Design and Field Study of Motion-based Informal Learning Games for a Children's Museum

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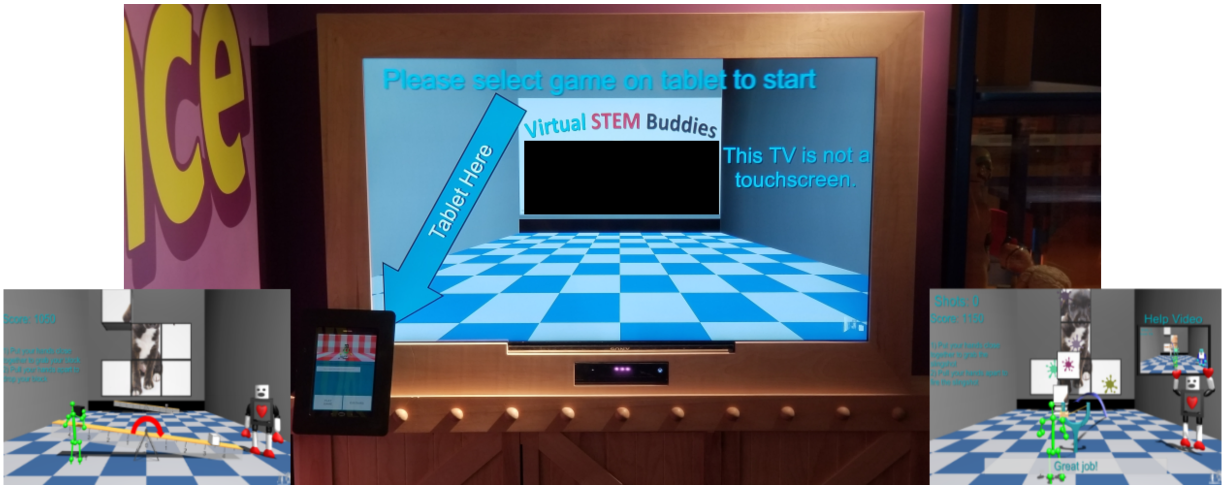

Figure 1: The Virtual STEM Buddies kiosk at the museum along with screenshots of the Lever Hero (left) and Slingshot (right) minigames.

Abstract

This paper discusses our experiences, lessons learned, and future research directions in designing and running a field study of a motion-based gaming system for visitors of a local childrens museum. The system, named Virtual STEM Buddies, uses a large-screen kiosk to present minigames with interactive 3D content, such that the level of performance exhibited by participants indicates a level of understanding about the STEM concepts. The evolution of the system is presented, alongside evidence of improved usability and engagement throughout several prototyping iterations where the system has been used by thousands of visitors. We also describe a recently integrated mid-air free-hand interaction technique that facilitates selection and manipulation while staying accessible and intuitive to child visitors. Ultimately, we aim to learn how to best enable longitudinal interactions with the system that integrate virtual learning with the physically-rich museum learning environment.

Keywords: Public display, Kinect, Virtual Agent, Gesture.

Index Terms: K.6.1 [Management of Computing and Information Systems]: Project and People Management—Life Cycle; K.7.m [The Computing Profession]: Miscellaneous—Ethics

1 Introduction

Early childhood is a critical time for learning and forming attitudes about science, technology, engineering, and math (STEM) [1]. Early exposure to STEM ideas and experiences is widely recognized to serve as a strong indicator of future interest in STEM areas [26]. However, the majority of this research has taken place in formal settings (e.g. schools) and informal settings for older children (e.g. science museums). In such museums, visitors learn through reading or listening to messages at exhibits. Children's museums, who cater to families with young children (i.e. ages 3-6), by contrast, are underexplored as STEM motivators [8], and largely unexplored with respect to technological interventions.

