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History of the (Virtual) Worlds

By Steve Downey

ABSTRACT

Virtual worlds represent a small but dynamic sector of the computer technology field with global applications ranging from art and entertainment to online instructional delivery and educational research. Despite their worldwide acceptance and usage, few educators, researchers, or everyday gamers fully understand the history and evolution of virtual worlds – their genres, platforms, features, and affordances. Many of the innovations we readily recognize today (e.g., user creation of in-world objects in worlds like Second Life) began as grassroots efforts by gaming and computer enthusiasts who were long on passion but short on documentation. The end result is a twisted and often thorny history for a technology that now actively engages hundreds of millions of users worldwide and millions of users within education alone. This article synthesizes histories and definitions from virtual world developers, industry leaders, academic researchers, trade journals, and texts in order to form a coherent historical narrative of events that contributed to the evolution and shaping of the virtual worlds as we currently know and use them in education and society in general.

Keywords: virtual worlds, history, computer technology, evolution

INTRODUCTION

Virtual worlds represent a small but dynamic platform within the field of computer technology. A quick search of academic journals and respected Internet sources will demonstrate that there is a growing literature base addressing the application of virtual world environments for a variety of purposes, including educational research, the delivery of instructional courses and programs, community development, entertainment, and more. Within education, renowned institutions around the world have long been affiliated with virtual worlds (e.g., University of Essex, University of Illinois, and Carnegie Mellon University). In more recent years, Harvard University, Indiana University, and University of Wisconsin have led the way in educational research related to virtual worlds. However, for all of the growth and inroads virtual worlds have made into education and society at large, there are very few educators, researchers, and everyday gamers who understand how virtual worlds, their genres, platforms, features, and affordances have evolved over the decades to their current state. As virtual world pioneer, Richard Bartle, wrote on the 30th anniversary of the virtual world MUD (October 20, 2008), "Some old-timers know the history of MMOs and whence they came, but most of today's developers haven't a clue" (para. 5).

For demonstration purposes, the following is a short quiz; try it and see how you do. The answer key is at the end of this article.

1. In what year was the first virtual world created?
2. What was the first virtual world to enable its users to create in-world objects?
3. What is the connection between Luke Skywalker and virtual world avatars?
4. True/False: The word *dungeon* in the term *Multi-User Dungeon* is a reference to the Dungeons & Dragons game from which early virtual worlds drew inspiration.
5. Rank the popularity of the following virtual worlds from most to least popular, based upon total user accounts at the height of their popularity: Club Penguin, EverQuest, Habbo, Second Life, and World of Warcraft.

If you didn't get all five correct, don't feel bad. It's surprising how much virtual world literature cites conflicting dates, events, and definitions as being correct. For example, not everyone agrees which virtual world was created first – see the section on First Generation Worlds for the varying views. To better understand this area of technology and how its evolution has established and supported a variety of teaching, learning, and socialization affordances taken for granted nowadays, this article synthesizes histories and definitions from virtual world developers, industry leaders, academic researchers, trade journals, and texts in order to form a coherent historical narrative of events that contributed to the shaping of the field as we currently know it.

PROBLEM BACKGROUND

Brought to the attention of mainstream education and society in the mid-2000s through commercial successes such as World of Warcraft and Second Life, virtual worlds represent one of the fastest growing segments of the gaming industry during the first decade of this century (Dafferner, Chan, & Valette, 2010; International Business Times, 2010). The history of virtual worlds, however, stretches back more than 35 years and was slow to develop during its first few decades. Similarly, literature from the early days is comparatively sparse and much of the documentation from this period in virtual world history (e.g., magazine articles, user manuals, software code) is slowly disappearing (Koster, 2009).

Only during the last 10 years, driven by the rise in popularity of computer games, has there been a rapid increase in publications related to virtual world environments. This recent literature, however, is largely fragmented and widely dispersed across a variety of disciplines – for example, computer science, education, sociology, anthropology, and communication, (Downey, 2012). Although this can be good in that it demonstrates an examination of the field from different perspectives, it also produces a significant challenge to people entering the field as they typically gain only a partial understanding of the domain and its history.

A lack of a coherent history is not the only problem stemming from the fragmented literature. To date, no common agreement exists for defining or even naming these virtual spaces (Bell, 2008; Downey, 2010; Schroeder, 2008). They are interchangeably called massively multiplayer online games (MMOGs), massively multiplayer online role playing games (MMORPGs), multi-user virtual environments (MUVEs), persistent worlds, synthetic worlds, virtual environments, and virtual worlds (Bartle, 2003; Bell, 2008; Combs, 2004; Damer, 2006; Doppke, Heimberger, & Wolf, 1998; Spence, 2008). In some cases, these labels reflect meaningful, albeit subtle, differences in the various types of environments. For example, MMORPGs and MUVEs are meaningfully different in their purposes, social rules, and so on; however, they are both large-scale, multi-person, virtual spaces. Recognizing both the commonality and nuance differences between these different environments, the umbrella term of *virtual worlds* is used in this article to broadly refer to all of these environments and their shared history.

Purpose, Target, and Scope

To address some of the challenges brought about by fragmented literature bases and an unstable lexicon, this article seeks to synthesize and clarify key definitions and historical information in order to aid others in extending their understanding of virtual worlds. In fulfilling this purpose, the content in this article revolves around two primary research questions: (a) what are the major milestones in virtual worlds history and (b) how have virtual worlds evolved from one generation to the next to reach the highly social and collaborative spaces we know today?

In reporting the major milestones of virtual worlds, the scope of this article is simply to identify what happened, when it happened, and how it affected later events in the evolution of virtual worlds. This article does not attempt to interpret these events through the lenses of different disciplines – for example, through anthropology: Boellstorff (2008), psychology: Turkle (2008), or others. It does, however, provide a linear timeline of the major events – many of which still influence the design, operation, and usage of virtual worlds today.

Given the summative nature of this article, the target audience for its contents is individuals who are new to virtual worlds. This article will aid them in gaining a chronological overview of the evolution of these worlds and a working definition of what currently constitutes a virtual world, from which they could continue their work within their own specialized disciplines and perspectives related to virtual worlds.

Methods

In completing this research, a historical research methodology was employed (Rowlinson, 2005; Johnson & Christensen, 2008). This approach utilizes four stages: (a) formulate problems to be addressed in the historical review, (b) collect data and literature, (c) evaluate materials, and (d) synthesize data and report findings.

The formulating of problems for this review is straightforward. Virtual worlds have a fragmented history due to poor and disappearing documentation; they also have poorly defined terminology and are not well understood conceptually . To address these problems, materials were collected and analyzed with separate but related objectives in mind: (a) generate a formal working definition of what constitutes a virtual world and (b) delineate a timeline of major milestones in the evolution of virtual worlds.

For stage two, the collection of materials included both primary and secondary sources of information. Primary sources have direct involvement with the event being investigated, such as an original map or an interview with the person who experienced the event (Gall, Gall, & Borg, 2007; Rowlinson, 2005). In this article, these included information emanating directly from a world's developer, such as articles, blogs, presentations, and so on. Secondary sources are artifacts emanating from sources other than those having first-hand experience with the event. These sources include articles by academics and individuals not directly involved in the world's development (e.g., research journal articles), blogs of industry experts and academics (e.g., Terra Nova), news stories, game/world reviews, critiques, and others.

When evaluating materials, as was done in stage three, we considered Rowlinson's words: "Historians often use three heuristics in handling evidence to establish its authenticity or accuracy: corroborations, sourcing, and contextualization" (Rowlinson, 2005, p. 298). *Corroboration* involves cross-checking of statements, dates, and other information within a document (i.e., internal criticism) with other external sources and documents (Gall, Gall, & Borg, 2007; Johnson & Christensen, 2008). Sourcing relates to the authentication (or "external criticism") of documents and artifacts as a whole (Gall, Gall, & Borg, 2007; Johnson & Christensen, 2008). *Contextualization* is determining where and when an event took place. In this article, most of the evaluation work pertained to corroboration of developer claims (e.g., which virtual world came first). Contextualization was of lesser evaluative importance given the scope of this article; however, when possible, the author tried to acknowledge originating institutions where games/worlds were developed (e.g., Essex University for MUD1).

The final stage of data synthesis and reporting involved three major elements: selecting, organizing, and analyzing (Rowlinson, 2005). Selecting draws upon the evaluation process in stage three, above, to identify and select the most authentic and accurate information to include in the reporting (Johnson & Christensen, 2008). Organizing addresses how selected information is arranged to form a cohesive whole. Finally, analyzing relates to critiquing (and frequent re-evaluation) of findings as they related to one another to assess the overall accuracy and continuity of the information being reported.

Limitations

As with all studies, there are limitations associated with this research. In particular, three limitations affect the scope and potential quality of the findings presented in this article. First, only games/worlds that conformed to the formal definition presented in this article were selected in stage four for inclusion in the historical review. As a result, precursors and ancillary inspirations are omitted, for example, the original tabletop version of Dungeons & Dragons and novels such as Snow Crash (Stevenson, 1992). These exclusions were necessary to focus attention on the digital environments themselves, their traits, the terminology, and the conceptual heritage associated with these environments.

The second limitation is the lack of primary source documents and artifacts. Virtual worlds emerged as a grass-roots movement by enthusiasts, who often worked informally on a world in their free time. As a result, few of the early worlds were developed with any formal documentation and very little of that documentation still remains publicly accessible today. Similarly, virtual worlds of the current generation typically are developed by for-profit, corporations (e.g., Sony, Blizzard, Electronic Arts) and do not readily publicize many of the innovations associated with their worlds in order to retain a competitive advantage.

The final limitation is a product of the second. Due to the lack of primary source documents and artifacts, information must be acquired from secondary sources (blogs, wikis, new reports, etc.) that may be biased, inaccurate, or purely personal opinion – even if they are statements from highly credible sources. Consequently, some findings may be omitted from the review because they couldn't be confirmed by additional sources.

VIRTUAL WORLDS THROUGH THE AGES: MAJOR MILESTONES

General agreement can be found in the literature that virtual worlds began during the 1970s (Bartle, 2004; Damer, 2008a; Kent, 2003; Koster, 2002; Mulligan, 2000); the exact date depends on whom you ask. The following narrative highlights prominent contributors to the three generations of virtual worlds and how their milestone contributions affected future worlds.

The three generations of virtual worlds defined in this article are based upon the changing nature and traits of worlds from one generation to the next (see Figure 1). First generation virtual worlds were primarily text-based, small in scale (250 users or less), and set in the realm of fantasy adventure (e.g., Dungeons & Dragons and Middle Earth). Second generation worlds witnessed the growing use of graphical worlds, larger scale systems (1,000 or more users), the introduction of social-oriented worlds, and the development of worlds in which users could create objects and shape their world in real time. Finally, the third (current) generation marks the age of massive systems (10,000+ simultaneous users), visually striking 3D worlds, and a growing array of genres and types of virtual worlds (e.g., MMOGs, MUVEs, MMOLEs; fantasy, science fiction, pseudo-reality) that target adults and children alike.

First Generation Virtual Worlds (1978 – 1984)

In reviewing numerous articles, dissertations, blogs, wikis, news stories, and other artifacts, no documentation was found that anyone intentionally set out to create the virtual world genre. This genre emerged through grass-root activities comprised of a series of one-step improvements, borrowed ideas, and ad hoc creations by computer enthusiasts who also were fantasy game hobbyists. Many of the early environments were just multiplayer versions of existing single player games. Given that many of these early worlds were developed either for fun and/or as personal challenges (Bartle, 2004), there is little documentation on these environments to ascertain which was truly the first virtual world. The literature points to multiple environments as being the "first" virtual world – Maze Wars (Damer, 2008a), MUD (Bartle, 2004, 2006; Kent, 2003; Ondrejka, 2008), Avatar (Call, 2010), and Habitat (Sharkey, 2009), among others. Each of these was innovative in its day and contributed to defining what we now think of as virtual worlds. As such, they all are discussed in the narrative that follows. However, MUD spawned a line of successors that can be traced to today's generation of virtual worlds (Bartle, 2006; Keegan, 2003; Mud Genealogy Project, 2005), thereby making it the digital equivalent of Ardi – the oldest known human fossil (Shreeve, 2009).

First Generation	Second Generation	Third Generation
Persistence	Persistence	Persistence
Small-scale systems	Larger scale systems	Massive scale worlds
Text-based displays	Graphical displays	Striking 3D presentation
Fantasy-based games	Games & social worlds	Games, social, & edu worlds
	Avatars (in-world persona)	Highly customizable avatars
	User control over objects	User driven communities
		Adult & child user bases
1978 – 1984	**1985 – 1996**	**1997 - present**

Figure 1. Generational Traits of Virtual Worlds. This figure presents a summary comparison of the prominent traits associated with each generation of virtual worlds.

Multi-User Dungeon or MUD was written by Roy Trubshaw in the fall of 1978 at the University of Essex (Bartle, 1990). Sometimes referred to as MUD1 to denote the first widespread release of the MUD system, MUD1 was actually the third iteration of the game that was started by Trubshaw and finished by Richard Bartle in 1979 (Bartle, 1990, 2004). Often mistakenly associated with the widely popular Dungeons & Dragons fantasy game, Bartle stated that the "D" in MUD does stand for "dungeon," but it does not relate to the game published by Gary Gygax and Dave Arneson in 1974 (Bartle, 2004). Trubshaw was inspired by ADVENT (aka Adventure, by Will Crowther and Don Woods) and ZORK (by Tim Anderson, Marc Blank, Bruce Daniels, and Dave Lebling at the Massachusetts Institute of Technology); he wanted to create a multiplayer version of those games (Bartle, 2004). The particular version of ZORK that Trubshaw played had been ported to Fortran and named "DUNGEN" [sic]. As a result, the acronym MUD (Multi-User Dungeon) readily presented itself and was adopted.

MUD1's contribution to virtual world history is nearly immeasurable. First and foremost, MUD1 demonstrated that users could share space, interact, and work toward a common goal, just as they had enthusiastically done in tabletop versions of games like Dungeons & Dragons. Numerous virtual worlds can trace their lineage back to MUD1 (Doppke, Heimberger, & Wolf, 1998; Keegan, 2003; Mud Genealogy Project, 2005). Examples of this can be seen in second generation worlds (described below), where MUD1 inspired TinyMUD, which lead to TinyMUCK, which lead to MOO, which lead to LambdaMOO, and so forth. As a result of this type of propagation, by 1992 there were more than 170 different multi-user games on Internet, using 19 different world-building languages (Rheingold, 1993). Witnessing this potential, computer programmers, university students, and hobbyists set about creating their own versions of a MUD, and the genre was born.

