STEM in Elementary School Education: Evaluating a STEM and Augmented Reality Professional Development Workshop for Educators

by

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The purpose of this study was to analyze modes of professional development that prepare educators to deliver STEM (Science, Technology, Engineering, and Math) based instruction at the elementary school level through the integration of technology. The study demonstrates the complexity and advantages of STEM centered learning which utilize technologies such as augmented reality. Developed from the study are the next steps and recommendations for designing professional development and STEM programming originating from the research outcomes.

The problem of practice for this research study focuses on existing instructional pedagogies at the elementary school level which have a dearth of integrated technologies to support and engage students in Science and STEM (Science, Technology, Engineering, and Math) based learning. The insufficient utilization of technologies to teach STEM skills and concepts is guided by three questions addressing the teachers' perceptions of STEM education, and the professional development workshops ability to provide educators the understanding, and structures to introduce STEM centered learning by means of augmented reality integration. The supporting data was captured in questionnaires, observations, and discussion groups that verified the themes and findings. Elementary school science and math educators from the third and fourth grades participated in a series of STEM and Augmented Reality workshops designed to promote STEM literacy, identification, and application with technologies.

The results of the study indicate that the professional development workshops and team planning effectively prepared the educators to integrate augmented reality tools into STEM centered learning, raised student engagement, and in turn, promoted a positive learning environment. Both the qualitative and quantitative data indicate a change in the organizations ability to infuse technology integration. The study identifies the general trend in the mean average scores that indicated an increase in the educators understanding, comfort, and integration of augmented reality tools within STEM based education. The positive results yielded from the study establish a prerequisite for future research, professional development, and technology integration that supports a culture of learning.

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1.0 Introduction to the Problem of Practice

Science, technology, engineering and mathematics (STEM) have been the building blocks of America's industrial innovation, concomitant to the country's prosperity and security. The 2018 report, *Charting a course for success: America's strategy for STEM Education* from the United States Committee on STEM Education, and the National Science and Technology Council echoes the influence science, technology, engineering and mathematics (STEM) has had on American society, "Since the founding of the Nation, science, technology, engineering, and mathematics (STEM) have been a source of inspirational discoveries and transformative technological advances, helping the United States develop the world's most competitive economy and preserving peace through strength," (p. 5). World-wide research studies have validated the importance of STEM (Science, Technology, Engineering, and Math) based education, seeking to understand and harness the skills needed for future workforces (English, 2016). Within the United States, the lack of skilled labor and increasing career opportunities in the STEM fields have caused state governments and education systems to invest in STEM based learning and skill development. According to the National Science Board's Science and Engineering Indicators (2018), in the last 20 years America has only made small gains in STEM skills and remains behind other countries.

In 2018 Pennsylvania Governor Tom Wolf addressed the labor and skills deficit of the next decade, where 70% of workers will be required to use new technologies and computer systems. "In order to meet that demand, I launched PAsmart in 2018 to expand science and technology education. These grants will help our schools and communities to expand STEM and computer science education. That will strengthen our workforce, so businesses can grow, and workers have good jobs that can support a family," said Governor Wolf, (2021). Integrating twenty-first century

STEM skills into classroom curriculums depends on the effective implementation and delivery of STEM based learning from educators. Therefore, education professionals must embrace transformative educational processes, utilizing technology and innovative pedagogical methods to create a dynamic learning environment that engages students with 21st century skills necessary for future employment and civil progression. “Improving teaching and learning in STEM education has become an economic factor in developing countries, emerging economies, and in long established economies such as Europe and the United States,” according to Kennedy, T. J., & Odell, M. R. L. (p. 248 , 2014). Educators must become STEM literate, grasping the crucial need for STEM based learning that accelerates 21st century skills. Mohr-Schroeder, Bush, Maiorca, & Nickels (2020), stated:

> STEM literacy is the ability to identify, apply, and integrate concepts from science, technology, engineering, and mathematics to understand complex problems and to innovate to solve them. To understand and address the challenge of achieving STEM literacy for all students begins with understanding and defining its component parts and the relationships between them. (p.65)

Introducing new technologies and instructional practices can be challenging for school systems. Lasica, I. E., Meletiou-Mavrotheris, M., & Katzis, K. (2020), discuss their findings where educators are not equipped with the expertise and stratagems to effectively integrate technology enhancing applications and tools, thus there is a lack of realization and a potential resistance to the technologies. Interactive technology systems such as virtual reality (VR) headsets and augmented reality (AR) have been recognized as a cutting edge tools that will greatly impact our world. As suggested by Bower, Howe, McCredie, Robinson, & Grover, D. (2014), augmented reality is in a position to transform the education landscape. AR systems and tools are integrated into phones, computer systems, tablets, and everyday technologies. The integration into school settings has been slow, but is now closer to adoption. Integrating AR tools into STEM (Science Technology, Engineering, and Math) based learning will help to accelerate STEM based skills and learning in the K-12 educational environment. The scholarly research seeks to qualify two areas of investigation, first, the inherent value of STEM skills in the educational environment, and secondly, educator's integration of new technologies such as augmented reality into 21st century learning pedagogies.

1.1 Local Context

The study will be conducted at a Western-PA public school district. The schools consist of just over 1800 students in kindergarten to twelfth grade. Each grade level is between 130-160 students. Within the last three years the overall student population has grown over 10%, with grade levels at the elementary school expanding by over 20%. The population growth has allowed the school district to hire additional staff. Due to retirements and teachers changing position within the elementary school, over 70% of the current staff are in a different position from just three years ago. In the 3rd and 4th grades, where there is a heavy focus on Math, Science, and STEM concepts, four out of the six teachers are new to the positon within the last year. The accumulation of new staff, compounded by the educational challenges of the Covid-19 Pandemic have reduced the cohesive STEM program that once thrived at the elementary school level.

The district has committed to STEM based learning for over a decade, establishing a STEM Academy, hiring new technology and programming teachers, as well as hiring a STEM administrator. Through grants and local funding the school has become a strong example of an integrated STEM School District. The middle and high schools have continued to develop and integrate their STEM programs and courses, while the elementary school has seen many changes to the program. STEM, coding, and technology programs that were well established and implemented into curriculums at the elementary school are no longer fully integrated into grade level curriculums. Over the last two years the district has distributed thousands of STEM kits in an effort to continue engaging the elementary school students in STEM based principles of learning. The administration has revisited professional development and curriculum building to create a cohesive educational environment to help revitalize the STEM programs.

In addition to rebuilding the STEM based programming, educators need professional development for the schools technology systems. The school district is one-to-one with digital tablet devices for students as well as laptops for teachers. The integration of apps and technology tools within the learning management system can be difficult for a new educator within the school district. This study will seek to use the schools advanced technology structure, (i.e., Digital tablets, Computers, Augmented Reality Apps) to address the needs for a more integrated STEM based curriculum.

1.2 Problem of Practice

The problem of practice for this research study focuses on existing instructional pedagogies at the elementary school level have a dearth of integrated technologies to support and engage students in Science and STEM (Science, Technology, Engineering, and Math) based learning.

1.2.1 Science, Technology, Engineering, and Math - STEM

The foundational problem solving skills in STEM curriculums, along with the application of the engineering and design process engages students in procedures for critical thinking and problem solving. Bybee (2013), states that students must be given the opportunity to apply the skills and knowledge they attain through STEM based education. Students should be engaged in real-world problem solving that is relevant to their culture and personal goals. Prinsley and Baranyai (2013), identify what employees see as the top skills needed for STEM careers as, "Active learning (i.e. learning on the job), Complex problem-solving, Creative problem-solving, Critical thinking, Design thinking," (p. 3). Apart from on the job training, all of the other skills can be taught and developed in the K-12 educational settings. Preparing students to compete for those positions indicates that school districts must engage students with STEM and Science based learning at a young age, immersing students in their learning experience through new technologies such as augmented reality (AR) apps and tools. Students who are engaged in STEM educational programs will be able to apply the skills they have learned to future career pathways. Educational institutions must focus on developing foundational STEM skills that are imperative to education, industry, and future careers. The goal of this research is to assist teachers in understanding the importance of STEM/Science based education, and technologies that can enhance student learning.

1.2.1.1 The call for a STEM Future

International concerns for advancing STEM education have escalated in recent years and show no signs of abating. The study by English (2016), indicates that industry, governments and educational institutions have highlighted the need for advanced STEM skills to meet the social and economic issues of today and the future. Based on the US STEM Education Strategic Plan, educational models should introduce STEM based skills and literacy that prepares students for future careers. The strategic plan reinforces the need for science, technology, engineering, and mathematics STEM education, founded in the innovative history of America. The plan “Charting a course for success: America’s strategy for STEM Education” (2018), states:

> Science, technology, engineering, and mathematics (STEM) have been the foundation for discovery and technological innovation throughout American history. Americans with a strong foundation in STEM have electrified the Nation, harnessed the power of the atom, put men on the Moon and rovers on Mars, developed the internet, designed computers that fit in your pocket, created imaging machines that reveal the inner workings of the body, and decoded the human genome. These stunning achievements have transformed the human experience, inspired generations, and fostered the strong public support for STEM education and research. (p.1)

The Industrial Age is gone, but according to the PA Department of Education, new technical careers, STEM fields, and skilled labor opportunities remain strong. The education system in United States holds a vast amount of power and opportunity to develop career and skill based learning into education curriculums. In the 1980’s Secretary of Labor, Elizabeth Dole said that, “As we continue the shift from a manufacturing-oriented economy to one that is dominated by service and information based firms, our competitive advantage increasingly relies on a skilled and adaptable work force,” (p. 12). Dole’s comment has held true for 40 years, and the American education system must institute learning that is focused on the technical skills, critical analysis, problem solving, and ingenuity found in current industry and STEM careers. Carnevale, Smith, & Strohl, (2013) note in their study, *Recovery: Job Growth And Education Requirements Through 2020,* that STEM Literacy will become increasingly important, with 65% of all jobs in the U.S.

requiring some sort of STEM Literacy by 2020. Global capital is driven by new innovations, ideas, and intellectual property that develops new market opportunities. Background information on the website for the US Dept. of Education regarding STEM Education states that:

> If we want a nation where our future leaders, neighbors, & workers have the ability to understand & solve some of the complex challenges of today and tomorrow, & to meet the demands of the dynamic & evolving workforce, building students' skills, content knowledge, & fluency in STEM fields is essential.

