Integrating Educational Technology into the Classroom: How Augmented Reality Can Aid in Student Comprehension

Patricia Tanner and Carly Karas

State University of New York at Oswego

Abstract

The classroom integration of an innovative technology called augmented reality was investigated in this study. Although the process of adding new technologies into a classroom setting is daunting, this concept, which is seemingly straight out of a science fiction novel, has demonstrated the ability to educate students and to assist with their comprehension of a procedural task. One half of the students of a sixth grade class were exposed to augmented reality technology when they were assigned the procedural task of building robots. As a control feature, the other half of the class learned how to construct their robot by using the static manual that was provided by the manufacturer of the robot kit. The students who experienced the technology did so by utilizing an animated version of the same static manual. Through the collaboration of Apple iPads and the augmented reality application Aurasma, the experimental group observed video tutorials that were overlaid onto the static manual to provide an augmented representation of each step. Results indicated that the students who used the animated manual to learn the procedural task showcased significantly higher comprehension scores when compared to those who used only the static manual. Based on these findings, the integration of augmented reality into a classroom setting may be beneficial to student learning.

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Introduction

As the presence of classroom technology continually grows, the critics of academic innovations vie to be heard. Some teachers claim that the use of technology, such as the iPad, in a classroom setting produces more distractions than learning outcomes (Mulholland, 2011). Notions resembling these have inspired much study into whether or not they are true. One emerging technological tool that has seemingly refuted negative claims about classroom technology is augmented reality. As explained by El Sayed, Zayed, and Sharaway (2010) in their article about the benefits of augmented reality in education, “augmented reality is the technology of adding virtual objects to real scenes through enabling the addition of missing information in real life”. This innovation can be very useful in an academic setting because, in a different article by Thornton, Ernst, and Clark (2012), the authors make the claim that students who use augmented reality are likely to participate more in their education because “AR allows greater detail, explanation, and clarity of examples through the establishment of visual and spatial relationships”. The “Aurasma” application for the iPad is a great example of this. The application works to “seamlessly animate the world as seen through a smartphone [or tablet]” (Mills & Roukaerts, 2012). Since there have been many claims about the prospective success of augmented reality technology systems being used in the classroom, it is important that more research is conducted. Due to critics of education technology, it was the goal of this study to explore whether the use of the Apple iPad, in conjunction with the Aurasma augmented reality application, aided in student learning when integrated into a classroom project. At the time of the study, the participating classroom was to begin a segment on simple robotics. The integration of the augmented reality technology was designed to correlate with this prearranged assignment.

Research Objective and Development of Hypotheses

This study examined sixth grade students at Fitzhugh Elementary school using the LEGO© brand “Education WeDo” construction kit. The kits were comprised of many LEGO© brand parts, downloadable software, and a very simple, picture only instruction manual. Students were able to construct one of two animals with the goal being to build them into functioning robots. The LEGO© manual that was provided with the kits coincides with Greenough and Fakun’s (2002) description of traditional manuals. They agree that it is common for procedural information to be displayed as “drawings on paper” and that “despite the trend toward digital documentation, many business processes rely heavily on paper documents” (2002). The issue with this practice is that, generally, there is no analysis of usability involved when designing these traditional procedural manuals (Greenough & Fakun, 2002). Because many digital manuals are tested for ease of use, they allow for better “problem solving and visualization, thus enhancing the motivation and engagement in learning” (Burbaite, Stuikys, & Marcinkevicius, 2012). “Animated” manuals are considered better than “static” representations of a procedural task because “animation can facilitate mental representation of a procedure clearly, present step by step sequential actions and show the specific behavior or dynamic movement of the equipment, as it changes over time.” (Lee & Shin, 2012). The Aurasma application has afforded the users of their augmented reality technology the ability to enhance traditional manuals, such as the LEGO© WeDo manual’s static representation of each step with an animated version. As Lee and Shin (2012) suggest, the animated visual representations are ideal for a procedural task because it aids in student’s mental model of the assignment.