For the purpose of presenting both sides of the "*which virtual world was first*" argument, next is a quick note about Maze War (or Maze as it is sometimes known). Maze War was released in 1974 and was innovative in multiple ways; however, even though it supported multiple players (up to 8) it is not a virtual world – it lacks persistence among other elements. Conversely, it was one of, if not the first, networked first-person shooter games (DigiBarn, 2004). Also, its use of graphics gave the illusion of a 3D space, something not seen in virtual worlds until Avatar in 1979. Even though it is not a virtual world based upon the definition used in this article, Maze War is still noteworthy because it utilized instant messaging, non-player bots, and levels of play—all of which are features commonplace in virtual worlds today.

Avatar (developed by Bruce Maggs, Andrew Shapira, and David Sides at the University of Illinois) was released for the PLATO system in 1979. According to Bartle (2004) and Goldberg (1996), it was the first fully functional graphical world. It should be noted, however, unlike Habitat (see second generation, below) Avatar's graphics only utilized a small portion of the user's screen; static text and a chat interface consumed the remainder. Although Avatar was remarkable in several ways (e.g., it introduced the practice of "spawning" to repopulate monster/bots), it is the ease of player communication and use of group-oriented content that significantly advanced the practice of in-world collaboration. In doing so, it prompted other developers to create more in-world interactions and social elements in their worlds.

Second Generation Virtual Worlds (1985 - 1996)

A relatively quiet period in terms of commercial successes, the second generation was critical to the rapid growth witnessed during the current third generation. During the second generation developers learned valuable lessons about players' styles and tolerances, refined underlying technologies, and developed new business models for today's marketplace. Noteworthy worlds during this generation include Habitat, TinyMUD, TinyMuck, and Meridian59 – all of which are discussed next.

Habitat was a remarkable world developed by Randy Farmer and Chip Morningstar at LucasArts. Released in 1985, it marked the start of the second generation. It was the first world to employ the use of an avatar to establish a user's in-world presence (Morningstar & Farmer, 1991). Unlike first generation worlds, Habitat scaled well, supporting more than 20,000 users (Morningstar & Farmer, 1991). It also offered more in-world player interaction activities than the hack-n-slash dungeons of the first generation. Given its highly interpersonal nature (Farmer, 2003), Habitat arguably served as the first social-oriented virtual world (Damer, 2008a).

In 1989, *TinyMUD*, developed by Jim Aspnes at Carnegie Mellon University, was released. TinyMUD was innovative in that it focused less on combat and more on user cooperation and social interaction (Stewart, 2000). Its social focus and the fact that TinyMUD ran on widely popular Unix systems propelled the growth of TinyMUD, and MUDs in general, around the world. TinyMUD also spurred a series of innovations that Second Life users would find commonplace. For example, TinyMUD allowed users to create objects from within the virtual world (Doppke, Heimberger, & Wolf, 1998).

After playing TinyMUD, Stephen White (University of Waterloo) wrote his own variation, *TinyMUCK* (released in 1990), which further extended the functionality of TinyMUD and eventually created “MOO” (Bartle, 2004). MOO (MUD Object Oriented) provided a robust scripting language that allowed users to create in-world objects for social-oriented virtual worlds. Paul Curtis came along shortly thereafter and created LambdaMOO (Curtis, 1997), which gained popularity in the press and education.

As a result of these innovations, two distinct genres of virtual worlds emerged: game-oriented worlds and social-oriented worlds. Virtual worlds were no longer combat-driven realms in which players sought to get the upper hand on their peers. Thanks to customizable and cooperation-supporting venues such as Habitat, TinyMUD and LamdaMOO, virtual worlds began employing cooperative models of play versus purely player vs. player model (Jones, 2003).

Meridian59 (released in 1996) marked the end of the second generation and the beginning of the third. It was designed for slower 14.400 modems, but it began incorporating play styles and 3D perspective graphics found in today’s worlds. It also was the first commercial game to use the new business model of directly employing the Internet, versus a proprietary network like CompuServe or AOL, to provide player access (Kent 2003). This model would become a common business practice for the highly profitable worlds of the third generation.

Third Generation Virtual Worlds (1997 – present)

The third generation of virtual worlds experienced an explosion of user growth and the entry of virtual worlds into mainstream society. No longer developed on shoestring budgets, third generation worlds have seen budgets from a few million dollars (Ondrejka, 2008) to hundreds of millions of dollars (Morris, 2012). They capitalize upon, and in some cases push the limits of, the increasing computational and graphic-rendering power of today’s home computers in order to produce rich, vibrant visual worlds that draw users into the game and feed their desire to explore and play.

As much as Meridian59 was a stepping stone toward this success, Ultima Online (UO) was the first to begin realizing the enormous potential of virtual world games. Released in 1997 by Origin System Inc. (Electronic Arts), UO was designed from the beginning to be a richer and deeper world in terms of content than previous MUDs and worlds. In a recent interview (Olivetti, 2010), Richard Garriott, creator of the Ultima lines of games, explained that UO was intentionally designed to be different:

> [A] vast majority of MMOs are about running around, killing monsters and collecting treasure. They’re not about interacting with the physical world in detail. Ultima Online was about this. Things such as placing cups and plates and silverware on tables, and being able to pick up rings off the ground were important to me. (para. 8)

The end result was that UO brought about a firestorm of changes in virtual world design. For example, different playing styles were accommodated (e.g., casual vs. hard core gamer) and first- person graphical views were used instead of the normal overhead view.

EverQuest, released by Sony Online Entertainment in 1999, served as the de facto standard for graphical virtual worlds during the early 2000s. Within six months of its release, it overtook UO in total subscribers and maintained the leading market share in the United States until 2005 (Woodcock, 2008). In EverQuest, casual players no longer had to fight for their lives as they did in UO’s player vs. player format. This made it even easier and more enjoyable for newbies to join their friends online. Further, EverQuest was designed to encourage group play, prompting players to get their friends online and in-world. Witnessing the rapid success of both Ultima Online and EverQuest, more than 100 graphical virtual worlds were developed during 2000-2001 (Bartle, 2004). Each of them tried to capitalize upon the growing market defined by these worlds.

To date, the king of all virtual worlds (in terms of revenue generation) is Blizzard's World of Warcraft (WoW). Released on November 23, 2004, WoW sold 240,000 copies overnight – more than any other game in history (Van Autrijve, 2004). While at their heights, EverQuest and Ultima Online reached over 300,000 and 230,000 subscribed users, respectively (Bartle, 2004; Woodcock, 2008). WoW, in turn, reached more than 11 million subscribers around the world (Blizzard, 2008) and held more than a 50% market share among subscription-based MMOGs for more than four years (Woodcock, 2008).

Building on the lessons learned from Ultima Online and EverQuest before it, Blizzard designed World of Warcraft for multiple playing styles; then it went further. Blizzard designed content for multiple age groups, including pre-teens through retirees – market segments that previously received little attention. In addition, they made game play for each of these different age ranges and playing styles fun from the beginning. "World of Warcraft was one of the very first MMOs that you could hop right into and have fun – right away" writes Michael Zinke (2008, para. 6), lead contributor for Massively.com. He also to stated that, "In the original EverQuest, at launch, you spent long minutes waiting for your character's health to regenerate after every fight. Spellcasters had to meditate, essentially vulnerable to everything in the gameworld, for even longer minutes to get mana back" (para. 9). All of this downtime left the non-hardcore gamer bored and unengaged.

In addition, well-scripted scenarios also aided novice gamers in getting their avatars up and going. In doing so, players felt an immediate direction and purpose as well as experiencing early successes as they are learning to play. Open-ended end-game features and dungeons designed for both small and large groups also were contributing factors to its success. With open-ended end-game play, once your avatar reaches the highest level of experience within WoW, there are numerous options for continued play – achievements, guild building, player vs. player rankings, and so forth. In addition, small group and large group dungeons allow users to select content suited to their social preferences. Small group dungeons (5 or 10 person) are shorter in length and are easier to find willing participants to join the group. Large group dungeons (20 or 40 persons) are highly difficult and require a great deal of social organization and reliance upon others in order to successfully complete a dungeon. These features along with WoW's artistic presentation and articulate storylines have made World of Warcraft the leading example for how to design engaging, easy-to-play, content-rich worlds that are suitable for a variety of age ranges and playing styles.

Picking up where the MOOs of the second generation left off, Second Life differs from the previous milestone makers of Ultima Online, EverQuest, and World of Warcraft in that its content is user-created. Although it is not the largest social-oriented virtual world, Second Life (launched in 2003 by Linden Labs) is one of the most well known due to its popularity with the media and education.

Due to the ease of in-world object creation and a culture of sharing and collaboration (Luban, 2008), Second Life users have created a wide array of content from realistic replications of real-world buildings and towns to highly imaginative fantasies to scientifically based simulations. In addition, breaking established rules used by most virtual world games, Second Life not only allows but often encourages its users to sell and exchange items through forums and auction houses like eBay (Ondrejka, 2004). This approach has continued to feed the Second Life economy with more than $160 million in user-to-user transactions in the first quarter of 2010, a 30% increase of the previous year (Caoili, 2010). Given its open format for creating virtually anything a user wishes in-world, Second Life remains a highly popular venue for educators wishing to establish a virtual world presence for their institutions or who want to take their students on a virtual field trip to the ancient days of Rome or to role play the part of the characters in a literary epic.

THE DAWN OF A NEW AGE?

Recent changes in the virtual world field during the past five years have signaled the possible beginning of a new age. Changing trends in user profiles, business models, and the introduction of reality-augmented virtual world platforms (e.g., Activision/Blizzard's Skylanders and Disney's Infinity) may serve as precursors for new worlds and platforms yet to emerge.

The earliest of these signs was the emergence of the pre-teen demographic segment among virtual world players. *Habbo* is one of the oldest (launched in 2001 by Sulake Corp, Finland) and most successful of the worlds to target this rapidly emerging market segment. A pioneer in kid-oriented virtual worlds, Habbo boasts 15 million unique users from 150 different countries (Caoili, 2010). Habbo provides its users with furniture, pets, and other accessories to build their own spaces and customize their play; the rest users create. Lead designer, Sulka Haro states:

> One of the key things is that practically all the content on the servers is created by the players themselves, so it's not like we have to do that much to keep up with the times if you look at the content itself, because it's the players bringing the stuff in (Sheffield, 2009, para. 31).

Even more interesting is that Habbo, like many kid worlds, has a nearly 50/50 girl/boy demographic balance (Nutt, 2007); this is particularly noteworthy given that virtual worlds historically are male-dominated venues.

In addition to early forerunners like Habbo, the entrance of international conglomerate and teen/pre-teen media heavyweight, Disney, into the virtual world scene caused shockwaves when it spent $350 million to acquire the kid-oriented world, Club Penguin (Barnes, 2010). In addition Disney has spent millions more creating new worlds targeting teens/pre-teens, such as ToonTown, Pirates of the Caribbean, and Pixie Hollow. Although not massive commercial successes, these worlds marked Disney's commitment to expanding the presence of virtual worlds to the teen/pre-teen demographic. In January of 2013, Disney announced a new gaming platform, Infinity (released in August, 2013), that integrates real world toys with virtual world style environments (Ha, 2013). Within the Infinity platform, kids and parents alike are given the ability to create their own virtual world spaces and incorporate their favorite Disney movie characters into these spaces – effectively creating a "virtual toy box" to create and share with their friends (Gaudiosi, 2013). Together with the Skylanders platform (pioneered in 2011 by Activision), these new environments are blurring the lines between real worlds and virtual worlds.

In addition to creation of new virtual world platforms, a new business model "Free-to-Play" (F2P) has emerged in recent years. This new model was devised in direct competition to the subscription-based model used so successfully by WoW, UO, and EQ. The end result has been the erosion of subscription rates of established games as users opt for smaller but less expensive virtual worlds. As a case in point, WoW's subscriptions have fallen from a high of 12 million in 2010 (Holisky, 2012; Kain, 2013) to 7.7 million in 2013 (Kain, 2013).

It remains to be seen if a new age in virtual worlds has truly emerged; if the history of virtual worlds has taught us anything, it is that change is constant and inevitable.

SUMMARY

While the popularity of virtual worlds in education and society has risen rapidly in recent years, the history of virtual worlds, themselves, can be traced to more than 35 years ago. Unfortunately their ill-defined history has left many educators, researchers, and everyday users partially informed and often confused about terminology and the evolution of these worlds.

The historical review in this article should help researchers and practitioners better delineate and understand the field, its history, and its potential future. In doing so, participants in virtual worlds — whether active gamers, content developers, researchers, students, and/or teachers — can gain a greater understanding of the chronological history and conceptual heritage of virtual worlds. With a colorful and diverse heritage, the history of virtual worlds will continue to grow as new worlds emerge and new applications of these worlds are devised.

GLOSSARIES

Terminology Associated with Genres

Virtual World	Generic, overarching term used to describe online environments (text or graphical) in which users collaborate communicate for the purpose of gaming and/or socializing.
MMO	Massively Multiplayers Online. A generic term like virtual worlds used to describe a spectrum of worlds.
MMOG	Massively Multiplayers Online Game. A subset of MMOs specifically oriented towards gaming.
MMORPG	Massively Multiplayers Online Role Playing Game. A subset of MMOGs specifically oriented towards role playing games such as World of Warcraft.
MUVE	Multi-User Virtual Environment. A term promoted by Harvard researcher Chris Dede to designate virtual worlds that are social oriented versus gaming oriented.

Names and Descriptions of Influential Worlds

First Generation Worlds (1978-1984)

Avatar	Introduced the practice of “spawning” (e.g., re-populating a world with monsters/characters) and facilitated players’ communications to be more collaborative.
Maze Wars	Multiplayer environment incorporating wireframe graphics, giving the illusion of a 3D maze in which players interacted.
MUD (aka MUD1)	Multi-User Dungeon, arguably the first virtual world; initiated by Roy Trubshaw and finished by Richard Bartle in 1979.

Second Generation Worlds (1985-1996)

Habitat	Technology Experience
Meridian59	First commercial game to directly employing the Internet versus proprietary networks like CompuServe or AOL.
MOO	MUD Object Oriented provided a robust scripting language that allowed users to create in-world objects for social-oriented worlds.
TinyMUCK	First world to allow users to create objects from within the virtual world.
TinyMUD	One of the first worlds to focus on social interactions versus gaming and combat; in doing so, it promoted a new genre of virtual worlds.