1.2.1.2 STEM Careers and Workforce

As governments and industries around the world continue to promote the idea of STEM education, defining STEM and the direct application of the term in education can be difficult. English, (2016) eludes to the fact that the competencies and definition can be vague depending on the interpretation. It is very apparent that even with a diluted identity, the word STEM has permeated into all realms of education and industry. In K-12 education, STEM learning mainly pertains to the four disciplines that denote the name, Science, Technology, Engineering and Math. Although math and science are the only content areas of instruction, technology and engineering have become prime targets for industry's influence in education.

The Pennsylvania Department of Education initiative PAsmart (2019), states that Governor Wolf has allocated over 40 million dollars in grant funding to support career and STEM based initiatives that will educate and prepare students for upcoming careers. Pennsylvania Secretary of Education Pedro A. Rivera writes online that:

> There are abundant opportunities available for careers in STEM fields, and we know that students interested in these fields deserve access to training programs and cooperatives that can help them develop needed skills and knowledge. Ecosystems bring STEM education

to communities across the commonwealth, providing students from all areas with the resources and tools they need to pursue an interest in science and technology.

Pennsylvania has identified the need for STEM professionals across various industries, and promoting those careers in the K-12 public schools will ensure continued development of curriculum and learning designed for student's post high school pathways. The educational systems must be prepared to deliver the STEM based skills. The goal of school districts and educators is to prepare and adapt to the needs of industry and commerce to effectively prepare their students for the future careers. English (2016), states that nations around the world are have identified the importance of STEM curriculums within their educational systems. Many nations are investing in programs that enhance STEM disciplines and principles to develop more robust learning for future generations.

1.2.2 STEM Education

STEM (Science, Technology, Engineering and Mathematics) Education programs and curriculums look differently across America due to state and local school districts abilities to determine their own curriculums. Becker and Park (2011), research indicates that integrating STEM curriculum content is a highly effective instructional method. Project and interdisciplinary based leaning integrate real world experiences for students to understand and explore career based learning objectives. Supporting this idea, the California Department of Education (2014), addressed the need for the content areas of STEM education be taught in unison, where all disciplines are utilized to solve real-world problems. STEM provides teachers a platform for interdisciplinary learning that addresses the needs and appetites for future career markets. Educators must be the conduits for connection and interdisciplinary STEM learning. Moore et al.

(2014), stated that although STEM concepts might be emphasized in coursework, students may not identify the connections between the disciplines.

Designing an effective system is key to delivering the expected outcomes of any engineering project, (Silk & Schunn, 2008). In STEM careers, engineers, designers and scientists use specific problem solving processes that allow them to understand and resolve an issue, problem or assignment. The Engineering and Design process is a series of steps that lead an individual or group from an initial idea to a completed thought or product. The process allows the user to find optimum solutions, (Roth, 1973).

How do teachers instruct in areas they are not familiar? STEM careers are interdisciplinary and so should the educational environment. English (2016), notes that developing interdisciplinary processes and learning will advance core content. Integrating STEM learning will increase student aptitudes for all of the core disciplines. The barriers to effective instruction and curriculum are compounded by ill prepared educators and administration, underutilized technologies, lack of professional development for teachers, and reduced support for STEM integration and engagement from students and professional staff (Ejiwale, 2013). Supporting the need for a strong student engagement, Milaturrahmah, Mardiyana, and Pramudya (2017), studied the need for interdisciplinary learning as the foundation for a healthy STEM pedagogy, "In order to compete in the global economic system of the 21st century, a country must establish an education where students gain an understanding of STEM and Produce the product using the skills required in the field," (p. 2). The development of interdisciplinary learning and cross curriculum projects allows for students to utilize multiple skill sets from various educational pedagogies. The foundations of STEM education can be built on the principles of investigation, innovation, and problem solving found within the engineering and math disciplines within STEM learning, (Milaturrahmah, Mardiyana, and Pramudya, 2017).

Students need to understand various ways of solving challenges that engage them in content, analyze objectives, and results. While developing STEM learning experiences teachers need to be aware of the hierarchy of principles. Project and interdisciplinary learning can be focused on a single subject or content area. Developing valuable curriculum relies on balancing content areas, and utilize the standards based skills that promote the overall learning objectives. Ejiwale (2013), states that STEM teachers should engage students through hands-on projects that relate to real world issues students relate to.

The integration of real world problem solving and role play allow students to experience all aspects of STEM education. Research has shown that not all components of STEM education take a forefront in the learning process. Developing STEM programming that integrates math concepts efficiently is difficult and more often math becomes a tool for the students and not a concept of study, (Tytler, Williams, Hobbs, Anderson, 2019).

Math and science content can be utilized to promote creative thought processes through project based learning, and interdisciplinary curriculum planning. Students must be engaged in a flexible learning environment that challenges them to explore and investigate real world problems. Developing projects and content that applies to student interests and culture allow for connection to the areas of learning, (Honey, Pearson, Schweingruber, 2014). Education must transition from the traditional model of academic rigor based on reading, writing, and arithmetic. In regards to project based learning, Lantada et al., (2013), reviews the effectiveness of project based learning in engineering programs:

> In fact enormous benefits can be gained from project-based teaching–learning strategies where students face realistic situations or problems and, as well as acquiring knowledge, take an in-depth look at issues including: the integration of knowledge and job skills from various areas or the development of high-level intellectual skills like forming judgments, decision-making and an ability for analysis and synthesis. (p. 13)

Educators understanding and implementing STEM and interdisciplinary learning will provide students with academic rigor, while challenging problem solving and analysis that is vital to industry professionals. The U.S. Educational System has been tasked with developing highly qualified and skilled students that will challenge for careers in global STEM industries. Educators must develop and deliver instruction that engages students in interdisciplinary STEM learning throughout curriculums and grade levels. Augmented reality tools feature interactive experiences that immerse students in the content of the curriculum. Since the development of AR systems, the size, scale, and availability of AR tools have become cost effective for implementation into primary school learning environments, (Chiang, Yang, & Hwang, 2014). With school districts investing heavily into computer tablets, digital tablets and laptops, AR tools and apps are able to become more integrated into classroom curriculums.

1.2.2.1 STEM Educators

STEM professional development has yielded few positive results, as many of the studies suggest more complications than solutions. One study noted that students have identified teacher's lack of expertise when instructing areas foreign to the teacher's core content. The most effective results have been developed from teachers who have a deep understanding of the content and are able to shift their instructional techniques to align with STEM pedagogy (Han et al., 2015). The research provides few indicators of overwhelmingly effective professional development for teachers integrating STEM and project based learning into classroom instruction.

While fulfilling the global demand for STEM education, teacher must be supported with professional development, resources, and curriculum planning that allows for effective and efficient instruction. The introduction of new technologies such as augmented reality apps has provided teachers with immersive tools to help engage and challenge student learning. In research by Shernoff, Sinha, Bressler, and Ginsburg (2017), the group found that although educators were interested in developing STEM principles into classroom learning, they did not feel prepared to integrate STEM learning into regular education curriculums. The study provides evidence to suggest the need for professional develop and curriculum planning to assist teachers in identifying and implementing STEM concepts into student learning through new technologies. Curriculum preparation, training and professional development workshops would need to be facilitated by school districts to adequately prepare their teachers to integrate STEM principles effectively into grade level learning, (Shernoff et al., 2017). The group of Honey, Pearson, and Schweingruber (2014), discussed the most comprehensive framework that addresses the need for STEM Literacy, engagement, identity, and the transfer of knowledge across curriculums. The various views of STEM education make it difficult to identify a single framework that works for all districts and educators.

Models for STEM instruction such as Project Lead the Way have given positive results towards sufficiently enabling teachers to instruct STEM principles and curriculums (Keith, 2018). The pair of researchers Brown, and Bogiages (2019), developed a multiyear interdisciplinary STEM professional development training designed to promote cross curricular instruction and learning among new teachers. Brown established the importance of STEM education, and interdisciplinary learning. The research analyzed professional development that immersed teachers in science and math pedagogy through tasks and experiences that promoted cross curricular learning by the teachers. The research attempted to determine that teachers present their understanding in two main ways as either engaged or an observer. During Brown's research, the team discussed the difficulty they had building projects and experiments that meet various components of STEM Professional Development. The group tried to present advanced concepts in science and mathematics during professional development training, which can lead to significant learning roadblocks and implementation by the teacher groups.

Teachers need to identify the importance of STEM skills and the opportunities they provide students. How can new technologies such as augmented reality impact curriculums and cause teachers recognize interdisciplinary learning opportunities? Becker and Park (2011), discussed that different types of integrative approaches could help educators implement technology and engineering concepts cross circularly. The goal of this research is to evaluate the effectiveness of augmented reality (AR) apps and tools into STEM/Science based learning for elementary school students.

1.2.3 Augmented Reality as a Learning Tool

Augmented reality is a digital representation of objects transposed into the real world. The objects digitally and visually exist in the real world, (Azuma et al., 2001). Examples of AR appear all around us, from retail shopping apps where you can place a digital piece of furniture in your home, to viewing the stars and constellations in the sky on your mobile phone. These AR apps and tools can be used to enhance the educational environment.

