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ORIGINAL PAPER

Educators' Interests, Prior Knowledge and Questions Regarding Augmented Reality, Virtual Reality and 3D Printing and Modeling

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Abstract

Innovative new technologies, such as augmented reality (AR), virtual reality (VR) and 3D printers, provide new affordances for education. While each of these technologies has been shown to positively impact learning, they have not yet been widely adopted in schools. With the interest in these technologies growing among educators, this study explores why educators are motivated to learn about these tools, what they already know about these tools, and what they want to know. This paper presents data from 265 educators who completed a pre-course survey before engaging in an open online course to learn about these technologies. Findings from the data reveal significant variance in educators' prior knowledge, interests, and motivations. This paper yields new insights that can support the design of professional learning experiences for educators and potentially increase mainstream adoption and use of these tools in education.

Keywords 3D modeling · AR · Emerging technologies · Teacher learning · TPACK · VR

Extended reality technologies, such as virtual reality and augmented reality and 3D printers have skyrocketed in popularity in recent years. When the augmented reality (AR) game Pokemon Go was introduced to the world in 2016, it became a global phenomenon with an upward of 28 million users per day (Iqbal 2020). When Facebook bought Oculus VR in 2015, it helped consumer-based VR gain momentum (Barnard 2019). After the Fused Deposition Modeling printing process patent expired in 2009, the price of 3D printers dropped significantly, making them available to consumers worldwide (Schoffer 2016).

The *2013 NMC Horizon Report: K-12 Edition* identified 3D printers as an emerging technology that would enter mainstream teaching and learning practices around 2017 (Johnson et al. 2013) and the *2020 EDUCAUSE Horizon Report: Teaching and Learning Edition* selected extended reality (XR) technologies, including AR and VR, as emerging technologies with significant relevance and promise for education (Brown et al. 2020). While early adopters have found ways to incorporate these tools into their classrooms and research shows the benefits of these tools (Cheng and Tsai 2013; Jensen and Konradsen 2017; Maloy et al. 2017), AR, VR and 3D printers have not yet become mainstream teaching and learning technologies. However, the interest among teachers is growing.

With few opportunities to develop knowledge and skills related to these technologies, Dr. Trust and graduate students created an open online course about AR, VR and 3D printing and modeling in education to aid teachers' professional learning. The course featured three modules to introduce educators to the three topics through multimodal content and interactive activities. Upon completion of the free-standing open online course, individuals were given an International Society for Technology in Education (ISTE) Certificate of Participation.

As educators signed up to participate in the course, they filled out a pre-course survey, which consisted of a series of

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questions and prompts regarding their interest in and prior knowledge about these three technologies. For this paper, we discuss the results of the pre-course survey data to address the following research questions:

- RQ1: Why are educators interested in learning about AR, VR and 3D printing and modeling
- RQ2: What do educators already know about AR, VR and 3D printing and modeling
- RQ3: What do educators want to know about AR, VR and 3D printing and modeling

Review of the Literature

Extended Reality Technologies & 3D Printers

AR merges physical and digital realities in real-time by overlaying computer-generated imagery on top of a real-world environment (Ibáñez and Delgado-Kloos 2018; Lee 2012). There are two main types of AR: 1) triggered - which consists of physical or digital markers, location and motion tracking features that "trigger," or activate, a digital overlay and 2) view-based augmentation, which consists of adding a digital object to a physical space, like taking a photo of a room and seeing how new furniture would fit (Edwards-Stewart et al. 2016). AR can support knowledge acquisition, motivation, engagement, spatial ability and practical skills in science, technology, mathematics and engineering (STEM) learning (Cheng and Tsai 2013; Ibáñez and Delgado-Kloos 2018; Lee 2012). Additional benefits of AR include location-based exploration of information for inquiry learning (Cheng and Tsai 2013), social and collaborative learning through AR gameplay (Hantono et al. 2018) and transforming printed text into an interactive experience with virtual manipulatives (Billinghurst et al. 2001; Lee 2012).

As opposed to AR, which overlays digital objects on top of the physical world, VR allows individuals to explore or become part of a virtual environment that they can interact with and manipulate (Milman 2018; Brown et al. 2020). *Immersive virtual reality* is where the user becomes surrounded by the virtual environment, such as through a headset, while *non-immersive virtual reality* is where the user looks into a virtual environment from the outside (Jensen and Konradsen 2017). Traditionally, virtual environments were digitally animated, however, with 360-degree photos and videos, such as those provided in Google Virtual Tours, users can immerse themselves in a distant real-world environment (Snelson and Hsu 2019). Affordances of VR in education include cognitive skill acquisition, psychomotor skill acquisition, increased engagement, constructivist self-directed learning, and distance learning (Jensen and Konradsen 2017; Kavanagh et al. 2017; Martín-Gutiérrez et al. 2017; Pomerantz and Rode 2020; Snelson and Hsu 2019). In the *Learning in Three Dimensions: Report on the EDUCAUSE/HP Campus of the Future Project*, Pomerantz and Rode (2020) identified multiple benefits of virtual reality, including active and experiential learning, multisensory experiences, sense of presence in a virtual space and the opportunity to practice skills in low-stakes settings. Additionally, VR technologies can support online, distance, and remote education as they "overcome the limitations of time and place without the burdensome budget of field trips" (Patterson and Han 2019, p. 468).

3D printers "print" a physical 3D object from a digital 3D model (Choi and Kim 2018; EDUCAUSE 2020). 3D printers are typically found in school makerspaces (Oliver 2016), however, given the low-cost consumer-based 3D printers available, some educators have purchased or received grants to buy a 3D printer for their classroom. Educators do not need to purchase 3D printers to engage students in 3D modeling with free online tools, such as TinkerCAD. In educational settings, 3D printing projects can aid students in developing their content knowledge, spatial abilities and several technical and employability skills, including 3D modeling, creative and critical thinking, problem-solving and technological literacy (Choi and Kim 2018; Ford and Minshall 2019; Leinonen et al. 2020; Trust and Maloy 2017).

