI and AR to teach personal finance problem solving skills, several implications for practice can be gleaned from the findings. First, practitioners can explore using AR as a platform for students to view video-based supports. HP Reveal is a free app that can be used on any mobile device to upload and view videos. By putting the videos on a mobile device that is controlled by the student, practitioners are making space for students to self-manage and even self-fade supports. The anchor and social problem solving videos in this study functioned like a social story to teach the hidden curriculum of executing personal finance tasks in the community. Relatedly, practitioners could create similar videos to prime students and give practice opportunities in a safe environment. Mobile devices such as iPods can decrease stigmatization and normalize supports that many adults use (e.g., calculator, to-do list). It is important to note that none of the participants in the current study needed more than on initial training on how to navigate between multiple apps on the iPod.

Teachers who work with young adults with extensive support needs are expected to teach both academic and functional skills to increase independence and facilitate successful transition into adulthood. The results of this study suggest a multi-component intervention combining TAII and MSBI can support acquisition of both mathematical problem solving skills and social problem solving skills in the functional context of personal finance. Given the poor post-school outcomes for individuals with ASD, teachers should consider utilizing teaching strategies that target and improve both academic and social skills.

Specific suggestions for practitioners working with students with ESN include:

1. Task analyses or checklists can help students monitor their own progress
2. Video models can help students check their work, and monitor their own mathematical thinking
3. Thematically based problems combined with anchored videos can provide context for mathematical content, facilitating an understanding of the relevance of what they are learning
4. Using contextually based mathematical word problems, with anchored instruction, may promote generalization of these skills into different contexts
5. Visual supports can be used to help organize complex mathematical content