Interactive technology systems such as virtual reality (VR) headsets and augmented reality (AR) have been identified as a cutting edge tools that will greatly impact our world. As suggested by Bower, Howe, McCredie, Robinson, & Grover, D. (2014), augmented reality is in a position to transform the education landscape. AR systems and tools are integrated into phones, computer systems, tablets, and everyday technologies. The integration into school settings has been slow, but is now closer to adoption. Integrating AR tools into STEM (Science Technology, Engineering, and Math) based learning will help to accelerate STEM based skills and learning in the K-12 educational environment. The scholarly research investigates two main topics, first, the importance of STEM education, and secondly, new technologies such as augmented reality that can enhance STEM/Science based learning.

While fulfilling the global demand for STEM education, teachers must be supported with professional development, resources, and curriculum planning that allows for effective and efficient instruction. The introduction of new technologies such as augmented reality apps have provided teachers with immersive tools to help engage and challenge student learning. In research by Shernoff, Sinha, Bressler, and Ginsburg (2017), the group found that although educators were interested in developing STEM principles into classroom learning, they did not feel prepared to integrate STEM learning into regular education curriculums. The study provided evidence to suggest the need for professional development and curriculum planning to assist teachers in identifying and implementing STEM concepts into student learning through new technologies.

Augmented reality tools have been used by scientists and militaries for a considerable amount of time. Pilot training devices were used over 20 years ago in the 1990's, (Thomas, P. C., & David, W. M., 1992). Technologies that promote interdisciplinary and project based learning allow for complex problem solving and analysis that provides students with essential STEM skills.

The principles and skills taught in STEM based projects and activities can be greatly increased with the introduction of new technologies such as augmented reality apps and tools. At a conference in 2016, Apple CEO Tim Cook said:

> I do think that a significant portion of the population of developed countries, and eventually all countries, will have augmented reality (AR) experiences every day, almost like eating three meals a day. It will become that much a part of you.

In order to prepare students to compete for future STEM positions, public education must engage in these STEM skills at a young age, embrace new technologies, and support the professional development to implement these educational pedagogies successfully. In an effort to build strong STEM programming within school districts, it is important to understand the need for STEM education. The PA Department of Education implemented the PAsmart initiative to revitalize industry skills and technical based STEM Learning.

Chang, Hou, Pan, Sung, & Chang, (2015) state, that AR apps are effective in studying scientific and historical sites:

> AR technology includes information on people and buildings on the site and allows users to switch between historical periods and observe the different appearances of a city throughout time. This combination of additional information and actual scenes enhances people's senses of reality and presence in a certain place. (p. 167)

Augmented reality tools continue to allow users to view parts of places and objects that would not normally be experienced. AR has been heavily applied in industry and engineering to assist with advanced problem solving. Engineers rely on critical analysis to assess their projects and systems.

Additionally, AR technologies provide teachers with a platform to integrate Science/STEM learning principles. Teacher investment in STEM pedagogy builds a strong environment for STEM principles, and interdisciplinary learning activities, (Becker and Park, 2011). Teacher professional development must focus on engaging students in real-world problem solving that is culturally relevant, (Bybee, 2013). AR tool and apps allow teachers to integrate problem solving skills with real world interactions and experiences for example, Augmented Reality can be seen in such tools as virtual maps and interactive environment games. Students who are engaged in STEM/Science educational programs will be able to apply the skills they have learned to future career pathways. School district officials, and educational institutions must emphasis teacher professional development that provides both curriculum comprehension, instructional tools, and institutional support will establish the best opportunity for success, (Han et al. 2015).

The integration of technologies such as augmented reality seek to improve teacher instruction and the student learning experience. Students become immersed in a concept, leading to their increased knowledge, acquisition and retention of the content. With the continuous development of augmented reality tools and apps on mobile devices and tablets, there has been an increase in AR applications in the education realm, (Chin, K. Y., Wang, C. S., & Chen, Y. L. 2019). In their research Chin, K. Y., Wang, C. S., & Chen, Y. L. (2019) state that AR based learning showed significant students learning successes. The study revealed that students using AR felt more confident, and demonstrated an increased comprehension of coursework in comparison to prior instructional strategies.

Cheng & Tsai, (2013) research has demonstrated that AR technologies have made a positive influence on student learning and motivation. One of the main goals of introducing AR into the STEM/Science based learning is to increase engagement which can correlate increased academic achievement. Chen C.H., (2020) found the integration of augmented reality technologies into language learning program increased student motivation and learning achievements. The research from this particular study showed positive improvement for students with lower academic achievement. Additionally, the AR technologies also contributed to having a positive effect on the learning environment, providing immersive experiences for the learners that increased their knowledge of content, (Chen C.H., 2020). The research will continue to evolve as AR technologies become more integrated into daily learning tasks within the educational environment. How can teachers in our current school system use these AR tools to enhance STEM based learning? The goal of AR technologies in my research is to determine their effectiveness within STEM/Science based learning.

1.2.4 Conclusions

The research indicates that there is an overwhelming call for STEM education, STEM skills, and a need for professional development for educators to effectively deliver STEM education principles. The delivery of STEM based instruction has taken many forms, and new technologies provide some of the best methods for continuous growth of STEM in education and industries. Enhancing the STEM/Science based instruction through new technologies such as Augmented Reality apps and tools will engage and immerse students in a transformative manner of learning. There is sufficient evidence demonstrating that AR technologies can be an effective tool in the learning environment, but there are few studies on professional development encompassing AR within educational settings. The available research indicates that integrating STEM projects and interdisciplinary learning, connects and engages students to the curriculums and provides the most successful outcome, (Honey, Pearson, and Schweingruber, 2014). In order to prepare students to compete for future career opportunities, public education must engage in developing STEM skills at a young age, and support the professional development of teachers to implement these educational pedagogies successfully. When integrating AR technologies into primary grade levels for science based learning, Lu and Liu (2015), found that students effectively acquired the learning content in a positive manner. The integration of AR tools into STEM/Science learning should strengthen the STEM/Science curriculums. This research project replicated the current trends of augmented reality integrations in the learning environment to positively affect teacher instructional strategies, student engagement and academic achievement. This educational study examined a STEM (Science, Technology, Engineering, and Math) and Augmented Reality Professional Development Workshop for educators. The study investigated the effectiveness of the workshops to inform and prepare educators to teach 21st century STEM skills using technology tools. Elementary teachers learned STEM Literacy and strategies to implement Augmented Reality (AR) applications into Science/STEM based curriculums.

2.0 Theory of Improvement and Implementation Plan

2.1 Theory of Improvement and the Change

Science, technology, engineering and mathematics (STEM) skills and learning have been identified by the school district as an important part of the educational curriculums. Over the last three years, the altered instructional models and staffing changes have reduced the district's ability to assimilate STEM principles into classroom curriculums. Reinvigorating an environment of creativity, problem solving, and critical thinking is essential to developing educators and youth that are prepared for 21st century professions. As suggested by Bower, Howe, McCredie, Robinson, & Grover, D. (2014), Augmented Reality is in a position to transform the education landscape. My theory of improvement is designed to provide teachers with professional development that promotes a foundational knowledge of STEM Literacy, and an understanding of new technologies (augmented reality) that support the integration and implementation of 21st century STEM based skills and learning. This is an educational study that will examine a STEM (Science, Technology, Engineering, and Math) and Augmented Reality Professional Development Workshop for educators. The study seeks to determine the effectiveness of the workshop workshops to inform and prepare educators to teach 21st century STEM skills using technology tools. Elementary teachers will learn STEM Literacy and strategies to implement Augmented Reality (AR) applications into Science/STEM based curriculums.

2.1.1 Drivers Diagram

Based on the Drivers diagram below, the AIM Statement has been fully realized through the professional development workshops. The initial thought processes regarding research in STEM education was to provide educators the time, resources and investigative learning through a first hand through collaborative experience. The on-going goal would be to support the STEM and augmented reality initiatives with a policy and financial structure to ensure longevity.

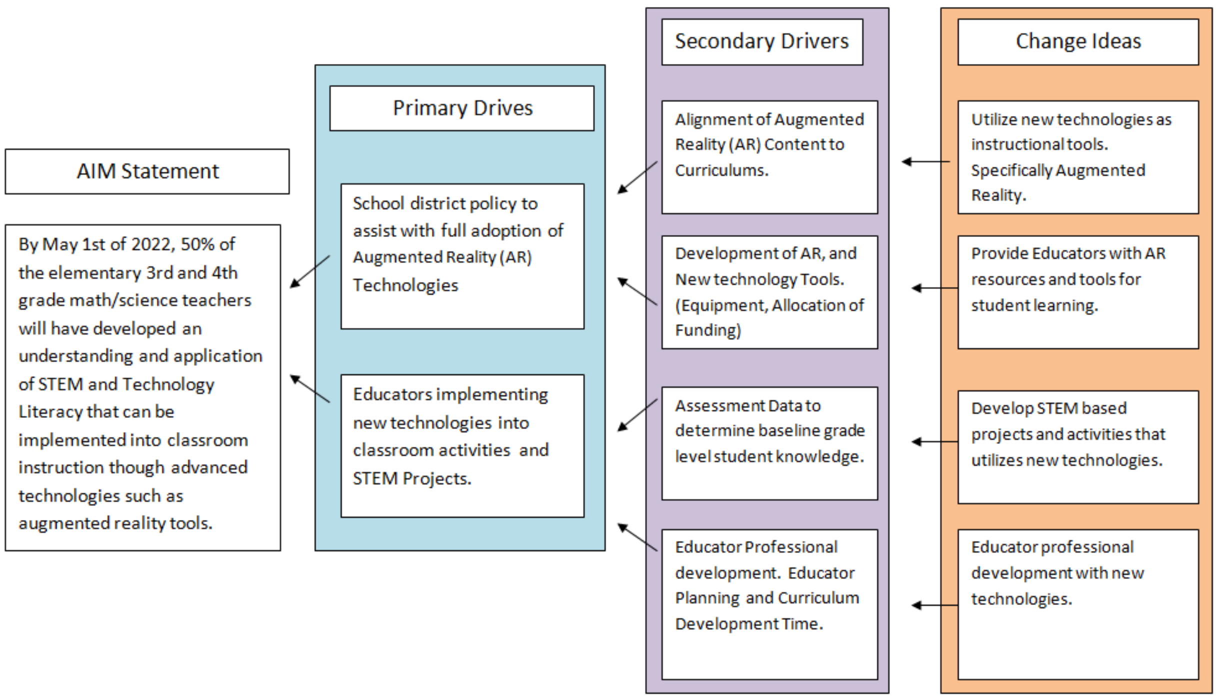


Figure 1: Drivers Diagram

2.1.2 Guiding Questions

The following questions will be used to guide the research study:

1. GQ1: What are the educator's perspectives of STEM education?

2. GQ2: Based on the professional development workshops, what is the educators understanding of STEM principles and 21st century skills after completing the workshops?
3. GQ3: Based on the professional development workshops, how are educators prepared and adept to effectively integrate augmented reality tools into STEM-based instruction?

2.2 Methods & Measures

2.2.1 Intervention

The Augmented Reality Professional Development (ARPD) workshops are a framework for educators to gain STEM and technology literacy to effectively engage students through new immersive technologies and pedagogy. Elementary school educators will be participating in professional development (PD) workshops that utilize components of effective STEM education, and augmented reality programs and studies. The professional development module framework is derived from the scholarly work of IIiona- Elefteryja Lasica, Maria Meletiou-Mavrotheris, and Konstantinos Katzis in their study, "Augmented Reality in Lower Secondary Education: A Teacher Professional Development Program in Cyprus and Greece", and utilizing Darling-Hammonds Seven Design Elements of Effective Teacher Professional Development, which was focused on in the "Design Principles for Effective Teacher Professional Development in Integrated STEM Education: A Systematic Review" research by Chung Kwan Lo in Hong Kong.

For the purpose of this study, I have developed four workshops that aim to increase teacher's technology literacy and integration, with a focus on STEM learning. The Augmented

Reality Professional Development (ARPD) workshops will address; *STEM Literacy and 21st Century Skills, Technology in STEM Learning: Augmented Reality Applications, Augmented Reality within Curriculums: Integrating Augmented Reality Tools, and a Reflection of Augmented Reality Integration.* The workshops provide teachers an understanding of the importance of 21st century STEM skills, how augmented reality can be used to enhance STEM based learning, and the development process of identifying effective AR tools that can be integrated in the classroom curriculums.

Teachers will progress through the training in a collaborative and active learning environment that allows teams to build on grade level standards and curriculums (Lo, 2021). During the workshops, participants will meet in-person as well as utilize digital resources, training sessions, and background materials (Lasica, Meletiou-Mavrotheris & Katzis, 2020). The Augmented Reality Professional Development (ARPD) workshops one and two are designed to create teacher competence in STEM and AR principles. Module three focuses on the implementation of the AR tools in the classroom during science coursework and lesson planning. To investigate the effectiveness of AR implementation at the elementary school level, traditional science instruction will be replaced/supplemented with augmented reality instruction within the content area. After module three, teachers will implement their lesson plan in science class. Module four is designed for reflection of the process and implementation of the augmented reality tools in the classroom setting.

The Augmented Reality Professional Development (ARPD) workshops will begin at the end of January and continue into February of 2022. The teachers will be part of the planning process as well as the leaders in the AR integration into classroom learning. The ARPD workshops will be the backbone of the initial training, but can serve as a framework for continuous technology development within curriculums.

2.2.2 Timeline

Teachers will participate in the STEM/Augmented Reality Professional Development (ARPD) workshops begin January 2022. Teachers will be contacted by email regarding the opportunity to participate in the workshops. Educators joining the study will receive a professional development outline and overview plan (see Appendix B). The four workshops which include the professional development trainings, through augmented reality integration will commence from January to early March 2022.

Table 1: Timeline

Time Frame	Task
Fall of 2021	• Introduce STEM /Augmented Reality workshop to the Elementary School Teachers (Math and Science – 3rd and 4th grade) • Introduce the workshop overview and evaluation process to participating teachers.
Winter 2021	Teachers participate in: • Workshops 1-2: STEM and AR Literacy • Workshop 3: Lesson and Curriculum Planning • AR integration into classroom curriculums. • Workshop 4: Reflection of AR Integration
Winter 2021 - Spring 2022	• Data Collection – from Teachers • Data Compiling and Analysis

	• DiP Development and Writing

2.2.3 Setting and Participants

The professional development study will be conducted at a Western-Pennsylvania public elementary school with math and science teachers in the third and fourth grades. There are six teachers within two grade levels at the elementary school. The math and science teachers will be participating in the professional development, planning, and implementation of the intervention. The PD workshops will take place during non-instructional times for the teachers while the AR in-class intervention will take place within the normal learning environment.

2.2.4 Data Collection

Elementary school math and science teachers in the third and fourth grades will be participating in the STEM/AR professional development study. Limited teacher experience data is collected in the pre-workshop questionnaire, and only grade level indicators are collected for the additional questionnaires. The educators will be sent an email inviting them to participate in the professional development workshops (see Appendix A). Educators joining the study will receive a professional development outline and overview plan (see Appendix B). The teachers will complete a pre-workshop questionnaire (see Appendix C) during workshop one. After the first three workshops, teachers will develop their lesson plans and identify the AR tools being integrated during the science lessons. Teachers will complete a post-workshop questionnaire, (see Appendix D). Teachers will complete a post-workshop and AR integration questionnaire, (see Appendix E).

During or immediately after the implementation of the AR lesson teachers will complete an observation and reflection sheet (see Appendix F). Participants in the study will complete a post-implementation questionnaire. A teacher focus group will assist in understanding the perceived and gained knowledge, and pedagogical strategies attained during the workshops (see Appendix G).

Augmented Reality Professional Development (ARPD) workshops:

1. *STEM Literacy and 21st Century Skills*
2. *Technology in STEM Learning: Augmented Reality Applications*
3. *Augmented Reality within Curriculums: Integrating Augmented Reality Tools*
4. *Reflection of Augmented Reality Integration*

2.3 Data Analysis

Data collected from the Augmented Reality Professional Development (ARPD) workshops will be analyzed to understand the effectiveness of the professional development training. Quantitative data will be collected from questionnaires. Qualitative data will be collected from the questionnaires and teacher focus groups. Data analysis will consist of the following steps:

1. Participant's scores will be entered into a spreadsheet for analysis (all data will be anonymous, only identified by the teachers' grade level).
2. *Pre-workshop Questionnaire 1* - Calculating the mean and percentages of Likert-scales questions. (see Appendix C)
3. *Post-workshop Questionnaire* 2- Calculating the mean and percentages of Likert-scales questions. (see Appendix D)

4. *Post-AR Integration Questionnaire 4-* Calculating the mean and percentages of Likert-scales questions. (see Appendix E)
5. *Observation Questionnaire 3* - Calculating the mean and percentages of Likert-scales questions. (see Appendix F)
6. *Teacher Focus Group 4* - Coding responses to determine themes. Use to support main data themes. (see Appendix G)
7. Analyzing and comparing the data, questionnaires and themes form the focus groups to determine identifiable trends in the data.

The results of the analysis will provide insights into the teacher perceptions and understandings of STEM and AR technologies within instruction, as well as student engagement. Likert scales will be used to identify the emerging themes of the study. The themes will be supported by coding from the focus group discussions.

2.3.1 Safeguards

The study being reviewed by the University of Pittsburgh Human Research Protection Board (IRB). An initial discussion with the IRB indicates the research will be exempt under 45 CFR 46.104 as an educational study for program evaluation, with a focus on teacher professional development.

3.0 PDSA Results

The purpose of the study is to determine the degree to which the STEM and Augmented Reality (AR) professional development workshops prepared educators to introduce AR apps into a classroom environment. Specifically, questionnaires and a discussion group provided feedback regarding how educators understand STEM education, and integrate new technologies to effectively introduce STEM based learning. Teachers participated in a professional development workshop series, completed questionnaires and contributed to a discussion group. Participants gave consent to participate in the study, record data, and discussion groups. All data has been compiled on secure devices and storage units. The questionnaires and task load index surveys were translated into quantitative data to reflect the major trends in the data that correlating to the inquiry questions. The discussion group responses were used to support trends in the quantitative data and task load indexes. Moore et al. (2014), stated that educators are the conduits for interdisciplinary learning. The study seeks to investigate the educators' ability to access and implement new technologies that will positively influence the learning environment.

3.1.1 Descriptive Educator Statistics

The professional development (PD) workshops were completed by six elementary school educators from the third and fourth grades. Three educators from each of the grade levels participated in the PD and augmented reality integration. In the pre-workshop questionnaire educators indicated their level of professional teaching experience, and baseline comfort and understanding of STEM education.

