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Work-in-Progress: Testing Content of a Spatial Skill Learning Supplementary App

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Introduction

Spatial skills education research has repeatedly demonstrated a disparity in gender performance favoring males. Voyer et al [1] meta-analysis identified varying gender differences depending on the assessment; Maeda and Yoon [2] showed that the gender gap widened when the assessment was stringently timed; Levine et al [3] determined that socioeconomic status also contributed to the gender differences in spatial abilities of third graders and Johnson et al [4] also found similar results among elementary school students; and Gold et al [5] found gender differences in spatial abilities for undergraduate geology students. Spatial skills education research has broadened to include the development of approaches to help students with the visualization of objects. Sorby [6], [7] and Sorby et al [8] showed that specific strategies and a spatial skills development course improved first-year female engineering students' academic success and retention. The research also includes the development of tools that assess spatial visualization skills and the validity of these measurements.

However, emerging research has also called for a critical approach in deconstructing the understanding of what spatial skills and abilities mean, how they have been measured, and how they have been developed [9], [10]. Our larger research grant contributes to this need by developing an augmented reality (AR) based app that provides students with a supplementary tool to help them visualize while learning to construct the isometric view from the two provided orthographic views of an object. Developing these skills are important as orthographic and isometric views are a primary form of graphical communication within the field of engineering [6], [11]. Our learning supplementary AR-app differentiates itself from other visualization apps in that it provides color-based feedback, step-by-step guidance, and gamified learning opportunities to assist and motivate students in solving the provided visualization problems [12]. This specifically addresses the gap in spatial skill education literature and approaches where a supplementary app combines all these different features to assist students in this learning process.

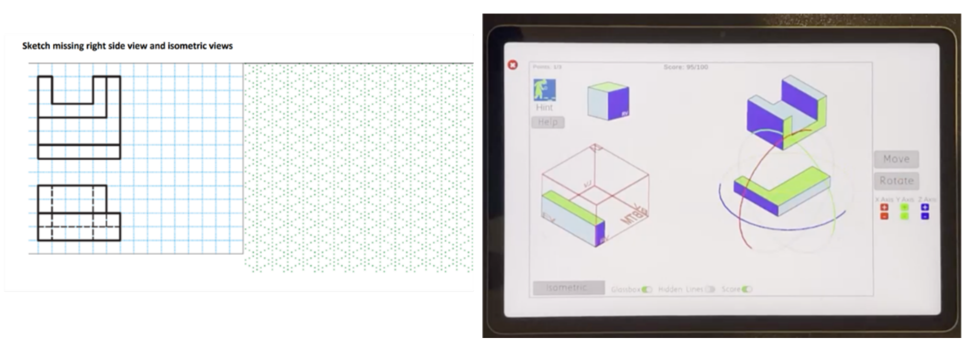

Figure 1: The isometric drawing exercise and the latest version of the AR app, SSTAR. The app provides help for students to complete drawing exercises.

The app provides students with the typical isometric glass box, divided portions of the final object, and the coloring of the object's surfaces to assist in the identification of the aligned face within the isometric box, as illustrated by Figure 1. Students can then translate or rotate these portions of the object to the appropriate orientation and location within the provided isometric glass block. If the final placement within the isometric glass box is incorrect – the app will automatically remove the incorrect portion and inform the student to "Placement is incorrect and to please try again." If placed correctly the app informs the student "correct." Through this process students can build the intended object's missing orthographic and isometric views from the two provided orthographic views. Students also learn the relationship of the shared surfaces between the different orthographic views and how these views create the isometric view.

For this work-in-progress paper, we want to share our journey in testing the first prototype of the app focusing solely on the development of the educational content. Specifically, the objective of this work is to explore how engineering students who have completed a graphical communication course experience and perceive the educational content of the app. The development of the AR environment for the app will be presented in later work.

Background

An area of particular interest is the intersection of spatial learning and technology, especially applications involving touchscreens and augmented reality (AR) [11], [13], [14], [15], [16]. When testing or evaluating educational technologies it is crucial to learn about the interaction between the user and the tool. It is important to measure the benefits and impacts of technological tools [17]. Such benefits span several components, including the tools' impact on learning outcomes [18], providing a complete learning experience [19], and engaging and motivating students [20]. It is important to identify the advantages and challenges with the user interface in educational technologies, Lai and colleagues [21] showed the need to have instruments that can evaluate the use of technologies in education. Mendoza-Franco and their colleagues [19] state the importance that both the pedagogical (content) and the technological (interface/delivery) must be well developed for the AR app to be successful. Specifically, that learning digital tools must be "designed within a didactic or educational strategy," and development of such technologies "should take into account the pedagogical objective as the main one and consider technology as a means to achieve it" (pg. 756).

The larger objective of this research is to develop an app that utilizes AR to provide students with a supplemental tool to assist them in developing their spatial visualization skills. It is the intent to design this AR app with full consideration of student engagement, achievement of learning outcomes, skills-transfer, and retention. Activities will be framed to ensure 'ease-of-use and learnability'. We are focused on evaluating the user interface and ultimately the AR technology as a crucial component in the development and improvement of spatial visualization skills. This work-in-progress focuses on testing the pedagogical component of the AR app, instead of the technological component.

The SSTAR Application

The SSTAR application is designed to address a gap in existing literature that shows the scarcity of a spatial skill education supplementary application that provides a step-by-step, color-based, gamified, and touchscreen environment to help students visualize an object (Figure 1). This app is currently being built in the Unity environment on Samsung tablets, focusing on students using the app while working on the drawing problems that illustrate different views as illustrated in Figure 1. The application is currently designed for content testing, with the development of the AR environment to occur following the validation of the content.

Methods

Our team has decided to conduct a think-aloud protocol to test the learning app prototype for its pedagogical strategies. A think-aloud protocol is appropriate for understanding a participant's thought process while working on tasks [22]. Think-aloud protocols or interviews have been widely used for the testing and evaluation of tools and instruments [23], [24], [25], [26]. For our testing, we want to understand students' perceptions and experiences while using the application that either assisted, or did not assist, with visualizing the complete solution to the objects and completing the isometric drawing problem as illustrated in Figure 1 [22].

We are in the process of finalizing the recruitment of approximately 15 participants for the think-aloud testing of the app. Participants will be undergraduate students from within the College of Engineering and who have completed the first-year course, EGR 120, *Introduction to Graphical Communication.* Participants may be first-year, sophomore, junior, or seniors from any of the following degree programs: aerospace engineering, civil engineering, engineering physics, or mechanical engineering. Specific demographics of the participants will be presented during the conference.

There are three phases within this content study. The first has the participants watch a tutorial video on how to use the app. The participants will then practice verbalizing their thoughts while solving several visual or logical puzzles. This will allow the researchers the opportunity to provide feedback/guidance on the participants' verbalization. Next, the participants will use the app to help them solve an isometric drawing problem while verbalizing their experience using the app. The participants' verbalizations and their hand movements will be recorded. The final phase will have the participants complete a semi-structured interview to reflect and discuss their experiences with the app. It is expected that each interview and think-aloud protocol will take 90 minutes to complete. Analysis of the interviews and think-aloud will involve coding of the transcribed verbalizations and interview, along with the hand movements.

Future Work

Data collection is currently ongoing, and we expect preliminary findings to be presented as part of this work-in-progress during the conference. These findings will inform the next revision of the pedagogical/content component of the application. Of particular interest is the impact on students' ability to visualize the different orthographic and isometric views. Additional next steps will also include the development of the AR component of the SSTAR app.

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