A Usability Study on Shape Shape Hooray: an Adaptive Educational Game Associating 3D Geometric Shapes to Daily Objects

Winna Mia Victoria D. BUENVIAJE[a*]**, Ma. Anniela B. DELA CRUZ**[a] **& Ingrid Marie Therese P. FADRIQUELA**[a]
[a]*Graduate Studies, Ateneo de Manila University, Philippines*
*winna.buenviaje@obf.ateneo.edu

Abstract: Situated learning theory argues that learning is embedded within an activity, context, and culture. It posits that students are more likely to learn if they have an exposure to the authentic context of the learning environment. Based loosely on this theory, Shape Shape Hooray is an adaptive educational game that aims to teach basic 3D geometric shapes by allowing basic education students associate 3D shapes to daily objects. As an adaptive game, this paper discusses the paths developed for different kinds of players (no prior/low prior, average, and high prior knowledge). A usability test was conducted to which a generally positive score was acquired. Various kinds of metrics (task success and task indicators) and the Systems Usability Scale (SUS) were also tested to find out the game's impact on user experience and to evaluate possible design directions and improvements for Shape Shape Hooray. We found that respondents were highly impressed with the game's usability, scoring 81.5 on the SUS. Future work will include educators' testing on the game's usability, testing of learning to students, and consultations with programmers for expert validation.

Keywords: adaptive learning, educational game, stealth assessment, situated learning theory

1. Introduction

In the discussion of shape recognition and properties as a skill by Virginia Kindergarten Readiness Program, it is stated that learning shapes is an essential building block of a child's early stages of development which makes it very important as children tend to notice objects by shapes rather than by color. A learner who is able to understand shapes specifically and accurately can connect with the objects around them, and use them more effectively in the context of their environment.

Situated learning means creating meaning from the real activities of daily living (Stein, 1998). It posits that learning is embedded within an activity, context, and culture (Lave, 1989). Experiments show that situated learning occurs best when done in the context of authentic tasks (Oppermann, 2006). This allows for an increase in learning effectiveness, efficiency, and satisfaction as well as the replicability of learning results.

Shape Shape Hooray is an educational game designed for students in grades 1-2 of the Philippine K-12 curriculum. Players drag digital 3D shapes into containers and the game will issue correctness feedback. When players are able to correctly drag chosen shapes to their proper containers, the objects would rotate to show and demonstrate their dimensions in 3D space. In addition to this mechanic, it was designed to be adaptive such that students have control over the pace with which they interact with in-game objects and finish levels. Features to engage active participation as well as goal-directed storylines were included. As the narrative of the game unfolds, student users are afforded the capacity to experience local culture by interacting with digital representations of their local vicinity embedded within the game. The game covers basic 3D geometric shapes i.e. cube, cylinder, cone and sphere. A drag-and-drop mechanism was implemented.

This paper presents a usability study as well as metric tests to see the games impact on user learning experience (R1). Testing was also conducted to uncover improvements that may be implemented in future work to enhance user learning experience (R2).

2. Shape Shape Hooray

2.1 Storyline

The importance of narrative in game-based learning is that it provides a cognitive framework for problem-solving (De Freitas, 2011). In Shape Shape Hooray, the game depicts a story of how the character follows the story of a student life, or specifically the last day of school. When a player chooses a character, the character will explain how from preparing from home, he or she heads to school, and then eats after a long day, and then eventually goes for vacation. This story is the framework of Shape Shape Hooray, making the locations the levels of the game itself.

This storyline is a derivative of common Philippine living. Living in a tropical country, students and their families head to the beach during the school vacation. This idea was brought to life in the game so that students may be able to relate it in their lives embedding the situated learning theory by creating meaning from real activities of daily living.

2.2 Adaptive Paths

Shape Shape Hooray would adapt based on the player's learning progress before playing and during the game. Before the actual game starts, the game will test the students of the following: 1) knowledge of the shapes, 2) spelling of the shapes, 3) association of shapes in real life objects in order to determine whether a player's knowledge about the shapes is high, average or no prior knowledge at all.

A total of ten questions are given and the player will be directed to three different paths depending on the scores they acquire. The player needs to answer all of the questions and that is the only time the scores will be generated. Pretest scores will be the key indicator as to which path the players will be led to as a starting point. Generally, the target users of Shape Shape Hooray are students with low or no prior knowledge of the shapes.