The opportunity to influence the STEM knowledge, skills, and attitudes of children and their families in this space is vast, as, according to the Association of Children's Museums, over 30 million visits are recorded each year in hundreds of institutions around the world [15]. Studies show that parents consistently struggle to help children learn in informal settings [6]. Exhibits for young children often involve "messy", energy intensive, creative activities, such as painting, building blocks, ball-pits and sand-pits, playground equipment, and dress-up. They also tend to have little educational messaging explaining exhibits and providing additional facts, mainly due to the low average reading ability of child visitors and inability of parents to attend to children and these messages simultaneously. While STEM concepts may be embedded throughout, discovering these concepts may be challenging for both children and parents. Thus, making STEM learning opportunities and STEM foundational knowledge more salient in children's museum exhibits without diminishing the appealing qualities and experience is a major need within informal learning research.

To help meet this need, we introduced the Virtual STEM Buddies (VSBs) exhibit. A VSB is a pedagogical agent who is designed and personalized by a child visitor and attempts to promote STEM learning by engaging the child in social interactions, particularly 3D educational games with a body-motion-based user interface. While children play games by moving their bodies and performing gestures, the VSB provides motivational messages to the child, helps children discover STEM conceptual knowledge used to play the game, and relates game concepts to physical exhibits within the museum. In other words, the VSB is intended to be a playmate, co-learner, and guide.

In this paper, we describe how the VSB system, games, and interface have been designed with guidance from research in embodied cognition and within the constraints of the physical environment, target audience, topic area, and technology. In addition, the exhibit has been installed and running at a local children's museum since January 2017, and has undergone several major design revisions, particularly with respect to the user interface and gaming features.

2 Related Work

2.1 Virtual Pedagogical Agents in Museums and with Children

The VSB exhibit has been inspired by previous research projects involving animated virtual agents being deployed in museums and with children. One of the earliest was "Sam", a virtual playmate for children with autism [20, 23]. Though driven primarily through a Wizard-of-Oz interface, children with autism could engage in social interaction with the virtual playmate in a more controlled way than would otherwise be comfortable for them with a real one.

Several virtual museum guides have been built, with the majority of research studying how to improve agent-visitor interaction. "Max" could engage in verbal conversation with visitors, answer questions, and provide information about exhibits [13]. "Ada and Grace" had a similar focus, but added more narrative and graphical appeal [22,25]. Another approach was taken with "Coach Mike", which had a more pedagogical, exhibit-specific role, i.e. it was not an exhibit itself [14]. "Tinker" was a highly innovative museum guide, in that it not only catered to new visitors, but also returning ones through the use of biometric authentication [4]. An integrated hand-reader eliminated the need for external identifications, such as wrist-bands or lanyards, and also served to locate the user at a specific spot.

2.2 Virtual and Augmented Reality Exhibit Interfaces

Prospective exhibits for public spaces have highly unique constraints limiting their interface. Chief among these is a need to be safe and robust, particularly if left unsupervised. This greatly reduces the design space for virtual and augmented reality exhibit interfaces. For example, hand-held devices would be quickly lost or broken, and may require perpetual replacement of batteries. Even the inclusion of instrumented mechanical interfaces (e.g. buttons, levers, etc.) is a daunting prospect, as these may need frequent calibration and repair. As a result, the vast majority of exhibits use highly resilient interactive surfaces [7] or require users to bring their own devices [2, 3]. For similar reasons, few exhibits use head-mounted/hand-held displays or glasses, instead employing projectors or LED/LCD displays (e.g. [12] and [19]). Also, 2D content and interaction techniques are more common than 3D content and interaction techniques [16]. As such, though interactive computer technology, graphics, and games are certainly on the rise in public spaces, there are great differences in their interfaces relative to other settings, such as at home or in a research laboratory.