When technology can be effortlessly integrated into a classroom project, it is anticipated that students will show improvements in their work (Lee & Lehto, 2013). For example, the incorporation of the Aurasma augmented reality application into a classroom by animating the LEGO© WeDo kit's static manual is expected to save time, improve learning and efficacy, and help students to avoid mistakes (Greenough et al., 2002). Lee and Lehto (2013) assert that as long as the technology fits the procedural task, it will be considered a useful tool among its users. Lee and Shin (2012) would agree because they claim that one factor of the comprehension of a given task involves making connections about how well the technology enhances the task. Additionally, the US Navy avoids the use of paper manuals when their soldiers are expected to comprehend a procedural task because the military claims that digital manuals "can reduce the mean time to [perform a task] by 50% and increase the accuracy of [performing a task] by 40%" (Greenough et al., 2002).

Due to the considerable differences between a static and animated manual within other studies, this experiment predicted that the students of Fitzhugh Park elementary school would produce similar results when comparing the LEGO© WeDo static manual to the same manual after it was animated by augmented reality technology using the Aurasma application on an iPad. Several variables were tested to detect significant differences between the traditional manual and the enhanced version. These variables included comprehension, errors, efficiency, engagement, enjoyability, ease of use, and learnability.

With a control group that used only the static manual for two days in a row and an experimental group that used the animated manual on the first day then the static manual on the second day, comprehension was operationally defined by the time it took for the experimental group to build their robot on the second day of testing (where significantly less time = a higher level of comprehension when compared to the control group).

H1: There is greater comprehension of a procedural task when learned through the use of a manual animated by the augmented reality iPad application Aurasma than when learned through the use of a traditional static manual.

Data about the number of errors made, efficiency, engagement, enjoyability, ease of use, and learnability were collected on the first day only.

H2: There are fewer errors made by participants who use the manual animated with the use of the augmented reality iPad application, Aurasma, than by those who use the static LEGO© manual, regardless of robot type.

Efficiency/self-sufficiency is defined by how often the student raises their hand to ask for help from the teacher, asks for help from a peer or a proctor, when a student watches a peer assemble their robot, when a student asks to start their robot over, and when the student produces visual or audible frustration. The more often that a student yields one of these indicators the student is considered less efficient/self-sufficient.

H3: The students who use the manual animated with the use of the augmented reality iPad application are considered more efficient/self-sufficient at completing the procedural task when compared to the participants who use the static LEGO© manual, regardless of robot type.

Engagement is defined by the number of times a student is distracted, how often a student talks to their peers, how many times the student focuses on something other than building their robot, and how often the student complains about the project. The more often that a student yields one of these indicators the students is considered less engaged.

H4: The students who use the manual animated with the use of the augmented reality iPad application are more engaged during the project than the participants who use the static LEGO© manual, regardless of robot type.

Enjoyability, ease of use, and learnability are being measured because "user satisfaction is considered an important factor affecting the success of learning systems" (Lee & Lehto, 2013). H5: The students who use the manual animated with the use of the augmented reality iPad application will find the use of their manual to be more enjoyable, easier to use, and easier to learn how to use during the project than the participants who use the static manual, regardless of robot type.

Method

Participants

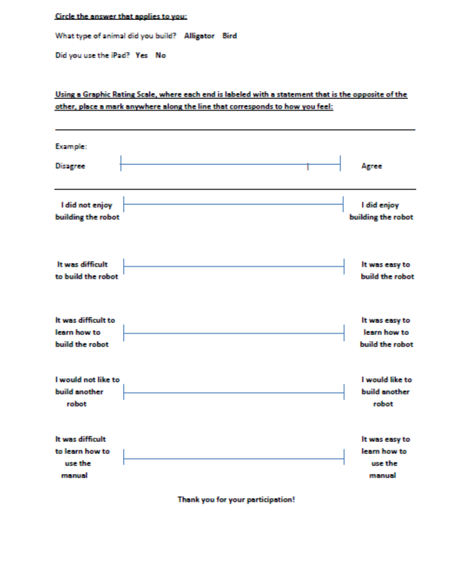
Subjects in this experiment consisted of one sixth grade class, composed of 19 students between the ages of 11-13. No demographic information was collected. The participants were recruited via Project SMART of SUNY Oswego's affiliation with Fitzhugh Park Elementary in Oswego, NY.