Classification of players will depend on the paths as follows:
1. High prior knowledge path - for players who gets a score of 8-10 points in the pretest. Game will automatically set on a hard level with all the shapes possible to be learned in the game. Confusing and more distracting objects are also added.
2. Low prior knowledge path - for players who get a score of 5-7 points in the pretest. Players on this path will be on the average level of difficulty. Designated shapes to learn per location in the map will be followed. Cube—Bedroom (Level 1) *(See Figure 1)*, Cylinder—Classroom (Level 2), Cone—Diner (Level 3), and Sphere—Beach (Level 4).

Figure 32. Level 1: Bedroom (Cube) sample.

3. No prior knowledge path - for players whose scores ranges from 0-4 points, manifesting that the player has no background knowledge at all. This will be on easy mode and players will be familiarized with a 3D shape following rote learning or memorization through repetition, showing only the shapes needed for a corresponding level.

Once the game determined which path the player takes, the map will appear for the player to proceed in the first level. In each location, the player should find the specific shapes needed to surpass a certain level. When an object is clicked and dragged to the backpack, the object will zoom in and rotate to emphasize the object's 3D shape for the visualization of the player.

2.3 Assessment

Some features of the game are designed in order to evaluate the player's learning progress:

1. Bonus rounds throughout the game will serve as the stealth assessment—a quiet, powerful process by which learner performance data are continuously gathered during the course of playing (Shute et al., 2009). A bonus round *(See Figure 2)* will appear after 2 levels and players of Shape Shape Hooray will be asked to identify shapes of real life objects presented. This round is to test whether the player is able to associate the shapes the game is trying to teach in real life objects. If the player shows an improvement, the game would adapt and proceed to the higher or lower path from originally the player was based on the score he got on the bonus round.

Figure 33. Bonus round sample.

2. The character's energy in the form of a battery will determine whether the player is using the trial and error method or merely guessing. Players are only allowed to make mistakes four times or else the game resets on the particular level it was on. This is to ensure that the players are still trying to play in terms of the objectives of the game.

3. Hints are in the game in order to give an idea to the players who are unsure of what the shapes look like. Every time a player clicks on the hint button, it will show an instruction to look for the objects that look like the shape the level is trying to teach. To give a general idea, an outline of the shape will be shown.
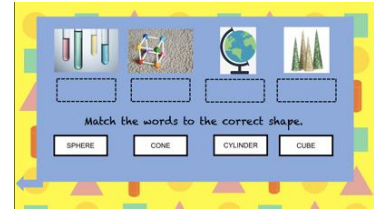
3. Methodology and Limitations

In this section, target participants, metrics used for usability, platform of the prototype, testing, limitations and methods used in conducting the study will be discussed thoroughly.

3.1 Target Participants and Testing

Shape Shape Hooray is intended for children with ages from 7-8 years old or Grades 1-2 students. Since the game is adaptive and has different paths set to their prior knowledge, the main focus in this study are those players with low to no prior knowledge regarding the basic 3D shapes. The game is ideally to be conducted in schools to test both its usability and learning, but due to time constraints, the researchers conducted the testing with students individually, meeting them up at their preferred time and place.
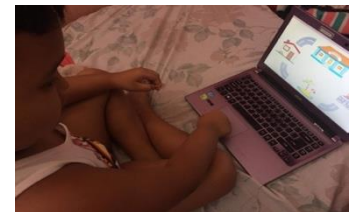
Figure 34. Prototype

An animated version of the prototype was made using an existing software application. Since the focus of the research is Shape Shape Hooray's usability to its potential respondents and not its effectiveness, we gathered respondents with ages 5-8 years old due to time constraints of the approval to test in schools.

The testing started by presenting the game to the players and letting them play without the intervention until asked. After the pretest, the results will determine which path of the game will the respondent be on and shall continue playing the game until after the posttest. The researchers, on the other hand, observed the players and took down notes through data collection sheets with regards to their behavior and comments during testing through the use of Task Success and Tasks Indicator Metrics. After finishing the game, they were asked to answer the SUS and a debriefing interview.

3.2 Limitations

a. *Participants* - The researchers ended up testing 5-8 years old players since the researchers were not able to gather a great number of participants that will fully represent the age range of 7-8 years old. Moreover, the usability of the game, and not its learning outcome, was to be tested so it was possible for Shape Shape Hooray to be played by children within that age range.

b.   *Time Constraint* – Researchers have always intended to conduct the study to more students and players but if were given a sufficient amount of time, teachers can also be asked to play the game and gather feedback from. Getting an approval to test 7-8 years old children in schools has also been a limitation to the researchers as the schools are mandated by law to practice the data privacy act.

c.   *Limited Programming Knowledge and Equipment* - The researchers wish to disclose that the team does not have enough background in advanced programming. As a result, an animated prototype using a computer was used. This may have also affected players' perception about the game features were not as robust in production.