Some more recent systems have been exploring 3D user interfaces in public spaces that work with young children. Non-invasive object sensing has become popular, with many systems derived from cheap and widely available depth-sensing cameras such as the Microsoft Kinect series. Such technologies have been used successfully to make objects at existing exhibits more interactive and visually engaging. For example the augmented reality sandbox uses an overhead Microsoft Kinect and projector combination to visualize elevation contours on a physical sandbox [17]. Virtual water can be unearthed by digging, and created when it rains from their hand when held above the sandbox, flowing through the watershed created by the sand structure. Another recent approach is to provide real world task feedback through sensors. One such system tracks colorful building blocks using a Kinect, providing congratulatory feedback when children achieve goal structures detected by the sensor [5].

Another approach taken with the non-invasive technology is a body-motion-based game, which requires less physical infrastructure and maintenance, but still engages the user's body and mind. For example, Homer et al. describes a game to help children read [10]. Children engage with a digital storybook and progress through the book by holding body postures. However, motion-based games come with many usability challenges, particularly when employed without a tangible interface or controller (i.e. free-hand, mid-air interaction). Without effort in designing a high usable interface, free-hand mid-air interaction may become more about the interface itself rather than the virtual content, as exemplified by users "dancing" in front of displays rather than playing the game as intended by the designers [24]. Lack of a physical button or sensing surface makes selection more challenging, and often unintuitive. In addition, when employed in a public space, the interface must cope with a variety of unfamiliar users without much (if any) opportunity for training or calibration [18]. Attempting to make the interface more intuitive is one solution. For example, Hespanhol et al. tested four one-handed gestural metaphors and one bi-handed metaphor based on similar actions in the real world (pushing, dwelling, lassoing, grabbing, and enclosing) [9] for selection. Results supported dwell-based selection, which did not involve motion and as such was not confused with object manipulation, although newer technology may better support grab metaphors [27]. For manipulation, one of the most comprehensive techniques was described by Peng et al., who introduced a "handlebar" metaphor. This bi-manual technique uses both hands to move and rotate selected objects [21]. Though requiring both hands, the handlebar metaphor holds promise for intuitive 3D manipulations. However, the extent to which children are capable of learning and using this technique has not be measured

3 Current System Implementation

3.1 Hardware

Our VSB exhibit is a kiosk (shown in Fig. 1) which consists of a 60-inch large screen LCD television, a Microsoft Kinect for Xbox One (Kinect 2 Time of Flight RGB-D camera) behind a clear acrylic panel, and the computer (Alienware Core i5 5600K, NVIDIA GeForce GTX 1060). These components are enclosed in a wooden structure that was designed by a local company to be consistent with the surrounding exhibits at the museum. Attached to the enclosure is an Android Tablet (Samsung Galaxy Tab S2), protected by its own metal enclosure, with a power/charging wire running into the kiosk. The kiosk was placed in the corner of the science exhibit area of the museum in December 2016, where it remains as of January 2019. It occupies relatively little space within the exhibit when not in use but does require a substantial (approximately 2m x 3m) clear area in front of the display for user motion. This compromise was seen as acceptable, as the space can be occupied for other purposes when not in use.

We opted to include the tablet for two main reasons. First, in previous studies, we found that the Kinect was cumbersome to use as a mid-air selection interface for game menus [11]. A touch screen interface would allow for efficient, exact selection and manipulation (relative to the Kinect interface) and younger visitors would likely be familiar with how to use such an interface. Additionally, several exhibits around the museum utilize a tablet interface. Thus, we opted to try a combined Kinect and tablet interface where the Kinect could be used for playing the games and interacting with the VSB and the tablet could be used for efficient, exact selection and manipulation when required, such as selecting a game to play. Second, the tablet could act as an identification sensor, which could detect various types of NFC/RFID technology. This way a user could login to the exhibit for a tailored experience if desired.

3.2 Software

One of our requirements we have for this system is that it needs to be tested and upgraded in-place. To make deploying these upgrades easier, we set up the computer for remote access using the Google Chrome remote desktop application. This also allows us to observe (anonymous) interactions with the game in real time from our laboratory. While we have this remote link, we still have spent several days observing interactions in person to collect more information about how the system is being used. Both of these observations allow us to make informed changes to the system based upon user interaction.

