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Augmented reality in educational activities for children with disabilities

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ABSTRACT

This study explores a new way to integrate advanced display technology into educational activities for children with different disabilities. A free interactive mobile augmented reality (AR) application was developed to facilitate the learning of geometry. Twenty-one elementary school children participated in an experiment. The results show that the AR system could help the school children to finish puzzle game activities independent of teacher's assistance. With the use of AR display technology, the participants demonstrated improved ability to complete puzzle game tasks when compared to the use of traditional paper-based methods. Performance data indicated that the use of AR technology could enhance learning motivation and frustration tolerance in children with special needs.

1. Introduction

Recent technological advances have led to products, such as smart phones and tablet devices, being used in educational programs for children with developmental disabilities [1,2]. Image overlay navigation has proven helpful for anatomical understanding of a target in a given environment [3,4]. Chang, Kang and Huang demonstrate that with augmented reality (AR), users are not required to match picture cues with reality, which is a prompting strategy used in the studies [5]. AR is used in a wide range of fields, such as medicine, manufacturing and education, and the number of applications of AR has increased [6]. New possibilities for teaching and learning provided by AR have been recognized by educational researchers [7].

DePriest contends that 'social media technology and corporate America are currently building an augmented reality dimension layered upon our everyday lives. A virtual world of augmented reality is being layered over advertisements, buildings, signs, clothes and more all over the world through the placement of indoor and outdoor tracking and the download of applications to your smart phones and tablets' [8].

Smith investigated using Aurasma to develop educational AR applications based on simple image recognition [9]. Aurasma is a freely available AR platform for iOS and Android devices. Haag argued that mobile augmented reality systems provide educational content designers and educators with new opportunities to think more deeply about the mobile learner's context and situation [10]. AR technologies can take any situation, location, environment or experience to a new level of meaning and understanding. AR is uniquely changing the way people learn with mobile devices.

The use of technologies to link the physical world with the digital world in the educational field has been investigated. In a paper describing an Aurasma application for deaf students, Parton and Hancock point out that barcode and radio frequency identification technologies [11] have been used in educational applications. Atherton, Javed, Webster and Hemington-Gorse demonstrated the use of the Aurasma platform in an AR application for smartphones and tablets and proposed a mobile device application for surgical education and poster presentations to supplement the information conventionally available through paper-based presentations [12].

Smith allowed students to use AR to transform their end of semester poster presentations. Participants were invited to download the Aurasma application to view previously created 'auras', which is Aurasma's term for an AR experience, and to experiment with creating their own auras. The participants were able to learn about new educational technology concepts as well as the process for creating AR experiences [9]. Lakin developed and implemented a course in computer-generated imagery at the University of Rochester's Memorial Art Gallery. Works in the collection were integrated with student-created animations or videos. Ten individual projects were created [13].

Technology can be used to mitigate shrinking school budgets by reducing the need for printed materials. Teachers can cooperate to create AR-based teaching materials and the materials can be shared via the Aurasma cloud.

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Tangram is an ancient Chinese puzzle game that is often used as an educational tool. The puzzle consists of seven flat shapes that are put together to form composite shapes [14]. Bohning and Althouse pointed out that the seven pieces of a geometric tangram could be arranged in many different ways to create figures of birds, animals, people and objects [15]. Many researchers have recognized that learning through play and teacher guidance from teachers can help children overcome their initial fears and even begin to enjoy learning. For example, a tangram puzzle could be used as an assistive tool to develop children's observation skills, imagination, shape analysis, creativity and logical thinking [16,17]. Puzzle-based learning enhances learning by developing problem-solving and independent-learning skills [18]. By touching and rearranging real objects, puzzle games can also enhance hand-eye coordination. In particular, for children with disabilities, puzzle-based activities could reduce the learning burden and frustration.

2. Material and methods

2.1. Participants

Twenty-one students (14 boys and 7 girls, 6–12 years) with different disabilities participated in the experiment. Some students were enrolled in regular classes but had been identified as needing extra support.

