Real World Geometry

Supplimental Geometry Instruction via an Augmented Reality Application

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1 INTRODUCTION

Geometry is an essential area of mathematics but considered difficult by kids when they first access it in school. By learning geometry, students may be able to identify shapes and space around them. However, kids know 3D shapes even before going to school. They intuitively investigate and interact with 3D shapes/objects by exploring it, since everything around us is three-dimensional. Then they go to school and learn to write and draw in two dimension [5]. It is getting more challenging that after kids already know that everything at school is 2D, they need to learn 3D geometry. Unfortunately, traditional teaching methods failed to assist kids to smoothly transition from 3D to 2D and go back to 3D. In addition, due to kids' own cognitive gap between 2D and 3D shapes, it is hard for them to get knowledge of geometry. Therefore, it is the time for teachers/parents seeking a new perspective to help kids with geometry learning.

In recent years, digital technology is employed in education since technology tools are very interesting and engaging for kids [1, 2, 6, 9]. Augmented Reality (AR) is one of the most explored and successfully used technologies. According to Piaget's Constructivism theor [4]. kids easily acquire new knowledge if learning occurs in a specific context and is embedded in a physical environment. Thanks to AR, it allows users to be completely immersed inside a synthetic environment, which makes learning more effectiv [3]. Since AR permits to create interaction experiences that are enhanced by the overlapping of information between virtual and real objects, it improves the involvement of kids during their learning proces [8].

In 1999, van Hiele proposed a theory named "Levels of Geometric Thinking", which claimed that the geometric thinking could be divided into four levels, from "lowest" to "highest" were: visual level (figures were judged by their appearance), the descriptive level (figures were the bearers of their properties), the informal deduction level (the properties of figures were logically ordered) and the deduction level (used axioms, definitions, theorems to identify figures [10]. The best way to help kids develop geometric thinking was to follow the sequence from lowest level to the highest, i.e. developing thinking from the visual level and gradually transition to the descriptive level, at the end reaching to the final deduction level.

2 PROBLEM STATEMENT AND RELATED WORK

2.1 Probelm Statement

Due to the reason that geometry plays an essential role in math but is too abstract for kids to learn, a new method which helps kids to build a connection between 2D and 3D geometry, develop spatial imagination and the capacity of abstraction geometry is urgent. Augmented Reality (AR), as a promising technology, allows kids to be completely engaged in the environment. Moreover, some AR-based multimedia is able to display both 2D and 3D objects by showing every part of the objects in detail [7]. Based on the above reasons, our goal for the project is to develop an AR app that makes tangible the geometric properties they learn about. Each level of the app will include three steps (based on van Hiele's "Levels of Geometric Thinking"): (1) visual identification (2) kids interact with their environment in AR to discover geometric ideas (3) combines conceptual content (definitions and characteristics) with procedural content

(applying formulae and calculus). Our app will provide a new perspective for kids to better understand geometry, and increase geometry motivation and mathematics with AR.

2.2 Related Work

There are some AR based geometry learning applications. For example, Arloon Geometry is an application designed for middle school students (> 11 years old) to improve their 3D thinking skills. This application features 3D models with AR for most geometric shapes, such as pyramids, prisms etc., and the pupil interacts with the game by viewing geometric shapes from all angles and listing their properties and the formulae that define their area and volume. However, this application requires an Android system and is not suitable for younger kids. Shapes 3D is another AR based application which allows students to interact with real 3D shapes by placing solids everywhere and even rotate a 3D shape to better understand the geometric shapes. However, due to the complexity of this application, it does not implement AR technology with detecting objects. Kyle Wang and Ray Patt's last year's project, Real-World Geometry, includes three steps: kids identify shapes through visual identification, using AR interact 3D geometric shapes to identify them, and the highest level is interacting with the surrounding environment to better understand geometric concepts. This application is very promising, but due to time limitations, they only applied to three simple shapes, and did not reach to the highest level, deductive thinking level.

3 NEED FINDING

We plan to perform need finding using interviews with domain experts. Here we define domain experts as teachers that have experience working with K-5 children and that have experience teaching basic geometry. We will send out an email to education majors at the University of Delaware. Our goal is to get an sufficient understanding of what material students struggle with the most and therefore get an understanding of what topics our app should address. We also want to get guidance for how to best communicate instructions to these students and what techniques tend to keep them engaged. A sample interview protocol is included in appendix B.

4 PROTOTYPING

We first used wireframe prototype via Miro. Describe the process via which users will interact with our application. In doing so we focus more on breadth of the features we covered rather than depth; we aim to show the majority of the features involved in our applicaiton, but our prototype will not impliment any real functionality. Our initial prototype can be found in appendix A.

5 IMPLIMENTATION

We consider the spatial relationship between items on the page and structure the page according to importance. We carefully place the items which helps kides draw attention to the most important information,(the geometry shapes and equations) and aids in scanning and readability.