While scholars have found numerous benefits to AR, VR and 3D printing in education, there has not yet been widespread adoption of these technologies in school settings. According to the 2019 Project Tomorrow Speak Up survey, featuring data from 343,500 K-12 students, parents, teachers and administrators, emerging technologies, including AR and VR, have been adopted in less than 10% of schools in the U.S. (Evans 2019). The State of Technology in Education Report (Promethean 2019), which included data from more than 1800 educators across the United Kingdom and Ireland, noted that 3D printers and virtual reality tools are still not well utilized in schools, with only 16% of those surveyed reporting using 3D printers and 4% reporting using virtual reality in their practice. A 2018 survey of 3247 educators in Seoul indicated that access to 3D printers in schools ranged by grade level, with less than 5% of participants in elementary school reporting having access to 3D printers, while 33% of high school teachers indicated they had access to 3D printers (Choi and Kim 2018). Ultimately, even though these technologies have been used for decades in healthcare, military, aerospace and other fields, their adoption in schools is rather limited. Therefore, for this study, we sought to examine educators' interests, knowledge and questions regarding these technologies to identify ways to improve professional learning experiences to increase adoption and use of these tools to enrich and advance education.

Teacher Technology Integration

Integrating technology into classroom practice is a complex process that requires synthesizing technological knowledge with pedagogical knowledge and content knowledge (Koehler and Mishra 2009). Building on Shulman's (1986) pedagogical content knowledge concept, Koehler and Mishra (2009) designed the TPACK model to illustrate the multifaceted nature of teaching with technology. The TPACK model features three primary types of teacher knowledge as well as the types of knowledge that arise in the intersections among these three (see Table 1).

According to Koehler (2012), "effective technology integration for pedagogy around specific subject matter requires developing sensitivity to the dynamic, transactional relationship between these components of knowledge situated in unique contexts" (para. 3). In order to incorporate new technologies, such as AR, VR and 3D printing and modeling, into classroom settings, educators first must assess how these technologies influence, and can be influenced by, their pedagogical and content knowledge. Then, they need support and training for identifying effective practices based on their technological pedagogical content knowledge.

Unfortunately, as Patterson and Han (2019) noted, it can be challenging for educators to find quality professional development (PD) to support their use of emerging technologies. More than three decades of research on educator professional development has shown that educators need professional learning opportunities that are hands-on, situated in their practice, aligned with their curriculum, socially supported by peers or coaches and take place over multiple sessions or long periods of time (Darling-Hammond et al., 2017). Yet, formal PD opportunities, such as workshops and school or district training, rarely fit these criteria (Keay et al. 2019). Educators also engage in informal and self-directed learning experiences, such as Edcamp Unconferences (Carpenter 2016), however, these alone might not meet the criteria for quality PD. Additionally, informal learning can be influenced by individual characteristics, job characteristics and school or broader contexts (Kyndt et al. 2016). For instance, an educator might attend an hour-long Edcamp unconference session and develop technological knowledge about 3D printers, but then return to work where they do not have support or training opportunities in their school or district that would assist them in synthesizing the technological knowledge with their pedagogical approaches and content knowledge. In this case, job characteristics and lack of ongoing, socially supported learning opportunities may limit the educators' ability to incorporate 3D printers into their practice. Given the limitations of formal and informal PD, it is not surprising that the most commonly reported technologies in education are those that support traditional teacher-centered practices, such as disseminating information, managing behavior and grading (Evans 2019; Vega and Robb 2019). Ultimately, educators need high-quality professional learning opportunities to develop their TPACK knowledge in a way that supports the integration of emerging technologies into their practice.

Additionally, teachers face multiple barriers when incorporating new technologies into their practice. Ertmer (1999) identified both first-order and second-order barriers that can influence technology integration. First-order barriers refer to external obstacles, such as equipment, time, technical support and training. Second-order barriers are those that are internal to the teacher, such as underlying beliefs, attitudes and mindsets. While Ertmer identified these barriers more than two decades ago, they continue to influence teaching and

Table 1 Types of Knowledge in the TPACK Model

Type	Knowledge	Description
Primary	Pedagogical Knowledge (PK)	An understanding of the practices, methods and processes for designing instruction based on the research and theories guiding how people learn.
Primary	Content Knowledge (CK)	An understanding of the content (subject matter) being taught.
Primary	Technological Knowledge (TK)	An understanding of how to use, troubleshoot and work with technology, including hardware, software, digital tools and apps.
Intersecting	Technological Pedagogical Knowledge (TPK)	An understanding of how technology and pedagogy influence one another and shape student learning experiences.
Intersecting	Technological Content Knowledge (TCK)	An understanding of how technology and content influence one another and shape subject-matter learning.
Intersecting	Pedagogical Content Knowledge (PCK)	An understanding of how to identify, use and teach with content-specific pedagogical practices, including exposing content-related misconceptions and selecting the most appropriate strategies based on the content being taught.
Intersecting	Technological Pedagogical Content Knowledge (TPACK)	An understanding of the interplay among technology, content and pedagogy and the ability to design technology-rich, content-specific instruction based on how students learn.

learning with technology in the present day (Makki et al. 2018). In, Tsai and Chai (2012) posited adding design-thinking as a third-order barrier to address the challenges related to knowledge creation and synthesis as part of the TPACK model. Patterson and Han's (2019) study of a teacher's integration of VR into their practice illustrated how embedding an emerging technology into a classroom setting required overcoming multiple barriers (e.g., equipment costs, technical difficulties) and collaboratively engaging in design thinking with the study authors to develop technology-rich learning experiences.

Integrating technology into educational practices is a complex, multifaceted process that involves assessing and expanding technological pedagogical content knowledge and evaluating and identifying ways to overcome technology-related barriers. Given the challenges faced when integrating technology into teaching, for this study we sought to explore educators' knowledge, motivation and concerns related to AR, VR and 3D printing and modeling to identify ways to reduce barriers and support integration of these tools in classroom settings.

Methods

Instrument

For this study, Dr. Trust developed the pre-course survey protocol in collaboration with the graduate student cohort that designed the open online course. The purpose of the pre-course survey was to get to know the participants in order to provide quality instruction and feedback during the open online course. The survey featured four types of pre-course questions and prompts as identified by Wilson (2018): demographics, prior knowledge, curiosity and setting goals. Demographic questions focused on participants' professions, grade level and subject taught, age, gender, years of teaching experience and school community type. To assess prior knowledge, participants were asked to list three things they already knew about each technology. For curiosity prompts, participants shared why they were interested in participating in the open online course and what questions they had about the technologies. For goal setting, participants were asked to list their learning goals for the course. As this was an exploratory study, we relied on pilot testing to enhance the reliability and validity of our survey. During the early stages of the survey design, we shared the survey draft with a few practicing educators and then made revisions to the final instrument based on their feedback.