The kiosk software was made using the Unity3D game engine. Currently, players walk up to the kiosk and use the tablet to begin interacting with it. Using the tablet, a player can select a game to play and choose whether or not to customize the VSB. If players choose to customize the VSB, they are able to name their VSB from a dropdown menu as well as select an area of interest. This area of interest is used to select the image players will complete as they play minigames. Players can then choose the change the shape and colors of various parts of their VSB, such as their head, arms, legs, and body. Examples of customized VSBs are shown in Fig. 2. Additionally, players can also choose whether or not to save and retrieve their customized VSB for later visits by entering a unique code that is sent as a text to their parent's cell phone. If the player does not choose to save the VSB as a code, the system simply updates the current default VSB. This updated default VSB is saved so that even the default VSB can change game to game.

Figure 2: Six customized VSBs made using various shapes and colors.

While interacting with the kiosk, the VSB is intended to act as a guide and friend, explaining how to use the system and the scientific concepts behind the game mechanics as well as providing encouragement when the player gets an answer correct or hits a block. This encouragement consists of a verbal remark as well as a "cheering" gesture. The VSB does this by displaying help text at the bottom of the screen whenever the player starts the game. If a player did not successfully perform actions, such as grabbing or releasing the slingshot, within a certain time, the VSB prompts the player again with the appropriate help message. In addition to showing up as text, these help messages are also read aloud using text to speech to make them more salient. This was added as we noticed that parents were not always reading the instructions to the kids. Thus, we decided text to speech might help show kids how to play the games better than just text on the screen. There is also a prompt to instruct players to stand back if they are too close to the Kinect and cannot be detected. Finally, we also have help videos demonstrating how to play the game. Currently, these help messages and videos only cycle through once per game. To address players walking away from the kiosk mid-game, there is a timeout that automatically exits the game if a player cannot be found and we have basic instructions on how to play the game displayed on screen at all times. Examples of these messages can be seen in Fig. 3 and Fig. 5.

Currently, we have two minigames deployed at the kiosk: Lever Hero and Slingshot. The Lever Hero minigame is designed to introduce children to the concept of balance by getting them to balance incoming see-saws (a recognizable form of a lever). The Slingshot game is designed to introduce children to the concept of trajectories by getting them to hit target blocks with a paintball by using a slingshot. We will cover the implementation of these minigames in more detail in the next section. Once a game has been started, players control their on-screen avatar by moving their real world bodies. The VSB then guides them through a series of nine problems, providing additional information about the game. As players complete problems, the blocks being using during the game are used to generate a picture. This picture is based upon the area of interest selected when customizing the VSB. Finally, players are also able to build up their score the faster they complete the problems up to a max of 200 points per problem. There is no score penalty for answering incorrectly or missing a target. Scores were added to promote motivation for game mastery and competition. Finally, these games are designed to be completed in two minutes or less to allow for many visitors to play games each day.

3.2.1 Lever Hero Minigame

As stated earlier, the Lever Hero minigame is designed to introduce children to the concept of balance by getting them to balance incoming see-saws (a recognizable form of a lever), shown in Fig. 3. Its name is a play on words of the name of a commercial game, "Guitar Hero". Similar to Guitar Hero, where notes approach the player, see-saws approach the player with a single weight (a cube) falling down at a random location on them. In order to progress through the game, the player needs to balance the lever closest to them by placing their own weight block at the correct location on the lever. The player's weight is equal to the weight on the lever. The player can grab their block by bringing their hands close together, causing the block to snap to their hands. They can move the block by moving their body side to side. Their avatar is snapped to the lever so that they only move side to side along the lever and not forward and back away from it. When they think they are at the correct location, the player can release the block by pulling their hands apart (Fig. 4). The balance of the lever is only adjusted when a weight is added or removed. Additionally, there is an arrow at the center of the lever that visualizes the current torque. Once the player answers correctly, the VSB congratulates them and the next lever advances automatically while the original weight block flies to the back of the scene, becoming part of the picture from their area of interest. When the player has completed all nine problems, the picture is also completed and the game ends. The sequence of these blocks is randomized every time so that every play through the game is likely to be different from the last.