Materials

Technology. Each student was provided with their own LEGO© brand WeDo kit that encompassed dozens of individual LEGO© brand pieces and computer attachments. Apple iPad devices were borrowed from the Fitzhugh Park Elementary school's library. The Aurasma application was downloaded to each iPad and featured tutorials with which each step of the static manual was to be animated. These tutorials presented verbal representations of the instructions along with a video demonstration of the process indicated by each step. Those participants using an iPad also received a set of headphones in order to properly hear the procedural information. A timer was set up on the SMART board in front of the classroom, as well. Once they were excused from data collection, participants were permitted to use laptop computers in an adjacent room to test their robots with the software that accompanied the LEGO© brand WeDo kits.

Manual. Each student was provided with the instructional manual that accompanied the LEGO© brand WeDo kits, as well as a laminated green square that was held up to signal when the student was finished with their robot. The participants who belonged to the groups using the animated manual also received a laminated red square, which indicated an application malfunction. Since the static instructional manuals that accompanied the LEGO© brand WeDo kits did not offer a vocabulary associated with each piece, all participants received a vocabulary sheet that was developed by the investigators.

Questionnaire/Survey. The questionnaires were distributed after every participant had assembled their assigned robot on the first day. In this questionnaire, they were first asked to identify the type of animal and to which manual type they were assigned. Subsequently, using a graphic rating scale that was anchored with opposing declarations, the questions assessed the participant's opinion about their enjoyability regarding the project, the ease of use regarding the LEGO© brand WeDo kits, the learnability of the kits, their satisfaction rating of the project, and the learnability of their manual type. At the end of the second day, participants were given an open ended survey that asked whether they prefered the animated or static manual, to provide descriptions of what they liked and disliked about the animated manual, and to suggest any changes that may improve the augmented reality application.



Circle the answer that applies to you:

What type of animal did you build? **Alligator** **Bird**

Did you use the iPad? **Yes** **No**

Using a Graphic Rating Scale, where each end is labeled with a statement that is the opposite of the other, place a mark anywhere along the line that corresponds to how you feel:

Example:

Disagree ——— Agree

I did not enjoy building the robot ——— **I did enjoy building the robot**

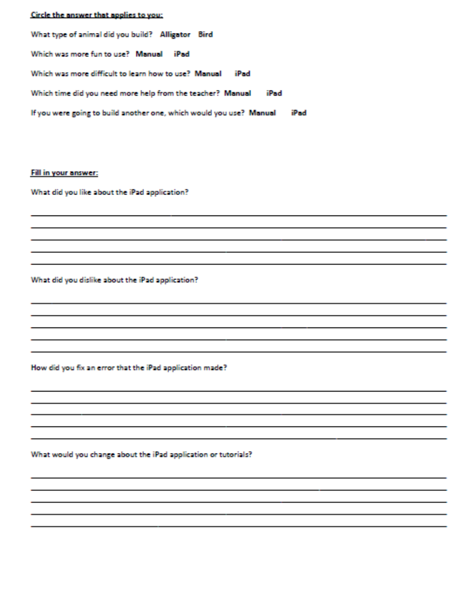
It was difficult to build the robot ——— **It was easy to build the robot**

It was difficult to learn how to build the robot ——— **It was easy to learn how to build the robot**

I would not like to build another robot ——— **I would like to build another robot**

It was difficult to learn how to use the manual ——— **It was easy to learn how to use the manual**

Thank you for your participation!



Circle the answer that applies to you:

What type of animal did you build? **Alligator** **Bird**

Which was more fun to use? **Manual** **iPad**

Which was more difficult to learn how to use? **Manual** **iPad**

Which time did you need more help from the teacher? **Manual** **iPad**

If you were going to build another one, which would you use? **Manual** **iPad**

Fill in your answer:

What did you like about the iPad application?