Data Collection

The survey was included as part of the sign-up form for the "AR, VR & 3D in Education: Teaching and Learning with Current and Emerging Technologies" open online course. The sign-up form was created on the Qualtrics survey design platform. The first part of the survey featured demographic, curiosity and goal setting prompts. Then, participants had the option to review and agree to the IRB consent form before continuing to answer additional questions. The sign-up form was shared via social media sites (e.g., Twitter, Facebook), Dr. Trust's College of Education listserv and in the ISTE online discussion forums. The course was run two separate times: March 2020 and August 2020. For this paper, we combined the pre-course survey results from the two different data collection points. A total of 360 participants completed the sign-up form. Out of these participants, 265 gave consent for their sign-up form and survey responses to be included in this study. A chi-square analysis of the demographics of the group of participants who opted into the survey ($n = 265$) and those who opted out ($n = 95$) indicated no statistically significant difference in demographics between the groups.

Participants

The majority of the participants were between the ages of 35 and 54 years old ($n = 167$; 63%) and identified as female ($n = 194$; 74%). Out of the participants, 100 (38%) were PreK-12 classroom teachers, 52 (20%) worked as educational support staff (e.g., technology specialist, professional development coordinator, paraprofessional), 48 (16%) were higher education faculty or staff, 34 (11%) were graduate or college students, 25 (9%) were librarians or media specialists and 18 (7%) worked in PreK-12 administration. Years of educational experience ranged from 0 to 45 years, with an average of 18 years. A little more than one-third of the participants worked in suburban settings ($n = 87$; 35%) and another third worked in urban settings ($n = 85$, 33%), while 17% ($n = 43$) reported working in rural settings. The remaining participants either did not report the type of school they worked in or selected "other" ($n = 37$; 15%). Most of the participants were located in the United States ($n = 216$; 82%), the remaining participants were located around the world, including Canada, Saudi Arabia, India, Spain, China, Australia, Philippines, Trinidad and Tobago, Switzerland, Netherlands, Pakistan, Malta, Kuwait, Italy, Barbados, Ireland, the Democratic Republic of the Congo, United Arab Emirates, United Kingdom of Great Britain and Northern Ireland and Columbia.

Data Analysis

Descriptive statistics were generated for the multiple answer questions. For the open-ended prompts, we engaged in open coding to generate a list of initial codes, which were then synthesized into broader themes as part of a thematic analysis (Braun and Clarke 2006). Each open-ended prompt was reviewed individually and an initial list of codes was developed based on common patterns in the data. For example, many participants indicated an interest in discovering best practices, ways of teaching with the technologies and examples of using the technology in practice. These responses were coded together as "best practices."

We engaged in multiple rounds of coding and discussing and resolving discrepancies before generating a final codebook for each open-ended prompt (see Appendix Tables 4, 5, 6, 7 and 8). Each codebook featured examples and descriptions of the most common and interesting themes. The codebooks were used as a guide to complete the final round of coding of the data for each open-ended prompt. To increase credibility and trustworthiness, we engaged in investigator triangulation by having multiple researchers involved throughout the data analysis process (Nowell et al. 2017; Twining et al. 2017). Additionally, we collected two sets of data - once in February 2020 and once in August 2020 - which broadened our participant pool and allowed us to compare codes between the two sets. There was no significant difference in the coding results between the February and August datasets, indicating that data saturation was reached. Upon evaluating the codes across the open-ended prompts, we identified connections to the TPACK model, which we then used as an overarching theme for the analysis and discussion sections.

Findings

RQ1: Why are educators interested in learning about AR, VR and 3D printing and modeling

Participants were asked to select from a list of options the reasons they wanted to enroll in the open online course to learn about AR, VR and 3D printing. Most commonly, participants wanted to learn about these new technologies (n = 212; 80%), expand their professional knowledge (n = 208; 78%) and discover new teaching strategies (n = 198; 75%). More participants were interested in discovering ways to use these technologies to improve the student learning experience (n = 191; 72%) compared to improving student learning outcomes (n = 135; 51%). These findings indicate that the participants were most interested in developing or expanding their technological knowledge (TK), pedagogical knowledge (PK) and technological pedagogical knowledge (TPK).

In response to an open-ended prompt, participants identified several reasons that they were interested in AR, VR and 3D printing and modeling (see Table 4 Codebook). The most commonly cited interest, listed by slightly more than half of the participants (n = 152; 54%), was updating their TK. For instance, one participant expressed that their motivation was "to stay up to date on new technology and help my students feel confident with the technology they encounter both in high school, college and their personal lives." In addition to staying current on emerging technologies, some participants (n = 26; 9%) expressed a desire to learn how to use the AR, VR and/or 3D printing equipment they had access to in school. These participants were motivated to build their TK so that they could take advantage of the resources available to them for teaching and learning.

Several participants (n = 83; 29%) indicated an interest in discovering best practices for teaching. These individuals discussed wanting to learn how to bring AR, VR and 3D printing and modeling into their teaching and how to create "innovative," "transformative," "progressive," and "effective," learning experiences with these technologies. Furthermore, 31 participants (11%) specifically mentioned an interest in learning how to use the technologies to improve student engagement, as one educator noted, "technology is an incredible tool to provide differentiated instruction and also add to student engagement." In summary, participants seemed to be most interested in developing TK to stay current with and use emerging technologies as well as TPK to identify how the technologies might fit within or transform their teaching and increase student engagement.

RQ2: What do educators already know about AR, VR and 3D printing and modeling

To assess prior knowledge, participants were asked to list three things they knew about each of the three technologies. Out of the 265 survey participants, 211 responded to these three prompts. While participants' responses ranged quite significantly, we identified 10 themes that captured commonalities across the dataset (see Table 2).