Table 2: Educator Professional Experience

Answer #	Answer Description	Percent (%)	Educator Count per Answer
1	0-3 years	33.33%	2
2	4-6 years	0.00%	0
3	7-9 years	16.67%	1
4	Above 10 years	16.67%	1
5	Above 15 years	0.00%	0
6	Above 20 years	33.33%	2
	Total	100%	6

Based on the descriptive data from the educators, there is a wide range of teaching experience. Two of the educators are new to the profession, while the remaining two have been in the profession for over 20 years. The mix of educator experience allowed for a diverse range of feedback. As discussed in the literature research, teachers can be hesitant towards new learning models in STEM education, contributing factors such as a lack of professional development, underutilized technologies, or lower levels of experience with the curriculum content can hinder teacher comfort with STEM based learning, (Ejiwale, 2013). To minimize any of these factors the professional development aligns to the Darling-Hammonds *Seven Design Elements of Effective Teacher Professional Development Model*. The premise of the professional development model is shown to be effective in developing a collaborative and experimental type of PD that a wide range of educators can thrive within, (Lo, 2021).

3.2 Research Question: STEM Education

3.2.1 Educators Perspectives of STEM Education

While analyzing the educators' perspectives of STEM education and principles, the primary investigator used a pre-workshop questionnaire, post-workshop questionnaire, and discussion group. Specifically, the guiding questions; GQ1. What are the educator's perspectives of STEM education, and based on the professional development workshops, GQ2. What is the educators understanding of STEM principles and 21st century skills after completing the workshops? The pre-workshop questionnaires provided educators background knowledge and application of STEM Education. In the first section of the questionnaire, educators selected content areas that they consider as STEM Education. Researchers Shernoff, Sinha, Bressler, and Ginsburg (2017), identified that educators were interested in utilizing STEM education principles, but were not prepared to integrate them into the learning pedagogy. The initial questionnaire investigated the educators' comfort and experience with STEM education, specifically the STEM terms that they personally identify as STEM education. The terms are a collection of the most common STEM and educational terms identified throughout the research, as well as a few non-traditional STEM terms such as; field trips and soft skills, both of which may be parts of STEM learning initiatives. Question three of the pre-workshop questionnaire asks, GQ3. When you hear the words STEM education, what do you think about? Educators are asked to select as many of the following options apply. The table below displays the selection of the educators.

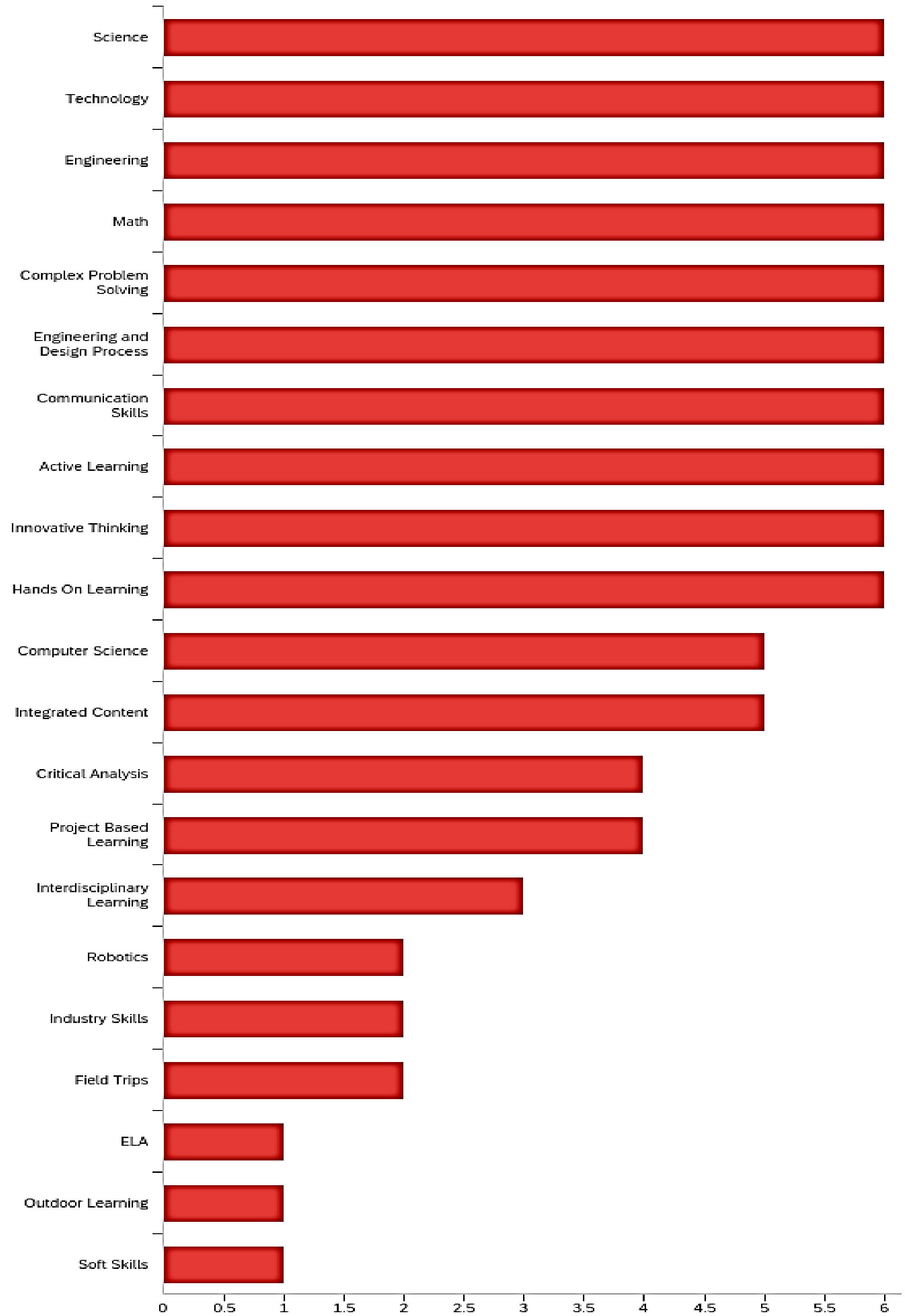


Figure 2: Educator Perspectives of STEM Terms

This initial data helps to answer the guiding question regarding the educators' perspectives of STEM education pre-workshops. Based on the list above of common STEM terms, strategies and educational terms, all six educators identified 10 out of the 21 (48%) terms as STEM related, with a focus on science, technology, math, problem-solving, and learning strategies. The majority of the group (5 out of 6 participants) identified four additional terms of importance (19% of terms), these included engineering, soft skills and interdisciplinary/integrated leaning. Half of the educators selected terms referring to field trips, industry, and outdoor experiences, while only two selected robotics as a STEM term. In the post-module questionnaire two, the teachers' selected almost identical terms to the first questionnaire, as a group the educators confirmed their perception of STEM terms.

The questionnaires asked the educators to evaluate their comfort and understanding with STEM and augmented reality tools. To develop a robust set of quantitative feedback, data was collected using the Likert scales, which Awang, Afthanorhan, & Mamat (2016) suggest are a proven method for accurately identifying trends in data. The data indicates that the majority of the educators view STEM education as a science and math related problem-solving process. The cross-sectioning of the first two questionnaires provided three main trends regarding educators perspectives on STEM education and the professional development provided during the study:

1. The professional development was effective in providing educators a strong understanding of STEM skills and principles.
2. The professional development increased educators' ability to identify student application of STEM skills within the learning environment.
3. The professional development was effective in preparing educators to integrate STEM skills into curriculum learning.

The educators demonstrated an encouraging knowledge and comfort level with STEM education principles, but after the workshops, there was a significant increase in scores to justify a strong level of successful professional development. Each questionnaire has been separated into Question (Q) data groups regarding Educator Perspectives, STEM education, and AR Integration.

Questionnaire one, the pre-survey provided the primary investigator with insights into the participating educators' perspectives, understanding, and experience with STEM education and augmented reality tools. Figure three below displays the educators' responses to the following questions:

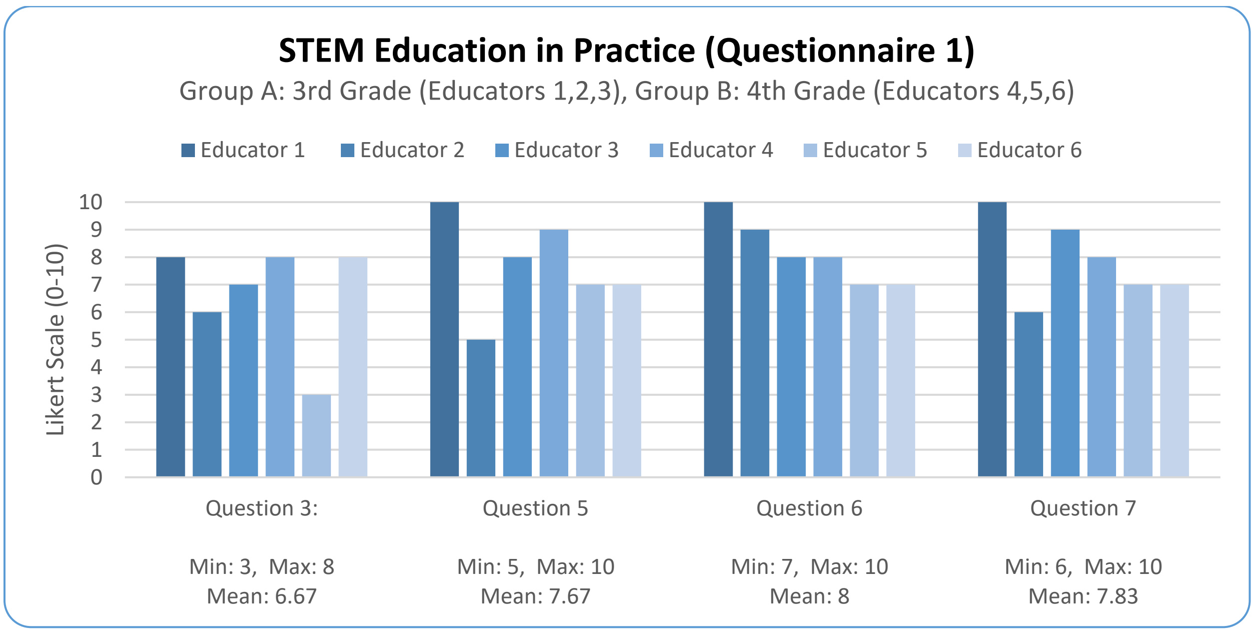


Figure 3: Educator - STEM Education in Practice

- *Q3: I have a strong understanding of STEM Education Principles*
- *Q5: I am comfortable integrating STEM concepts into my lessons*
- *Q6: The development of STEM skills is an important part of my curriculum*
- *Q7: I use all disciplines of STEM (Science, Technology, Engineering, Math) in my instructional pedagogy*