Appendicies

Figure 1

Theme Menu

Figure 2

Example worksheet

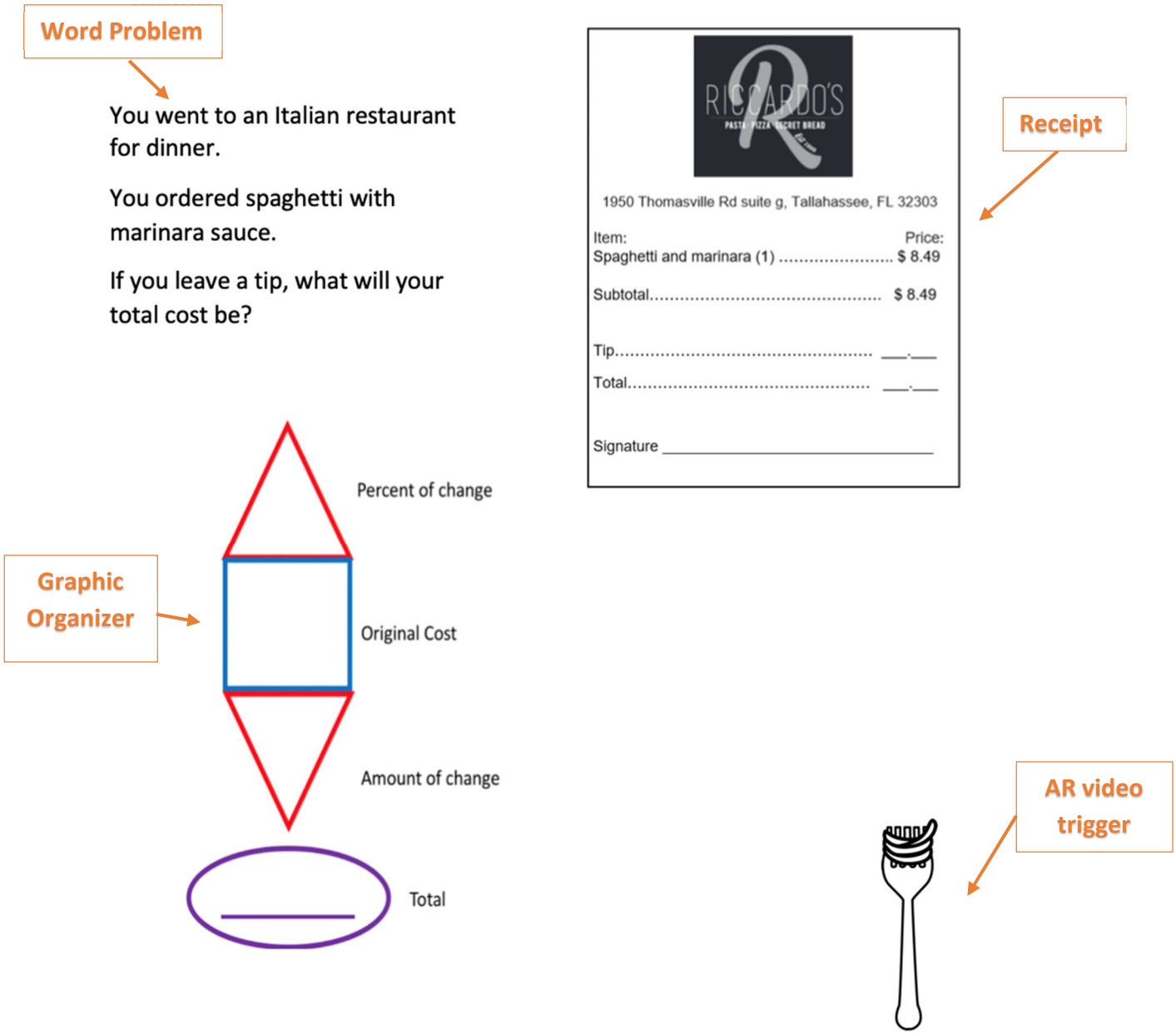


Figure 3

Electronic checklist

Figure 4

Number of steps solved independely correct during study one

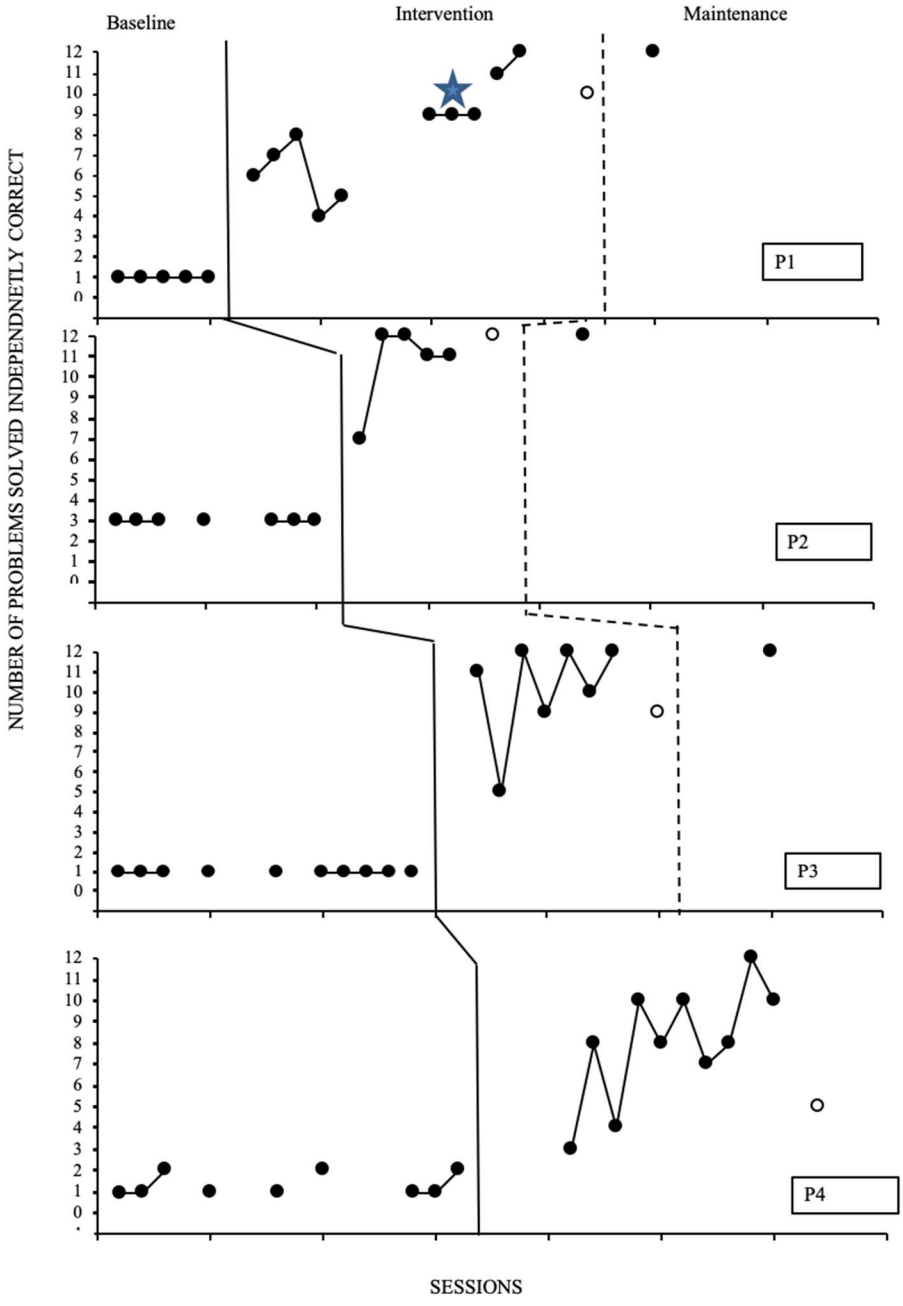


Figure 5

Self corrections during study number one

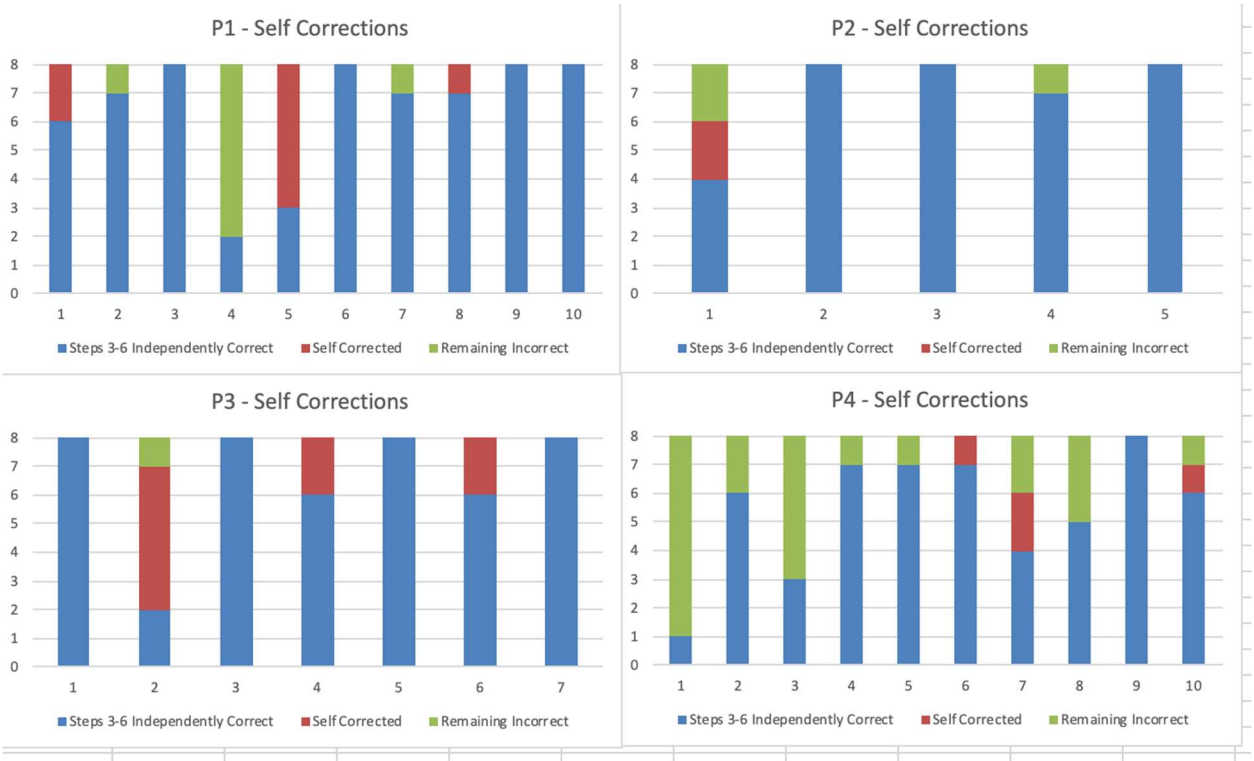


Figure 6

Number of steps solved independely correct during study two

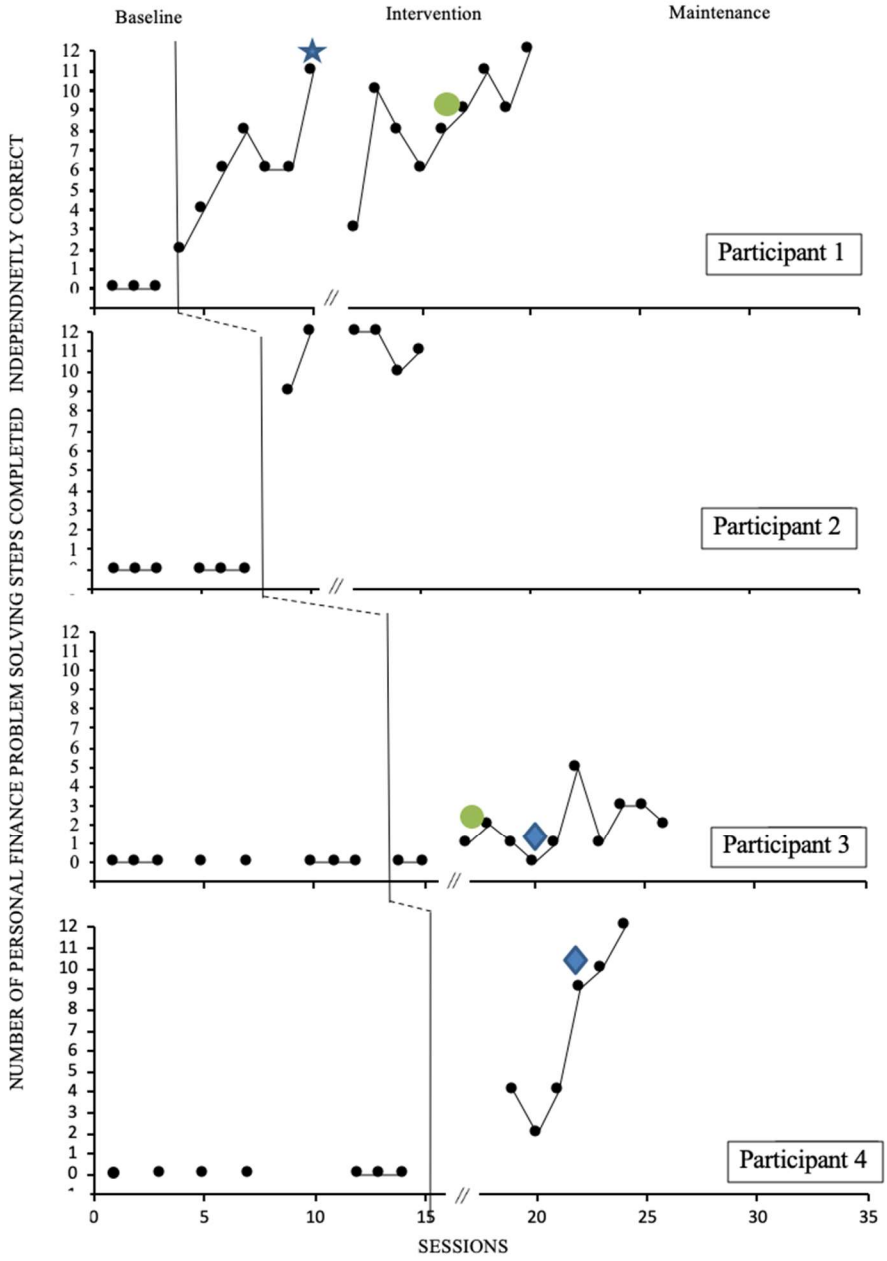


Figure 7

Paper-based detailed checklist

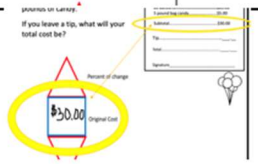
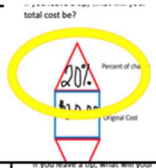
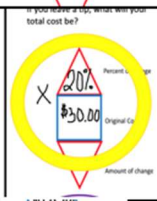