2.2. Teaching materials

Eight teachers at university, elementary, junior and senior high school levels and a graduate student participated. All participants work in the field of special education. The participants designed teaching materials and created corresponding Aurasma videos to enhance learning. The teaching material involved two games, the traditional Chinese tangram puzzle and a square puzzle game. Here, note that after installing the Aurasma application, any user with a 3G- or WiFi-capable smart phone or tablet can register free of charge. In this study, both the static content and the dynamic corresponding teaching materials were shared. A user can then scan the trigger image placed on a poster with a mobile device to view videos, animations or data. Further interaction can direct the user to a website for more content.

2.3. Environment setup

The experimental setup included the Aurasma© application with a 3G or WiFi connection and access to the channel via a smart phone. The two classrooms the experiment was conducted in had WiFi connectivity.

2.4. Experimental procedure

Six games were used in the experiment. Three were traditional Chinese tangram puzzles and three were square puzzle games. The participants stood in front of a table. There were physical blocks on the table. A researcher is positioned close to the table. The participants used the blocks to attempt to replicate the pattern. If the participant could not replicate the figure, they were permitted to tell the researcher they required assistance. Prior to beginning the experiment, the teacher explained and demonstrated the process. Each participant attempted to perform the task associated with each of the six games manually. Even via the assist of Aurasma, the participants could refer to the Aurasma videos. The experimental process is shown in Fig. 1.

3. Results

3.1. Data analysis

Because the participants were children with different disabilities, this study focused on allowing participants to succeed. The primary goal of the study was to increase self-confidence. Children with disabilities require opportunities to enhance their performance; however, the games were always difficult for them. Using the Aurasma videos, they could attempt to finish the games by themselves (see Fig. 2).

Analysis of the results indicates that all participants could finish the traditional Chinese tangram puzzles and the square puzzle game by themselves and that the support times was shorter than expected. A Wilcoxon test was used in the analysis.

3.1.1. Traditional Chinese tangram puzzles data analysis

For tangram game 1, the participants were allowed to refer to the AR materials. When participants used Aurasma AR as an aid once, the success rate was better than when no AR aid was used ($p = .003 < .05$); When participants used Aurasma AR as an aid twice, the success rate was better than when no AR aid was used ($p = .000 < .05$); When participants used Aurasma AR as an aid twice, the success rate was better than when used Aurasma AR as an aid once ($p = .025 < .05$). Therefore, for tangram game 1, the results indicate that using AR twice is significantly better than using it once and that using it once is significantly better than not using any AR clues.

For tangram game 2, the participants were allowed to refer to the AR materials. When participants used Aurasma AR as an aid once, the success rate was better than when no AR aid was used ($p = .002 < .05$).

For tangram game 3, the participants were allowed to refer to the AR materials. When participants used Aurasma AR as an aid once, the success rate was better than when no AR aid was used ($p = .014 < .05$); When participants used Aurasma AR as an aid twice, the success rate was better than when participants used Aurasma AR as an aid once ($p = .025 < .05$); When participants used Aurasma AR as an aid twice, the success rate was better than when no AR aid was used ($p = .001 < .05$); When participants used Aurasma AR as an aid three times, the success rate was better than when no AR aid was used ($p = .001 < .05$); When participants used Aurasma AR as an aid four times, the success rate was better than when no AR aid was used ($p = .000 < .05$). There were no significant differences between twice, three times and four times of Aurasma assistance. Therefore, the results indicate that significantly better results were obtained when AR was used.

In the data analysis for the traditional Chinese tangram puzzles, participant performance was significantly better when the Aurasma AR aids were used than when paper-based operations were performed.

3.1.2. Square puzzles data analysis

For the square puzzles game 1, the participants were allowed to refer to the AR materials. When participants used Aurasma AR as an aid once, the success rate was better than when no AR aid was used ($p = .003 < .05$); When participants used Aurasma AR as an aid twice, the success rate was better than when no AR aid was used ($p = .000 < .05$); When participants used Aurasma AR as an aid twice, the success rate was better than when once AR aid was used ($p = .025 < .05$);Therefore, the results indicate that using AR twice was significantly better than using it once, and using it once was significantly better than not using AR. There were no significant differences between using Aurasma AR twice and using it three times, however, when Aurasma aids were used three times,