What did you dislike about the iPad application?

How did you fix an error that the iPad application made?

What would you change about the iPad application or tutorials?

Procedure

On Monday March 25, 2013, the participants had the entire process of the experiment described to them. The investigators explained what the participants would be asked to do, the vocabulary associated with the project, and allowed them to familiarize themselves with the parts of the LEGO© WeDo robot kits that they would be using.

On the following day, students were randomly placed into one of four groups. Each group was assigned to either an alligator or a bird animal type and either the static or animated manual type. One group featured the alligator/static manual and was observed by a principal investigator, Patricia Tanner. Another group was comprised of participants who were assigned to bird/static manual and was observed by a colleague of the investigators, Anthony Kirkpatrick. A third group consisted of those with a bird/animated manual and was observed by a principal investigator, Carly Karas, and one last group involved the alligator/animated manual and was observed by a colleague of the investigators, Bryan Kern.

It was explained to the participants that the observers were merely proctors and that they would not answer any questions or help to remediate the issues that may arise. The students were asked to raise their laminated red square to indicate an Aurasma application malfunction and to raise their hand to prompt teacher assistance, as traditionally practiced. Additionally, the subjects were asked to raise their laminated green square to indicate that they have finished building their robot. The observers agreed to make a tally into individual boxes on a sheet that referenced each of those prospective actions, whereas the red square equals “Application malfunction”, a raised hand equals “Efficiency/Self-Sufficiency,” and the green square would prompt the observer to look at the timer on the SMART board and record the time it took for that individual student to complete their build.

Specifically, the tally sheet measured errors made by the participant, the student’s self-sufficiency while building the robot, and their engagement with the task at hand. “Errors” were operationally defined as “student places block incorrectly”, “student skips a step”, “student must reassemble”, and “student must repeat a step”. This section was not measuring the Aurasma application errors; this section was measuring the actual observed errors made by an individual student. For the two groups that observed the use of the iPad Aurasma application, a separate tally box was available to record a student’s perceived application malfunction. “Efficiency/Self-Sufficiency” was measured by marking a tally when an observer witnessed the following; “student raises hand”, “student asks for help from teacher, peer, or proctor”, “student watches peer assemble their robot”, “student asks to start over”, “student shows visible/audible frustration”. Similarly, “Engagement” was measured by marking a tally when the observer noticed the student attending to “distractions”, “student talks to peers”, “student focusses on something other than project”, or the “student complain about the project”. The teacher and the student teacher were both available for every group to fill the traditional classroom teaching role when a student raised their hand. Proctors simply observed each group with as little intervention in the environment as possible. When the participant raised their green square, and their proctor recorded their build time, they were excused from data collection to test their robot with the laptop computers. No data was obtained from their work with the software.

When every subject had completed their robot and had the chance to test it with the software, a questionnaire regarding their satisfaction, ease of use, and learnability was passed out. They had approximately ten minutes to answer each question. At the end of ten minutes, the questionnaires were collected.

On the following day, a class of fourth grade students was invited by the sixth grade classroom teacher to observe the experiment. The limitations associated with this issue are discussed in section 7 of this paper. Each participant was assigned to their same group and was asked to build the same animal as on the previous day. On the second day, no participants used the animated manual. Also, there was no data collection about errors, efficiency, or engagement. The only variable being measured for the second day was the time it took for the participant to complete their robot using the static manual. They were asked to raise their green square when they were finished to indicate to the investigators that they had completed construction. Their time was then recorded on a data collection sheet. When each participant had completed building their robot, the students were given another survey which featured open ended questions about the project, prior to the investigators completing a debriefing phase that took about twenty minutes. The survey rated participant’s enjoyability, ease of use, and learnability of each manual.