Third Generation Worlds (1997-present)

EverQuest	Designed to encourage group play, EverQuest stood at the de facto standard in virtual worlds prior to the arrival of World of Warcraft.
Habbo	The most popular virtual world, in terms of user accounts created, although it hasn't become the cash cow that World of Warcraft was.
Second Life	Highly popular world, especially in the education arena, due to its extremely diverse content and ability for users to create and collaborate together on projects, activities, and lessons.
Ultima Online	Ushered in the third generation of worlds by introducing a wide array of changes in virtual world design, including variable playing styles (e.g., casual vs. hard-core gamer) and new graphical views versus the traditional overhead view.
World of Warcraft	Due to its eye-catching graphics and numerous gaming innovations, World of Warcraft captured 50% market share among subscription-based MMOGs for more than four years, making it the most commercially successful virtual world to date.

ANSWER KEY FOR QUIZ

1. In 1978, Roy Trubshaw created MUD, Multi-User Dungeon. MUD inspired a series of subsequent worlds traceable to today's highly diverse array of social and gaming virtual worlds.
2. TinyMUD, created in 1989 by Jim Aspnes, enabled users to create in-world objects.
3. George Lucas. In 1977, Luke Skywalker hit the movie screens in the original Star Wars film by George Lucas. In 1985, LucasArts released Habitat, which was the first world to employ the use of an avatar to represent a user in-world.
4. False. The "dungeon" in MUD was a reference to a FORTRAN version of the game ZORK entitled "DUNGEN" and not a reference to the popular tabletop game Dungeons & Dragons.
5. According to market research by K-Zero (2013) and press releases from game manufacturers, at the height of their popularity Habbo was the most popular, followed by Club Penguin, World of Warcraft, Second Life, and EverQuest respectively.

Dr. Steve Downey is an Associate Professor in the Department of Curriculum, Leadership, and Technology at Valdosta State University (VSU).

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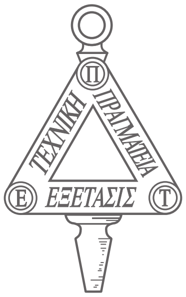
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Technological Literacy Courses in Pre-Service Teacher Education

By By Roger Skophammer and Philip A. Reed

ABSTRACT

The goal of this study was to determine to what extent technological literacy courses were required in K-12 teacher education. A documents review of the appropriate course catalogs for initial teacher preparation was conducted. The documents review identified general education requirements and options for technological literacy courses, as well as requirements and options for these courses for English, social studies, mathematics, and science education majors. For this study, technological literacy was defined as "the ability to use, manage, assess, and understand technology" (ITEA, 2000/2002/2007, p. 9). This definition of literacy is broader than technology literacy associated with computer use and instructional technology, as well as courses limited to the history or philosophy of technology. A finding from this study is that there is very little exposure to technological literacy courses for prospective K-12 teachers. This may be due in part to the confusion between instructional technology literacy and technological literacy.

Keywords: Technological Literacy, Technology Education, Teacher Education

INTRODUCTION

The increasing rate of technological change in the United States requires a technologically literate populace that can think critically and make informed decisions about technological developments. The International Technology and Engineering Educators Association (ITEEA), National Assessment Governing Board, and the National Academy of Engineering (NAE), along with other organizations, have called for a larger involvement in K-12 education for the development of technological literacy in students (ITEA, 1996; National Assessment Governing Board, 2013; Pearson & Young, 2002).

Technological literacy is defined as "the diverse collection of processes and knowledge that people use to extend human abilities and to satisfy human needs and wants" (ITEA, 2000, p. 2). A broad range of academic subjects encompass technological literacy; therefore, development of technological literacy for K-12 students necessitates that all K-12 teachers develop a level of technological competency. According to the NAE and the National Research Council, "the integration of technology content into other subject areas, such as science, mathematics, social studies, English, and art could greatly boost technological literacy" (Pearson &Young, 2002, p. 55). The purpose of this study was to investigate the development of technological literacy in accredited pre-service K-12 teacher education programs in the United States. To guide this study, the following research questions were developed:

1. Are technological literacy courses a part of general education requirements for K-12 education majors at 4-year, accredited institutions?
2. Are technological literacy courses used to fulfill program requirements for K-12 education majors at 4-year, accredited institutions?
3. Do the required technological literacy courses focus on the development of broad technological literacy awareness or is the focus on learning how to use instructional methods similar to those used in technology education activities?
4. What, if any, are the differences in K-12 education majors in requirements for technological literacy courses?

CONTEXT OF THE STUDY

For this study, a distinction was made between *technological literacy* as defined by the ITEEA and technology literacy as defined by the International Society for Technology in Education (ISTE). Technology literacy is concerned with student literacy in computer and information technologies as well as teacher abilities to use computer and information technologies for instruction (ISTE, 1998). Technological literacy is concerned with "how people modify the natural world to suit their own purposes" (ITEA, 2002, p. 2). In reference to Research Question 3, technological literacy includes this definition as well as the relationship among technology, the sciences, and society.

Instructional methods that utilize technology education activities generally involve the design and development of a product, physical or virtual, as a means to improve learning of the subject content (Foster, 1995). These activities promote problem-solving skills essential in a complex society (Schwaller, 1995). Activities include the design process, but may or may not address additional technological literacy content.

The need for a technologically literate populace has been broadly recognized by the relationship between other academic fields and technology education. The National Science Foundation (NSF) and the National Aeronautics and Space Administration (NASA) provided funding for the Technology for All Americans Project (TfAAP) (ITEA, 1996). Many other organizations supporting technological literacy include the National Research Council (NRC), the National Academy of Engineering (NAE), the National Science Teachers Association (NSTA), the American Association for the Advancement of Science (AAAS) Project 2061, and the National Council of Teachers of Mathematics (NCTM) (Dugger, 2005). Additionally, the disciplines of science, mathematics, and social studies have standards that address technological literacy (Achieve, 2014; Foster, 2005).

The NAE and NRC publication, *Tech Tally* (Garmire & Pearson, 2006), includes recommendations in the assessment of technological literacy relevant to this study. Primarily, the focus and recommendations suggest a strong need for teachers to develop technological literacy in K-12 pre-service education programs and to include technological literacy as part of the assessment of K-12 teachers and K-12 teacher education programs. An important step in meeting these recommendations is to develop an understanding of the current status of technological literacy, both in the extent to which coursework is required in K-12 teacher education as well as what aspects of technological literacy are covered in those courses.

METHODOLOGY AND RESEARCH DESIGN

The research design of the study was content analysis. Content analysis is "a detailed and systematic examination of the contents of a particular body of material for the purpose of identifying patterns, themes, or biases" (Leedy & Omrod, 2005, p. 142). For this study, a documents review of current undergraduate course catalogs was performed to address the research problem and the content analyzed in order to answer the research questions.

Population and Sample

The K-12 education programs reviewed in the study were randomly selected from the combined lists of education programs accredited through the National Council for Accreditation of Teacher Education (NCATE) and Teacher Education Accreditation Council (TEAC). A single list of 697 accredited education programs within the United States was created by entering the data, available online, into a spreadsheet. The sample size of 248 education programs was determined using a table based on the formula by Krejcie and Morgan (1970) (as cited in Patten, 2007) for a finite population at a 95% confidence level. The random sample was created using the random number generator and sort functions in the spreadsheet software. The sample size and random sample procedure allows for the sample to be proportionally representative of the NCATE and TEAC accredited education institutions in terms of geographic location in the United States, as well as the distribution among liberal arts colleges, regional institutions, and research universities. The education majors to be reviewed represent the academic areas that K-12 students are required to study.

Data Collection Methods

This study used a qualitative analysis of electronic sources of course titles and course descriptions. In a documents review, the researcher makes the judgment on how to code the appropriate data in the document (Creswell, 2007). The data were collected for the study by reviewing the appropriate catalogs for each institution of the 248 education programs in the sample. General education options and requirements as well as education program options and requirements were reviewed to identify courses that may have technological literacy or engineering content. Potential courses were identified and course descriptions were reviewed to determine if they contained technology or engineering content. Additionally, a search was done of all courses offered at the institution using technology, technological, engineering and design. When a course was identified as having technological literacy or engineering content, it was checked against the courses listed in general education and education program options and requirements.

A spreadsheet was used to record data from each institution with categories for mathematics, science, English, social studies, and elementary education programs. Subcategories for elementary education majors included English, social studies, mathematics, and science content specializations. Categories for secondary subjects included a subcategory for middle school majors. Subcategories for secondary social studies included history, geography, economics, political science (including civics), and sociology. Subcategories for science included biology, chemistry, physics, and earth science. There were no content subcategories for mathematics or English.

In order to answer Research Question 1, the general education requirements at each university or college where the teacher education program resided were reviewed. Courses that were identified as developing technological literacy that were general education requirements were identified in one column and those that were an option in a separate column. When the general education courses were not intended for science majors they were coded with an E. Data for Research Question 2 were collected from the teacher education requirements in the undergraduate catalog for each of the education majors evaluated in this study. Where distinctions existed between middle school and high school majors, both sets of requirements were reviewed and recorded separately. Likewise, when differences in science education majors' course requirements existed, they were also recorded separately. Codes for courses are explained in Table 1, which follows. Courses that were identified as developing technological literacy that were teacher education requirements were coded R and those that were an option in teacher education requirements recorded as O. In order to address Research Question 3, the content focus of the required courses, TL or IM was added to the initial code. Courses that focused on instructional methods and technology education activities were coded IM, and courses that focused on technological literacy as content were recorded TL. Courses that addressed both were coded with TL-IM. Therefore, a course that was an education requirement for elementary teacher education that focused on technology education methods as well as content was coded R-TL-IM.

Course content was considered to focus on the development of technological literacy (TL) when the course title or course description indicated that the course curriculum promoted technological literacy as defined in *Technically Speaking* (2002) and *Tech Tally* (2006). *Tech Tally* provided a matrix of the cognitive dimensions of technological literacy and the content areas for technological literacy that were used as a rubric for determining whether a course promoted technological literacy (see Figure 1).

Course content was considered to be technology education instructional methods (IM) when

Table 1: *Codes and Descriptions for Teacher Education Programs*

Codes	Description
R	Required course
O	Optional course used to fulfill requirement
TL	Technological Literacy awareness
IM	Instructional Method using technology education activities

technological literacy courses included instructional methods or activities in the description or title of the course. For example, the course description that follows was an option for an elementary education track at the institution. It clearly describes technological literacy with terms such as systems, products, and technological design. The activities model an instructional method relevant to education majors by having students complete design projects using methods that would be similar and appropriate for the elementary classroom. There were not required courses that met the criteria at this institution, therefore this course is coded O-TL-IM for Optional, Technological Literacy, and Instructional Methods.

> This is a foundational course that looks at the elements and principles of design as related to practical products, systems, and environments. It introduces students to the creative process practiced by artists, designers, and engineers, valuable to them as both future producers and consumers. Content includes thinking, drawing, and modeling skills commonly used by designers; development of a design vocabulary; the nature and evolution of technological design; the impacts of design on the individual, society, and the environment; patents and intellectual property; human factors; team design; and appropriate technology, risk analysis, and futuring techniques. Design problems are presented within real-world contexts, using field trips and outside speakers. Students complete a major design project, document their work through a design portfolio, and present their solutions before the class. Weekly critiques of class projects build fluency, confidence, and creativity. (College of New Jersey, 2008, p. 3).

COGNITIVE DIMENSIONS

CONTENT AREAS	KNOWLEDGE	CAPABILITIES	CRITICAL THINKING AND DECISION MAKING
TECHNOLOGY AND SOCIETY			
DESIGN			
PRODUCTS AND SYSTEMS			
CHARACTERISTICS, CORE CONCEPTS, AND CONNECTIONS			

Figure 1. Assessment matrix for technological literacy (Garmire & Pearson, 2006, p. 53).

Courses that were not included for this study are those that focused on information-technology literacy, computer literacy, or instructional technology as defined by the ISTE (1998) standards. Required courses that focus on these areas were not included in this study because several recent studies have been done in these areas (Baylor & Ritchie, 2002; Hinchlifee, 2003; Kelly & Haber, 2006; Garmire & Pearson, 2006; Sanny & Teale, 2008; Topper, 2004).

FINDINGS AND ANALYSIS

A general conclusion of this study is that there is very little exposure to technological literacy courses for prospective K-12 teachers. The review of literature suggested that this might be due in part to the confusion between instructional technology literacy and technological literacy (Dugger, 2007; Pearson & Young, 2002; Zuga, 2007). All teacher education programs require the acquisition of skills in computer use and instructional technology. This is in large part due to the inclusion of the International Society for Technology in Education (ISTE) National Educational Technology Standards in NCATE accreditation standards for all academic areas (Hinchliffe, 2003; Hofer, 2003). The following are the findings and analysis for each of the four research questions.

Research Question 1: Technological literacy as a part of general education for K-12 education majors

Data analysis identified technological literacy courses as being either a requirement of the institution or an option to fulfill a requirement of the institution. The review of the 248 course catalogs determined that 80 institutions included technological literacy courses as part of their general education requirements. Typical course titles included Science, Technology, and Society, Technology and Society, and Technology and Civilization. At a few of the institutions, these courses were part of a technology track or sequence that would include computer technology courses as well as industrial technology and design courses. Seventy-six of these institutions allowed a technological literacy course to fill a general education requirement, and four institutions required a technological literacy course as part of the general education requirements. Of the 76 institutions that offered a technological literacy course as an option for general education requirements, 42 excluded that course as an option for secondary science majors. Eight institutions identified a technological literacy course that was an option for general education as a requirement for the teacher education program (see Figure 2). The

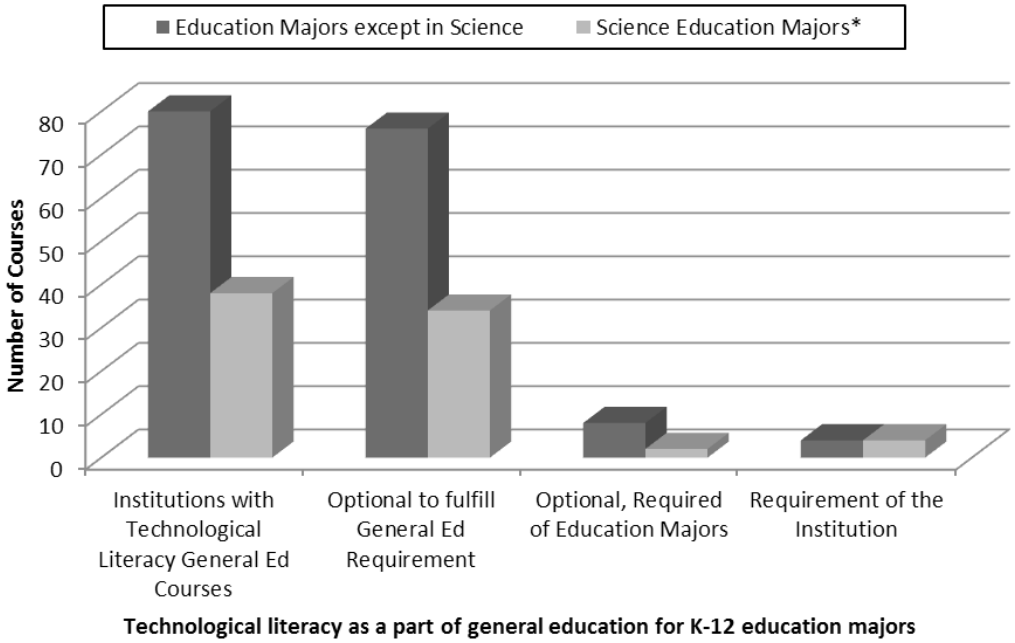

Figure 2. Technological literacy general education courses (* Including elementary science specialization).

narrow understanding of technological literacy as computer literacy may lead some to believe the technological literacy is being addressed in the general education curriculum. A study by Rose (2007) found that administrators in higher education generally believe that science, technology, engineering, and mathematics (STEM) initiatives are addressing technological literacy through computer and digital communication coursework.