3.2.2 Slingshot Minigame

As stated earlier, the Slingshot game is designed to introduce children to the concept of trajectories by getting them to hit target blocks with a paintball by using a slingshot (Fig. 5). The slingshot minigame consists of nine targets (textured cubes) the player must hit with paint balloons fired from a virtual slingshot. When fired, the paint balloons travel in ordinary projectile motion. As in Lever Hero, the game proceeds in stages, each consisting of a target cube to hit balanced on a pedestal. When a target cube is struck, that stage is complete, and the cube moves to the background, gradually forming an image from the interest area that they selected. Targets spawn randomly in a grid in front of the player, varying in height and location. In addition, when the fired balloon hits an object, it bursts, turning into a splat on that surface. If the object is the target, this splat will stay on the final image. This motivates trying to hit the top or sides of the target cube rather than the front, which is a harder

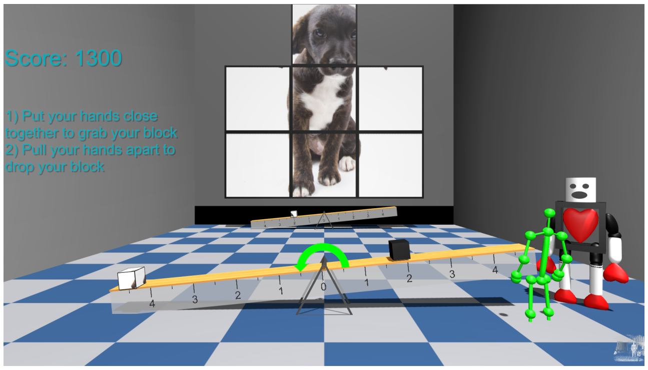

Figure 3: An example of a player playing Lever Hero. The player must move their body to balance the torque from the object. The VSB stands by, observing the player. A partially completed picture shows game progress.

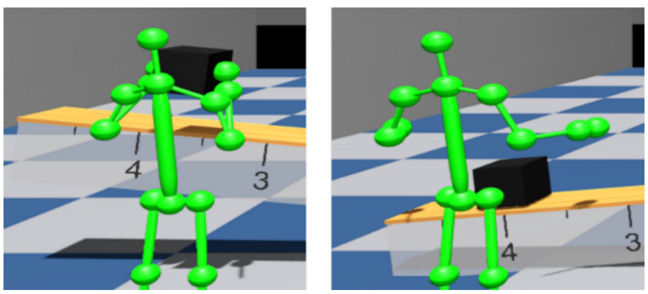

Figure 4: A player holds a block and is moving it to the correct location in Lever Hero (left). A player has placed the block on the lever (right).

problem in 3 dimensions. To facilitate 3D targeting, particularly on a non-stereoscopic display, the trajectory of the slingshot is shown with a series of arrows, terminating at the object the balloon will hit. Grabbing and releasing the slingshot is done in a manner similar to grabbing and releasing a block for Lever Hero: when the player brings their hands together, the slingshot pouch snaps to their hands; when they pull their hands apart, the slingshot fires (Fig. 6). In order to aim the slingshot, the player moves their hands and body around.

