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An AR Enhancement of Printed Educational Resources: Keeping printed educational materials competitive in a digital age

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AN AR ENHANCEMENT OF PRINTED EDUCATIONAL RESOURCES

Keeping printed educational materials competitive in a digital age

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ABSTRACT

Digital resources have begun to take over our educational system and overshadow traditional printed resources. While these digital resources are becoming increasingly popular research has shown that printed resources have notable benefits that should not be dismissed. Enhancing these printed resources with augmented reality (AR) technology will allow them to be competitive with digital resources while preserving their academic benefits. The readily available smart devices carried in the pockets of most students have already prepared many classrooms for the use of AR. The interactive and visual potential of AR makes it an appealing educational tool that can dramatically improve the experience of learning with printed resources. This project will utilize 3D and animation graphics to simulate the use of AR on a selected set of existing texts.
DEDICATION

I dedicate this work to my parents because without the relentless care and energy that has been put in to keeping me on track and their love and support I would not have been able to make it to grad school let alone complete this project.
INTRODUCTION

The traditional printed resources used in our educational system are being overtaken by digital resources. Modern technological developments have resulted in this rapid growth in popularity of digital resources. There are several benefits to printed resources that make them worth keeping. Further development has resulted in the production of augmented reality (AR) technology which has lots of academic use potential. Enhancing printed resources with augmented reality (AR) technology will allow them to compete with digital resources while preserving their noted academic benefits. The personal smart devices that can be found in the pockets of most students basically have classrooms ready for the use of AR technology. The visual and interactive potential of AR makes for an appealing and efficient educational tool that can vastly improve the experience of learning with printed resources.

Printed educational materials have worked adequately for a very long time. Constantly developing technological abilities have dramatically changed the way we can view academic content. This has occurred to the point where static two-dimensional images can only portray a segment of the information potentially gained from an animation or interactive experience. Regardless of this there are still benefits to be gained from the continued use of printed resources. Studies have shown that while both types of resources lead to success in the classroom those who use printed study materials grasp a more detailed and in depth understanding of the material than those who go digital. There are also other benefits such as to the eyes it’s easier to read text off of a printed page than off a back lit screen.¹ Notation in printed study texts is much easier to do quickly and efficiently while reading is occurring. The main thing that print materials lack the ability to do is show all the sides and movement of an object or system. The integration of AR technology with printed resources could be a solution to this.

Augmented Reality or AR for short is the use of various lenses to apply a visual overlay of digital content on the real world. AR has been around since 1968 when the first instance of virtual/augmented reality was developed by Ivan Sutherland at Harvard

University. However it took until 1990 for the term Augmented Reality to be coined and two years after that until “Louis Rosenburg created the first operational augmented reality system”. After this many uses and applications for AR systems began to be developed. A more notable use is the well-known yellow first down line that has been used in football television broadcasts since its development in 1998. In 2000 Hirokazu Kato made a very important contribution to the AR field by developing the ARToolKit software which has been the basis for many modern AR involved apps. AR has been around for some time, but only recently has it begun to take a more central cultural role.

Today probably the most well-known example of the use of AR technology is the popular mobile game Pokémon go. This game uses AR technology to let players see Pokémon on ground in front of them. Another popular video game that has also recently released an AR involved version is Minecraft. AR technology is being used for many other things including airport way finding, interior designing, and even fighter pilot helmets. The ability to overlay digital objects or screens on real life has made all this possible. Using digital overlays allows us to view more information than what used to be possible all at once which can vastly improve performance and efficiency.

AR is essentially the projection of a virtual image or interface over a real-life object or space. AR can work in several ways. There is constant digital overlay of changing information like what a fighter pilots' helmet would be equipped with. There are also AR animations that are triggered by a camera being pointed at a designated object or image. In the very popular game of Pokémon go AR is used by having Pokémon at specific real world coordinates that appear on screen when you are looking in the right place. AR visuals can be projected on a multitude of lenses. These include smart phone cameras, glasses, regular cameras, AR headsets, TV screens and helmet visors. The visual capabilities of AR technology paired with its growing interactive abilities makes it a great tool for balancing out the capabilities of digital and print academic resources.

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AR can and has vastly improved academics as evident by the experiments that have been done with it so far. Google expeditions has already helped create many working system replications in AR. On a slightly more advanced note Hannes Kaufmann and Bernd Meyer experimented with a more involved AR process that lets you interact and conduct experiments in an AR environment.