Educators indicated that they had a relatively moderate understanding and integration of STEM education principles (Q3 = 6.67% mean, Q5=7.67%). The Q3 mean score could be attributed to the wide range of educator experience and knowledge of programs within the school district, as noted by Jim," It was good for us to define what STEM is within the district." The teacher group did identify that incorporating STEM skills and content within their curriculums is important to the group, (Q6 = 8.17% mean, Q7 = 7.83% mean). As noted in Q8, (Q8 - I have integrated STEM projects and activities into my classroom curriculum), all six of the educators responded that they, "Sometimes integrate STEM on a Monthly Basis." Educators were asked to identify if students were demonstrating STEM skills in the classroom.

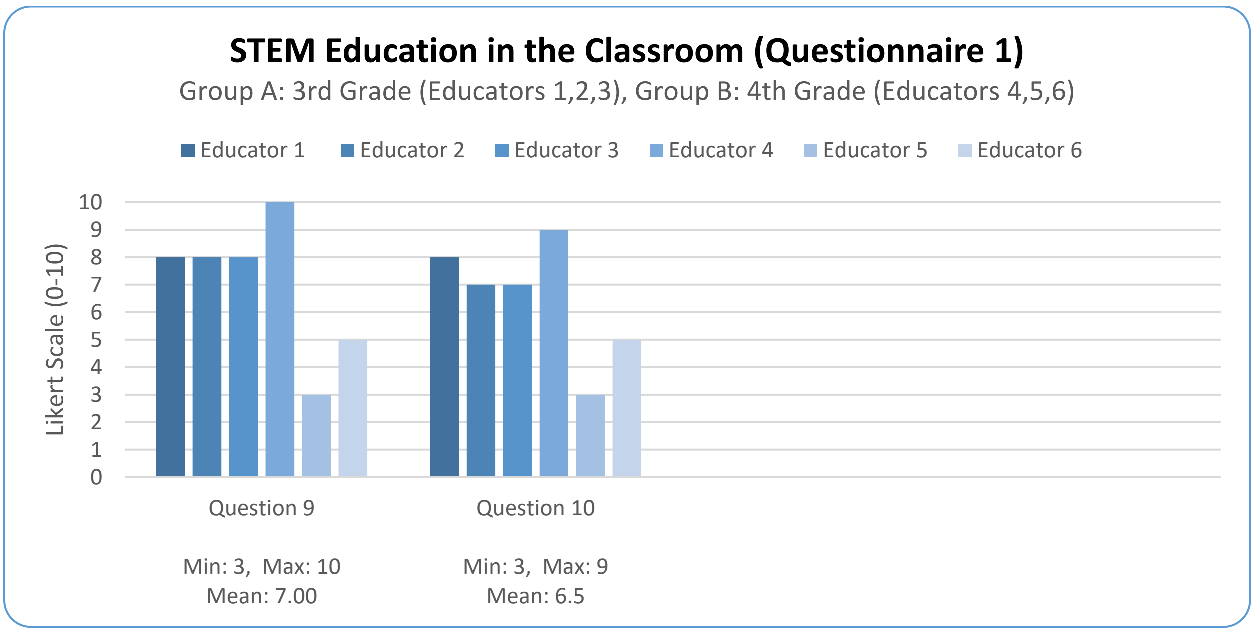


Figure 4: Educator - STEM in the Classroom

- *Q9: My students demonstrate strong STEM skills (Ex. Creativity, Problem Solving, and Technology Literacy.)*
- *Q10: My students demonstrate how to apply STEM skills to solve complex problems*

The teacher group has indicated that while their students demonstrate moderate STEM skills in the classroom (Q9 - 7% mean), there is a need to improve problem-solving skills among students (Q10 - 6.5% mean). Group B has less experienced educator, indicated that they have not seen high levels of STEM skills and application by the students. This data was collected prior to any of the STEM and augmented reality workshops to provide baseline data that can assist in identifying the effectiveness of the professional development workshop model.

3.3 Research Question: STEM Professional Development

3.3.1 Educator Perspectives of STEM Professional Development

The PD workshops were designed to educate the teachers regarding STEM and AR principles, and provide a framework for implementing AR tools in the classroom. The workshops promoted a collaborative team environment for the grade level educators to engage STEM education concepts. The study was developed to gain insights into the educators understanding of STEM education and 21st century skills. As noted above in the literature, Prinsley and Baranyai (2013), identify what employees see as the top skills needed for STEM careers as, “Active learning (i.e. learning on the job), Complex problem-solving, Creative problem-solving, Critical thinking, Design thinking” (p. 3). During the PD workshops educators reviewed these concepts and strategies for future instruction.

Following the STEM/Augmented Reality Workshops 1-3, the teachers completed Questionnaire 2. During the professional development workshops educators were introduced to principles, concepts, 21st century skills, and STEM terms that help in defining the districts STEM programming. The district considers STEM education the application of STEM skills, concepts, methods, and principles within curriculums. A number of the teachers mentioned in the discussion group that it was very beneficial for both grade levels to be together for the professional development, to hear about each other's application of STEM and science.

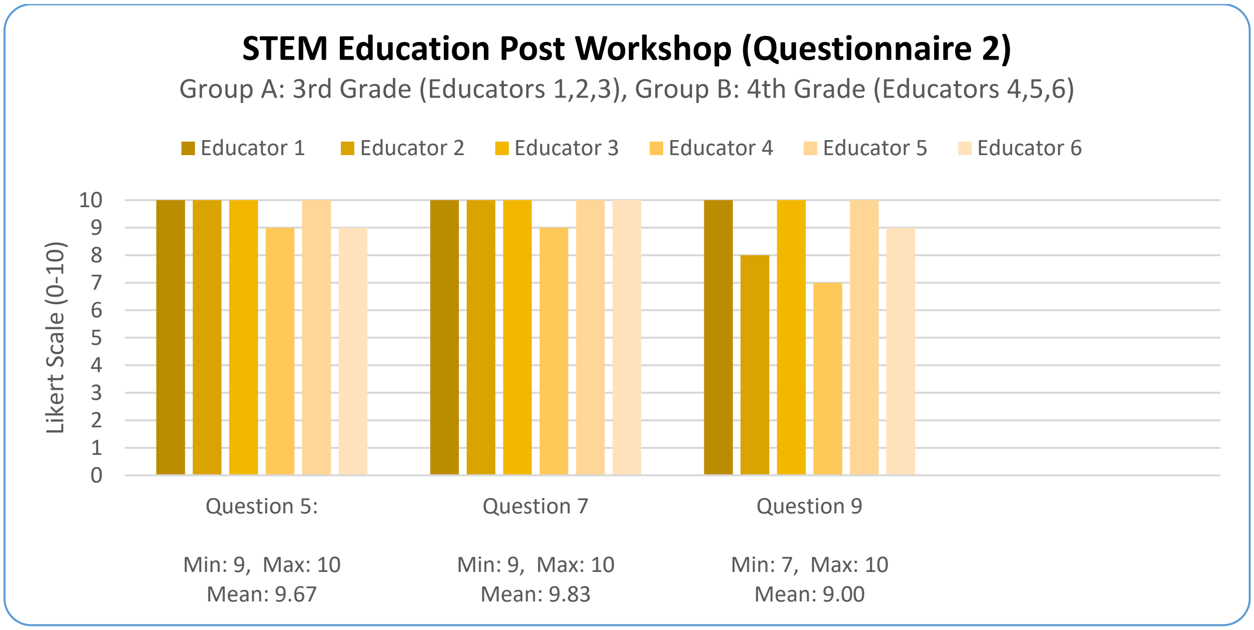


Figure 5: Educator Perspectives of STEM Education Post-Workshops

- *Q5: The STEM/ Augmented Reality Professional Development gave me a professional understanding of STEM principles and skills.*
- *Q7: The STEM/ Augmented Reality Professional Development prepared me to effectively integrate STEM skills into chapter lessons.*
- *Q9: I can identify 21st century STEM skills my students are displaying in their learning.*

Integrated and interdisciplinary learning is a key component to effective STEM education. The second questionnaire addressed STEM education concepts from the first questionnaire, comparing educator responses from pre-workshop to post-workshop. Based on the data table above, Questionnaire 2 supported the effectiveness of the professional development workshops. Educators indicated across the data sets that they understand STEM principles, and can identify these skills in student learning. Data from the third Questionnaire, shown below confirm the accuracy of the teacher data.