4 Lessons Learned

4.1 Hardware

Our system has been running, nearly continuously, for the last two years since the installation of the software in January 2017 without any intervention or maintenance from the museum staff. This was somewhat surprising, and relieving, to us, that a research-quality exhibit could survive the children's museum environment. Our first problem that occurred was that children spun around the Tablet PC enough times that the power cord became frayed and broke. The tablet was better secured and the problem has not reoccurred. Our second problem was that the graphics card (NVIDIA GeForce GTX 970) within the computer broke twice. We attributed the first break to a fault with the graphics card itself or due to poor ventilation. After the second broken card, holes were drilled into the kiosk to provide better ventilation, we also replaced the graphics card with the NVIDIA GeForce GTX 1060, and the museum staff began turning the computer on/off daily so that it is not running when the museum is empty. We have not had any further problems as of 1/21/2019 since replacing this card on 8/10/2017. Thus, our kiosk implementation can be considered a success as it is a robust interface that can withstand the daily use at the museum with minimal

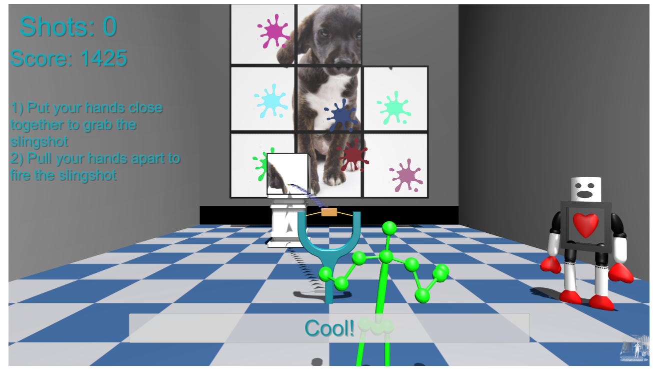

Figure 5: An example of a player playing the Slingshot minigame. The trajectory of the paint ball is shown with the purple arrows and paint splats indicate where the player hit the block.

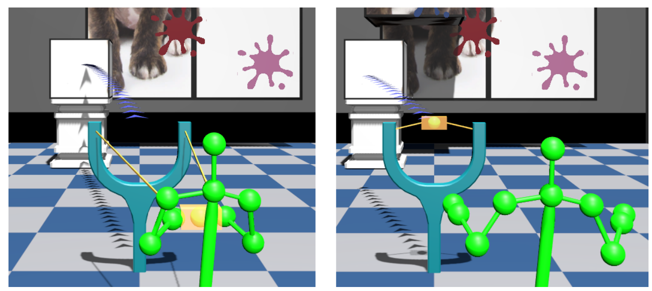

Figure 6: A player pulls back the slingshot to attempt a shot with the trajectory is shown (left). A player has fired the block by separating their hands (right).

maintenance.

4.2 Software

While we consider our kiosk hardware design a success in regards to its durability, we have struggled on the software side. For this content, we constrained ourselves, initially, to a single topic — the six simple machines. This was to simplify the prototype development and to align with an existing exhibit that involved a larger machine that demonstrated use of those simpler machines. Combining this limitation with using the Kinect as the main interaction device has made it hard to design minigames for VSB. These minigames not only have to be controlled with a Kinect but also must have an intuitive interface that can be used by younger children. They not only need to be fun and engaging but also scientifically valid. As a result, our first prototype, which ran from 1/10/2017 until 5/31/2017, only consisted of the Lever Hero minigame. This version had a few differences from the current version: no permanent on-screen instructions (only had the prompts from the buddy), no score, and different control scheme. For this older version, players would just move their body and their weight block would move with them, gradually balancing the lever as they approached the correct location. To answer problems, the player could either jump (over to the next lever) or wait for a few seconds in the correct location and the game would advance automatically. This control scheme made Lever Hero much easier than it is now, reducing the problems to a binary decision to move more left or right depending on the direction and magnitude of the torque arrow. The player could also see when they had the right answer before they submitted it. As a result, players did not need to think about what was happening in regards to balance in order to get the correct answer most of the time. As a result, this version was viewed as too simplistic to motivate even young children and did not afford opportunities for parents to help children learn the concepts.