Results

Results indicate that the average amount of time it took for participants who used the animated manual to build their robot on the first day was approximately 25 minutes on the second day (M=24.75, SD= 5.29) while the mean amount of time it took for participants who used the static manual to build their robot on the first day was approximately 32 minutes on the second day (M=32.18, SD=8.49). A two tailed independent groups t test indicated that the difference between these two groups was significant; t (17) = 2.32, p=.033. According to the operational definition for comprehension, these results indicate that the participants who used the animated manual on the first day comprehended the instructions about how to build their robot better than the group that used the static manual to learn how to build their robot on the first day.

A 2(animated versus static manual) X 2(alligator versus bird robot) ANOVA revealed that results from the questionnaire and tallies of errors (F = .840, p = .374), efficiency/self-sufficiency (F = .308, p = .798), engagement (F = .835, p = .375), enjoyability (F = .218, p = .647), ease of use (F= 2.384, p = .143), and learnability (F = .368, p = .553) were not significant and had no significant interaction.

Discussion

As predicted, in hypothesis 1, results indicate that there is greater comprehension of a procedural task when learned through the use of a manual animated by the augmented reality iPad application Aurasma than when learned through the use of a traditional static manual. This may be explained by the Dual-Coding theory which emphasizes that when a student learns something with both visual and audible stimuli, they have a greater opportunity of making connections, and therefore, a greater ability to recall the information that was learned. For example, if a student does not remember the information based on the visual stimulus, they have the opportunity to retrieve the information from their auditory memory, and vice versa. Since the static manual only offered one type of learning stimulus (visual), the animated manual which used both visual and audible learning stimuli provided a better opportunity for the students to recall the learned information (Lee & Shin, 2012).

There were no significant differences in the number of errors made or the efficiency/self-sufficiency for each group. A study by Greenough et al. (2002) that focused on testing digital manuals found similar results where, although the time to complete a given task was reduced in their experimental group, the mean number of errors were simultaneously increased. Eiriksdottir and Catrambone (2011) clarify why the experimental groups in each study did not produce less errors or showcase a higher level of efficiency/self-sufficiency. They assert that more errors and less self-sufficiency is common when a procedural manual very closely resembles the task at hand because it is likely that the users are merely mimicking the actions illustrated in each step. Student imitation of the animated manual, in this experiment, may have hindered them from creating the mental models required to perform a procedural task without teacher assistance.

In any classroom, it is the primary goal to maintain the student's attention and, often times, teachers use the Learning-Through-Play theory to reach this goal (Alejos, del Rio, Isasa, de Lorenzo, Cuinas, & Sanchez, 2012). Alejos et al. (2012) assert that, by appealing to the student's desire to play, students respond with high levels of satisfaction regarding their assignment. In this study, results indicated no difference between the levels of engagement found in each group. This may be explained by the claim that "using robot based tools for learning," such as the LEGO© brand WeDo robots, can "increase the engagement level in learning for all students despite their abilities" (Burbaite, et al., 2012). Therefore, the mere act of playing with the LEGO© brand WeDo robotic kits may have influenced the equally high levels of engagement among all of the students regardless of manual and robot type.

Although literature shows that learning procedural information from an animated manual can be beneficial for students, most people prefer to use static paper manuals (Greenough et al., 2002). When participants from this experiment were surveyed, 90% agreed with those reports, claiming that, if given the opportunity to build another LEGO© brand WeDo robot, they would prefer to use the static paper manual over the version of the manual that was animated using the iPad and Aurasma application. This reaction speaks to the participant's level of enjoyment with the animated manual because usability often affects the level of enjoyment regarding technology. Even though the statistical analysis found no significant differences in enjoyability between the groups, the majority of students reported that the iPad application was difficult to use and to understand. The technology acceptance model explains that a user's perception of usefulness and the ease of use of a technology impacts their desire to use it (Lee & Lehto, 2013). The perceived ease of use of each manual was not significantly different between the groups but it is possible that complaints about the ease of use concerning the animated manual were because the Aurasma application was not developed specifically to animate a static manual the same way it was utilized in this study.