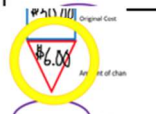
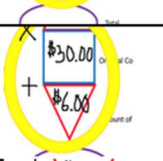
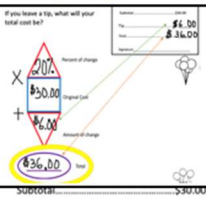
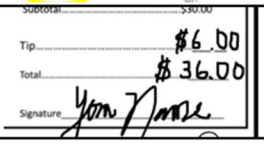
	Task		
Step 1	Check if the receipt is correct		☐
Step 2	Write the subtotal in the blue square for original amount		☐
Step 3	Write the percentage of tip you want to leave in the top red triangle		☐
Step 4	Multiply 20% by the original amount to find your tip		☐
Step 5	Write the amount of change in the bottom triangle – this is your tip		☐
Step 6	Add the original cost and the amount of change		☐
Step 7	Write the final cost in the purple oval		☐
Step 8	Write the total amount you want to leave on your receipt		☐
Step 9	Sign your name on the receipt and return to the cashier		☐

Figure 8

Performance Reinforcement Graph

12																	
11							X										
10							X										
9							X										
8				X			X										
7				X			X										
6			X	X	X	X	X										
5			X	X	X	X	X										
4		X	X	X	X	X	X										
3		X	X	X	X	X	X	X									
2	X	X	X	X	X	X	X	X									
1	X	X	X	X	X	X	X	X									
date	11/13	11/15	11/18	11/19	11/20	11/21	11/22	12/2									

To earn my break, I will complete at least _____ steps correctly, by myself.