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The Pedagogical Potential of Augmented Reality Apps

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ABSTRACT: *Experimental research in the field of augmented reality has increased in recent years. So has investment and interest among the education industry. This manuscript analyses the current state of augmented reality applications for stationary, mobile, and wearable devices. Specifically, we will highlight the areas within education that have been positively impacted, and provide a short list of outstanding apps. Also, we specify the major technical components of augmented reality applications. Alignment with solid educational theory will promote the effectiveness of the new technology. Several barriers to the full integration of augmented reality into education are discussed. Finally, using our understanding of educational technology as a lens, we project the future state of augmented reality in pedagogy. We conclude that augmented reality has been proven effective among multiple subject matters. This technology will soon become pervasive not only in education, but in society in general.*

KEYWORDS : *Augmented Reality, Educational Technology, Embodied Learning*

I. INTRODUCTION

Some technologies are preordained to impact every industry, and multiple societies. Augmented Reality applications (AR apps) are one such technology. AR apps utilize an ever increasing assemblage of software, sensors, and devices to display information and media on a device simultaneously with the real world in a sort of digital phantasmagoria. AR Apps are already available in large numbers for advertising, education, healthcare, and entertainment. Most AR apps are available for smart phones and tablet computers, downloaded through the Android and iTunes app stores. Here we will focus on the potential for AR apps to support education, across subjects and grade levels. Specifically, we will scrutinize the demonstrated effectiveness and limitations of AR apps. Numerous features common in AR apps are worth mentioning, as is the imminent potential for educational features still being developed. A short list of useful, innovative, AR apps is also provided as a reference titled, "Apps You Can't Live Without". With origins dating back to the 1960s, you could say AR apps are the emergent result of advances in other educational technologies. The theoretical underpinnings of AR effectiveness also go back decades. Finally we will dream about the future of augmented reality.

Table 1: Apps You Can't Live Without
Note: This figure was developed by the author and not previously published.

AR Application	Platform	Key Features
AR Compass http://www.apple.com/itunes/affiliates/download/	iOS	Displays real-time weather, elevation, slope, distance, landmarks, and bearing.
Google Goggles https://support.google.com/websearch/answer/166331	Android, iOS	Recognizes books & DVDs, landmarks, barcodes & QR codes, logos, contact info, artwork, businesses, products, and text
Ingress https://www.ingress.com/	iOS	Alternate reality game elements, massive amounts of content, cutting edge graphic design, physical real-world markers
instaMOTION http://instamotionar.com/	Android and iOS	Designed for educational purposes, interactive features reactive to plain paper notebooks.
Invizimals http://invizimals.eu.playstation.com/en_GB/home	PS Vita	Can be used on any floor, ceiling, wall or surface, no markers are required, motion sensor and touch screen integration
Penguin NAVI http://penguinnavi.erba-hd.com/	Android, iOS	Motion captured animal avatars, GPS

		integrated avatars,
Virtual Money Machine https://www.growfinancial.org/	Proprietary	Skeletal structure recognition
Star Chart http://www.apple.com/itunes/affiliates/download/	iOS	Accurately displays stars and planets above users.
Walgreens AR App unreleased	Project Tango Tablet	Highly accurate GPS position tracking to within 3 centimeters, Large database of store architecture specifications

II. LIMITATIONS

In recent years, privacy and ethical concerns will continue to act as barriers to AR app advancement, and social technologies in general. Social acceptance of being constantly photographed, videotaped, and analyzed by government agencies and citizens will take time. As with most modern educational technologies, you also have the digital divide to content with. The most funded schools and supported students will have access to the most modern mobile devices, while many schools and students will not. On the most basic level, there are practical limitations on the use of AR apps including budgets, time constraints, teacher interest, internet connectivity, and administrative support [4].

Since AR Apps are a relatively new educational technology, there is a limited body of knowledge regarding their effectiveness in specific educational contexts versus other, more established technologies. It is commonly understood that live action video is recommended for teaching procedural knowledge. It is not hard to imagine that real-time video, enhanced with the benefits of AR Apps, would also be useful. It could possibly be more useful and effective, but we will have to wait for empirical evidence to make strong arguments. Several limitations have been identified by research results. Learners have had difficulty focusing on other things while using AR apps. Some users of AR apps report them to be difficult to use. This combination of inexperience and large amounts of information displayed on screen has resulted in the perception of cognitive overload. However, some resistance to change is expected with any new medium [13]. AR apps also lack effectiveness when used with high-achieving students [21]. Several research projects to date have had difficulties relating to the myriad technologies required to produce a highly usable, effected AR app. Infrared sensors, processing power in small devices, and display technologies are all making large advancement strides. Still, research in this area shows promise notwithstanding the likelihood of advances in the various subfields. There are quite a few new technologies with educational potential. Social media, maker projects, virtual worlds, gesture based interactions, digital video libraries, and mind mapping are all new options for education. There needs to be focused experimental research that will identify specifically which technologies are most effective for a given grade level, subject, learner, and context. This type of evidence would equiponderate the large effort required to research, select, train, and use a particular technology. Once these criteria are identified, each technology will see more usage in educational institutions.