Similar to the participant's perception of how easy they were to use, it was determined that there was not a significant difference in the learnability of each manual. Lee and Lehto (2013) would suggest that the animated manual was not easier to learn, as originally hypothesized, because people tend to avoid learning how to use a device when the design is complicated or errors occur. The most common responses regarding the features that participants disliked when using the animated manual was that the application would often malfunction by showing the wrong tutorial for the step that they wished to animate. It is likely that encountering this error decreased the learnability for the animated manual.

Although, statistically, there was not a difference between the animated and static manual in terms of errors made, efficiency, engagement, enjoyability, ease of use, and learnability, results indicated that those participants who had used the animated manual experienced a significantly higher level of comprehension. It is probable that these usability issues emerged due to the fact that the Aurasma application, in conjunction with the iPad, was not designed to animate a static procedural manual. With the input of the participants of this study, it is expected that the Aurasma augmented reality application, could be an essential tool aiding in student's comprehension of a procedural task.

Conclusion

Augmented reality in education is a viable option for educators to improve subject comprehension. Critics may wish to reconsider their claims that educational technologies are merely a distraction in the classroom. While the students of this experiment did not perceive any additional benefits hypothesized by the investigators (ie. ease of use, enjoyability), they nevertheless retained the information that was relayed to them through the manual that was animated with augmented reality well enough to conclude that the technology can be utilized in the classroom to their benefit.

To a great extent, further research should be conducted in the emerging process of augmented reality for education. Concerning the investigators of this study, a second study is planned for the future. This project entails teaching another class of sixth graders at Fitzhugh Elementary how to create their own animated images by using Aurasma on school-owned iPads. Students plan to use this technology to create book reviews for their school library, allowing any student to view their animated review of a selected book in the elementary library. This research could be extended, with the consideration of usability feedback from students, applying the technology to developmentally and physically disabled students, and by discovering other ways to utilize iPad and augmented reality for various academic subjects. This technology is expected to aid in the growth of STEM fields by encouraging students to learn through education technology.

Limitations

There were some limitations of this study that should be addressed. Perhaps the most obvious is that this study was conducted within an established classroom, where the teacher was highest authority. Control of the experiment may have been better managed under different circumstances. Additionally, the friendships tht existed between students were likely to cause disruption and disengagement because all four groups of students built their robots in the one classroom. Due to this arrangement, the students who constructed their robots at a slower pace were able to witness some of their peers finishing before them, which undoubtedly increased frustration. One limitation that was a concern since the design of the experiment involved the selection of two different animal robot types. The decision to involve more than one type was aimed at avoiding the fatigue effect among the students. It was only through the promise that they would soon be building the other animal robot type that they were content with building the same animal two times within two days. A considerable disadvantage of the study was the sample size, which was only one classroom of 19 students. Most statisticians would agree that the sample was too small for a definitive result.

There were several usability issues with the Aurasma application, as well. For example, the students had to hold the iPad over their static manual through the entirety of the animation before setting it down to perform the task showcased in that step. Also, in most cases, the students had to stand to get the entire page within the iPad camera's view, possibly causing greater discomfort than what was perceived by the students who used the static manual. To rectify this issue, further research into use of smaller devices, such as the Apple iPod Touch or Apple iPhone, is recommended.

Because the pictures from step to step in the original static manual were so similar, the Aurasma application would often recognize the wrong step and play the incorrect animation over the static picture. The application seemed to work based on color and contrast values when determining the images it would create into trigger pictures. Students were visibly frustrated when this happened, especially because the application would not show the correct tutorial after several tries. Based on research that claims that it is valuable to incorporate user feedback in the design of a digital manual, the lack of user contribution in the development of the Aurasma application as a tool to animate a static procedural manual probably impacted the participant's perceived ease of use (Greenough et al., 2002).

Day 2 of the experiment featured, not only the original sixth grade class, but also a fourth grade audience which was invited to observe the study in an effort to introduce peer-led education into the curriculum. All sixth graders were paired with a fourth grader; it is understood that every student may have been helped or distracted by the observer, and may have influenced or skewed the data collected on this day.

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