science fiction no longer: augmented reality and the technology engineering education classroom

by Justin Egresitz

While AR technologies have not yet reached the capabilities of their big-screen counterparts, there are useful everyday applications for AR technologies, including as part of the T&E education classroom.

Augmented reality (AR) has long been a part of the canon of science fiction. One of the most famous recent examples of AR in science fiction is in the Marvel Cinematic Universe. This is often centered around the character Tony Stark, the fictional billionaire engineer genius who employs AR in combination with his Iron Man suits of armor and in everyday sunglasses. Depictions of technologies in science fiction films often set the stage for what is to come, as they inspire the next generation of technologists and engineers to make real the fantasy they saw in their youth (Longhi, 2014). In addition to inspiring, science fiction can also introduce us to needs and wants that we may not have been aware of. This can lead to the desire to create new technologies to meet these new needs. While AR technologies have not yet reached the capabilities of their big-screen counterparts, there are useful everyday applications for AR technologies, including as part of the technology and engineering education classroom.

What is Augmented Reality?

Augmented reality, as Azuma (1997) defines it is, "a variation of virtual environments (VE)… AR allows the user to see the real world, with virtual objects super-imposed upon or composited within the real world" (pg. 356). According to Puchar and Coulton (2014), sensor-based AR is the most widespread solution, utilizing GPS, accelerometers, magnetometers, and gyroscopes as data sources to interpret camera positioning in the software. This camera positioning data is then used with computer vision software to display and manipulate 3D objects over a real-world view. AR technologies tend to come in two form factors, one being a mobile computing device such as a smartphone or tablet, and the other being a head-mounted display (HMD) that takes the shape of smart glasses, helmets, and visors (Blanco-Novoa et al., 2018).

AR, in the mainstream sense, is an emerging technology that has come to the fingertips of the average user through their smart devices and as standalone pieces of technology. Despite the newness of the technology to the mainstream citizen, the idea of a functional, head-mounted, three-dimensional display dates back to around the mid-point of the twentieth century. There had not been much progress made toward functional AR until the new millennium. Miniaturization of computing devices was spurred by smart phone sales and mobile AR hardware capabilities began to catch up with the imaginative ideas of AR technologists (Arth et al., 2015). Today, the mainstream user can quickly download AR apps to their

smartphones and begin to familiarize themselves with the concept in novel and engaging ways through games and lifestyle utilities or purchase standalone HMD that produces a richer and polished experience. This has been accelerated by increased app development thanks to the creation of developer kits from Apple and Google that streamline the use of the onboard sensors to create AR environments. It appears that as the app development market has boomed, so too have new and novel uses for AR technologies in smart devices.

Current Hardware and Software

In July of 2018 it was estimated by AR Insider that there were 762 million AR-compatible smartphones in use (Boland, 2018). Given the worldwide sales of smartphones and tablets that are capable of running AR apps, the most available modality of AR hardware is the mobile computing device. Most smartphones and tablets manufactured within the last three to five years come equipped with the requisite sensor arrays and operating systems to run the AR apps that can be found within the app stores. Developing AR capabilities has been a goal for the makers of operating systems for some time, so much so that they have created protocols for developers to use to make the creation of AR apps more efficient. This has sparked a competition between the platforms for supremacy in the highly profitable AR space that is seen as the next platform for personal computing just as the cell phone was a generation prior.

Alongside the AR-capable smartphone market is the HMD modality. The first modern foray into this market was made by Google with Google Glass in 2014. Upon initial implementation Glass was met with pushback due to the camera functionality and, while floundering as a consumer device, it has transitioned into a training and maintenance device. In terms of HMD that can be purchased today, Microsoft currently sells the HoloLens 2 that features eye-tracking technology and is fully self-contained, eliminating the need to be tethered to a waist-mounted computing device or separate device entirely. A competitor to the HoloLens in the general-purpose AR smart glasses space is the Nreal Light. A relatively new product, Nreal uses an HMD that is tethered to a computing device and allows users to watch videos, play games, and read websites. Outside of the consumer hardware, there is a developer version with additional features that will be coming to the consumer product in future iterations (Robertson, 2020). HMD, like other wearables, will need to find a marketable use case that will drive sales, or they will suffer the same fate as other wearables and be seen as a flop and fall into obscurity.

To go with the AR hardware, there is a burgeoning AR software market filled with games, utilities, and educational content that consumers can download and experiment with for varying costs. In 2016, the category of AR games took off when Pokémon Go was released. The overnight and massive success of Pokémon Go spawned a trend of games that incorporate a popular franchise into a game with AR elements featured. Following in the footsteps of Pokémon Go, games such as Harry Potter: Wizards Unite and Minecraft Earth were developed and continue to be popular among users and generate revenue for their developers.

In addition to games, there has been a trend in shopping apps that allow consumers to use AR technology to help them make choices about the items they buy. One stumbling block for shoppers can be visualizing how a piece of furniture or a certain color will look in the room they are decorating. To fill in this gap, companies have produced apps that allow models of available furniture to be placed, in AR, into a room to see how it would look in the space. Apps from IKEA, Pottery Barn, and Wayfair all have this feature to assist consumers and even allow multiple pieces of furniture to be placed in a room to see how multiple items would look together.