**PROCESS**

The goal of this project is the AR enhancement of printed educational materials of all levels. In order to prove the overall feasibility of this project four printed academic resources each representing a different level of education were selected. From each of the selected resources a single page and image was also chosen to be used for the AR demo. The name, subject and academic level of these resources as well as the selected page from each are as follows:

**Resource #1:** Worksheet about the layers of the earth  
**Curriculum Level:** Elementary School  
**Subject:** Science  
**Description:** A cut and paste worksheet for young kids to learn about the names of the layers of the earth.  
**Note:** What you see here is a critical redesign of the original worksheet. This resource was the only one that received a redesign. The original version can be found in the bibliography.

**Resource #2:** CPO Science, Physical Science Textbook  
**Curriculum Level:** Middle School  
**Subject:** Physical Science  
**Description:** A middle school level textbook covering the basics of physical science.  
**Page & Topic:** P.148, the function of a wind turbine.

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In order to adequately show the effectiveness and value of the AR content being added to these texts, 3D animation and motion graphics skills and tools were utilized throughout the project. The use of a few different pieces of software was also required to complete the project. The most pivotal of the softwares used were CINEMA 4D and After Effects. CINEMA 4D is a multipurpose 3D animation program and After Effects is a motion graphics and film editing program. CINEMA 4D was used to construct the 3D portion of the four animations created for this project. After Effects was used for post rendering manipulation of the 3D models and the application and animation of the text.
METHODOLOGY & RESULTS

The development process of the animations yielded several iterations for each of the four pieces. These iterations progressively improved as they were produced until they reached their current and final versions. This section will delve into what the design process was for each animation and what the decisions were that led to the development of the successive iterations. This section will also discuss what makes the animations appropriate for the age and education level of the target demographic.

Animation 1: The layers of the Earth

This animation is intended to remind young kids of the names of the layers of the Earth in a fun and attention grabbing way.

Iteration 1:

In this iteration of the first animation the model scaled in and one at a time a quarter of each layer was pulled away revealing its label and the next layer underneath. The low model complexity and hand-crafted and toy-like texture was used in this version to better accommodate the young and often less focused target audience.
Iteration 2:

The second iteration of the first animation has a few consistencies with the previous one. The model complexity, texture, and physical render method of this version have remained the same as the last. The animation also begins with the model being scaled in as before. The first difference is that the layers are revealed by retracting their top halves. This iteration ends with the nested layers expanding upwards and 3D labels rotating in from behind the layer objects. An increase in movement of the animation involved in the revealing process of the layers in this version made the piece more exciting which was the main limitation of the previous version.
Iteration 3:

The third iteration of this animation included features from both of the previous versions plus a few new ones. Again the animation begins by having the model scaled in. The retraction of the layers from the second iteration has been combined with the section cutout concept from the first iteration. The model complexity, and render method have also remained the same. This iteration featured the first change in the textures which was done in an effort to further increase the excitement of the animation. The exterior was made to look a lot more realistic and the inside layers were given animated textures that represent the movement of their molten material. Being a later version the layer labels are accompanied by informative text that describes each of earths layers as their revealed.
Final Iteration:

This is the last iteration of the first animation. There are a few aspects of the previous versions used but also several considerable changes as well. The previous three iterations did not achieve the level of entertainment and excitement that the target audience would enjoy. The main features from the older versions that have been included in this one are the layer expansion animation and the 3D layer labeling from two iterations ago. This was due to the increased movement being more target age appropriate. Building on the need for more movement and excitement the beginning sequence was totally revamped. It now appears as a full size spherical globe popping up through a set of springloaded doors made out of the AR trigger image. The globe then bounces and settles before being slightly lifted up by the extruding diagram.
After this the rest of the animation is very similar to iteration two except for the retraction of the layers which happens together in a smoothly staggered manor. Due to the low age and beginner learning level of the intended audience the final iteration only contains layer labels and no additional detailed information. The realistic textures in the previous version were also too detailed and not playful enough for the target age group which is why the textures in this version have been changed to a slightly different toy like and playful look than the original iteration. The model complexity of this version went slightly up because an additional layer was added. The earths mantle layer was split into upper and lower parts in an effort to better balance out the look of the model in its extended form at the end of the animation. In order to accommodate this the resource in the back ground had to be redesigned.
The last changed aspect of the final iteration was the method used to render the animation. The previous three versions were rendered with Cinema 4D’s physical renderer. The first two did not have to be but the animated texture in the third iteration required the use of the physical renderer to work. The change was made to the independant Arnold renderer\(^8\) for the smoother looking textures and the faster render times.