4. Results, Analysis of Data, and Design Mock-Ups

4.1   Task success

To measure the success rate of three major tasks the game is asking to do which are: 1) locating objects, 2) using hints, and 3) map navigation, a task success metric was created in order to determine the easiest and hardest task for the players. Looking at Table 1, most players were able to complete tasks successfully without the need of assistance from the conductors.

Player	Locating Objects	Hints	Map Navigation
P1	1	1	1
P2	2	2	2
P3	2	1	2
P4	1	0	2
P5	2	0	0

Indicators: *2- User was able to perform the task; 1- Needed Guidance; 0- Not able to perform the task*

Figure 35. Average of raw data for task success.

- Locating objects is the easiest task of the game. All of the players were able to locate the objects needed at a certain level but there were two players who needed assistance to successfully locate other objects.
- Asking for help with the use of hint option was not totally utilized as some players did not see the need for help during the game. However, two of them asked for guidance on how to use the hint and one was able to discover on his/her own.
- Two of the players were aware of the narrative that the game is trying to tell. Although, one player was not given the chance to navigate the map because he was directed to the high-prior path where there is no need to explore the four different places and levels unlike those who were directed to the average and no-prior path.

4.2   Task Indicators

The researchers used a Task Indicators Metric containing more specific tasks that players may be able to do. Composing a name, answering the pretest and posttest questions, navigating the map, using hints and clicking all the objects needed per level are some of the tasks indicated in the metric. Most of the tasks were fully accomplished and utilized except the use of hint button.

It was observed that players found it easy to compose a name, answer the posttest, locate sphere and cube objects without seeing any assistance. On the other hand, the use of the hint button, although helpful, was not utilized.

4.3   Debriefing

After the game testing and posttest questions, a debriefing interview was conducted to the players. When asked if the instructions were clear and understandable, all of them agreed and said that the game was very easy to understand and the instructions were clear and presented in an uncomplicated manner. Generally, the players did not have much of a hard time moving from one location to another. However, not all of them were aware of the narrative of the game. Some students wanted to click and go to the beach first as maybe because the game was conducted during their summer break and was set in their mind that they were actually going to the beach. When asked if the game was confusing, most players said that it is not, but some objects in certain levels were confusing because of the similarity in shapes which results to giving second thoughts on whether they think that it is the right answer or not. According to the players, the illustrations are very colourful and attractive and commented that the

avatar cheering them up made the game more fun and encouraging. However, one player said that the voiceover of the avatar was scary.

Aside from conducting the interview, players were asked what are the shapes of physical things that were found around the house. For example, a tumbler or a box of tissue was raised and asked the player what shape it embodies and most of the players answered correctly despite not having prior knowledge on 3D shapes before playing the game. This shows that players learned and can already identify the said shapes after playing Shape Shape Hooray.

4.4 Systems Usability Scale (SUS)

SUS is a Likert scale (Brooke, 1996) which is done after the player made use of the system. System Usability Scale (SUS) contains ten questions about user experience of Shape Shape Hooray and the players will have to rate their agreement or disagreement on a 5-point scale, 1 being the lowest. This is to determine what the users think of the system's design and ease of use and data will also be used as a basis for future improvements of the game.

Indicator	S1	S2	S3	S4	S5	Overall Average
Shape Shape Hooray is easy to use.	4	4	4	4	4	
Shape Shape Hooray is easy to navigate.	3	3	1	4	1	
Instructions were clear and understandable.	4	2	4	4	4	
The drawing and graphics are presentable and appropriate.	2	4	3	4	4	
The music and sounds of the game are engaging.	4	3	2	4	1	
There were some parts of the game that is difficult to understand.	4	2	4	3	4	
I needed guidance in playing the game.	4	3	4	4	4	
I was able to learn about geometric shapes	4	2	4	4	2	
I needed to learn a lot before playing the game.	4	4	4	4	4	
I would play Shape Shape Hooray to learn and have fun at the same time.	2	1	1	2	4	
Average	87.5	70	77.5	92.5	80	81.5
Remarks	Excellent	Good	Good	Excellent	Good	Excellent

Figure 36. Systems Usability Scale for SSH based on John Brooke.