During this time, our system logs suggested that games were used approximately 4,000 times (an approximation is provided because we cannot be sure of what constitutes legitimate use from system logs, but we derive this from game play that was at least 15 seconds long, enough time to potentially solve a problem). To contrast these results, the next major prototype, which ran from 6/1/2017 until 9/5/2017, had 5,319 interactions with the exhibit. The average time played increased from 75s to 91s. Furthermore, since we can now track the statistics of solved problems, we can determine that most of this game play has been legitimate, with about 62% games (3,297) featuring at least one correct solution, and 37% (1,976) with all 9 stages completed. On average, 4 stages have been completed for each game played during the time period. Thus, these changes seem to be an improvement over the first prototype, due to the increased number of plays even in a shorter time frame.

We broke down this new prototype into three different upgrade periods to see the impact of changes between them. Our first upgrade added additional data logging to better track user performance and minor bug fixes to lever hero; it can be considered a baseline for this version (UPGRADE1). This upgrade ran from 6/1/2017 to 7/31/2017. The second upgrade added the Slingshot game after the graphics card was replaced on 8/10/2017 and ran until 8/19/2017 (UPGRADE2). During this time, the Slingshot game was played approximately twice as often as Lever Hero during UPGRADE2 (237 games vs 136 games). Seeing how much more often the Slingshot minigame was being played compared to Lever Hero, we decided to update Lever Hero to use the new grab and release interface used in the Slingshot minigame (UPGRADE 3). This upgrade ran from 8/20/2017 until 9/5/2017. After this upgrade, the discrepancy between number of plays between the games was reduced (441 Slingshot vs 321 Lever), showing that Lever Hero has likely become more popular. The median number of problems solved also increased to 6 out of 9 for the lever game, and 9 out of 9 for the Slingshot game. The effects of the revisions were noticeable and significant as shown in Table 1.

Table 1: Play stats for both minigames completed for each second prototype upgrade.

Upgrade	Duration (days)	Lever Games	Lever Play Time (s)	Lever Problems
BASE	140	4000	75	-
UPGRADE1	61	2162	82.5	3.519
UPGRADE2	10	136	88.32	5.132
UPGRADE3	17	321	139.81	4.913
Upgrade	**Duration (days)**	**Slingshot Games**	**Slingshot Play Time (s)**	**Slingshot Problems**
UPGRADE2	10	237	100	5.16
UPGRADE3	17	441	115.3	5.91

The only change made after UPGRADE3 was adding VSB customization, which was deployed on 9/6/2017. As of 1/21/2019, only 176 custom VSBs have been saved with a code. We currently do not have a mechanism to track how many times the default VSB has been changed. This number is very low compared to the number of games played during this time (20,825 combined). This is concerning as the buddy should be a focal point of the exhibit. Unless visitors choose to return to the exhibit, there is not an apparent benefit for customizing and saving their own personal VSB in our current implementation, which is likely a contributing factor. Another major problem with the buddy itself is that it is not directly engaging with the player. The buddy does jump or cheer when the player gets an answer correct, but it is not salient that the help/encouragement messages are coming from the buddy itself. Improving how the buddy interacts with the player is our next main focus for this project.

5 Conclusions and Future Directions

This research showcased the value of continuous iteration and redesign in the VSB system, which is part of the genres of public displays, virtual agents, and motion-based 3D games. These interfaces are notoriously difficult to design, with few examples of field-validated systems. Though early prototypes were seen as a partial failure, we also presented evidence that interface improvements yielded large gains in critical game play statistics, such as the time played and player success. Over time the VSB system has evolved into a successful exhibit with a consistent, usable interface and engaging STEM minigames that continues to be used and upgraded.