Most commonly, participants discussed the apps, materials and equipment needed for the technologies. For AR, participants

Table 2 Teachers' Initial Insights About AR, VR, and 3D Printing and Modeling

	AR		VR		3D	
	n	%	*n*	%	*n*	%
Unfamiliar/Unsure	31	15%	20	10%	40	19%
Accurate Description - Full	9	4%	40	19%	13	6%
Accurate Description- Limited	75	36%	60	29%	38	18%
Inaccurate Description	43	20%	5	2%	4	2%
How the Technology Works	17	8%	26	12%	33	16%
Apps/Equipment Needed	115	55%	113	54%	107	51%
Benefits	41	19%	54	26%	92	44%
Challenges	6	3%	32	15%	61	29%
Use in Society	29	14%	41	20%	31	15%
Personal Experiences	31	15%	33	16%	33	16%

listed equipment needed (e.g., mobile device with camera), materials (e.g., merge cube) or popular AR apps (e.g., Pokemon Go, Quiver). For VR, many participants identified the need for VR headsets (e.g., Oculus Quest, Google Cardboard), while some listed VR apps and digital tools such as CoSpaces and Google Expeditions. For 3D printing, participants most commonly wrote about 3D modeling apps (e.g., TinkerCAD, SketchUp) or materials needed to print (e.g., filament). Overall, many participants demonstrated some degree of TK by indicating that AR, VR and 3D printing and modeling require, or can be used with, certain apps, materials and equipment.

Many participants attempted to describe AR, VR or 3D printing and modeling or explain how they work. However, only a few participants were able to provide fully accurate descriptions for AR (4%) and 3D printing and modeling (6%), while 19% of the respondents were able to provide a fully accurate description of VR. Table 3 showcases the variability in responses and accuracy between two participants. In this example, the K-5 instructional technology teacher demonstrates an accurate understanding of VR and a limited understanding of 3D printing and AR. They also seem to have the misconception that AR requires GPS to work and that 3D printers can only print plastic models. The 7–8 grade teacher on special assignment seems to confuse AR with VR (AR isn't known for making people dizzy/sick) and, while they were correct in stating that VR can be used with Nearpod and Google Earth, they seemed to have a misconception that VR is more readily available than AR and 3D printing and modeling. Across the dataset, 20% of respondents listed inaccurate information or misconceptions regarding AR, compared to 2% of the participants' VR and 3D printing responses.

Overall, participants seemed to be slightly more familiar with VR ($n = 100$; 48%) than AR ($n = 84$; 40%) and substantially more familiar with VR than 3D printing and modeling ($n = 51$; 24%). Interestingly, though, more participants were able to describe how 3D printing and modeling works compared to VR and AR. This might indicate that participants' familiarity with VR and AR stem from indirect experiences, such as hearing about Pokemon Go in the news or watching a movie featuring VR, while participants' familiarity with 3D printing and modeling may stem from first-hand observation of, or experience with, 3D printers. It might also be due to the fact that 3D printers create tangible objects that can solve actual problems, which is less abstract and easier to understand compared to the virtual experiences of AR and VR.

Several participants identified benefits and/or challenges related to using AR, VR or 3D printing in education. Ninety-two (44%) respondents listed benefits of using 3D printers in school settings, such as increased student engagement, improved creative thinking and problem-solving skills and constructionist and experiential learning opportunities. For instance, one participant wrote, "3D printing allows students to create real-world solutions to problems," while another commented, "it engages reluctant learners. Assists in solving real-world problems." On the other hand, less than one-third of the participants listed benefits of using AR or VR in education. Identified benefits for AR and VR included improved interactivity, increased student engagement, improved content visualization and the ability for students to experience a place, object or situation not otherwise possible. While participants seemed to be more familiar with the tangible, real-world benefits of 3D printing and modeling, nearly one-third of respondents mentioned challenges with 3D printers (e.g., time, cost, learning curve), compared to 14% for VR (e.g., isolation, motion sickness, cost, addictiveness) and 5% for AR (e.g., device/app capabilities).

A small number of participants shared personal experiences with the technologies or identified how they are used in society. For instance, 14% of the respondents mentioned Pokemon Go when asked to share what they knew about AR. For 3D printing and modeling, some participants listed the medical and engineering benefits, as one individual commented, "almost anything can be made (i.e., food, body parts, machine parts)." For virtual reality, participants shared experiences with trying out VR headsets or digital tools (e.g., Google Earth, Google Tiltbrush, Playstation4) or discussed how VR is popular in the gaming industry.

Table 3 Example Descriptions of AR, VR, and 3D Printing & Modeling

	K-5 Instructional Technology Teacher	7–8 Grade Teacher on Special Assignment for Technology Integration
AR	1) It is a way for technology to appear in the natural world via a device. 2) It uses GPS technology. 3) It can be integrated with Google and other well-known applications.	1. It helps you to experience what you're learning. 2. It requires devices 3. It often makes me dizzy/sick.
VR	1) It uses a headset. 2) The user is immersed in a new reality which is virtual. 3) The user experiences the new reality as a part of it.	1. It's more readily available. 2. Using sites like NearPod or Google Earth can help people see places. 3. It excites me for the possibilities it can bring to my classroom.
3D	1) 3D printers are expensive. 2) You can design and print tangible 3D models. 3) The 3D printers print plastic models.	I really know nothing other than the fact that it's around.

Ultimately, participants' prior knowledge about the three technologies was rather limited. When asked to share three things they knew about the technologies, the majority of participants focused their responses on TK, while a few were able to identify the benefits and challenges of using these tools in educational settings (TPK). None of the participants discussed TCK (i.e., how the technology might fit within a content area) or TPACK knowledge (i.e., how to create technology-rich, content-specific instruction with these tools).

RQ3: What do educators want to know about AR, VR and 3D printing and modeling?

At the end of the survey, participants were asked to list any questions they had about the technologies. The respondents to this prompt ($n = 194$) shared a variety of questions and concerns. Participants seemed to be most curious about the best practices for integrating these technologies within their pedagogy ($n = 70$; 36%). For example, one individual asked, "What are easy ways to implement these technologies into the classroom in meaningful ways, not just for the sake of using technology?" This participant, like many others, wanted to know how to teach effectively with the technology and not just use it as an add-on for student engagement. Participants ($n = 38$; 20%) also wanted assistance in identifying curriculum connections. For instance, one educator wondered, "How can I incorporate them into my ELA/SS/Math curriculum?" Educators also wanted to know how these technologies fit within different grade levels ($n = 21$; 11%), how to manage the logistics of teaching with these technologies, such as troubleshooting, time, equity and accessibility ($n = 33$; 17%), how to afford or find funding for buying equipment to use AR, VR or 3D printing in their practice ($n = 31$; 16%) and how the use of these technologies would impact student learning outcomes ($n = 24$; 12%) (see the Appendix Table 8 codebook for more details). Overall, participants wanted to know how to teach with the technology (TPK), how the technology fit within their curriculum (TCK) and how to use, fund and troubleshoot the technology (TK).