To improve the prior work and design, we plan to use color and texture strategically. We use color, light, contrast, and texture to focus or shift users attention to the project. The different sizes, fonts, and arrangement of text help improve scannability, legibility, and readability to ensure that the system communicates and always notify users of location, operation, status changes or errors when they pass along the tasks.

In conclusion, we use various UI elements to communicate status and subsequent steps when necessary can reduce user frustration.

We are going to use matlab to refine the coding that prior team have done, and also we will develop the application to improve user experience in terms of accessibility, readability, entertainment value.

One challenge we may face is the need to balance our goal of adding new and interesting features to the existed application with our desire to maintain a simple simple and easy to interface for our users.

We are building a mobile app, and are currently targeting only iPhones. Hopefully will eventually be able to expand to android phones as well. We view a mobile app as the best medium for this project, as children will likely be familiar with mobile apps, and mobile app will allow us to easily access a camera which will be necessary for the AR functionality that the app will utilize.

6 USER STUDY / EVALUATION

The goal of our user study will be to assess the effectiveness of our project and motivate future changes that could be made to the app. Will perform this in one human subjects study where we will collect quantitative and qualitative information about the users' experiences using our application.

We will evaluate the following hypothesis question: Does usage of our application improve student performance on geometry assessments when compared to traditional teaching methods?

We will recruit elementary school students to participate in our study (likely through family/friends for convenience). The students will be asked to take a short geometry pre-assessment. We will conduct a between subjects experiment where students are exposed to one of two conditions: (1) a traditional teaching method simulated through a short video that explains geometric concepts (this is our baseline condition) (2) our Real World Geometry application. After this we will assess students from both groups on the same geometry assessment. We will then compare score improvements for each group, look to see if there is a significant difference between them. We will ask the students assigned to condition 2 to take a brief survey, to get a better understanding of their experience using our application.

7 ALTERATIVE APPROACHES

We planned to use ARKit 2 and paired it with Unity, however, it also has downsides, e.g. only supporting macOS and iOS systems. We prepared some backup plans: first, we can build AR with Vuforia with Unity or ARCore with Unity, because we can run it on Android system; second, we can also try ARToolKit5, since it is fast, intuitive and cross-platform, and can be run on macOS, iOS, Linux, Android or Windows.

8 TIMELINE AND DELIVERABLES

(1) We finished our storyboard during the week of October 25, 2021. (All the member)

(2) We discussed and finished our first draft proposal (also presented in class) during the week of November 1st, 2021. (All the members)

(3) We plan to write our second draft proposal (through word) during the week of November 15, 2021. (All the members involved discussion, each member was responsible for at least two parts and at the end modified and finished together)

(4) We plan to write and run the code during Thanksgiving week (November 22, 2021) (Jie and Connor) and also design and work on our survey, observations part. (All the members)

(5) We plan to finish the detailed user study/evaluation part during the week of November 29, 2021. (All the members)

(6) This project is expected to be completed by December 17, 2021. (All the members)

9 BIOGRAPHIES

Jie Ren

Field of Study Computer Science

Role Developer, Coding, Project Manager

Connor Onweller

Field of Study Computer Science

Role Developer, Research Informant

Interests Computer Accessibility, Computer Vision, Software Engineering

Tong Chu

Field of Study Biomedical Engineering

Role Developer, product designer, information search assistant

Interests Medical Design experience (Patent Pending)

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Appendices

A INTERVIEW PROTOCOL

(1) **Introduction**

Hello, my name is _____. I am a student at the University of Delaware studying the role that augmented reality software can play in geometry education. I am looking to gain some insight on your experience teaching students geometry.

(2) **Questions**

- What grade do you teach?
- How many classes do you typically spend covering geometry per year?
- Do you enjoy teaching geometry?

- Is teaching geometry ever difficult? If so, what kind of things make it difficult?
- Do you ever use resources like videos, websites, or games to help teach? If so, do you ever use any of these to help teach geometry?
- Could you see a geometry phone game as something that could be a helpful supplimentary tool for teaching?
- What topics would you think such a game should cover?
- How do you best communicate instructions for students to complete activities, assignments, and games? What types of considerations should be made when doing so

(3) **Conclusion**

Thank you for participating in this study. We will send you an update when we complete our paper.

B   PROTOTYPE

Real World Geometry

This is a geometry game designed for 10-15 year olds.

Welcome/Explanation For Parents

Real World Geometry

Your Email

Password

Confirm Password

Sign-up

Parent Sign-up Page

Real World Geometry

Do you give this app permission to use your phone's camera?

Yes

No

Request Camera Access

Real World Geometry

1	2	3
4	5	6
7	8	9

Select Level

Real World Geometry

1   Circle

Learn the Basics!

Real World Match!

Real World Geometry

Identify circle!

Great! Good job!

Real World Geometry

Find and Match!

Great! Good job!

Real World Geometry

Do some math!

3 mm

Area = π * r * r =

Circumference = 2 *π * r =