III. EFFECTIVENESS

Software developers are becoming promethean in their ability to find new ways to leverage technology. AR Apps have been used in many different ways for education. Museum guidance apps increase a learner's ability to understand exhibits on field trips, as detailed information and media is displayed on the device [10]. If there is an old, dilapidated historical structure on exhibit, an AR app can show what the building looked like when it was first built. Museum visitors are also able to be guided to specific exhibits which interest them the most. Game based AR apps are able to teach various subjects through practice, play, and learner embodiment. Gaming AR apps are also able to add a narrative to the learning experience, in which the learner must accomplish goals by increasing skills in the subject-matter. Impacts on learning include socialization, challenge, accomplishment, fantasy, stress-relief, alleviation of boredom, escapism, and exploration. Elements can be added to increase leaner motivation, including emotional investment, excellent storytelling, and heroes that can be identified with. Gaming AR apps can use a special non-verbal communication to communicate with and motivate users. Personal investment into a game draws players into the game world and its goals. Gaming AR apps are able to overcome the stigma of "learning" and "doing schoolwork" that some students experience. Mathematics education benefits greatly from AR apps. The ability to generate high quality media in real-time in response to learner input allows advanced math concepts to be demonstrated visually. For example, the coefficients in quadratic equations can be changed as the resulting graphs of the equations change instantly, and in 3D. In addition, the graphs of advanced algorithms can be superimposed onto real life surfaces.

Educational AR Apps that have been researched include *SMART*, *Virtuoso*, *Protein Magic Book*, *Alien Contact!*,*ARex*, *The Table Mystery*, *AR Physics*, *Tinkerlamp*, *Tapacarp*, and *Kaleidescope*[20] [4]. Overall these research projects found positive results related to increased collaboration, deeper understanding, and motivation. AR apps were found to help students that have difficulty conceptualizing complex information. Clothing design education programs can benefit from static AR displays. These displays enable clothing of any type to be superimposed on the mirror image of a user. The clothing displayed on screen can be manipulated via an interface on the screen, or with a networked smart phone. This could save weeks of design time, and save money on wasted materials. These same benefits apply equally to geotechnical engineering, architecture, fabrication and manufacturing programs [17]. AR apps have also been developed for teaching chemistry, biology, physics, languages, English, religious studies, astronomy, geometry, medical practice, musical education, education support, visual art, and library studies [1][16][11][23][3][5][2].AR Apps are more effective than print, books, and software when teaching spatial subjects, like geometry. AR apps are more effective than textbooks for teaching the meanings of words, and students retain knowledge longer than from text and video. Positive effects also include increased collaboration and motivation. [21]

IV. TECHNICAL COMPONENTS AND CONSIDERATIONS

Four general categories of AR app display have been defined, ranging from most real to most virtual: The real world, augmented reality, augmented virtuality, and a complete virtual world. Currently available AR apps are built using presentation devices, stimulus devices, tagging of known objects, and computational estimators. [22] Tagging of physical objects is what makes a device recognized a specific object in the real world. This is accomplished with a system of GPS sensors, magnetic sensors, accelerometers, digital cameras, wireless sensors, digital compasses, and ultrasonic sensors. The accuracy of a tagging system depends on the sensitivity of the various components. The data processing components of AR systems require large amounts of RAM. Currently most AR Apps run on hand carried devices, but the future could see an explosion in the wearable device market, including head mounted devices. The image capture can be performed with a binocular or monocular lens. Binocular lenses allow for magnification. There are also optical recording and video recording systems.Video recording systems require more computing power, as the system must first generate the real-world video, then generate the digital imagery, and then coordinate the two elements in time. Spatial Augmented Reality combines radio waves, video projectors, optical components, holograms, and computers to enable AR without requiring a portable screen. Gesture based AR Apps include sensors for movements made by the user [24]. For example, the LG G3 smart phone allows you to take a photo by closing your hand on screen. The use of advanced screens, made with advanced materials like synthetic sapphire allow for high resolution, high contrast, bright images to be displayed. These detailed, information rich displays have also been linked to positive learning outcomes in education [9].