Forty-eight (25%) participants indicated that they either did not have any questions or were unsure what to ask since they knew very little about the technologies. For instance, one educator commented, "I don't know what I don't know yet, so I'm just trying to learn more so I can know what questions to ask." This indicates that many participants are so unfamiliar with the technologies they don't know where to get started in thinking about how these tools might fit in educational settings.

Discussion

While scholars and educators have explored how AR, VR and 3D printers are used in education and how these technologies influence student learning outcomes (Cheng and Tsai 2013; Ibáñez and Delgado-Kloos 2018; Jensen and Konradsen 2017; Maloy et al. 2017), there is limited research regarding educators' interests, prior knowledge and questions related to these technologies. This study looked beyond early adopters' uses of these technologies to the broader population of educators, including current and future teachers, technology integration specialists, librarians, administrators and higher education professionals, who were interested in learning about these tools.

Ultimately, the majority of participants were generally unfamiliar with these technologies. Although these technologies have been around for decades and these tools have been featured in popular media (Barnard 2019; Iqbal 2020; Schoffer 2016), most participants were not able to fully describe what these technologies were or how they worked. These findings indicate that there has not yet been widespread adoption of, or training about, these technologies in school settings. Based on these findings, we recommend that teacher education programs, schools and districts consider providing high-quality PD opportunities (Darling-Hammond et al., 2017) for educators to discover, learn about and develop their TPACK competencies for emerging technologies, including AR, VR and 3D printing and modeling. We also encourage teacher educators to identify ways to support and augment the professional learning of teachers who discover and learn about AR, VR or 3D printing and modeling through informal or self-directed activities and need assistance bringing these tools into their practice (Kyndt et al. 2016).

Additionally, given the diversity in participants' prior knowledge about AR, VR and 3D printing and modeling, we recommend that teacher educators conduct a survey similar to the one we developed or use a data collection tool to learn more about what educators already know before designing professional learning experiences. Understanding what educators know already can be useful in creating professional learning experiences that build on educators' knowledge and address any misconceptions or concerns they may have about the technologies. For instance, some of the participants shared misconceptions, such as AR causes dizziness, VR is only for gaming or 3D printing and modeling can be used to teach coding. Additionally, several participants identified affordability as a major concern for using current and emerging technologies like AR, VR and 3D printing and modeling. Setting aside time during the start of training to address misconceptions, barriers and concerns, like how to fund these technologies or use free versions (e.g., having students create 3D models on Tinkercad without needing a printer), might increase educators' use of these tools in their practice (Ertmer 1999; Patterson and Han 2019).

While participants were generally unfamiliar with the use of these technologies in education, they all shared a desire to learn more about AR, VR and 3D printing and modeling. Specifically, participants wanted to update or expand their

TK. They seemed to want to learn about AR, VR and 3D printers first, including what these technologies are, how they work and how to troubleshoot them, before determining whether to incorporate them into their practice. This indicates that current and future teachers might benefit from a technology showcase or playground where they can observe demonstrations of the technologies in action, try them out in a safe space without worrying about breaking them and speak with technology experts about their TK concerns, such as troubleshooting and accessibility (Tables 4, 5, 6, 7 and 8).

Beyond TK, most participants wanted to discover how these tools could fit within, shape or be shaped by their pedagogical practice (TPK). Several participants expressed an interest in using these tools to increase student engagement and improve student learning experiences, while a smaller number of respondents wanted to know how these tools could be embedded into teaching to positively influence student learning outcomes. While integrating novel technologies, like AR, VR and 3D printing and modeling, into classes is a popular way to increase student engagement, previous studies have found that there are numerous other benefits to the educational uses of these tools, including improved academic knowledge, enhanced visual and spatial skills, increased interactivity with content leading to deeper learning, overcoming spatial and temporal barriers and developing twenty-first century and employability skills (e.g., Cheng and Tsai 2013; Choi and Kim 2018; Ibáñez and Delgado-Kloos 2018; Jensen and Konradsen 2017; Kavanagh et al. 2017; Lee 2012; Patterson and Han 2019; Trust and Maloy 2017). Only a small number of participants were able to identify the benefits of educational uses of these tools other than student engagement, indicating that an exploration of research studies and model lessons might help shift educators' thinking about whether and how to use these technologies in their practice. Therefore, we suggest that teacher educators and pre-service and in-service teachers collaboratively explore the literature, best practices and model lessons for teaching with these tools and identify and discuss potential benefits and applications.

Less than one-quarter of the participants indicated an interest in learning about how AR, VR and 3D printing and modeling might fit within their curriculum (TCK). This may be because several of the participants were working in support positions and may have been more interested in learning about the technologies and pedagogical implications to share with others rather than specific content and curriculum connections. It could also be due in part to a lack of understanding of whether these tools can be used to address curriculum and learning standards, given that only 51% of the participants indicated an interest in exploring how these tools could improve student learning outcomes. A previous study by Maloy et al. (2017) found that while educators considered 3D printing and modeling exciting, they were unsure how to embed 3D printers into standards-driven curriculum topics. Based on these findings, we suggest that teacher educators provide personalized coaching, support and examples for integrating these technologies within different content areas and standards. Additionally, educators need time to brainstorm and design content-specific lessons featuring these tools. Teachers might benefit from a creative thinking exercise in which they are given a randomly selected emerging technology and randomly selected curriculum standard and then they have to brainstorm in groups at least 5 different ways to teach the standard using the selected technology. This activity could be repeated multiple times with new technologies and standards each round.

Ultimately, while the interest in exploring these novel technologies is there, educators need significant training and support in developing their TPACK knowledge before there is widespread adoption of these tools. The findings from this study indicate that educators need high-quality professional learning opportunities that allow them to develop and expand their TK, TPK and TCK before they are ready to holistically and effectively integrate technology into their practice (TPACK).