Research Question 2: Technological literacy courses used as program requirements for K-12 education majors

For this question, technological literacy courses were identified as either an option or a requirement for the education majors at the institution. Forty-six institutions included technological literacy courses to fulfill program requirements for K-12 education majors. Twenty-seven institutions included technological literacy courses in elementary education; 19 required courses, and eight were optional. For secondary education majors, 29 institutions used technological literacy courses to fulfill program requirements. In addition to the course titles found for general education, some of the course titles required for education majors included Critical Literacies in Childhood Education, Teaching Mathematics, Science and Technology, and Science and Technology. Table 2 shows whether the technological literacy courses were used as a requirement or an option for each of the education majors included in the study. The total number of courses listed in Table 2 does not equal the number of institutions because an institution may have had more than one major with a technological literacy course requirement or option.

Table 2: *Technological Literacy Courses in Teacher Education Institutions, N* = 248

	Required		Option to Fulfill Requirements		Totals	
	#	%	#	%	#	%
Institutions with courses in both elementary and secondary majors	6	2.42%	2	0.81%	8	3.23%
All majors	2	0.81%	1*	0.40%	3	1.21%
Specific majors	4	1.61%	1*	0.40%	5	2.02%
Just elementary majors	12	4.84%	6	2.42%	18	7.26%
Generalist	10	4.03%	6	2.42%	16	7.26%
Specialists	2	0.81%	0	0.00%	2	0.81%
Just secondary majors	14	5.65%	6	2.42%	20	8.06%
All majors	4	1.61%	1	0.40%	5	2.02%
Specific majors	10	4.03%	5*	2.02%	15	6.05%
Totals	32	12.90%	14	5.65%	46	18.55%

* Institutions that had a major with a requirement and a major with an option were included in the option column.

Research Question 3: Technological literacy awareness or instructional methods

The analysis for this question differentiates between technological literacy courses that focus on the nature of technology and/or the relationship of technology and the subject content referred to here as technological literacy awareness. Technological literacy courses that focused on the use of technology education activities as an instructional strategy are referred to as instructional methods. Technological literacy awareness courses were more likely to be found as part of the requirements for secondary education majors, while the distribution between technological literacy awareness and instructional methods was evenly represented in elementary education. Of the 46 institutions identified as having technological literacy courses as part of the requirements for the K-12 education majors, 34 required broad technological literacy awareness courses such as Science, Technology, and Society. Sixteen institutions included broad technological literacy awareness courses as an option. Instructional methods courses, such as Methods for Teaching Math, Science, and Technology, or course descriptions for methods courses that included "the use of robots," "creating maps," and "building models" were required by 19 institutions and were options at three institutions. The total of these is greater than 46 because there were 11 institutions that required courses that address both technological literacy awareness and instructional methods. Most often, these were a single course for elementary education majors such as Critical Literacies in Childhood Education or Elementary Education taught by a technology education department.

Table 3: *Types of Technological Literacy Courses*

	Technological Literacy Awareness		Instructional Methods		Both	
	#	%	#	%	#	%
Required	**23**	**9.27%**	**8**	**3.23%**	**11**	**4.44%**
Elementary Programs	6	2.42%	4	1.61%	8	3.23%
All majors	4	1.61%	4	1.61%	7	2.82%
Specific majors	2	0.81%	0	0.00%	1	0.40%
Secondary Programs	17	6.85%	4	1.61%	3	1.21%
All Majors	3	1.21%	1	0.40%	0	0.00%
Specific Majors	14	5.65%	3	1.21%	3	1.21%
Optional	**14**	**5.65%**	**1**	**0.40%**	**2**	**0.81%**
Elementary Programs	7	2.82%	1	0.40%	2	0.81%
All Majors	7	2.82%	1	0.40%	2	0.81%
Specific Majors	0	0.00%	0	0.00%	0	0.00%
Secondary Programs	9	3.63%	0	0.00%	0	0.00%
All majors	1	0.40%	0	0.00%	0	0.00%
Specific majors	8	3.23%	0	0.00%	0	0.00%
Total Institutions	30	12.10%	6	2.42%	10	4.03%

The findings for elementary education suggest there is a growing understanding of the value of technology education activities for integrating other subjects, as well as the need to develop technological literacy in elementary education. Linnell (2000) identified five programs in the United States that required elementary education majors to take technological literacy courses and 10 institutions that provided these courses as on option. This study, using a sample that is approximately 1/3 of the population, found 18 institutions that required these types of courses for elementary education majors and 10 that provided them as options. Table 3 shows the number of programs that had either required or optional courses for each of the three variables (Technological Literacy Awareness, Instructional Methods, or both).

Research Question 4: Technological literacy course differences in K-12 education majors.

The focus of this question was to determine if there were differences between the education majors of elementary education, English, social studies, mathematics, and science for required or optional technological literacy courses. Technological literacy course requirements were found primarily in elementary education, with secondary science majors having the most courses requirements for secondary education majors.

Table 4: *Comparison of Technological Literacy Courses by Education Major*

	Required		Option		Totals	
	#	%	#	%	#	%
Elementary Education	**19**	**7.66%**	**8**	**3.23%**	**27**	**10.89%**
Generalist	16	6.45%	8	3.23%	24	9.68%
English		0.00%		0.00%	0	0.00%
Social Studies		0.00%		0.00%	0	0.00%
Mathematics		0.00%		0.00%	0	0.00%
Science	3	1.21%		0.00%	3	1.21%
Secondary Majors	**9**	**3.63%**	**5**	**2.02%**	**14**	**5.65%**
All Secondary Subjects*	4	1.61%	1	0.40%	5	2.02%
English		0.00%		0.00%	0	0.00%
Social Studies	3	1.21%	4	1.61%	7	2.82%
Mathematics	2	0.81%		0.00%	2	0.81%
Science Majors	**15**	**6.05%**	**6**	**2.42%**	**21**	**8.47%**
All Sciences Majors	13	5.24%	4	1.61%	17	6.85%
Biology		0.00%		0.00%	0	0.00%
Chemistry		0.00%		0.00%	0	0.00%
Physics	2	0.81%	1	0.40%	3	1.21%
Earth Science		0.00%	1	0.40%	1	0.40%
Total	**43**	**17.34%**	**19**	**7.66%**	**54**	**21.77%**

Note: The findings for middle school and high school are identical, therefore are reported under "Secondary". There were no differences between social studies majors, therefore social studies are listed as one category. *Includes science majors.

Elementary education had the largest number of programs with required or optional technological literacy course requirements; this included 19 required courses and eight optional courses.

The analysis of the data obtained from the documents review showed differences between the secondary education majors that reflect the literature and standards for these academic areas. Secondary science had 21 programs that include technological literacy courses as part of the requirements with 15 required courses and six optional courses. The rest of the secondary education majors had 14 programs that included technological literacy courses as part of the requirements. This includes the four institutions that required technological literacy courses in all other secondary education programs (including science) and the one institution that provided a technological literacy course as an option in their requirements. Secondary English, except when required by all secondary education majors, did not include programs with requirements for technological literacy courses. There were no differences for the course titles that addressed broad technological literacy in the secondary education majors with titles such as Science, Technology, and Society, and Technology and Society common throughout. The instructional methods course titles included Teaching Math, Science, and Technology, or a description in the methods course that addressed technology education activities. See Table 4 for the complete analysis of the number of programs with required or optional technological literacy course requirements.

The differences between the secondary education majors suggests that the relationship between technology and science is better understood at teacher preparation institutions than the relationship between technology and social studies, and that the relationship between technology and mathematics or English is very poorly understood. These findings are consistent with the literature (AAAS, 1993/2008; Foster, 2005; IRA & NCTE, 1996; NAS & NRC, 1996; NCSS, 2008; NCTM 2000; Newberry & Hallenbeck, 2002; NSTA, 2003).

The standards for science teacher education clearly identify technological literacy as important and include the study of technology and the relationship with science (NSTA, 2003). This is also reflected in *Benchmarks for Science Literacy* chapter on “The Nature of Technology” (AAAS, 1993, pp. 49-52) as well as in *Next Generation Science Standards* (Achieve, 2014). There were 17 institutions that identified technological literacy courses such as Science, Technology, and Society as an option or a requirement for all science education majors.

The standards in social studies also discuss the importance of understanding the relationship between technology and society (NCSS, 1994; Foster, 2005). “Students will develop an understanding of the cultural, social, economic, and clinical effects of technology” and “Students will develop an understanding of the role of society in the development and use of technology,” are two examples from the curriculum standards (Foster, 2005, p. 55). Seven institutions included technological literacy courses as a part of the requirements.

The NCATE/NCTM standards for mathematics teachers describe the role of technology as a tool for teaching and understanding mathematics as opposed to the role of mathematics and technological literacy. Standard 6: Knowledge of Technology states, “Use knowledge of mathematics to select and use appropriate technological tools, such as but not limited to, spreadsheets, dynamic graphing tools, computer algebra systems, dynamic statistical packages, graphing calculators, data-collection devices, and presentation software” (NCTM, 2003, p. 2). The findings from the review reflect this—only two institutions require technological literacy coursework.

The National Council of Teachers of English standards lists technology as a tool for research and writing. The standard, “Develop proficiency with the tools of technology” (NCTE, 2008, p. 1) does not distinguish between the broader technology literacy and the ISTE definition, but the supporting literature focuses primarily on the use of computers and the Internet (IRA & NCTE, 1996). There were no institutions, except for the four that required it for all secondary education majors requiring technological literacy coursework for secondary English majors. The professional standards in relation to technological literacy for all these academic areas were reflected in the findings of this study.

RECOMMENDATIONS FOR FURTHER RESEARCH

The inclusion of technological literacy in the Next Generation Science Standards (Achieve, 2014) and National Science Teachers Association's Standards (NSTA, 2003) is reflected in many state standards. This study suggests that there is a discrepancy between the state standards and science teacher education curriculum based on course titles and course descriptions reviewed in this study. State-level studies that identify discrepancies between the state standards and the science teacher education curriculum are needed. These studies could also explore in greater depth the extent of which technological literacy is included in the teacher education curricula through a documents review of course material and data collected from science teacher educators.

Studies by Foster (1997, 2005), Park (2004), Holland (2004), and others have identified the value of elementary school technology education. These qualitative studies show how technology education activities promote learning in an integrated curriculum that is consistent with constructivist learning theory. The value of elementary school technology education has a growing acceptance that is reflected in the number of technological literacy course requirements for elementary teachers. Similar qualitative studies are needed at the middle school and high school levels to show how using technology education instructional methods improve learning in an integrated curriculum.

Studies by Dyer, Reed, and Berry (2006), Culbertson, Daugherty, and Merril (2004), and Satchwell and Loepp (2002) have shown a relationship between student academic achievement and participation in technology education courses. Further research is needed to better understand this relationship. These studies need to address more than the value of technology education for the development of technological literacy; they also should consider the relationship of the development of technological literacy and academic performance in other subject areas.

Finally, this study infers technological literacy of teachers by assessing the extent to which technological literacy courses are included in teacher preparation. Further understanding of the technological literacy of teachers should be addressed through the direct assessment of K-12 teachers through an inventory or survey instrument.

Roger Skophammer is Associate Director for Curriculum and Instruction at the STEM*Center for Teaching and Learning, International Technology and Engineering Educators Association, Reston, VA.

Philip A. Reed is Associate Professor in the Department of STEM Education and Professional Studies at Old Dominion University, Norfolk, VA. He is a member of the Beta Chi Chapter of Epsilon Pi Tau.

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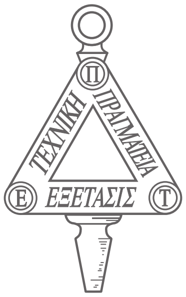

Technology and Engineering Education Doctoral Students' Perceptions of Their Profession

By Gene Martin, John Ritz, and Michael Kosloski

ABSTRACT

The growth and vitality of both technology and engineering education professions rely on the quality of contributions of its new and emerging leaders. Many of these leaders are currently enrolled students in doctoral programs. These students will be challenged to assume leadership roles in which they are not currently engaged (Ehrenberg, Jakubson, Groen, So, & Price, 2007). Some students may choose to focus their careers in developing new curricula; some will become active in grant writing and grant procurement; some will choose to serve as officers in their professional organizations; and others will contribute to the body of literature in their discipline. Wherever these future leaders decide to focus their efforts, they will likely have an impact on their profession. This study reports on currently enrolled doctoral students' perceptions related to the focus of content taught in formalized K-12 technology and engineering education programs, methods used to prepare future technology and engineering teachers, characteristics of their planned professional involvement, and future forecasting for their school subject. This is the second study by the authors focusing on doctoral students' perceptions.

Key words: Doctoral Students, Perceptions, Professions, Technology and Engineering Education

INTRODUCTION

University faculty work to pass on knowledge of their disciplines and some add to this knowledge through research and development activities. This amalgamation of knowledge is a result of synthesizing one's own ideas, others' ideas, and concepts generated through practice and research. Universities that offer doctoral degrees educate students in best research practices, as well as the knowledge of their disciplines. These same university professors also mentor doctoral students as they guide them through their classes and research projects. Some faculty have expectations that students will present at conferences, write professional papers, and become active members within the professions that operate to support their disciplines (Campbell, Fuller, & Patrick, 2005; Wright, 1999).