A particular area of growth in the AR software space has been in educational apps. A quick search in the Apple App Store reveals a litany of educational AR apps that serve different functions and different content areas. For example, JigSpace allows educators to present content using manipulatable 3D models. Another app, CoSpaces Edu allows students to generate solutions to design challenges by placing models in space, code models to behave in certain ways, and even integrate a physics engine to simulate the effects of gravity (Chen, 2020). For a more personalized experience, the 3DBear app is affiliated with Makerspace Thingiverse, which facilitates the use of user-generated models in its software. With the popularity of Chromebooks as the computer of choice in many schools, some AR app developers have worked to meet students where they are. AR app availability is growing for the Chromebook platform, with similar functionalities as their mobile device counterpart.

Educational Benefits of AR

While AR technologies remain novel and niche, there are still educational benefits to be gained from their implementation. Wu et al. (2013) discussed the utility of AR as a way for students to learn content in 3D perspectives. This allows students to view a model or object from a multitude of angles and even manipulate it. This active engagement with a digital model, through AR technology, allows students to deepen their understanding of interconnected concepts and engage with the content in a modality beyond abstraction.

Another benefit, as noted by Dunleavy, Dede, and Mitchell (2009), is that AR-enhanced pedagogy can parallel 21st century work. This is accomplished through a combination of factors. Use of AR technologies allows educators to create pedagogy where learning is authentic and similar to real-world experiences students may engage with outside of school. AR also allows educators to plan for the practice of problem finding and problem solving, key aspects of creative problem solving. Finally, students exercise metacognitive strategies for constructing meaning out of complex experiences. These facets of AR-enhanced education mimic themes that students will encounter in the workforce and that will make them more desirable to employers later in life.

Billingshurst and Dünser (2012) discuss the potential for AR technology to help students who struggle with traditional forms of education. Lectures and textbook reading do not facilitate the learning of all students. AR can assist an educator who teaches this way by increasing interactivity with the learning materials, thus reaching students who struggle in text-heavy environments. The authors also mention the positive impacts that AR has on student engagement, motivation, and involvement.

Drawbacks of AR in the Classroom

AR technologies can bring benefits to the classroom but have limitations and challenges that must be navigated. A sizable challenge that educators implementing AR in their classroom will have to navigate is the technological capacities of themselves and their students (Bowers et al., 2014). Educators and students who are inexperienced or lack a fluency in using and troubleshooting these technologies may struggle with implementation of them in their classroom. An educator will likely need to be fluent in the specific software and hardware they are using prior to instruction and be flexible during implementation to assist students when they have issues.

Another issue that educators wishing to implement AR in the classroom may happen upon is accessibility. Not all students have the same access to the same kinds of technology so planning any technology-enhanced lessons can be difficult. While there are millions of AR-capable devices in the hands of consumers, they are not all created equally. Some may be better suited to handle the computing demands of the software, and some may crash, hampering the learning experience. In general, modern smart devices that are within two to four years old and have the ability to run the latest version of the operating system will likely be able to run AR educational software, however research into specific requirements and what devices students have should be a part of the planning process. Apps may be available on some platforms and not others, or only available on an HMD and not on a smartphone platform. Some students may experience fatigue or discomfort while using an HMD in the classroom or they may be ill-suited for a student with special needs (Arvanitis et al., 2009).

Perhaps the most effective deterrent to implementing AR technologies in the classroom is the cost. Mobile devices that are compatible with AR technologies can cost hundreds of dollars, with similar prices for HMD as well. Compounding this problem, because of the qualities of AR technologies, they do not align themselves well with being developed for laptops or desktop computers. Given the prevalence of Chromebooks and the countless number of desktop computers and laptops, the technology provided by schools is often insufficient to run AR applications, although developers are working on this problem. In addition to the cost of devices, educational software packages frequently have a paid tier with additional features that make implementation smoother and less convoluted that using the free tier.

AR and Technology and Engineering Education

The technology and engineering education classroom stands to gain tangible and enduring benefits by implementing AR into the curriculum. Bartholomew (2017) discussed the opportunities for teaching science, technology, engineering, and math (STEM) content in an integrative way through the use of the Pokémon Go app. Mobile apps like Pokémon Go present opportunities to integrate math and science content through an AR experience. In addition to this, the use of these apps presents a natural pathway to discussions about AR, software engineering, GPS, and digital mapping. These apps also feature the use of physical landmarks in a community that can facilitate a discussion about civil engineering, architecture, and even historical concepts. Bartholomew frames the discussion of AR integration around the use of a design challenge and points to specific content areas such as web design, manufacturing, and computer science as areas where a creative curriculum fit can be found.