Limitations & Future Research

This study was limited by convenience sampling and survey research methods. Participants were recruited through specific networks, including the ISTE professional learning networks as well as school email listservs in which the authors were connected. Additionally, participants were specifically interested in engaging in an open online course related to these technologies. This may indicate that participants' responses are not representative of the general population. While the findings may not be generalizable, the data provides initial insights that can improve how professional learning opportunities are designed to support the adoption of these technologies in schools.

The study was also limited by survey research methods. While the use of the survey was necessary to collect data from a significant number of participants who were located around the world, the survey responses provided just a brief glimpse into educators' motivations, prior knowledge and questions about these technologies. For instance, educators were asked to list three things they knew about each technology rather than provide a detailed definition or description of the tools. Educators may have known more about the tools than what they provided in the survey. Future studies are needed to provide a deeper exploration of educators' thoughts, interests, experiences and concerns regarding AR, VR and 3D printing and modeling. Additionally, this study raised several questions, such as:

- Why might teachers place less value on these technologies for supporting student learning outcomes?

- Are educators interested in exploring these tools just to add another technology to their teaching toolkit or do they want to use them to transform teaching and student learning?
- How might scholars and teacher educators draw on popular media and teachers' personal experiences with these tools to support the widespread adoption of the technologies in classrooms?

Together, these questions and our findings indicate that the field of education could benefit from more research related to teaching and learning with emerging technologies.

Conclusion

This study explored why educators wanted to learn about AR, VR and 3D printing and modeling, what they already knew about these technologies and what they wanted to know about these technologies. The findings from this study suggest that educators are generally unfamiliar with these technologies or have limited conceptualizations about how these tools work, but also, they are interested in discovering how these tools can be used within and across curriculum and grade levels to enrich and advance learning. The findings from this study offer insights to aid the design of professional learning opportunities that support the mainstream adoption of AR, VR and 3D printers in K-12 schools and higher education.

Appendix

Table 4 Codebook for Participants' Interests in Learning About AR, VR, and 3D Printing (n = 150)

Code	Description	Example	*n*	%
Update Technological Knowledge (TK)	Participant stated that they are interested in learning about these emerging technologies in order to stay current and expand their knowledge of technology.	"As a technology teacher, you always need to enhance your skills and stay up to date with the latest technology for your students."	152	54%
Best Practices (TPK)	Participant stated that they are interested in learning about best practices for integrating these technologies into their classes.	"I'm always interested to see what other people are doing with AR/VR and if I can incorporate that into my program."	83	29%
Faculty Training & Resource Sharing	Participant stated that they are interested in learning about these technologies so they can pass on the knowledge to others.	"I am a teacher, but also a tech coach in my building and would like to learn more about these topics and how to integrate them into teaching in all areas so that I can share that information with my colleagues."	59	21%
Engage Students (TPK)	Participant stated that they would like to use these technologies to enhance learning, engage students in meaningful ways, and/or improve student achievement.	"To get new ideas in order to create more engaging lessons for my students."	31	11%
Utilize Equipment (TK)	Participant stated that they own, will own, or have access to AR, VR or 3D printing equipment and are interested in learning how to use it.	"We recently purchased Google Expeditions kits for our STEAM teachers to use and I'd like to learn more about VR and AR"	26	9%

Table 5 Codebook for "List 3 things You Already Know About Augmented Reality"

Code	Description	Example
Unfamiliar/Unsure	Participant stated that they do not know anything about the technology.	"Nothing. Surely not a thing. Not one single morsel."
Accurate description - full	Participant presented a fully correct description of the technology or used key terms that align with scholarly definitions of the technology.	"AR is where you have an image, video, etc... that is superimposed over your surroundings. An example would be when you look at the Merge Cube through your phone and there is a globe in the room."
Accurate description - limited	Participant presented a partial description or a partially accurate description of the technology.	"It usually requires a phone or tablet, it can be interactive, it shows an object in our world using the camera."
Inaccurate description	Participants' description of the technology is inaccurate or presents misconceptions, such as confusing AR with VR.	"Oftentimes a map is needed for the image to project itself."
How it works	Participant detailed how the technology functions and performs.	"Augmented reality basically uses multiple camera lenses and detection of surfaces to place something within an environment."
Apps/equipment needed	Participant identified equipment, software, devices, and/or apps needed to use the technology.	"Merge Cube, 3D Bear, Co-Spaces, Metaverse."
Relate to personal experience	Participant drew connections to their own lives.	"I experienced Augmented Reality when I played Pokemon Go."
How it is used in society	Participant discussed how the technology is used in society and/or education.	"Augmented reality has been successful in the gaming industry."
Benefits	Participant described the value of the technology for education.	"AR allows students to observe and interact with topics/objects that they normally wouldn't be able to."
Challenges	Participant identified barriers to using the technology.	"Many of our iPads aren't able to use AR because of the lack of AR kit in the older iPads."

Table 6 Codebook for "List 3 things You Already Know About Virtual Reality"

Code	Description	Example
Unfamiliar/ Unsure	Participant stated that they do not know anything about the technology.	"I have no in-depth knowledge about how VR is used in education."
Accurate description	Participant presented a fully correct description of the technology or used key terms that align with scholarly definitions of the technology.	"Is a simulated experience so it gives you a look at something such as a site (ruins in Greece) like you are there but you are not really there, you are seeing it through something such as VR goggles. It can be a game like Minecraft. It can be used in training to simulate an experience."
Accurate description - limited	Participant presented a partial description or a partially accurate description of the technology.	"Virtual reality takes you out of your world and puts you into a virtual world."
Inaccurate description	Participants' description of the technology is inaccurate or presents misconceptions, such as confusing AR with VR.	"It allows you to photoshop pictures."
How it works	Participant detailed how the technology functions and performs.	"1) It uses a headset. 2) The user is immersed in a new reality which is virtual. 3) The user experiences the new reality as a part of it."
Apps/ equipment needed	Participant identified equipment, software, devices, and/or apps needed to use the technology.	"1. Google Expeditions with Google Cardboard is a cheap method to use in class. 2. If you choose to use Oculus Rift, Rift S, or the Vive you need a beefy PC. 3. Oculus Quest is my favorite."
Relate to personal experience	Participant drew connections to their own lives.	"I have experimented with NYTimes VR as a learning tool with educators."
How it is used in society	Participant discussed how the technology is used in society and/or education.	"Virtual reality is used for training in different careers. It immerses the user in a virtual environment where they can interact with a variety of features."
Benefits	Participant described the value of the technology for education.	"It is a great way to take students to other places in the world without leaving the classroom."
Challenges	Participant identified barriers to using the technology.	"Can cause claustrophobia/motion sickness. Requires 1:1 devices for participants/not a social or paired experience."