In the area of technology and engineering education, there are fewer programs for the preparation of teachers and university faculty (Moye, 2009; Ritz & Martin, 2013). New doctoral students have many tasks ahead of them as they graduate and move into professorships. One area of their work will be to recruit and teach students to become future teachers. Depending upon their employment (e.g., research universities), some will be required to design and undertake an active research agenda. In this task, they will develop research proposals for funding and publish manuscripts on the data they collect. Depending on whether they are employed with a teaching or a research university, some will provide service to school systems, their K-12 state departments of education, and state and national professional associations.

The content for technology education, now called technology and engineering education, emerged from ideas considered in the 1940s that translated to the knowledge that needed to be taught to students, so they might achieve technological literacy (DeVore, 1968; International Technology Education Association [ITEA], 2000; Warner, 1947). With ideas and research produced through the National Center for Engineering and Technology Education (Householder & Hailey, 2012), and the research and development efforts of others, engineering content and processes have moved into the technology and engineering curriculum. In addition, STEM educational reform has added additional attention to science and mathematics within technology and engineering curriculum and instruction (Banks & Barlex, 2014).

With the reformulation of the content for K-12 technology and engineering education, a change has occurred in the focus of activities taught in this school subject. Projects made from templates have been replaced with open-ended design problems where engineering design is the focal point of instruction. Along with the development of new content and instructional practices, changes are emerging in how future teachers will be prepared. Digital technologies now allow courses to be delivered online using various instructional delivery methods.

Professional associations that support the teaching of K-12 programs are also changing. How are associations meeting the needs of professionals teaching technology and engineering education? Will associations also change as the content, methods, and the delivery of teacher education programs change within our school subject? How will new Ph.D.s provide leadership to these organizations as they professionally mature in the 21st century? This research seeks answers to questions of those educators who should emerge as the new leaders of the professions for technology and engineering education. The researchers wanted to further explore the perceptions of current doctoral students in technology and engineering education to determine their views on the content and methods that will be used to deliver K-12 education, strategies to be used to prepare future teachers, if and where they plan to publish, and if they plan to take on an active role in service to their professions.

RESEARCH PROBLEM

This study seeks to identify and provide a better understanding of the perspectives of graduate students currently seeking the doctoral degree on the future of the K-12 school subject of technology and engineering education and the professions that aid in guiding its practice. It was guided by the following research questions:

RQ_1: What are doctoral students' opinions concerning the focus of content to be learned in K-12 technology and engineering education?

RQ_2: How do these scholars believe technology and engineering teachers will be prepared in the near future?

RQ_3: What is the commitment level of these scholars to their technology and engineering teaching professions?

RQ_4: What does this population expect to happen in the future to the technology and engineering teaching professions?

LITERATURE REVIEW

Literature related to doctoral education, professionalism and professional associations, and the future of professional education associations will be reviewed to provide the reader with a context for understanding the purpose of this study.

Doctoral Education

Debate exists regarding a singular specific purpose of doctoral education, although most descriptions share overlapping characteristics. Though a broad common ground is that doctoral education is intended for the formation of scholars (Walker, Golde, Jones, Bueschel, & Hutchings, 2008), discussion exists concerning the differences between professional and Ph.D. doctorates, how they will be used once completed, and in what type of setting (Neumann, 2005; Sweitzer, 2009; Walker et al., 2008). Although it may vary from field to field, a traditional viewpoint of a Ph.D. is that it primarily prepares scholars to conduct research in an academic setting (Boyce, 2012; Ehrenberg et al., 2007; Shulman, Golde, Bueschel, & Garabedian, 2006). At the other end of the spectrum, a traditional viewpoint of a professional doctorate is that it prepares practitioners who integrate scholarship in applied decision-making (Campbell, Fuller, & Patrick, 2005). Others posit that research theory and applied, practical scholarship should not be examined separately (Evans, 2007; Walker et al., 2008).

Some of the commonalities in most descriptions of doctoral education are that such programs are intended to develop citizens who are technical experts in their fields, contribute knowledge to their respective fields, and also contribute to their profession (Shore, 1991; Walker et al., 2008). In a five-year study sponsored by the Carnegie Initiative on the Doctorate, Walker et al. (2008) developed three broad-based categories in which all competent doctoral programs should be founded. First, doctoral education should provide scholarly integration, which includes not only basic research, but also integrative research and teaching. Walker et al. (2008) and Golde (2007) determined that because approximately one-half of Ph.D.s find careers in higher education, teaching is also an element that should be an integral part of doctoral education.

The second element consistent among doctoral programs is that they develop a sense of intellectual community, which includes the development of a culture within a program and the profession. In other words, it helps to identify one's professional identity and fosters a continuous exchange of ideas in the development of new knowledge (Gardner, 2010; Walker et al., 2008). The third intended purpose of doctoral education is to develop stewards of their professions. Completers are expected to consider uses and applications of their work in their respective fields and exercise responsible application of their knowledge, skills, and principles (Evans, 2007; Walker et al., 2008).

Professionalism and Professional Associations

Professional associations exist for the purpose of supporting and enhancing individuals and groups within their respective professions. However, although members of such associations are bound by a common profession in broad terms, individual members' professional roles may vary widely, posing a challenge for associations to serve all of their members in the same way (Berger, 2014; Jacob et al., 2013). Professional associations, regardless of individual differences among their members, work to unite individuals toward a common purpose and provide the members with a sense of belonging (Patterson & Pointer, 2007).

In the field of education, Berger (2014) believes that professional associations provide leadership for the field, professional development, advocacy, and resources. Jacob et al. (2013) identified a key role in providing specialized networking and collaborative opportunities, facilitating individual interaction, the exchange of ideas, and intellectual growth within a chosen profession. In a study of nursing professionals, Esmaeili, Dehghan-Nayeri, and Negarandeh (2013) identified the purpose of professional associations to include professional support, legislative advocacy, contending with professional problems, and providing clear explanations of their objectives. Patterson and Pointer (2007) stated that associations unite individuals with a common purpose, promote the profession, advocate on behalf of the profession, and offer numerous miscellaneous benefits to its members. Another key role identified is the cultivation of future leadership, as many professional associations are challenged in maintaining both leadership and membership (Shekleton, Preston, & Good, 2010). Blaess, Hollywood, and Grant (2012) held that effective leadership begets membership and growth. Though there are many varying descriptions for the purposes and benefits of professional organizations, some of the common threads among them are mentoring, leadership development, advocacy, and scholarship.

Professional organizations provide benefits to their constituencies in line with their purpose and mission. For example, an effective professional organization nurtures a culture whereby information is evaluated and shared throughout the organization and the profession (ASAE & the Center for Association Leadership, 2006). They tend to foster a sense of community and provide opportunities for professional collaboration, both formally and informally (Jacob et al., 2013). This type of collaboration allows individuals to better internalize not only the nature of their respective fields, but also allows them to congregate with others who share similar specific interests within that field (Berger, 2014). ASAE & The Center for Association Leadership (2006) identified seven benefits of successful professional associations, categorizing each of those benefits into one of the following categories: a sense of purpose, a commitment to analysis and feedback, and a commitment to action. Schneider (2012) studied the importance of the concept of social capital, which he described as aiding membership into understanding that associations and professions have their own unique culture that is dependent on "reciprocal, enforceable trust that develops over time" (p. 205).

Future of Professional Education Associations

As has been noted, professional associations exist to support the development of those who practice in professions. There are associations for most occupations (e.g., professional organizations and unions), and many people who advocate for individual groups (e.g., disabled persons, retired people, sport teams). Some individuals learn of these organizations from family members, teachers, and professors. *Professions* are defined as a collection of self-selected, self-disciplined individuals (professionals) who share a common identity and characteristics. The common "thread" of a profession as used in this study is a collection of individuals who identify themselves with furthering the mission of the technology education school subject (technology education, technology and engineering education, design and technology, etc.).

Professional organizations exist to support the aspirations of members. Some reasons for establishing professional organizations include (a) tackling professional problems, (b) attempting to increase the power of legislative authorities, and (c) clearly explaining their objectives for enhancing organizational power (Esmaeili, Dehghan-Nayeri, & Negarandeh, (2013). Phillips and Leahy (2012) believed professional associations (a) provide for the professional development for their members, (b) set standards for educational practice, (c) organize and host forums on issues important to the members, and (d) attempt to unify political action campaigns to better position the profession. These reasons closely align with the purposes of organizations that support technology and engineering professions (Epsilon Pi Tau, 2013; ITEEA, 2011).

Professional education organizations also debate the changing content and roles of their school subjects. Ritz and Martin (2013) found that new doctoral students consider professional associations as platforms for publishing (in their journals), as providing opportunity to make presentations at international conferences, and as providing professional development opportunities. However, the group studied by Ritz and Martin projected that only 37.5% of the new Ph.D.s would participate in leadership roles in teacher education professional organizations.

Martin (2007) explained the decline in memberships in professional associations. He noted that 9/11 and the resulting effect of tightened organizational budgets have contributed to membership declines. This is especially true of education organizations. The economic decline that began in 2008 has kept K-12 teachers away from conferences, because school systems do not have the funds to support teachers' absences (paying for substitute teachers). In addition, school systems do not have budgets to support teachers and administrators who want to attend conferences. Ritz and Martin's (2013) study found that new Ph.D.s do not see themselves holding leadership positions in professional organizations. Mellado and Castillo (2012) found low levels of satisfaction when the organization's performance has kept some members from choosing to participate in leadership roles. Could it be that new Ph.D.s see slippage in the contributions that these associations have made to members as a reason why they elect not to lead? Do they feel that too much investment of time and effort would be required to "right the ship"?

Although new Ph.D.s do not seek to lead, they do see professional organizations providing "specialized networking and development opportunities to a specific profession, group of individuals or field of study" (Jacob et al., 2013, p. 141). They perceive networking as contributing to their recognition and making partnerships in developing ideas and furthering research agendas. They consider such opportunities as important to their development to achieve tenure and promotion in higher education. However, if these highly educated technology and engineering teacher education students do not seek leadership positions in professional associations, who might fill these voids? This study seeks to provide a better understanding of current doctoral students and their perceptions of the technology and engineering education professions.

RESEARCH DESIGN

The survey method is a quantitative non-experimental research design selected by the researchers for this study. A potential internal threat to validity in survey research is attitudes of subjects. The researchers addressed this threat using a nomination process to select their sample. Lead professors at selected universities were contacted and asked to nominate currently enrolled Ph.D. students for the study. Thus, a purposeful sample of nominated technology/engineering education students became the population for the study. Though the researchers did not attempt to generalize the results of their study to a larger population, they believe that a potential threat to external validity of population generalizability is addressed because the purposeful sample is or very closely resembles the actual population of Ph.D. students. The value of conducting survey research is widely supported in the literature. McMillan and Schumacher (2010) described survey research as a method that is used to "learn about people's attitudes, beliefs, values, demographics, behavior, opinions, habits, desires, ideas, and other types of information" (p. 235). Clark and Creswell (2010) referred to survey research as a method to "determine individual opinions" and a way to "identify important beliefs and attitudes of individuals at one point in time" (p. 175). McMillan (2012) underscored the popularity of survey research because of its "versatility, efficiency, and generalizability" (p. 196). Creswell (2012) addressed the advantage of using cross-sectional survey designs because they have the "advantage of measuring current attitudes or practices" (p. 377).

PROCEDURES

The researchers administered a structured 12-question survey that also contained 5 additional demographic questions. The survey was administered anonymously using a web form in October 2013 with one additional follow-up letter sent to invitees. In the letter of invitation to participate, the researchers assured the invitees that (a) their individual responses would not be identifiable by a participant's name, (b) their participation was voluntary (e.g., lead professors who nominated them would not know if they accepted the invitation to participate in the study), and (c) there were no direct benefits to them by participating in the study. When the researchers received a confirmation from the invitees who were willing to participate, they were sent a URL to complete the survey. Thirty-four invitees (*N* = 34) responded that they wished to participate in the study, and all 34 invitees completed the survey for a 100% response rate. The total elapsed time from the initial letter of invitation to their completion of the survey was approximately two weeks.

The researchers followed best practices in designing the survey instrument, including making several assumptions about the participants prior to commencing their study. These assumptions included but were not limited to the following:

1. Participants were capable of identifying the focus of content to be learned in K-12 technology and engineering education.
2. Participants were capable of identifying the way technology and engineering teachers will be prepared in the near future.
3. Participants were capable of expressing their commitment level to the technology and engineering teaching profession.
4. Participants were capable of identifying what they believe will occur in the future to the technology and engineering teaching profession.

FINDINGS

The participants comprised a purposeful sample of Ph.D. students (N = 34) who are currently pursuing their degree in technology education/engineering education. Lead professors at five universities that offer the doctoral degree in technology/engineering education nominated the participants. (Lead professors at two other universities were invited to nominate participants but declined due to a lack of Ph.D. students in their programs.) Lead professors at North Carolina State University, Old Dominion University, The University of Georgia, Utah State University, and Virginia Polytechnic and State University nominated the participants.

Data were collected from 34 participants' responses to a 12-question survey. The participants consisted of 16 females (47.1%) and 18 males (52.9%). For purposes of this study, the researchers used the following categories for collecting data on participants' ages: 20-30 years, 31-40 years, 41-50 years, 51-60 years, and 61+ years. The participants reported their primary area of interest as being post-secondary grades (*n* = 15; 44.1%). When asked to identify their current position, the participants were predominantly classroom teachers (*n* = 14; 41.2%). Two participants chose not to identify their current position. Finally, all participants identified the United States as their home country and all were studying in the United States. A summary of the analyses of the demographic data is provided in Table 1. The following narrative reports on data that relate directly to the four Research Questions addressed in this study. The reported data are also presented following the same categories used in the survey – Part 1 and Part 2. Data collected for Part 1 focused on

Research Question 1 and data collected for Part 2 focused on Research Questions 2, 3, and 4.

Part 1

Part 1 of the survey contained four questions and, as previously noted, Part 1 focused entirely on Research Question 1. The participants were first instructed to respond to the question: "What should be the focus of content taught in formalized kindergarten (primary) through high school (secondary) technology and/or engineering education programs." The participants were instructed to "select all that apply" from a menu containing five possible choices: technological literacy, workforce education, design technology/engineering design, STEM integration, and other. STEM integration was selected most often (n = 27; 81.8%) by the participants, followed by design technology/engineering design (n = 23; 69.7%), and Technological Literacy (n = 21; 63.6%). In addition, workforce education was selected 9 times (27.3%). No participant selected "other" as his or her choice. One participant did not answer this question.