Animation 2: The function of a wind turbine

This animation is intended to demonstrate how a wind turbine functions and provide additional information about some of its parts in a fun and interactive manner.

Iteration 1:

The first iteration of the turbine model was built to resemble the diagram from which the AR animation is triggered. In this version of the animation the turbine is scaled in and a gust of wind starts moving the blades. The turbine continues to scale up and rotates so the open side of it is in clear view and the working parts are clearly visible. This version includes descriptive information about the operation of the turbine along the top as well as labels for the internal parts. The model complexity and realistic textures in this version were made to bring realism to the model. There are a few large issues with this version that prompted the development of the second and final iteration. One of the issues is the existence of a shadow on the textbook page from the digital object which would be an impossible occurrence. A second issue is the over simplified nature of the inside mechanisms of the turbine model.
Final Iteration:

The development of this animation began further into the project and as such only two iterations were produced. The model for this iteration was completely rebuilt and as a result almost no aspect of the original version exists as part of this one. The rebuild was done in an effort to increase the model complexity too more closely resemble a real life turbine and not the drawing in the book. The textures in this version are also made to add to the realism of the model. In order to be more interesting and engaging to the middle school demographic this iteration was animated to be interactive. The turbine still scales in but all other movements are shown as touch screen interactions. The animation shows one possible order of events that a user could produce. After scaling in the “user” rotates the turbine to look at all the angles then zooms in to look at the side.
While a user could do what they want this animation an order of events that follows the given on screen instructions. Once the side of the turbine is slid off by the user the inside mechanisms are revealed. The low model complexity was an issue with the earlier iteration so this one features a much more detailed working system. To get a closer look at this working system the user can zoom farther in.
When zoomed further in the user can see the moving parts much closer up. The user can then tap on a part they want to learn more about and a label and description will open up with information. This can be done for all the internal parts of the turbine. Throughout all of this a big red reset button can be seen that when hit will reset the turbine model to a closed up and all the way zoomed out position. Lastly this animation consistently used the Arnold renderer for all of the iterations.
Animation 3: The structure of a water molecule

This animation is intended to show the structure of a water molecule in a cool and interesting way.

Iteration 1:

![Water molecule animation iteration 1](image1)

The first iteration of this animation was built around the idea of showing the structure of water starting at the molecular level. This version starts by scaling in a red sphere that is then added to with two white spheres which come from off screen. The screen then begins to zoom out as more molecules connect to the original one to form a clump. The clump then continues to zoom further out until combine with more clumps to form a mass. This first iteration was made with text descriptions and a simple background. The mat texture was used in this first iteration to get a smooth professional look. The medium level model complexity in this iteration was intended to clearly show the simplicity of a water molecule but the messiness of a mass of them. This series of animations started off being rendered with the physical renderer.
Iteration 2:

This iteration has the same simple background but the text descriptions come from the top instead of the bottom. The texture for the molecule went through a few different iterations itself. Tests were conducted with metallic, glossy, and matt textures. While the first iteration settled on the matt texture, the metallic was used in this iteration because it looked more like it had a wet and shiny gleam to it. The model complexity of this iteration went slightly up in order to place more emphasis on the liquidity of water. This version starts with a red pool coming up off the floor in a fluid-like fashion. The hydrogen molecules emerge from inside the red sphere to form the water molecule. In this version, multiple copies of the molecule expand outwards from the original molecule to form a grid-like structure. The rendering method was still physical at this point.
Final Iteration:

Water plays a very important roll in our daily lives and has a relatively simple molecular structure!

The final iteration contains changes in most of the animation events, model complexity, textures and rendering method. The model complexity of this iteration greatly increased with the animated particles being included in the beginning. The textures were updated to have a transparent and bubbly liquid like appearance. The animated events in this iteration begin with a squirt of water from the location of the trigger image. After the water settles back down transparent water baubles are left hovering in the air.
The mass of water baubles zooms and expands until the focus is on a single sphere. At this point the color of the sphere transitions from a blue to a less transparent red. The main motivation for the drastic change in material texture is to have it look like liquid. In order to better achieve this look this iteration was rendered with Arnold.
Once the spheres color has changed the hydrogen molecules will appear from inside it forming the water molecule. This iteration includes the actual book page in the background. To better blend with the animation the informative text appears and disappears with an angled fading sweep it also no longer has its own background.