Spatial skills are considered to be of paramount value in technical education and as such are often taught early in a program of study (Katsioloudis & Jones, 2015). AR technologies can assist the technology and engineering educator in developing spatial skills within students. According to Thornton et al. (2012), "Models that students can simultaneously touch and see enhance information acquisition that cannot be experienced through the visual alone. Even though simulated, AR provides these dual sensory experiences that permit deeper understandings" (pg. 19). By implementing AR in the curriculum, teachers can further develop the spatial skills of students that are critical for their technology and engineering education experiences going forward.

In addition to those benefits, AR technology can also provide a platform for educators and students to discuss the big picture implications of AR and other emerging technologies. AR and other emerging technologies are undoubtedly novel and highly engaging for users, however, these technologies can have second- and third-order implications that are not inherently obvious when we set out to "catch 'em all" in Pokémon Go. Topics such as data retention policies, technology's impact on human-to-human interactions, and mindfulness of time consumption while using technology can be discussed while implementing AR technologies into curriculums. The ability to critically assess technology and its impacts is a key concept that students should be taking away from our classes and AR technologies provide us a platform to have those deeply important discussions.

AR and Standards for Technological and Engineering Literacy

In 2020, the profession of technology and engineering education underwent a reimagining of the foundational document of its field. The resultant *Standards for Technological and Engineering Literacy* (ITEEA & CTETE, 2020) shifts the emphasis from content-directed standards to standards that focus on developing a broad and conceptual understanding of technology while retaining the goal of building technological literacy among students. Using the three organizers of standards, practices, and contexts as a framework for what and how we teach, educators can highlight technological concepts, build bridges between STEM content areas, and develop skills in processes of designing and making.

AR technologies, while being beneficial to student learning in their own right, also contribute to the attainment of several standards within *Standards for Technological and Engineering Literacy* (ITEEA & CTETE, 2020). This is done by fulfilling benchmarks that ultimately lead to attainment of the standard. By fulfilling benchmarks STEL-2Q, STEL-2T, STEL-3J, and STEL-4N, integration of AR concepts into the technology and engineering education curriculum contributes to the attainment of the standards that form the foundation of high-quality curriculum.

AR integration fulfills benchmark STEL-2Q by providing students a way to visualize and assess their designs for possible outcomes such as manufacturing feasibility, potential waste, and human-centered design considerations. AR integration also fulfills STEL-2T when in the context of a design process as a modeling method. Similar to the previous benchmark, students can use AR models they create to assess for conflicting considerations, such as tradeoffs, while they decide the value of their current design. Using AR technology as an area of study, benchmark STEL-3J can be attained by discussing how it took several areas of knowledge progressing to a certain point before AR technology could become feasible and cost-effective for the mainstream user. Lastly, AR fulfills benchmark STEL-4N by providing a starting point for discussion about how we as people currently think and communicate with one another and how that could change in a future where AR technology could be providing us a hands-free and unobvious source of all kinds of information.

Application of AR in the Technology and Engineering Classroom

The confluence of content from technology and engineering education and other disciplines is an ever-growing theme in the literature surrounding the profession. By implementing AR technologies into the classroom, technology and engineering educators can engage with multiple content areas and still further the goal of technological literacy. The following example uses content and concepts from adjacent fields and mixes them together such that students engage with technology, engineering, and design concepts and put all of their work together in an AR space.

In this example, high school students are tasked with taking on the role of a zoo designer. Following a design log, students will select an animal, research its biological needs and habitat, design an appropriately sized and appointed space, model the space using 3D modeling software, upload it to Thingiverse, and present their designed solution to the class through the 3DBear AR application so students can interact with their solution during and after the presentation. In this lesson, students investigate biology concepts through an investigation of their selected animal's biological needs, such as food, other animals, and habitat. Mathematics concepts are found in the design process of the space in which the animal will be housed. Technology and engineering concepts play a role in the process of designing a physical object, modeling the object in a digital space, and manipulating the model during their peer's presentations. This example, while brief, illustrates how multiple content areas, when processed through the technology and engineering lens, can use AR technology to augment and enhance the learning outcomes.

Conclusion

The connective tissue between science fiction and technological development has left an enduring mark on humanity. Augmented reality, once the stuff of novels and comic books, is now fast approaching a point where average citizens will have a stream of information and models layered over their everyday reality. Students today, more than ever, are familiar and comfortable with highly technical and complex technology like AR. By implementing AR into our curriculum, students may feel that we are "meeting them where they live" and preparing them for a technology that will grow with them as they and the technology mature. This innovation, while still novel and emerging, can be harnessed by technology and engineering educators as a vehicle to integrate STEM content, develop spatial skills, and facilitate deep discussions about implications of new technologies. Rationale for integration of AR technologies is also grounded in *Standards for Technological and Engineering Literacy,* providing a standards-based argument for its value. While we may be a few years away from our students routinely proclaiming, "I am Ironman!" AR integration can provide technology and engineering educators with tools to improve the learning of their students.

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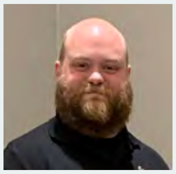

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