Table 7 Codebook for "List 3 things You Already Know About 3D Printing"

Code	Description	Example
Unfamiliar/ Unsure	Participant stated that they do not know anything about the technology.	"I really know nothing other than the fact that it's around."
Accurate description (TK)	Participant presented a fully correct description of the technology or used key terms that align with scholarly definitions of the technology.	"The general principle in 3D printing is one as the printing process is done by stacking the layers of the material (raw) on top of each other until the required body shape is complete."
Accurate description - limited (TK)	Participant presented a partial description or a partially accurate description of the technology.	"1. Able to produce almost anything 2. Can use templates 3. Use filament."
Inaccurate description	Participants' description of the technology is inaccurate or presents misconceptions, such as confusing AR with VR.	"Can be used to teach coding."
How it works (TK)	Participant detailed how the technology functions and performs.	"Whatever you want to print has to be designed with a program like Tinkercad, then read by the software that will tell the machine how to print it. The machine uses filament to print."
Apps/ equipment needed (TK)	Participant identified equipment, software, devices, and/or apps needed to use the technology.	"3D printers. Tinkercad. LegoCad"
Relate to personal experience	Participant drew connections to their own lives.	"I have explored 3D lesson plans on PrintLab and especially appreciate the assistive tech ones, encouraging students to design tools to assist those with disabilities."
How it is used in society	Participant discussed how the technology is used in society and/or education.	"3D printing allows students to create real-world solutions to problems. For example, we wanted to hang telephones in a link between two schools but had no way to do that. They designed a holder that could be drilled into the wall and the phones attached to the holders."
Benefits (TPK)	Participant described the value of the technology for education.	"There is a great opportunity for modeling in math and with special education students. The kinesthetic and iterative processes involved in both create rich learning environments."
Challenges (TPK)	Participant identified barriers to using the technology.	"There is a learning curve to teaching students how to utilize this feature and it requires an understanding of technology"

Table 8 Codebook for RQ3: What do Educators Want to Know About AR, VR, and 3D Printing?

Code	Description	Example	*n*	%
Teaching Strategies (TPK)	Participant is interested in best practices for using these technologies in their teaching.	"Best practices and lesson plans for integrating AR and VR with limited devices?"	70	36%
Unsure/No Questions	Participant stated that they do not have any questions or are unsure what to ask about.	"Nothing at this time. I am looking forward to the course and learning more, and I am certain that questions will arise."	48	25%
Curriculum Connections (TCK)	Participant is interested in how these tools can fit within the content they teach.	"Are there applications for these products that can work inside a history classroom? Or are these geared more towards science lessons?"	38	20%
Logistics (TK)	Participant shared questions related to logistics of using these technologies (e.g., accessibility, time, workflow, learning curve).	"How can I ensure that students have equitable access to these resources?"	33	17%
Affordability & Funding (TK)	Participant would like to understand associated costs and/or funding for these technologies.	"How much does it cost? Is it economically feasible for classroom application?"	31	16%
Student Outcomes (TPK)	Participant wanted to know how these technologies can shape student learning outcomes.	"How effective are they at improving student outcomes?"	24	12%
Grade Level Fit (TPK)	Participant is interested in how these tools can fit within the grade level they teach.	"What are best practices for each, but especially with VR, with youngest learners (given concerns about reality perception, brain development, and impact of VR on preschool through elementary grades)?"	21	11%
Technology (TK)	Participant would like to expand their knowledge of these technologies.	"I think I will have to play with these tools first before formulating questions as I am definitely at the beginning level when it comes to AR, VR and 3D printers."	18	9%

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Declarations

Research Ethics Statement All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards. The questionnaire and methodology for this study was approved by the Human Research Ethics committee of the University of Massachusetts Amherst [IRB Protocol 1522].

Informed Consent Informed consent was obtained from all individual participants included in the study.

Conflict of Interest Torrey Trust declares that she has no conflict of interest. Nathaniel Woodruff declares that he has no conflict of interest. Matthew Checrallah declares that he has no conflict of interest. Jeromie Whalen declares that he has no conflict of interest.

References

Barnard, D. (2019). History of VR - Timeline of events and tech development. Virtual Speech. https://virtualspeech.com/blog/history-of-vr

Billinghurst, M., Kato, H., & Poupyrev, I. (2001). The magic book — Moving seamlessly between reality and virtuality. *IEEE Computers, Graphics and Applications, 21*(3), 2–4.

Braun, V., & Clarke, V. (2006). Using thematic analysis in psychology. *Qualitative Research in Psychology, 3*(2), 77–101.

Brown, M., McCormack, M., Reeves, J., Brooks, D., Grajek, S., Alexander, B., et al. (2020). *2020 EDUCAUSE Horizon Report: Teaching and Learning Edition (ISBN 978–1–933046-03-7)*. Louisville, CO: EDUCAUSE.

Carpenter, J. P. (2016). Unconference professional development: Edcamp participant perceptions and motivations for attendance. *Professional Development in Education, 42*(1), 78–99.

Cheng, K., & Tsai, C. (2013). Affordances of augmented reality in science learning: Suggestions for future research. *Journal of Science Education and Technology, 22*(4), 449–462 Retrieved July 9, 2020, from www.jstor.org/stable/23442320.

Choi, H., & Kim, J. M. (2018). Implications for activating 3D printer use for education in elementary and secondary schools. *International Journal on Advanced Science, Engineering and Information Technology, 8*(4–2), 1546–1551.

Darling-Hammond, L., Hyler, M. E., & Gardner, M. (2017). *Effective teacher professional development*. Palo Alto, CA: Learning Policy Institute

EDUCAUSE. (2020). 3D printing. https://library.educause.edu/topics/emerging-technologies/3d-printing.