The first two iterations of this animation were structured to show the make up of water only at the molecular level where as the final iteration is structured to show the substance and molecular level. This decision was made to make the animation more entertaining and informative. The texture changes lead to a more vibrant and engaging look for the animation. The development of the action of the animation from building molecules to squirting water allowed this piece to be appealing to the target audience.
**Animation 4: The function of a 3 dimensional printing system**

This animation is intended to illustrate the function of a 3D printer and give more detailed information about its parts and inner workings.

**Iteration 1:**

This is the fourth and final animation produced for this project. For this first iteration the overall model complexity was higher than the rest. The printer case model was more detailed than the extruder which was changed in the final iteration. Realistic texturing was used for this iteration. This first iteration started with a full 3D printer being scaled in and then proceeded to print out the phrase “command P 3D!”. This iteration was an early one so it did not include any text descriptions.
Iteration 2:

This iteration has the same model complexity and textures as the first one. The main difference was that the printer was animated in by having it constructed one piece at a time. This was done to add a more technical aspect to the animation.
Final Iteration:

This is the final iteration of the final animation produced for this project. The biggest difference between this and the others is the extruder which is now more detailed inside and outside. The model complexity of the printer case was also boosted to feature a spline feeding apparatus. The texturing is similar to the previous versions but with a bit more effort being put in to the realism of them. This iteration begins with the scaling in of the extruder on its own. Like the turbine animation this one is designed to be interactive from here on out. The user is prompted to tap the cover of the extruder to open it and reveal the detailed inside mechanisms.
Once open the individual pieces in the extruder can be tapped for additional more detailed information. When the user is ready they can press the print button which builds the rest of the printer around the extruder and zooms out to reveal the whole thing.
The last phase of the final iteration is the demonstration of a 3D object being printed. The object being printed in the previous two iterations had several instances of floating pieces which were not realistic. Because of this the 3D object was changed to a simple chess piece that is printed in a more realistic manor and pace.

The biggest issue and most obvious theme of the changes between the different iterations of this animation was technicality. This had to be first and foremost as this animation is targeted towards college level students. The detail and interaction incorporated in this animation is crucial in order to make it sophisticated and engaging enough to meet the needs of this higher level target audience.
RECOMMENDATIONS FOR FURTHER DEVELOPMENT

The animations produced for this project adequately show the potential of AR technology on printed academic materials. The four animated pieces that were created each provide more in depth detail of the topic they are representing. This project only included the production of a series of test AR animations where as many more would be needed should this concept be developed further. That said one possible direction to take this concept would be the production of an application that includes many AR animations that are organized and search-able by resource and page number. A large accessible collection of these animations could provide a way for more people to get more out of using printed resources.
CONCLUSION

The point of this project was to produce a means by which the capabilities and benefits of printed educational resources could compete with digital resources. The proposed solution is the integration of AR technology with printed resources. The visual capabilities and growing interactive abilities of AR technology are what makes it a fantastic educational tool. The visuals and interactivity of AR technology can lead to increased student engagement and focus. Because this issue spans not one but all levels of education any solution had to be universally feasible. To accommodate this four AR animations were built each based on a different level of academic curriculum.

In order to adequately represent the four selected academic levels the stylization and feel of the animations were purposely different so that they could appeal to the targeted audience. The animation representing the lowest educational level was built to be more fun and textured with bright engaging colors that gave the action a playful and toy like effect. The animation representing the middle school level of education was more detailed and introduced interactive components. The last two animations continued with this pattern of detail and interaction while progressively increasing the amount of detail and information being conveyed.

AR technology and AR animations provide a great means of conveying more in depth information about many subjects. AR technology is rapidly becoming more relevant in society. The abilities of AR have already started catching the eye of the business and marketing industry likely ensuring it a role of continuously growing importance in the future. Right now the kinks are getting worked by early adopters of the technology. Right now the ability to take a 3D animation and place it in AR is tricky due to animation and model construction compatibility issues. However the early adopters of this technology that we have now are figuring out these problems. This will allow much smoother 3D model to AR space transitions in the future streamlining the process by which the large amounts of animations that will be needed to encompass the whole of educational content are produced and implemented. Apps like the new Adobe Aero app with its

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everyone can do it system that works by quickly importing many 2D and 3D files into AR space will further aid the future popularization of the use of AR. The ability of AR technology to work with and not just replace printed materials and resources is why it was selected for this project. That’s also why it’s a technology that should be and likely will be embraced in the future.

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**3D Printer**


**Earth**