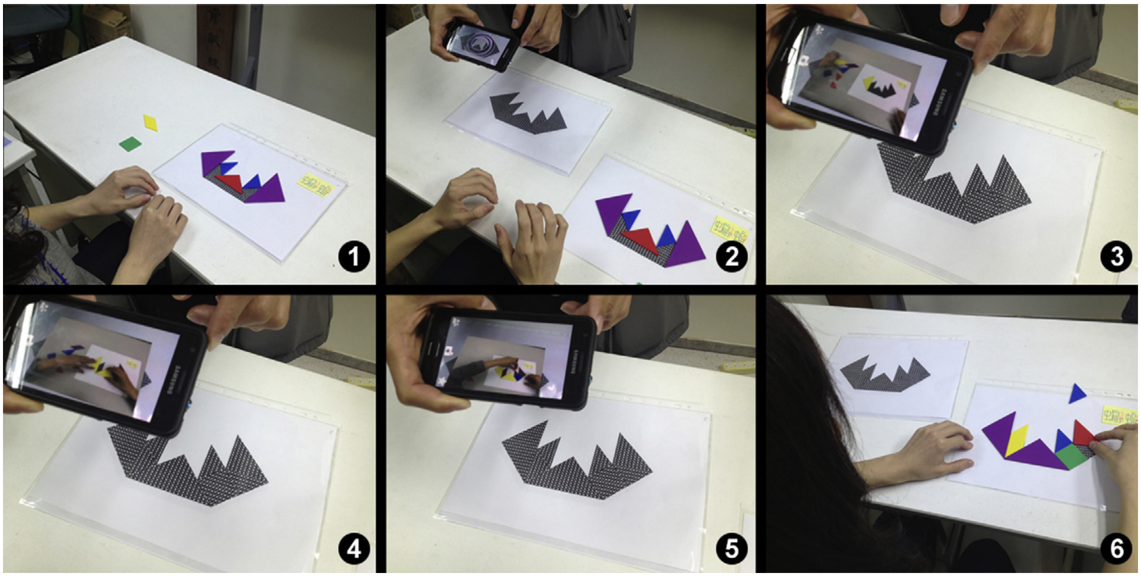

Fig. 1. The mobile AR concept.

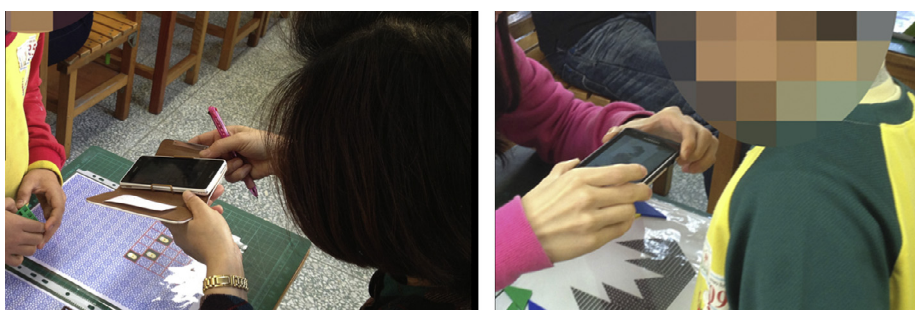

Fig. 2. The process of the experiment.

the results were significantly better than using it once or not using it.

For the square puzzles game 2, the participants were allowed to refer to the AR materials. When participants used Aurasma AR as an aid once, the success rate was better than when no AR aid was used ($p = .046 < .05$); When participants used Aurasma AR as an aid twice, the success rate was better than when no AR aid was used ($p = .005 < .05$); When participants used Aurasma AR as an aid twice, the success rate was better than when once AR aid was used ($p = .046 < .05$); When participants used Aurasma AR as an aid three times/four times, the success rate was better than when once AR aid was used ($p = .005 < .05$; $p = .003 < .05$); When participants used Aurasma AR as an aid three times/four times, the success rate was better than when once AR aid was used ($p = .046 < .05$; $p = .025 < .05$). However, there were no significant differences when Aurasma was used three times or two times, four or two times and four or three times. Therefore, the results indicate that using AR twice is significantly better than using it once and using it once is significantly better than not using it.