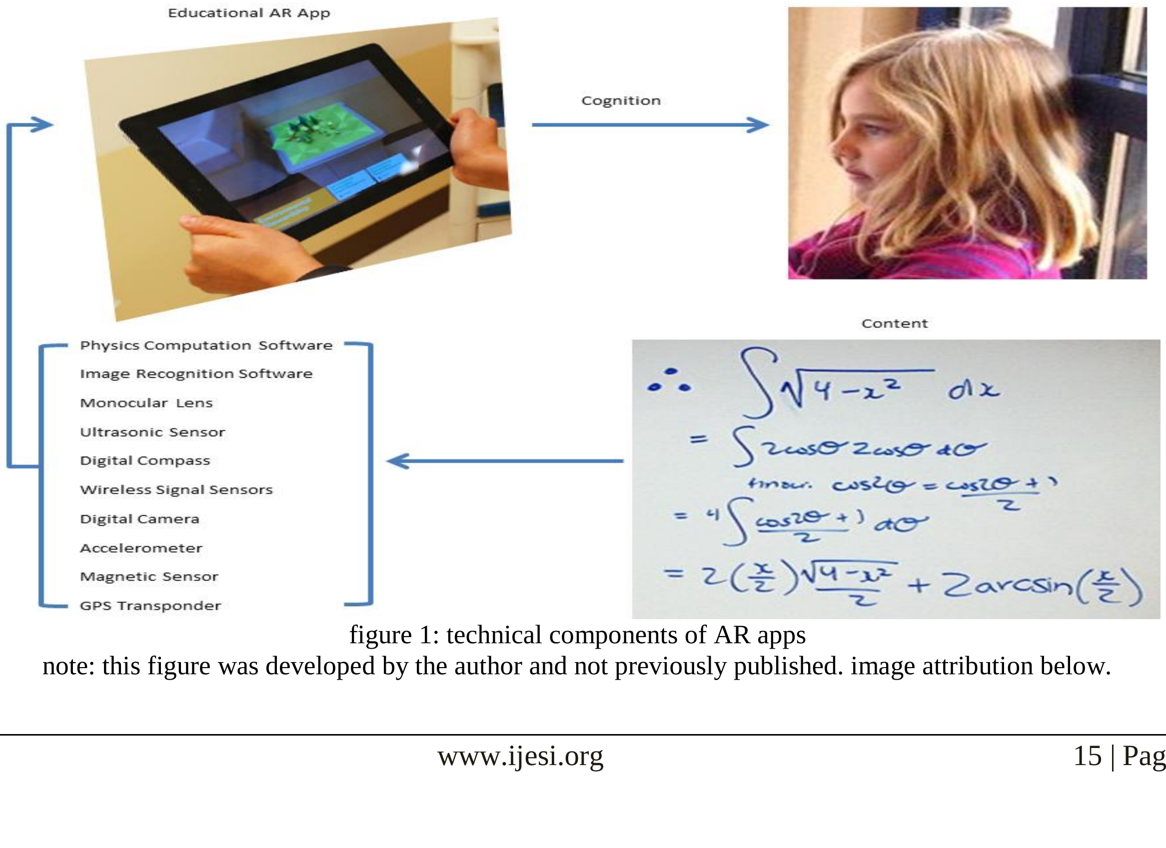

figure 1: technical components of AR apps

note: this figure was developed by the author and not previously published. image attribution below.

V. THEORETICAL UNDERPINNINGS

Cognitive Information Processing Theory relates to AR apps in that the displayed information may transfer to short term memory, further usage may transfer knowledge into working memory, and mastered apps may transfer information into long term memory [14]. Dual Coding Theory is a basis for understanding the effects of AR apps as well. Learners are presented with text and related images at the same time, which increases the cognitive mental load, which in turn increases overall learning [19]. Social Learning Theory strongly supports the increased collaboration resulting from AR apps. Environments are based on factual, professional information. Students can model the behavior of the professionals (physicists, designers, etc.) [18]. Communities of Practice Theory suggest that AR apps should use environments and characters based on appropriate contexts [15]. For example, in a physics based app, use people and places that physicists might realistically encounter. Other relevant, highly regarded theories of education include game-based learning theory, place-based learning, participatory simulations, problem-based learning, role playing, studio-based pedagogy, and jigsaw method theory [26].

VI. DREAMING ON

AR app solutions are already being planned and developed for implementation in the future. As mobile computing devices become more affordable, and the devices themselves become more advanced, the market will expand and diversify. There will be competition among retina display devices, wearable displays, and gesture based AR interfaces developed by leading electronics retailers. Once wearable mobile devices become mainstream, AR apps will become a part of popular culture and the economy on a large scale. AR app features will be combined with other technologies, and other physical objects. We will see the combination of gesture recognition devices with AR. Also available in the near future will be AR apps developed for standard textbooks, enhancing them with 3D graphics and supplementary information [12]. Perchance in the year 3014, everything we look at will be technologically augmented. AR apps are part of a larger, broad societal shift towards a global information society [25].

VII. CONCLUSION

As mobile devices like the iPhone 6, the Samsung Galaxy Tab S, and the LG G3 become more advanced, so too will the AR apps made for them. AR apps are just becoming known to the world, as are the many uses for them. The many successes in educational domains such as physics and math have been tempered by struggles with technology and educational policy. The technologies that come together to enable AR apps will continue to advance rapidly, providing us with richer, more usable apps with which to conduct research. As this happens, reviews like this manuscript will be necessary for education professionals. Many want to leverage the benefits of educational technology, but don't have the time to review the entire body of literature on each subject. The field of educational augmented reality applications could also benefit from increased research in specific fields of study.

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