Once the participants identified the "focus of content," the researchers directed them to consider the topic of instructional strategies by posing the following question: "What should be the focus of instructional strategies used in formalized kindergarten through high school technology and/or engineering education programs?" Once again, the participants were instructed to select "all that apply" from a menu containing five choices: project-based activity, design-based/engineering design-based activity,

Table 1: *Population Demographics*

Demographic	Selection	Number	Percent
Gender (n = 34)	Female	16	47.1
	Male	18	52.9
Age (n = 34)	20-30	8	23.5
	31-40	10	29.4
	41-50	8	23.5
	51-60	8	23.5
	61+	0	0.0
Area of Professional Interest (n = 34)	Primary/Elementary	5	14.7
	Middle School	5	14.7
	High School	9	26.5
	Post-Secondary	15	44.1
Current Position (n = 32)	Classroom Teacher	14	41.2
	Supervisor	3	8.8
	Teacher Educator	3	8.8
	Private Sector	2	5.9
	Full-Time Student	10	24.9

Note: N = 34. Two respondents chose not to answer the demographic question related to current position.

contextual learning, conceptual learning, and other. Design-based/engineering design-based activity was selected most often (*n* = 28; 82.4%) by the participants, followed by project-based activity (*n* = 24; 70.6%), contextual learning (n = 23; 67.6%), and conceptual learning (*n* = 20; 58.8%). No participant selected "other" as his or her choice.

"Who should be the primary audience for a formalized instructional program in technology and/or engineering education?" is a question that has been addressed by those in the profession for years, if not decades. This specific question directed participants to identify the primary audience while also being instructed to "select only one" possible audience from the following: (a) elementary aged/primary grade students, (b) middle grades (6-8) aged students, (c) high school students, (d) secondary students (middle grades and high school), (e) post-secondary students, and (f) "all of the above identified populations." The participants clearly believe the primary audience should be "all of the above identified populations" (*n* = 20; 58.8%). The next highest response category was secondary students (*n* = 6; 17.6%).

Technology and engineering educators stay abreast of the results of research conducted by others in their discipline by reading articles in professional journals. The final question in Part 1 focused on determining which professional publications they regularly read. A total of 20 publications were identified by the participants and those most often read were *Technology and Engineering Teacher* (*n* = 22), *Journal of Technology Education* (*n* = 15), *Journal of Engineering Education* (*n* = 6), *Prism* (*n* = 5), *Journal of Technology Studies* (*n* = 4), *Techniques* (*n* = 4), *International Journal of Design and Technology* (*n* = 4), and *Children's Journal of Technology and Engineering Education* (*n* = 4). Their responses reveal several insights into the reading interests of this emerging group of professionals. First, engineering journals (*Journal of Engineering Education* and *Prism*) are being read by Ph.D. students. Second, the *Technology and Engineering Teacher* continues to gain their attention because it was identified most often among the journals they read. Interestingly, this journal is considered a practitioner's journal, not a research journal. Third, the *Journal of Career and Technical Education*, published by the Association for Career and Technical Education (ACTE), once considered a staple in every technology education professional's library, now holds little value to this group of readers. Yet, *Techniques*, also published by ACTE, which purports on its website to bring its readership news about legislation affecting career and technical education and in-depth features on issues and programs, gains the attention of these Ph.D. students. Table 2 summarizes data on doctoral students' perceptions regarding current activities within the technology and engineering education profession.

Part 2 of the survey consisted of eight questions that focused on finding answers to Research Questions 2, 3, and 4. The first three questions in Part 2 addressed Research Question 2. In order to maintain a critical mass of classroom teachers who will teach in the technology and engineering instructional programs, students (future teachers) must be prepared to become classroom teachers. Participants were first instructed to identify the primary characteristic that best describes how technology and engineering students will ultimately become classroom teachers. In addition, they were directed to "select only one" possible characteristic from the following list of characteristics: (a) 4- or 5-year campus-based program, similar to what is most prevalent today in higher education; (b) a discipline degree followed by a teaching diploma (license) taking 4 or 5 years to complete; (c) documenting academic qualifications through professional testing; (d) a combination university-school-based program, and (d) other. The characteristic with the highest reported frequency was a discipline degree followed by a teaching diploma (license) taking 4 to 5 years to complete (*n* = 15; 44.1%) with the characteristic of a combination university-school-based program being the second most frequently selected characteristic (*n* = 13; 38.2%).

The researchers then instructed the participants to identify "where" this education/qualification will be received. The participants were instructed to "select all that apply" from a menu containing six possible choices. Clearly, the participants believe hybrid systems that involve blended methods of instructional delivery, including campus and distance learning will be the delivery of choice (*n* = 30; 93.8%). It also is

Table 2: *Part 1, Current Activity within the Profession*

Item	Selection	Number	Percent
1. Content for K-12 T/E ed. (*n* = 33)	Technological Literacy	21	63.6
	Design Technology/ Engineering Design	23	69.7
	STEM Integration	27	81.8
	Workforce Education	9	27.3
2. Focus of Instructional Strategies (*n* = 34)	Project-based	24	70.6
	Design-based	28	82.4
	Contextual	23	67.6
	Conceptual	20	58.8
3. Primary Teaching Audience (*n* = 34)	Elementary School	1	02.9
	Middle School	5	14.7
	High School	1	02.9
	Secondary School	6	17.6
	Post-Secondary School	1	02.9
	All Levels	20	58.8
4. Journals Regularly Read (*n* = 29)	*Technology and Engineering Teacher*	22	64.7
	Journal of Technology Education	15	44.1
	Journal of Engineering Education	6	17.6
	PRISM	5	14.7
	Journal of Technology Studies	4	11.8
	Techniques	4	11.8
	International Journal of Design and Technology Education	4	11.8
	Children's Journal of Technology and Engineering Education	4	11.8

Note: *N* = 34. These numbers exceed the N value and 100%, since respondents could select more than one choice for these questions.

clear that participants had an interest in two other choices provided in the survey: brick and mortar university classroom/laboratories (*n* = 15; 46.9%); and via distance learning technologies (*n* = 10; 31.3%).

Professional development of educators at all levels continues to be a growing concern among educators, administrators, and professional association members. The researchers sought to determine the participants' perceptions of "who" will be the service providers of professional development activities. The participants were instructed to "select all that apply" from a menu containing six possible choices with the sixth choice being "other." However, no participant selected the other category. Teacher education institutions received the highest frequency of responses (*n* = 26; 78.8%), followed by professional associations (*n* = 23; 69.7%), distance learning providers (*n* = 18; 54.5%), and national/regional/district supervisors (*n* = 17; 51.5%). The remaining choice (commercial vendors) recorded the lowest frequency (*n* = 10; 30.3%).

The researchers explored the participants' "commitment" to their profession through a series of four questions that addressed Research Question 3. First, the lifeblood of professional associations comes about through people who choose to hold membership and participate in an association's plan of work. Participants were instructed to identify the professional technology and engineering education associations that they would be members of in 2025. They were instructed to "select all that apply" from a menu containing eight possible choices. No participant selected the eighth and final choice, which was "other." Even though the possible choices represented a breadth of associations that serve the technology and/or engineering education professions, the International Technology and Engineering Educators Association recorded the highest frequency (*n* = 30; 90.9%) among the participants, followed by STEM associations (*n* = 21; 63.6%), American Society for Engineering Education (*n* = 20; 60.6%), and national- and state-level technology and engineering associations (*n* = 19; 57.6%). The participants gave little attention to the European Society for Engineering Education (*n* = 1; 3.00%) and the Design and Technology Association (*n* = 1; 3.00%) as both associations' primary membership service areas are outside the United States.

Another measure of the participants' commitment to their profession is identified by professional conferences they will be regular attendees in 2025. The participants were instructed to "select all that apply" from a menu containing eight possible choices. No participant selected the eighth and final choice, which was "other." Though the possible choices represented a breadth of professional conferences that serve the technology and engineering education professions, the International Technology and Engineering Educators Association recorded the highest frequency/percent (*n* = 26; 81.3%) among the participants followed by national/regional/state level technology and engineering conferences (*n* = 20; 62.5%), and the American Society for Engineering Education conference (*n* = 16; 50.0%). Few participants envisioned attending conferences sponsored by the Design and Technology Association (*n* = 1; 3.1%), Pupil's Attitudes Toward Technology (*n* = 7; 21.9%), Technology Education Research Conference (*n* = 4; 12.5%), and Pacific Rim Technology Education Conference (*n* = 1; 3.1%). It is understandable why these four international conferences might have a low frequency rate as they are typically hosted in countries other than the United States.

Professional publications provide a scholarly venue for professionals to report the findings of research investigations. When technology and engineering educators publish in refereed publications they are, among other things, extending or adding to the body of knowledge in this discipline. The researchers' goal was to determine if the participants planned to publish in the future (presumably after being graduated with the Ph.D.) and if so, in which journals they would be seeking to publish their manuscripts. The participants were instructed to "select all that apply" from a menu containing eight possible choices. No participant selected the eighth and final choice, which was "other." It is clear that our Ph.D. students plan to publish in what may be thought of as traditional United States-based technology education journals – *Technology and Engineering Teacher* (*n* = 27; 84.4%) and *Journal of Technology Education* (*n* = 27; 84.4%). The *International Journal for Technology and Design Education* was selected by 11 (34.4%) participants. A review of their responses to this question and their previously reported responses to the question related to the publications they read most often reveals that though they read engineering-related journals (e.g., *Journal of Engineering Education* and *Prism*), they do not plan to publish in those journals in the future. (See Table 3 for a listing of the most often identified journals that they plan to read and publish manuscripts in the future.)

Finally, the participants were instructed to project to the year 2025 and identify their planned involvement in their professions. They were directed to either check that they would or would not be contributing professionally to technology and engineering education organizations. In addition, if they planned to be active in professional organizations, they were instructed to explain their planned involvement. Clearly, participants (*n* = 30; 88.2%) plan to be actively involved in their professional organizations, while four (11.8%) participants indicated they would not be actively involved. It remains unclear why four participants would not be contributing members.

"What do you see happening to the technology and/or engineering education profession by the year 2025?" was the final question posed to the

Table 3: *Currently Read and Plan to Publish Manuscripts*

Journal	Currently Read Number	Percent	Plan to Publish Manuscript Number	Percent
Technology and Engineering Teacher	22	64.7	27	84.4
Journal of Technology Education	15	44.1	27	84.4
Journal of Engineering Education	6	17.6	0	00.0
PRISM	5	14.7	7	21.9
Techniques	4	11.8	0	00.0
Journal of Technology Studies	4	11.8	5	15.6
International Journal of Design and Technology Education	4	11.8	11	34.4
Children's Technology and Engineering Journal	4	11.8	0	00.0
Design and Technology Education	0	00.0	6	18.8

Note: *N* = 34. Respondents could have more than one response to questions posed.

participants to address Research Question 4. Participants were instructed to "select only one of the following" choices: (a) the profession will look very similar to what it looks like today, (b) the profession as we know it today will be integrated in a STEM organization, (c) the profession will be integrated into the science profession, and (d) technology and engineering education will disappear as a teaching profession. Clearly, the participants believe the profession will be integrated into a STEM organization ($n = 30$; 88.2%) and only two (5.9%) participants believe the profession will look very similar to what it looks like today. Will the profession disappear by the year 2025? Only one (2.9%) participant believed the profession would no longer exist in 2025.

SUMMARY

What did the researchers learn from undertaking this study? Data show that efforts to bring engineering design and STEM principles into the technology and engineering curriculum are now reshaping the content focus for this school subject. These shifts are evident in courses colleges and universities are now offering, publications shared among professionals, and presentations delivered at professional association meetings. This leads educators to ask if the focus of our curriculum and profession will move closer to the engineering or science disciplines in the near future. If this direction is sought, teacher preparation will also need to be transformed. How might new and existing teachers be prepared? Because conference expenses are critical to all school systems' budgets, will distance learning become the modality to update the knowledge and practices of this profession's teachers? With fewer universities and faculty available to provide professional development enrichments for practicing teachers, distance-learning technologies might provide a practical way of learning.

The professional commitment level of current doctoral students is high. This group is committed to the technology and engineering professions. Many plan to become teacher educators. They plan to publish, to attend and present at professional meetings, and to become leaders in their professional organizations. However, what will the profession they plan to lead look like in the future? Many envision moving technology and engineering education practices into engineering, science, or STEM educational communities, where they see themselves practicing their profession. This might change the focus and nature of the technology and engineering education professions. As this study has shown, future leaders are analyzing the content and delivery of technology and engineering concepts for K-12 populations. Time will provide evidence of how this group might reshape our professions in the near future.

Dr. Gene Martin is Professor and Graduate Secondary Education Program Coordinator in the Department of Curriculum & Instruction at Texas State University, San Marcos, Texas. He is a member of the Alpha Mu Chapter of Epsilon Pi Tau and has been awarded the Distinguished Service Citations.

Dr. John Ritz is Professor in the Department of STEM Education and Professional Studies at Old Dominion University, Norfolk, VA. He is a member of the Alpha Upsilon Chapter of Epsilon Pi Tau.

Dr. Michael Kosloski is Assistant Professor in the Department of STEM Education and Professional Studies at Old Dominion University, Norfolk, VA.

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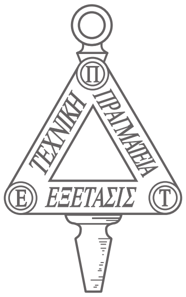
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Augmented Reality Applications in Education

By Misty Antonioli, Corinne Blake, and Kelly Sparks

ABSTRACT

Technology is ever changing and ever growing. One of the newest developing technologies is augmented reality (AR), which can be applied to many different existing technologies, such as: computers, tablets, and smartphones. AR technology can also be utilized through wearable components, for example, glasses. Throughout this literature review on AR the following aspects are discussed at length: research explored, theoretical foundations, applications in education, challenges, reactions, and implications. Several different types of AR devices and applications are discussed at length, and an in-depth analysis is done on several studies that have implemented AR technology in an educational setting. This review focuses on how AR technology can be applied, the issues surrounding the use of this technology, viewpoints of those who have worked with AR applications; it also identifies multiple areas to be explored in future research.