From square puzzles game 3, the participants were allowed to refer to the AR materials. When participants used Aurasma AR as an aid once, the success rate was better than when no AR aid was used ($p = .005 < .05$); When participants used Aurasma AR as an aid twice, the success rate was better than when no AR aid was used ($p = .003 < .05$); When participants used Aurasma AR as an aid three times, the success rate was better than when no AR aid was used ($p = .001 < .05$); When participants used Aurasma AR as an aid four times, the success rate was better than when no AR aid was used ($p = .000 < .05$);When participants used Aurasma AR as an aid four times, the success rate was better than when once AR aid was used ($p = .025 < .05$); When participants used Aurasma AR as an aid four times, the success rate was better than when twice AR aid was used ($p = .046 < .05$).

In the data analysis of the test trials for the square puzzles games, the participants were able to achieve significantly better performance using Aurasma AR compare to a paper-based process.

3.2. Questionnaire analysis

After the two previously described interactive activities, the participants answered a questionnaire with one open question and four questions with answer options. A 5-point Likert scale with 1 being ‘strongly disagree’ and 5 being ‘strongly agree’ was used. ‘Agree’ and ‘strongly agree’ were considered positive responses. ‘Strongly disagree’ and ‘disagree’ were considered as negative responses [19]. Twenty-one students in the experiment. Note that one child with an intellectual developmental disability and poor oral skills was only able to answer the first one question with answer options.

The open question was ‘Please answer the question that your past experience about augmented reality activity by answering YES or NO, if YES, please indicate the relative content’. The results indicate that none of the participants had previous experience with AR.

Overall, in the first optional question, the participants all strongly agreed that the experimental process was interesting; in the second optional question, the results show that 90.5% of the participants strongly agreed that the experimental content was plentiful, and 9.5% of the participants agreed that the experimental content was plentiful, all responses were positive; in the third optional question, the results show that 95.2% of the participants strongly agreed that the experimental process was interesting, and 4.8% of the participants agreed that the experimental process was interesting, all responses were positive; in the fourth optional question, the results also indicate that 95.2% of participants strongly agreed that assistive technology could help them learn and 4.8% of the participants agreed that assistive technology could help, that all responses were positive.

4. Conclusions

Augmented reality (AR) technology is an assistive bridge system in special education. Although this technology is not new, it is still interesting and has significant potential in special education. AR supports intuitive and interesting learning processes for children with special needs by combining the real and virtual worlds. In this study, we have presented an assistive functional educational AR application with mobile learning devices to develop an activity for children with special needs. In addition, we have used flexible methods to create interactive feedback.

The processes use an intuitive method; thus, instructions are easier to explain and demonstrate. Teachers can arrange an entire teaching process and learning activities using the AR system, and the AR system can present instructions in a step-by-step manner for special needs students, particularly those with attention deficit and memory disorders. Via such teaching materials, students can repeat operations independently, thereby reducing dependence on teachers. As a result, relative to group activities, teachers can design multi-level teaching strategies to help children with special needs adapt to independent learning.

For teachers, it was indicated that some assistive technologies were well designed; however, they are expensive. In addition, designing teaching materials that employ assistive technologies requires the acquisition of specific computer skills. The learning curve for a teacher without adequate computer skills is steep. This barrier could be removed through the use of Aurasma-based AR.

For children with special needs, the process adopts an intuitive method, and such children can use this method to practice instructions repeatedly, which can help resolve the problem of insufficient time for classroom practice.

Prior to conducting the experiment, the researcher explained how to complete the games and informed the participants that they could obtain additional instructions via a mobile phone with augmented reality application if they required assistance. This experimental process enhanced security and reduced frustration for children with developmental disabilities. Use of a mobile device could support the real-time information feedback. In addition, it could enhance concentration and motivation and stimulate curiosity. For the participants in the experiments, it represented a fresh approach to learning.

Students with low comprehension ability typically require more time to complete tasks. The games were designed with various levels of AR assistance, which improved confidence and increased the possibility of completing the game.

Through the AR system, curiosity about digital instructions can enhance opportunities for peer interaction. Special needs students can become more interactive in homogeneous groups and develop greater opportunities to interact with normal students, which could provide great benefit to traditional learning methods. AR techniques can enhance the frequency of operation and allow the learning process to employ game models and increase motivation for special needs students. In addition, special education teachers can cooperate with researchers in specific fields to design appropriate individual educational programs to help children with different needs.

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