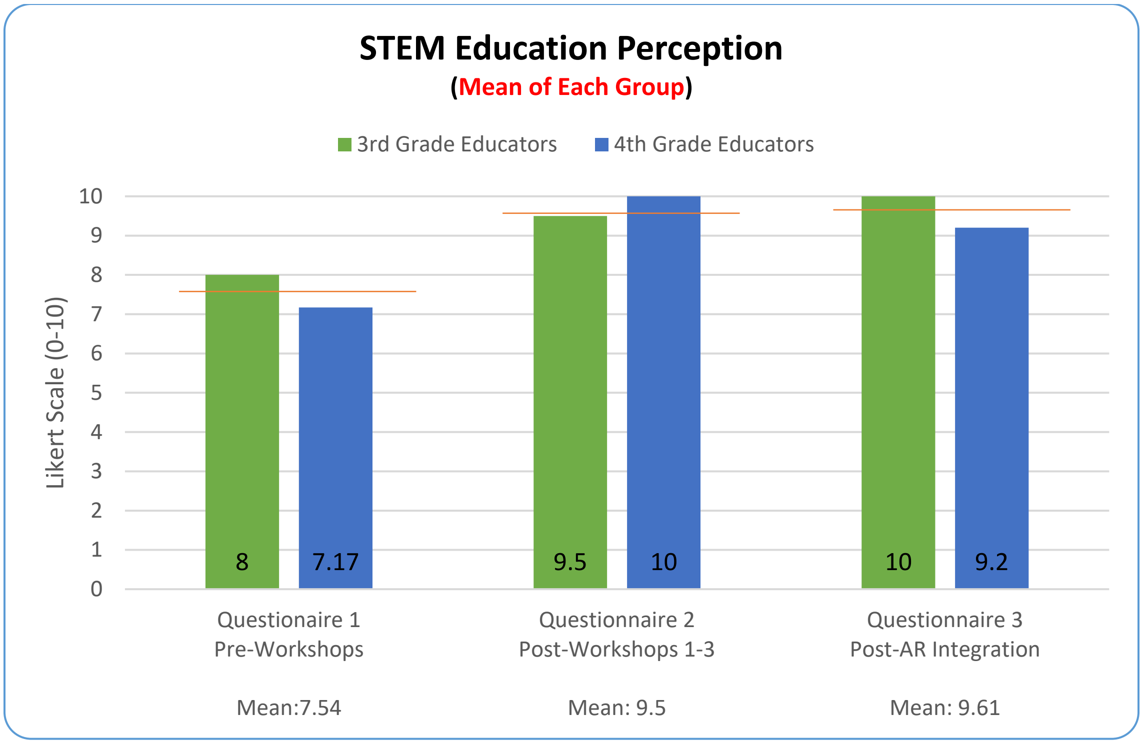


Figure 6: STEM Education Mean Score Analysis

Findings:

- Educators overall understanding of STEM education and skills **increased**
- Educators had a **positive evaluation** of the professional development workshops
- Both teacher groups indicated that the professional development gave them a **more in depth understanding** of STEM education within the school district and **how to use new technologies** to **engage students in STEM** activities

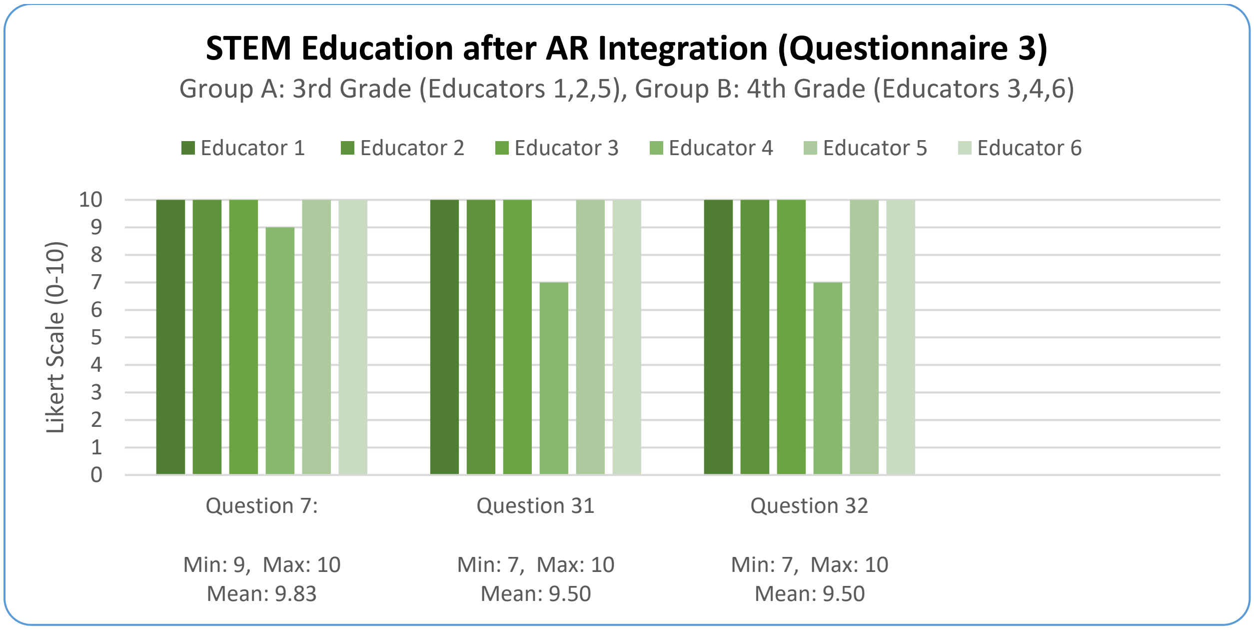


Figure 7: Educator Perspectives of STEM Education after AR Integration

- *Q7: The STEM/ Augmented Reality Professional Development prepared me to effectively integrate STEM skills into chapter lessons.*
- *Q31: I can identify 21st century STEM skills my students are displaying in their learning.*
- *Q32: The STEM/ Augmented Reality Professional Development gave me a professional understanding of STEM principles and skills.*

The table above displays the effectiveness of the professional development workshops to provide the educators the necessary understanding and preparation to integrate STEM curriculums. The questions are repeated form the prior questionnaire to ensure accuracy. All three response areas are within 5% of the prior data collected. The table in Appendix B compares the results of the first questionnaires, aligning the questions from each table to support additional analysis.

As seen in Appendix B, the mean average increases across the data sets show that educators had a positive experience in the professional development workshops. Although the mean average rose across the table, not all data points across the questionnaires a fully corresponding, but align in the content being investigated. The cross-sectioning of the questionnaires provided three main trends regarding educators perspectives on STEM education and the professional development provided during the study:

- The professional development was effective in providing educators a baseline understanding of STEM skills and principles.
- The professional development increased educators' ability to identify student application of STEM skills within the learning environment.
- The professional development was effective in preparing educators to integrate STEM skills into curriculum learning.

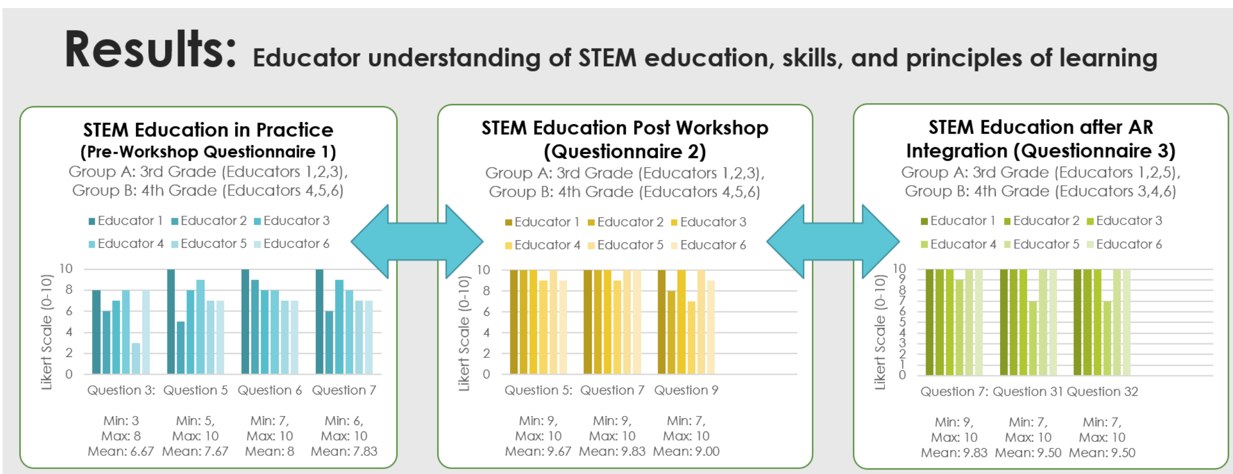


Figure 8: Educator Perspectives of STEM Education Comparison

- *Educators demonstrated an increased comfort and understanding of STEM education.*
- *Questionnaires 2 & 3 verify high levels understanding based on the workshops*
- *Most varied range of data found in Questionnaire 1, Least varied range of data found in Questionnaires 2,3*

The discussion group in workshop three and four confirmed the trends above as the educators mentioned how they effectively tested, planned, and integrated the augmented reality tools. Specifically, the guiding question, based on the professional development workshops, what is the educators understanding of STEM principles and 21st century skills after completing the workshops, was addressed in questionnaires two and three. The educators indicated they could identify and understand the 21st century skills and STEM principles that can be integrated into curriculums.

3.4 Research Question: Augmented Reality Professional Development

3.4.1 Educator Perspectives of Augmented Reality

Data collection regarding augmented reality was gathered GQ3, Based on the professional development workshops, how are educators able/prepared to effectively integrate augmented reality tools into STEM-based instruction? The initial AR data was gathered to determine the teachers' knowledge and use of AR in the classroom.