Keywords: augmented reality, science education, self-determination theory, flow theory, situated learning theory, just-in-time learning, constructivism

INTRODUCTION

In today's society, technology has become a crucial part of our lives. It has changed how people think and apply knowledge. One of the newest developing technologies is augmented reality (AR), which can be applied to computers, tablets, and smartphones. AR affords the ability to overlay images, text, video, and audio components onto existing images or space. AR technology has gained a following in the educational market for its ability to bridge gaps and bring a more tangible approach to learning. Student-centered activities are enhanced by the incorporation of virtual and real-world experience. Throughout this literature review on AR the following aspects will be discussed at length: research explored, theoretical foundations, applications in education, challenges, reactions, and implications. AR has the potential to change education to become more efficient in the same way that computers and Internet have.

RESEARCH

Research conducted for this literature review focused on educational applications of AR. The initial search of K-12 applications was far too broad to provide a valuable synthesis. The keywords included educational applications, science or STEM focus, and augmented reality. Journals with a concentration in technology and education that held significance to AR within the classroom setting were sought. References were included that explained the concept of AR as well as studies that implemented AR. Most of the references for this analysis were published within the past five years; however, a few articles included were published as early as 2001. The majority of the research found focused on applications in a middle or secondary level. AR appears to have potential extending into lower elementary grades. Additionally, research at the college level provides insight into windows of opportunity that may extend into the K-12 sector. Researchers often choose students at a middle school level because of the critical time period it is for increase in science interest and building self-confidence (Bressler & Bodzin, 2013).

Several studies seemed to take a mixed methods approach combining both quantitative and qualitative analysis. Researchers noted that providing case studies and opportunities for participant feedback extended the wealth of knowledge available and provided key insights to the quantitative data (Bressler & Bodzin, 2013; Enyedy, Danish, Delacruz, & Kumar, 2012; Iordache & Pribenu, 2009; Morrison et al., 2011; Serio, Ibanez, & Carlos, 2013). Qualitative data was also thoroughly inspected, specifically acknowledging the positive and negative components of AR that both students and teachers experienced (Arvanitis et al., 2009; Billinghurst & Dunser, 2012; Bressler, & Bodzin, 2013; DeLucia, Francese, Passero, & Tortoza, 2012; Iordache & Pribeanu, 2009; Morrison et al., 2011; Serio, Ibanez, & Carlos, 2013).

One of the quantitative research studies completed by Dunleavy, Dede, and Mitchell (2009), used a design-based approach with interviews to put the engagement of high school students under the microscope. The authors use the AR situation *Alien Contact!* with role- playing scenarios. The study was conducted over the 2006-2007 school year and used data from three schools in order to determine if AR technologies aid in the learning process. Jefferson High School, Wesley Middle School, and Einstein Middle School are all located in the northeastern United States. Through the collaboration of MIT and the University of Wisconsin at Madison, a hand-held AR program known as *Alien Contact!* was created. This game was designed to focus on several educational aspects such as math, language arts, and scientific literacy (Dunleavy et al., 2009). Students used this device throughout the study to participate in roles and collaborate as a team. The authors found that there was a high level of engagement.

Engagement was also found while using augmented books through a qualitative research study. Billinghurst and Dunser (2012) surveyed user studies concerning elementary and high school students to determine if AR enhances the learning experience. The authors found that, "AR educational media could be a valuable and engaging addition to classroom education and overcome some of the limitations of text-based methods, allowing students to absorb the material according to their preferred learning style" (Billinghurst & Dunser, 2012, p. 60).

THEORETICAL FOUNDATIONS

AR educational programs are student-centered and related to student interests. It allows students to explore the world in an interactive way. Constructivism also encourages students to work collaboratively, and AR provides students the opportunity to do this in a traditional school setting as well as in distance education. Dunleavy et al. (2009) believe that the engagement of the student as well as their identity as a learner is formed by participating in collaborative groups and communities. Constructivism has also changed the role of the teacher to become a facilitator, where the responsibility to organize, synthesize, and analyze content information is in the hands of the learner (DeLucia et al., 2012). Wang (2012) warns that because AR follows a constructive learning theory it does not generate consequences for students' actions as needed, compared to a behavioral learning environment; however, AR can be used to bridge the gap between practical and theoretical learning practices along with real and virtual components being blended together to create a unique learning experience.

AR also relates to the just-in-time learning theory. This theory suggests that students learn information that they need to know now. Collins and Halverston (2009) stressed that teachers should "reconceptualize" how they view learning and "rethink" what they should teach. AR allows them to do both of these things by letting educators use a new and engaging technology to view aspects of the real world in a different way.

Dunleavy et al. (2009) discussed the possible connection between the situated learning theory and AR. According to situated learning theory, learning occurs naturally during activities. Some AR situations, like *Alien Contact!*, allow students to use real-life experiences to facilitate learning. Some learning will occur naturally, as they go through their problem-solving environment. Students will use social interaction and collaboration to learn from one another.

Rigby and Przybylski (2009) identified that AR can be linked to the self-determination theory (SDT). SDT defines learning that occurs through motivation. People have the natural tendency to do what is healthy, interesting, important, and effective. The virtual learner hero situation created in the virtual worlds focused on in this study determined that students are engaged because they are in charge of their own learning. The same concepts can be applied to an educational setting.

Flow theory describes how people who are engaged in meaningful activities are more likely to stay focused. Bressler and Bodzin (2013) investigated a science gaming experience in relation to flow experience. Their study had a mean flow experience score of 82.4%, which indicates that the average student experienced flow throughout the science mystery game that they played on an iPhone. This particular type of AR, as well as various others, connects their real-world surroundings to learning in a new and engaging way.

APPLYING AR IN EDUCATION

AR allows flexibility in use that is attractive to education. AR technology can be utilized through a variety of mediums including desktops, mobile devices, and smartphones. The technology is portable and adaptable to a variety of scenarios. AR can be used to enhance content and instruction within the traditional classroom, supplement instruction in the special education classroom, extend content into the world outside the classroom, and be combined with other technologies to enrich their individual applications.

Traditional classroom uses

In any educational setting, there are often limitations in the various resources available. This is often seen foremost in the traditional classroom. Due to budget restraints or constraints on time, the means to teach students in scenarios that allow them to learn by doing can be a challenge. Desktop AR allows students to combine both real and computer-generated images. Iordache and Pribeanu (2009) used desktop AR that combined a screen, glasses, headphones, and a pointing device that allowed students to conduct a hands-on exploration of a real object, in this case a flat torso, with superimposed virtual images. It would not be feasible to explore the digestive process interactively as these students were able to do along with visualizing the nutrient breakdown and absorption in a classroom setting without the AR technology. Computer images could show the process, but the pointing device allowed students to guide their learning.

Classrooms can shift from the traditional lecture style setting to one that is more lab and student-oriented. A case study conducted with a visual arts class noted that allowing students to freely explore a room that was set up with webcams and desktops encouraged more activity while the students perceived that they were more motivated to learn (Serio et al., 2013). Instead of receiving information via images and lecture, students had access to multimodal representations including text, audio, video, and 3D models.

Quick response (QR) codes can also open up opportunities to have a mixed reality setting within the actual classroom. DeLucia, Francese, Passero, & Tortoza (2012) conducted an evaluation study on collaborative classroom environments in a university setting. Students had access via their mobile devices to information provided directly from the instructor and other students. The QR codes within the classroom allowed for location determination, which was necessary because the information was not available online. Having the virtual environment accessible in a single location encourages consistent and active participation in person instead of just the virtual environment. The learning experience of the traditional classroom was enhanced by the content sharing of both instructor and peers.

Special Education Uses

With the ability to bridge learning and physical barriers, AR has the potential to bring value and high quality educational experiences to students with learning and physical disabilities as well as the special education classroom. Billinghurst and Dunser (2012) found that using augmented storybooks have led to more positive results as students were able to recall stories and have better reading comprehension. Augmented storybooks could especially help students who were less able to comprehend only text-based materials. Physical movement is often a component and consideration for AR tasks. A student who may struggle to engage under normal circumstances can become more actively involved in the kinesthetic nature employed by augmented tasks. Dunleavy et al. (2009) found in their interviews that teachers felt that students who were identified as ADD as well as unmotivated students were 100% engaged in the learning process during an AR simulation.

Because of the variety of tools that can be overlaid in an augmented environment, students with physical disabilities can benefit from the potential learning aides that could be incorporated. Something as simple as overlaying audio for those with visual impairments or text for those with hearing disabilities can be effective tools when considering disability access (Forsyth, 2011). Physical limitations can make handheld AR devices more difficult to work with. Head-mounted displays (HMD) can provide a hands-free device to project the overlay visuals to a student and adjust the images based on the orientation of the student while other devices enable students to interact with the environment via voice recognition, gesture recognition, gaze tracking, and speech recognition (Van Krevelen

& Poelman, 2010). Bringing this technology to the classroom has the potential to allow for differentiated instruction and enrichment of the learning experience of students with special needs. Evaluation trials conducted by Arvantis et al. (2009) showed that using wearable AR technology with students who had physical disabilities produced, "interestingly comparable results with able-bodied users," (p. 250) in terms of "wearability" and pedagogy.

Outside the Classroom

Mobile applications can extend the traditional classroom beyond the physical walls. Annetta, Burton, Frazier, Cheng, and Chmiel (2012) reported that the percentage of 12 to 17 year olds who have their own mobile device is 75%, compared to 45% in 2004, and regardless of a student's socioeconomic status, the number of students carrying their own mobile devices is growing exponentially every year. Camera phones and smartphones allow users to gather information in a variety of locations. QR codes and GPS coordinates can be used to track and guide movement of the students. Although several researchers chose to take students off campus and conduct investigations in a field trip setting, others chose to remain within the grounds of the school.

In an off campus setting, the AR technology needs to be portable and relatively easy to use. Students traveling to a local pond have the ability to study water quality at specific locations while having access to overlaid media about the pond from the AR device (Kamarainen et al., 2013). This type of experience opens up a world of opportunities to mesh classroom information into the real-world environment. Morrison et al. (2011) used real paper maps and GPS coordinates in a treasure-hunt-style game that allowed for group collaboration. Participants in the game were aware of their surroundings and chose to work together on a task that fostered small group collaboration. An important point to note from this research is that GPS will not work inside of buildings. Therefore, any indoor activity would need to be conducted without a location-based AR technology.

Using QR codes allows individuals a means to avoid relying on location-based technology and focus on the augmented experience. Bressler and Bodzin (2013) chose to use vision-based mobile AR within the confines of the school campus. Students used iPhones that were Wi-Fi enabled to collaborate in small groups to complete a science inquiry game. Not only did the technology enable the students to move freely about the campus, but also the design of the game fostered a social constructivist approach by using a jigsaw method in which students had independent roles that relied upon one another to complete the task. Dunleavy et al. (2009) employed a similar approach to jigsaw collaborative methods for successful completion of an AR simulation.

Combined Learning

The technology employed with AR does not need to be exclusive to the AR experience. Motion sensors that modeled force and motion during Learning Physics through Play (LPP) activities and AR in the form of QR codes enabled students to use, visualize ideas and share them with others for discussion (Enyedy et al., 2012). Combining the technologies helped to enhance the learning experience, which is similar to research done by Kamarinen et al. (2013) who pointed out that the combination can help to enhance the learning experience in a way that neither could do alone.

If an educator is looking to model scientific practice, AR provides the opportunity to support the multifaceted world of science exploration. As a general rule, scientific researchers typically do not use a single tool for evidence to come to a conclusion. Likewise, a literature review that embodies just research from one scientific journal does not begin to tap the wealth of knowledge widely available. Using probeware and sensors to collect data and AR technology to guide and visualize helps to bring a more student-centered dynamic to a learning experience, resulting in gains in student engagement and content understanding (Enyedy et al., 2012; Kamarinen et al., 2013).

Applications Beyond Science

Research shows that the use of AR, regardless of grade level or subject area, allows students to be actively engaged in the learning process. "Building and using AR scenes combines active complex problem solving and teamwork to create engaging educational experiences to teach science, math, or language skills, and studies have found that this activity enhances student motivation, involvement, and engagement" (Billinghurst & Dunser, 2012, p. 60). Though most research shows the use of AR in education through middle school science, there are some implementations in other subject areas and age groups. For example, AR was utilized in a visual arts class as researched by Serio et al. (2013) and during the MapLens research by Morrison et al. (2011) when participants ranging in age from 7 to 50 were observed.

Outside of a traditional school setting, AR has many uses and can be applied to other areas of interest as well. The medical field can utilize this technology to see information about the body systems without having to leave the sight of the patient. In addition, families can see what furniture will look like in their house before purchasing, contractors are able to design different components and see how they will fit together before construction, and tourists can find information out about the area without an in-person tour guide. Van Krevelen and Poelman (2010), determined that AR can be particularly helpful in industrial situations in designing and assembling vehicles as well as military applications for combat training. Companies such as Volkswagen and BMW have already started to use AR technologies in their assembly lines (Van Krevelen & Poelman, 2010). Therefore, AR has many benefits outside of the educational field.

CHALLENGES

Training

Training is an important aspect of AR. "Most educational AR systems are single-use prototypes for specific projects, so it is difficult to generalize evaluation results" (Billinghurst & Dunser, 2012, p. 61). Each AR situation researched was unique and required a different program and requirements of the educator. Due to this uniqueness, training is needed for both educators and students to understand how to utilize each AR program to its fullest potential. During the Dunleavy et al. (2009) *Alien Contact!* AR lesson, teachers expressed a concern for more support. Teachers did not feel confident when setting up or implementing the program. In addition, teachers who are normally lecture focused had a hard time letting go and allowing students to explore the learning environment on their own. A training should be provided for teachers to learn a hands-off approach with their students and show them how this way of teaching will foster an effective learning environment. The fear of not knowing what is on each student's device can be elevated according to the authors through the process of allowing the students more control over their learning. In addition, Kamarainen et al. (2013) also found that teachers felt they would be unprepared to manage the same experience over again if they were by themselves without the researchers present. Training should be provided to the educators from the researchers if continued use of the AR technology is expected to be implemented.

Many AR applications require the use of the environment to set up areas for study. Students walk around and use their AR technology devices in order to receive information. The information must be triggered by either GPS coordinates or other methods when students get near the correct locations. The developer, as well as the educator, must be aware of the environment in order for this to work effectively (Van Krevelen & Poelman, 2010). Therefore, teachers need to either train themselves or attend training sessions on the environment that they can use. For example, if an AR application is specifically designed to be completed in a school where students get close to fire alarms, information appears on their device about fire safety, and the educator or developer must be aware of where all the fire alarms are located.