To determine the score of the SUS, first, the sum of the score per item needs to be computed and for the odd number questions (1,3,5,7,9), 1 should be subtracted from the score and as for the even number questions (2,4,6,8,10), 5 should be subtracted from the score. Afterwards, the sum of the scores should be multiplied by 2.5 to get the total value of the System Usability.

Since Shape Shape Hooray received good feedback from the players and got a total average of 81.5 that falls under an excellent-good category. It was found out that it is easy to navigate and really helpful if you want to know about geometric shapes. The instructions given were not difficult to understand and they liked it that if they would be given a chance, they will play it again to learn about shapes and have fun at the same time.

5. Conclusion and Future Work

This paper presented the usability study of an adaptive educational game that teaches 3D geometric shapes, Shape Shape Hooray. In this work, impact or impression of the target users in the experience of the game(R1) and possible improvements for the game(R2) are answered.

Based on the results of the systems usability scale, respondents were highly impressed with the game's usability. Conducting the SUS revealed that the game falls under the excellent-good category(R1). However, this is only indicative of its usability and not conclusive of the learning which is the main goal of the development of Shape Shape Hooray.

Through debriefing, respondents gave recommendations such as: varying hints, indicators not only on audio but also on the visuals, and using age-appropriate and phase of learning appropriate graphics used(R2). The group who conducted the study filtered these enhancements based on the frequency of comments done when the prototype testing was happening. Early projected design mock-ups were also created in order to implement it on the game to enhance both the gaming and learning experience.

Although the development of the game is still in the works and continuously progresses, the feedback that were collected in the study conducted were duly noted for the enhancement of this educational game. Educators' feedback on the game's usability, implementation of feedback, and testing of learning to students in the association of the shapes in real life objects would be conducted for further study. Further research and consultations with programmers and developers will also be part of the future work to consult expert validity of the game.

Acknowledgements

References

Bangor, Kortum and Miller. (n.d.). *Determining what individual SUS scores mean : Adding an adjective rating scale.* Retrieved from https://www.trymyui.com/sus-system-usability-scale?fbclid=IwAR3hvXDycFEhDihB0mDla9cuj ep0POavqSGuxsDQqfdPE18HQQVW-qgwnrI

Brooke, John, (1996). *SUS - A quick and dirty usability scale.* United Kingdom : Redhatch Consulting Ltd.,. Retrieved from https://hell.meiert.org/core/pdf/sus.pdf

Chapron, B. (n.d.). *The Importance of learning shapes in preschool.* Retrieved from htto://www.cedarwoodschool.com/the-importance-of-learning-shapes-in-preschool/

David, L. (2017). *"Situated Learning Theory (Lave)" in Learning Theories* [web log]. Retrieved from http://www.learning-theories.com/situated-learning-theory-lave.html

De Freitas, S. (2011). *Digital games and learning.* London, UK: Continuum International Publishing Group.

Druin, A. (1999). *The Design of children's technology.* San Francisco, CA: M. Kauffman Publication.

Lave, J. (1989). *Cognition in practice: mind, mathematics, and culture in everyday life.* Cambridge, UK: Cambridge University Press.

Mensa Education and Research Foundation. *Lesson Plan: Shapes.* Retrieved from http://www.mensaforkids.org/MFK2/assets/File/Teach/LessonPlans/Lesson_Shapes.pdf

Northern Illinois University, Faculty Development and Design Center. *Situated Learning.* Retrieved from www.niu.edu/facdev/_pdf/guide/strategies/situated_learning.pdf?fbclid=lwAR1jw3tPPGtjzRfckc fybwTn9C5

Oppermann, R. (2006). Situated learning in the process of work. In D. Hung & M. S. Khine (Eds.), *Engaged learning with emerging technologies* (pp.69-89). Dordrecht: Springer Netherlands.

Stein, D. (1998). *Situated learning in adult education. ERIC Digest.* Retrieved from https://www.ericdigests.org/1998-3/adult-education.html

Tobias, S. (2011). *Computer games and instruction.* Charlotte, NC: Information Age Publishing, Inc.

Verdine, B. N., Lucca, K.R., Golinkoff, R.M., Hirsh-Pasek, K., & Newcombe, N.S. (2016). The Shape of Things: The Origin of Young Children's Knowledge of the Names and Properties of Geometric Forms. *Journal of cognition and development: official journal of the Cognitive Development Society, 17*(1), 142-161. Doi:10.1080/15248372.2015.1016610