Our next steps include deploying the next prototype that is currently in development to the museum. The changes being implemented in this prototype are aimed at making the buddy a more integral part of the entire experience as well as overhauling the flow of each game. Currently, the VSB stands to the side, out of the way of the levers or targets, and provides instructions and encouragement from there. While being to the side declutters the game interface, the buddy is not interacting with the player directly. Additionally, our instructions and help videos are still very lengthy and can take most of the duration of a single game to complete. To address both of these problems, we are changing the minigames so that there is an interactive tutorial at the start of each game. For the lever game, this tutorial starts with the player picking up a block that the VSB is holding. The VSB will then instruct the player to place the block somewhere on the lever. This block becomes the weight that needs to be balanced, causing the lever to rotate. The VSB then instructs the user to retrieve another block from them and explains that they must balance the lever by placing the block in the correct location. Once the block is correctly placed, another lever approaches and the last step is repeated with a randomly placed weight. After this point, the VSB will step aside and provide players with the blocks they need to play the game. The game then proceeds as in previous prototypes. The VSB will provide guidance as needed if the player is struggling, repeating the same phrases from the tutorial. Throughout the tutorial, the VSB provides encouragement as each step is completed. A similar tutorial will also be implemented for the Slingshot game. This tutorial allows the VSB to provide instruction while also interacting with the player. It also allows the player to practice the moves they need to perform to play the game step-by-step rather than all at once. In future updates, we may make this tutorial optional for repeat users if it is seen as a hindrance for the exhibit.

Once this prototype is deployed, we intend to assess the changes between this prototype and our previous prototypes in terms of usability, engagement, and customizing VSBs. Second, we want to assess whether or not high-fiving the buddy throughout the tutorial impacts whether or not users continue to play the game and/or play additional games and whether or not it impacts the sense of copresence with the buddy. If the tutorial is found to be successful, our next iteration would be to make the current minigames become progressively harder, such as adding additional weights for Lever Hero and have part of the trajectory disappear for Slingshot. These additional levels would also allow us to go into more detail about the underlying STEM concepts without overwhelming the player or their parents by trying to cram it all into a single game. This way the basic level gives players an introduction to the concept and additional levels go a little more in depth.

Another major change for this or a future prototype is the addition of another minigame: a block stacking game. A major problem with the way our current minigames are implemented is that they are not ”temporally” engaging, meaning that users can take as much time as they want to complete a problem. We have tried to address this by adding a score that depends on time. However, this does not equally motivate all players as some want to improve their score/time and others do not. Our goal with this game is to better engage the users because they need to react in real-time to complete the game. To do this, we are working on a block stacking game, where the player must stack 9 blocks to complete the game. If users miss too many blocks or their stack falls, the game ends. This game will allow us to discuss more STEM concepts (such as gravity and friction) as well as provide a more temporally engaging game. Additional levels can be added to this game that incorporate different kinds of surfaces/materials that would affect how friction is acting on the stacked blocks.

We are also aiming to better utilize the massive amounts of data being collected from the system. While gameplay logs are relatively small, we are also logging tracking data frame-by-frame to the kiosk. The potential information within this data could be used to further tailor the system to visitors' needs (e.g. make the games easier to play for smaller or taller players), to better understand participant behavior (e.g. how they are attempting to solve problems), and to understand the dynamic situation in front of the kiosk (e.g. how many players are there, who is trying to play vs observing, or who is at another exhibit). Furthermore, we are adding new data collection to the system. Future versions will track visitors around the museum using RFID technology, also incorporating this technology into the VSB exhibit itself. This data will further allow the VSB to tailor the user experience. It may directly include references to exhibits the family has already visited, and can suggest new ones.

Finally, a major part of our future work with the VSB system will be actively investigating the educational outcomes of interaction with the exhibit, particularly in context with visitors' overall museum experience. Our current studies are limited in their power to determine such educational efficacy. This will require more in-depth observation and evaluations of children's and parents' experiences and how this changes behavior at this exhibit and other exhibits. However, we are encouraged by the present usability of the system and believe that future studies will yield great insights into how these technologies can help people learn in informal settings while not diminishing them.

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