Edwards-Stewart, A., Hoyt, T., & Reger, G. (2016). Classifying different types of augmented reality technology. *Annual Review of Cybertherapy and Telemedicine, 14*, 199–202.

Ertmer, P. A. (1999). Addressing first- and second-order barriers to change: Strategies for technology integration. *Educational Technology Research and Development, 47*(4), 47–61. https://doi.org/10.1007/bf02299597.

Evans, J. (2019). *Digital learning: Peril or promise for our K-12 students*. Irvine, CA: Project Tomorrow Speak Up Research Initiative.

Ford, S., & Minshall, T. (2019). Invited review article: Where and how 3D printing is used in teaching and education. *Additive*

Manufacturing, 25, 131–150. https://doi.org/10.1016/j.addma.2018.10.028.

Hantono, B, S., Nugroho, L, E., & Santosa, P, I. (2018). Meta-review of augmented reality in education. In 2018 *10th international conference on information technology and electrical engineering (ICITEE)* (pp. 312-315). IEEE.https://doi.org/10.1109/ICITEED.2018.8534888.

Ibáñez, M. B., & Delgado-Kloos, C. (2018). Augmented reality for STEM learning: A systematic review. *Computers & Education, 123*, 109–123.

Iqbal, M. (2020). Pokémon GO Revenue and Usage Statistics (2020). Retrieved July 09, 2020, from https://www.businessofapps.com/data/pokemon-go-statistics/

Jensen, L., & Konradsen, F. (2017). A review of the use of virtual reality head-mounted displays in education and training. *Education and Information Technologies, 23*(4), 1515–1529. https://doi.org/10.1007/s10639-017-9676-0.

Johnson, L., Adams Becker, S., Cummins, M., Estrada, V., Freeman, A., & Ludgate, H. (2013). *NMC horizon report: 2013 K-12 edition.* Austin, Texas: The New Media Consortium.

Kavanagh, S., Luxton-Reilly, A., Wuensche, B., & Plimmer, B. (2017). A systematic review of virtual reality in education. *Themes in Science and Technology Education, 10*(2), 85–119.

Keay, J. K., Carse, N., & Jess, M. (2019). Understanding teachers as complex professional learners. *Professional Development in Education, 45*(1), 125–137.

Koehler, M. (2012). TPACK explained. TPACK.ORG. http://matt-koehler.com/tpack2/tpack-explained/

Koehler, M., & Mishra, P. (2009). What is technological pedagogical content knowledge (TPACK)? *Contemporary Issues in Technology and Teacher Education., 9*(1), 60–70.

Kyndt, E., Gijbels, D., Grosemans, I., & Donche, V. (2016). Teachers' everyday professional development: Mapping informal learning activities, antecedents and learning outcomes. *Review of Educational Research, 86*(4), 1111–1150.

Lee, K. (2012). The future of learning and training in augmented reality. *InSight: A Journal of Scholarly Teaching, 7*, 31–42.

Leinonen, T., Virnes, M., Hietala, I., & Brinck, J. (2020). 3D printing in the wild: Adopting digital fabrication in elementary school education. International Journal of Art & Design Education. https://doi.org/10.1111/jade.12310.

Makki, T. W., O'Neal, L. J., Cotten, S. R., & Rikard, R. V. (2018). When first-order barriers are high: A comparison of second-and third-order barriers to classroom computing integration. *Computers & Education, 120*, 90–97.

Maloy, R., Trust, T., Kommers, S., LaRoche, I., & Malinowski, A. (2017). 3D modeling and printing in history/social studies classrooms: Initial lessons and insights. *Contemporary Issues in Technology and Teacher Education, 17*(2), 229–249.

Martín-Gutiérrez, J., Mora, C. E., Añorbe-Díaz, B., & González-Marrero, A. (2017). Virtual technologies trends in education. *EURASIA Journal of Mathematics, Science and Technology Education, 13*(2), 469–486.

Milman, N. B. (2018). Defining and conceptualizing mixed reality, augmented reality and virtual reality. *Distance Learning, 15*(2), 55–58.

Nowell, L. S., Norris, J. M., White, D. E., & Moules, N. J. (2017). Thematic analysis: Striving to meet the trustworthiness criteria. *International Journal of Qualitative Methods, 16*(1), 1–13. https://doi.org/10.1177/1609406917733847.

Oliver, K. (2016). Professional development considerations for makerspace leaders, part one: Addressing "what?" and "why?". *TechTrends, 60*(2), 160–166. https://doi.org/10.1007/s11528-016-0028-5.

Patterson, T., & Han, I. (2019). Learning to teach with virtual reality: Lessons from one elementary teacher. *TechTrends, 63*(4), 463–469.

Pomerantz, J. & Rode, R. (2020). Exploring the future of extended reality in higher education. *EDUCAUSE*. https://er.educause.edu/articles/2020/6/exploring-the-future-of-extended-reality-in-higher-education

Promethean. (2019). Promethean publishes the state of technology in education report 18/19. https://resourced.prometheanworld.com/state-of-technologyreport/.

Schoffer, F. (2016). How expiring patents are ushering in the next generation of 3D printing. *TechCrunch*. https://techcrunch.com/2016/05/15/how-expiring-patents-are-ushering-in-the-next-generation-of-3d-printing/

Shulman, L. S. (1986). Those who understand: Knowledge growth in teaching. *Educational Researcher, 15*(2), 4–14.

Snelson, C., & Hsu, Y. C. (2019). Educational 360-degree videos in virtual reality: A scoping review of the emerging research. *TechTrends, 64*, 404–412.

Trust, T., & Maloy, R. (2017). Why 3D print? The 21st century skills students develop while engaging in 3D printing projects. *Computers in the Schools, 34*(4).

Twining, P., Heller, R. S., Nussbaum, M., & Tsai, C. C. (2017). Some guidance on conducting and reporting qualitative studies. *Computers & Education, 106*, A1–A9. https://doi.org/10.1016/j.compedu.2016.12.002.

Vega, V., & Robb, M. B. (2019). *The common sense census: Inside the 21st-century classroom*. San Francisco, CA: Common Sense Media.

Wilson, K. (2018). How (and why!) to write a pre-course survey or questionnaire - SPS: Distance learning. *Northwestern School of Professional Studies*. https://dl.sps.northwestern.edu/blog/2018/04/write-pre-course-survey-questionnaire/.

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