Resources

Billinghurst and Dunser (2012) understood that there are many aspects of AR that are considered to be obstacles when trying to implement this type of technology in the classroom. Many teachers do not have the skills to program their own AR learning experience and therefore must rely on the ability to create this AR environment through pre-made creation tools, which are rare. This was slightly contradicting to the Annetta et al. (2012) statement that there are many free resources available for teacher use but stress that because teachers are not properly trained they are unable to use these available resources.

AR tools are becoming more user-friendly and require less programming skills making them more attractive to the common educator. Mullen (2011) focused his work around providing individuals with a resource for basic skills that would enable them to not only understand how AR applications run but also to get started with creating AR content. Kamarainen et al. (2013) pointed out that AR platforms could be employed that allow “an author to create augmented reality games and experiences with no programming experience required” (p. 547). In addition, Billinghurst and Dunser (2012) predicted that by the year 2030, students will be building AR educational content on a regular basis to connect collaboratively with the outside world from within their classroom.

Technical Problems

Dunleavy et al. (2009) showed that the GPS failed 15-30% during the study. A GPS error refers to either the software of the GPS itself or incorrect setup. This was considered the “most significant” malfunction. Other malfunctions identified in this study were the ability for the devices to be effectively used outdoors. The glare from the sun as well as the noisy environment could impair the learning of the students.

Morrison et al. (2011) identified that students who collaborate in teams score higher than students who worked on their own. These multi-user teams need to share information with each other. Therefore, one of the challenges identified in this study is the need for developers to create places for collaboration among team members. Without this additional platform, the successfulness of the AR environment can be compromised.

There are several different kinds of devices that can be used when implementing AR in the classroom. Glasses, hand-held devices, and headwear are ways for the user to see computer-generated images imprinted on their reality. Iordache and Pribeanu (2009) determined that the cameras the students were using should be hands free and that they should be set at table level for the maximum results. Carrying around large devices can make AR inconvenient and frustrating. Arvanitis et al. (2009) had students wear a backpack as part of their AR technology device. The study showed that students felt that it was hard to wear and made them feel embarrassed. If AR technologies hinder the self-esteem of the students, this can also affect how much information the student can retain within each lesson. Van Krevelen and Poelman (2010) also identify that certain AR technologies can be uncomfortable and embarrassing to wear. Gloves, backpacks, and headgear can all cause a student to become uncomfortable and distract them from the purpose of the assignment. In addition, such items could potentially discourage students from trying AR in the first place.

Van Krevelen and Poelman (2010) identified the need for the AR technologies to be designed effectively and with high usability. For instance, the video display must make sure that the images shown do not appear closer or farther away than they really are. This problem can lead to misconceptions if dealing with location-specific tasks. Some devices may require calibration, and this can potentially be very difficult to do. Acquiring devices that are calibration free or auto-calibrated can be beneficial to the user as to avoid malfunction and user frustration.

Bressler and Bodzin (2013) found that players involved in gameplay within the building did not fully utilize the GPS on their mobile device, since the students were familiar with their surroundings. This seemed to reduce the overall cognitive load; however, location-based AR can add a new level of frustration when students are placed in an unfamiliar place, where they must rely on GPS navigation to complete gameplay. Using AR technologies that include both audio and visual components can allow students to use their cognitive abilities to retain information more efficiently based on cognitive load theory.

Student Issues

One issue identified in Dunleavy et al. (2009) determined that some AR situations can be dangerous. In this particular *Alien Contact!* scenario, students must look at their handheld devices to participate. When engaging in activities outdoors the students are unable to work on their devices and watch where they are going simultaneously. Therefore, students were found to be wandering into roadways and needed to be redirected to safety by teachers.

Some of the AR learning experiences require the student to be mobile. Exploring the world is not an uncommon task; however, Annetta et al. (2012) were concerned with gaining approval from school administration for students to travel outside of the classroom. Without this component the teachers and students would be very limited in their use of the AR technologies. The authors found that classroom management is an important part of using AR technologies with students.

Certain health problems can arise from using AR devices if they are not properly designed. Tunnel vision can be a side effect of using poorly designed AR devices, and this should be avoided (Van Krevelen & Poelman, 2010). Developers and educators should be aware of the method and the amount of information being presented. This could prevent the brain from being overloaded. In addition, when the user feels overwhelmed, stress and other frustration can arise, which will distract the student from the objective of learning.

AR learning environments are often designed to have many roles in order for students to work in teams and collaborate with each other. Dunleavy et al. (2009) stated, "As is, if one of the roles is absent, it severely restricts if not disables the game" (p. 19). Student absences are a natural occurrence but affect the learning environment drastically. In addition, students who are working without constraints can rush through or skip information depending on the AR program, teacher assertiveness, and intrinsic motivation. Kamaraien et al. (2013) also found that students might rush through the activity without fully comprehending the information presented in that part. Therefore, though AR leads to a high engagement level students should be monitored to stay on task and on pace as well.

As AR scenarios are developed for the classroom the developers must be aware of their target audience. For example, Enyedy et al. (2012) made a point that the AR technology used in their experiment was made for students to be able to make right and wrong decisions in order to foster play; however, this would not be the ideal situation for older students learning physics. Therefore, the cognitive development of the students should be taken into consideration when developing programs as well as utilizing already existing AR applications.

REACTIONS

Students

Overall, students reacted positively to using AR technology both in and outside of the classroom. AR is a fairly new development within the field of education, and there are areas that students reported that need improvement. Annetta et al. (2012; as cited in Benford and colleagues, 2003) listed four educational uses to AR mobile technology, which are in no particular order: field science, field visits, games, information services, and guides. AR games can be played independently or dependently. Researchers, teachers, and students alike were very pleased to find more collaboration while using the AR technology (Annetta et al., 2012; Billinghurst & Dunser, 2012; Bressler & Bodzin, 2013; DeLucia et al., 2012; Dunleavy et al., 2009; Kamarainen et al., 2013; Morrison et al., 2011). Students reported after completing an AR game called *School Scene Investigators: The Case of the Stolen Score Sheets (SSI)* they had a desire to perform at a higher level, felt a sense of exploration, and 93% of students were more curious to learn about forensics (Bressler & Bodzin, 2013).

Students also reported that learning in an AR environment is more stimulating and appealing than viewing a traditional slide presentation (i.e., Microsoft PowerPoint, SmartNotebook) because they preferred the audio, video, and feeling as if they were part of the 3D model that was transposed into a real physical space (Serio et al., 2013). Finding "hotspots" also known as "triggers," and using the smartphone were both reported as what the students really enjoyed while using AR technology (Kamarainen et al., 2013). Utilizing handheld devices was considered the most motivating and engaging factor when students played the AR simulation game *Alien Contact!* (Dunleavy et al., 2009).

AR is continuously growing and improving every day, and using students' feedback allows AR technology developers to incorporate these helpful tips to improve user experience. Students had issues keeping the AR superimposed images in the right position; they could not select an image as well as they would have liked, and sometimes the image was shaky, which could ultimately lead the program to lose the image altogether (Iordache & Pribeanu, 2009; Serio et al. 2013). DeLucia et al. (2012) noticed that when using AR technology the students had to hold the mobile device in order to complete the activity, which limited the users' maneuverability. To work around these situations, Morrison et al. (2011) found that users would sit down to stabilize their device. Other researchers used head-mounted displays (HMD) for students with muscular dystrophy, cerebral palsy, and arthogerposis to experience

AR simulations (Arvanitis et al., 2009). These students used the HMD because they depended on a wheelchair for their mobility. Students felt embarrassed and self-conscious wearing the HMD, and they also found the device uncomfortable. Both Arvanitis et al. (2009) and Iordache and Pribeanu (2009) reported stress on student vision after completing the AR simulation. However, Goodrich (2013) noted that technology developers are already working on a more user-friendly AR technology called Google Glass. This device is set up like a pair of glasses the student could wear with ease and confidence. The superimposed images are displayed to the glasses through a small projector that is viewed only by the individual student. Researchers are working on expanding this technology to include bionic eyes that function without the glasses and would have far reaching potential for students with visual impairments (DNews, 2013).

GPS is a major factor in completing AR simulations. GPS signals are not normally obtained in a building and to adapt, in order for AR simulations to function properly inside a classroom, QR codes have been developed. The mobile device using AR technology can scan a QR code and retrieve the information, where it is then loaded on the device (Bressler & Bodzin, 2013; DeLucia et al., 2012). Dunleavy et al. (2009) found that the biggest limitation for students and teachers while completing a simulation was GPS error.

Educators

Educators may feel alarmed as if AR will "overtake" their classrooms; it seems that once students experience this type of learning, they will not go back to their previous ways of learning. However, Annetta et al. (2012) expresseed that AR can be an activity to engage students in future units and discussions. Billinghurst and Dunser (2012) believe that AR is a new form of face-to-face instruction, as students share the learning experience. Teachers have reported students taking responsibility and ownership of their learning (Kamarainen et al., 2013). Therefore, educators using AR technology are becoming facilitators to their students. Even within the elementary grade levels, teachers plays a very important role in engaging the students, especially when introducing complex technical equipment to their students so they can take part in AR activities (Enyedy et al., 2012).

Teachers are concerned with the programming and coding that is required to integrate AR activities into their classrooms. Software is being developed (i.e., The Art of Illusion) in order for teachers to focus on building educational content and not having to worry about programming skills (Billinghurst & Dunser, 2012). Another concern is how quickly some students are completing the AR activity in comparison to other students. Going through the activity too quickly, as the student cannot wait to see what will come up next on the screen, can hinder their comprehension (Kamarainen et al., 2013; Dunleavy et al., 2009). In contrast, Serio et al. (2013) mentioned that students who finished early or could fix technical problems were willing to help other students. When using AR on a field trip, teachers expressed concern with how they would manage all of the technology, along with technical difficulties that arise throughout the trip—on their own.

Some AR simulation games require a significant amount of complex material the student must process. For example, running the mobile device, using the AR software, following the navigation, completing all the required tasks for the activity, and collaborating with peers about the information, can be quite daunting tasks, even for a student who is advanced at multitasking. Teachers are always looking out for the best interest of their students resulting in worry that AR simulations may cause students to have cognitive overload. Students reported cognitive overload when participating in an outside AR game, and teachers could expect this to be more likely to happen when students are in an unfamiliar area (Dunleavy et al., 2009).

Administration

One of the advantages of AR simulations is it allows students to participate in multiple field trip-like experiences from the comfort of their own building, which can be a huge incentive for districts that are affected by budget constraints (Dunleavy et al., 2009). AR simulations can take place in or outside of the traditional classroom, and administrative support is needed in all cases. For example, administrative approval is needed anytime traveling outside of the school's premises. Innovative teachers can capture administrative support for their students using AR technologies by maintaining strong classroom management skills and, equally important, facilitating good instruction (Annetta et al., 2012).

IMPLICATIONS FOR RESEARCH

The importance of this literature review is that it not only showcases the current trends in AR technology but also its focus on the increased research and potential further application in the educational setting. Several components remain to be explored. When using AR outside of the classroom, teachers and students are able to use this as a tool for physical activity (Dunleavy et al., 2009). Linking learning with exercise and activity in an educational way can improve the perception that technology creates a non-interactive environment (NAEYC & Fred Rogers Center, 2012). Since AR varies in the amount of room required, there is a concern for how much space is needed in order to make implementation successful (Dunleavy et al., 2009; Morrison et al., 2011; Wither, Tsai, & Azuma, 2011). Particular interest within AR is that it has not expanded to fully utilize other learning styles, such as audio and kinesthetic (Billinghurst & Dunser, 2012). Another is that the amount of visual information that can be displayed on the screen can be overwhelming to students. Studies should further explore the effects AR has on cognitive load in the brain and how much information should be displayed before it turns from a beneficial device into a distracting device (Bressler & Bodzin, 2013; Van Krevelen & Poelman, 2010). Many educators are already concerned with how to hold students' attention to keep them engaged throughout the lesson and maintain focus beyond the novelty of the technology (Kamarainen et al., 2013). In one study, Serio et al. (2013) discussed how AR could potentially increase memorization and concentration skills and suggested that further research should be conducted to validate these claims.

Educators must be digitally literate with an understanding of child development theory to select digital tools that are age specific and avoid the potential negative impact on learning (NAEYC & Fred Rogers Center, 2012). Dunleavy et al. (2009) pointed out the challenges of using AR before students have collaborative problem solving skill sets and behaviors that are necessary for learning, the tendency for student competitiveness, and the infancy of effective instructional design. How these challenges factor into placement of AR materials in a single classroom or broad age level warrants extensive focus by future researchers. Although much of the research focuses on student or teacher reactions to AR in the classroom and how it can be used, the technology itself has not allowed for long-term studies on the appropriate guidelines to implementation that will assure student growth and achievement of learning goals. The long-term effect of AR past a single classroom or group of students needs to be evaluated and compared. DeLucia et al. (2012) suggested that the effects of their AR system be evaluated over a longer period of time. Supplementary research could explore what is the most appropriate range of members utilizing AR in groups and when is the best time for AR to be introduced (Dunleavy et al., 2009). To further expand upon possible future research, additional studies would need to seek out if students using AR communicate more effectively and frequently compared to students who are not exposed to AR platforms (Arvanitis et al., 2009; Rigby & Przybylski, 2009). Throughout the multiple studies that were examined, many of them suggested further analysis in what types of AR platforms would be the best fit for educational purposes (Azuma, Baillot, Behringer, Feiner, Julier, & MacIntyre, 2001; Dunleavy et al., 2009; Forsyth, 2011; Iordache & Pribeanu, 2009).

CONCLUSION

AR has already begun to help students learn more efficiently as well as increase their knowledge retention (Billinghurst & Dunser, 2012). However, before AR becomes mainstream in education, like desktops, laptops, tablets, and even cell phones have become, special consideration must be taken into account on the usability, cost, power usage, visual appearance and the like, in order for content AR simulations activities to become part of the regular academic curriculum (Van Krevelen & Poelman, 2010). AR has proved to be an engaging way for students to participate in their learning. This new technology allows the learning to be student-centered and create opportunities for collaboration that fosters a deeper understanding of the content. AR is on the way to becoming an important part of education, and its use will continue to grow.

Misty Antonioli is a high school mathematics teacher for the Bradford Area School District located in Bradford, Pennsylvania.

Corinne Blake is a middle school science teacher for the Clark County School District located in Las Vegas, Nevada.

Kelly Sparks is a high school science teacher and technology facilitator for the Roanoke Rapids Graded School District in Roanoke Rapids, NC.

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