Table 3: Educator Perspective - Augmented Reality

#	Q15 - Have you integrated Augmented Reality apps or activities into your classroom curriculum?	%	Count
1	Often - Integrating STEM on a weekly basis.	0.00%	0
2	Sometimes - Integrating STEM on a monthly basis	33.33%	2
3	Not very often - Integrating STEM on a Semester basis,	33.33%	2
4	No STEM integration at this time.	33.33%	2
	Total	100%	6

The teachers indicated they do not have very extensive experience with augmented reality tools. The chart below reflects the teacher's lack of experience and comfort with AR tools and applications. Teachers are very comfortable with technology tools like tablets, which assist in their use of AR tools on the device. The school is a one-to-one tablet devices for students and staff.

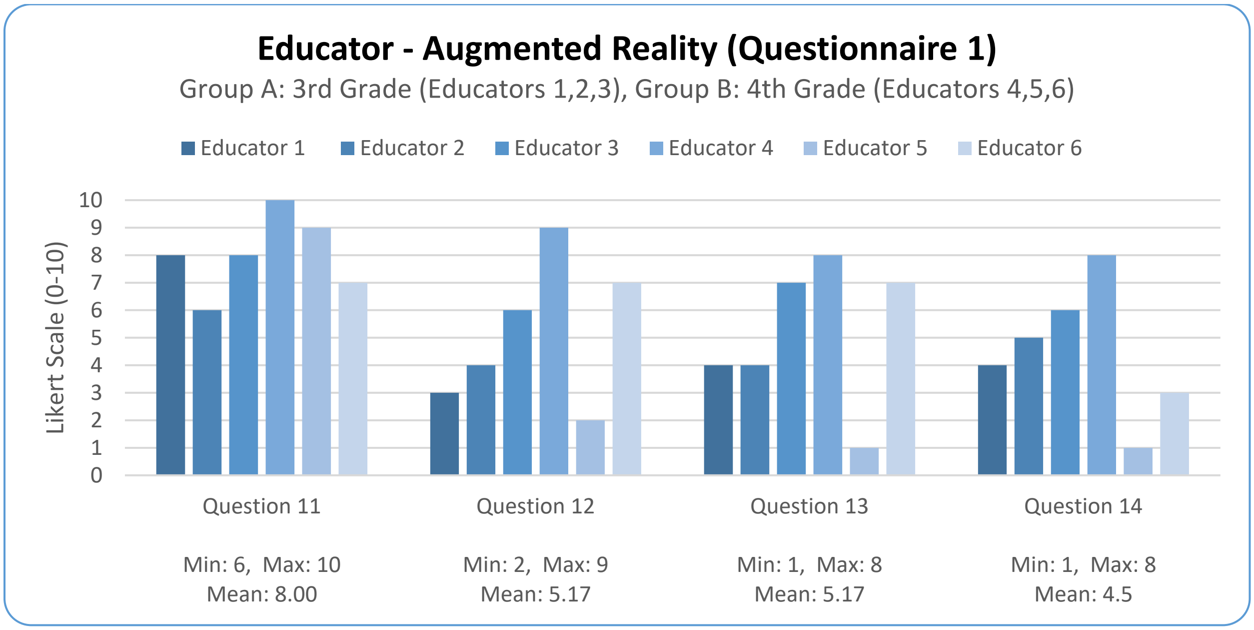


Figure 9: Educator - Augmented Reality

- *Q11: I am comfortable integrating technology tools (Ex. Digital tablets) into my lesson*
- *Q12: I am familiar with Augmented Reality tools and applications*
- *Q13: I am comfortable integrating Augmented Reality tools into my lessons*
- *Q14: Augmented Reality is an important teaching tool in my classroom*

Prior to the STEM and AR workshops the educator knowledge and application of Augmented Reality was relatively low as indicated in *Figure 8*. If teachers are not exposed to the technologies, they will not be comfortable utilizing them in classroom settings.

3.5 Educator Perspectives of Augmented Reality Professional Development

The chart below indicates a strong increase in teacher comfort, knowledge and readiness of AR app usage and implementation. Teachers indicated they are comfortable using AR tools into classroom lessons after the professional workshops equip them to integrate the resources effectively.

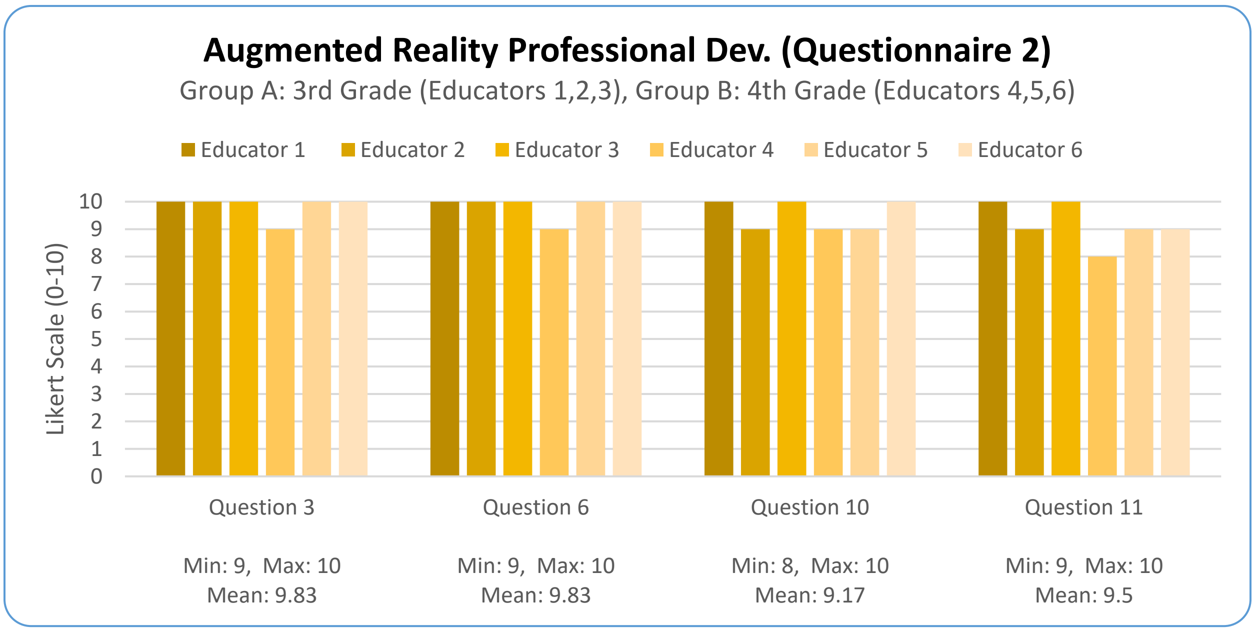


Figure 10: Augmented Reality Professional Development

- *Q3: The STEM/Augmented Reality Professional Development prepared me to effectively integrate AR into chapter lessons.*
- *Q6: The STEM/Augmented Reality Professional Development prepared me to effectively identify viable AR tools and apps.*
- *Q 10: I am comfortable implementing new technologies such as Augmented Reality in future lessons.*
- *Q11: Augmented Reality Apps are effective learning tools.*

Figure 10 confirms the findings from questionnaire three, as educators indicated a strong relationship between the workshops, integration their comfort, understanding and application of the AR tools into student learning. All mean scores collected ranged above the 96th percentile.

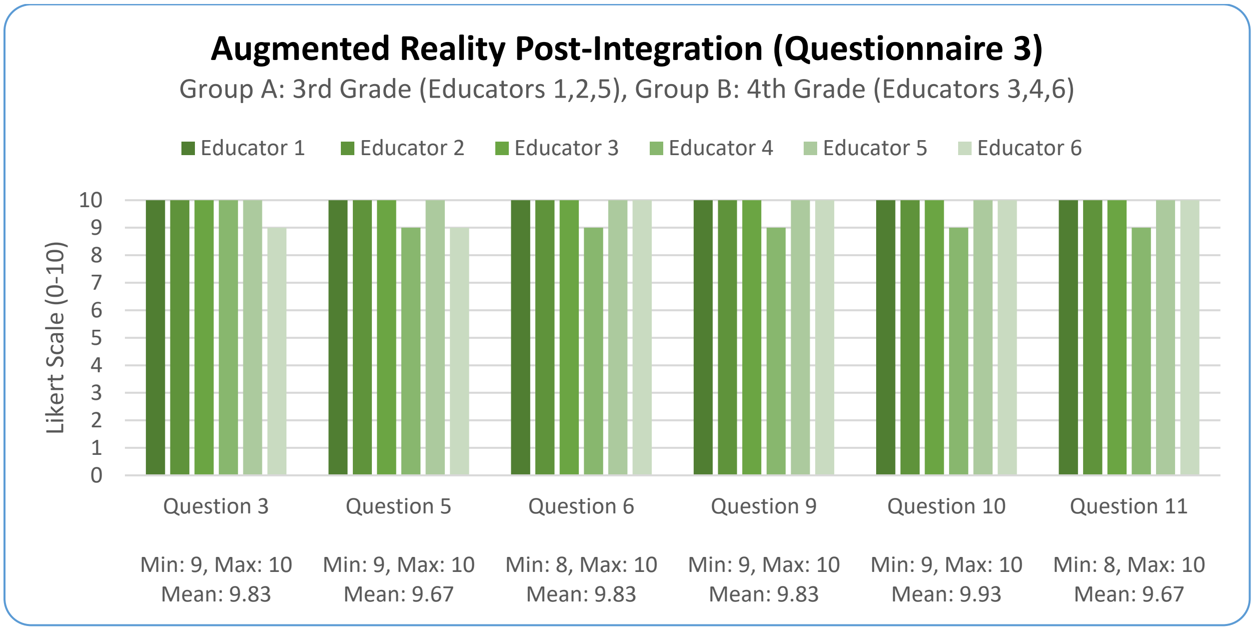


Figure 11: Augmented Reality Post-Integration

- *Q3: The AR App increased student engagement in the lesson.*
- *Q5: I was confident in my knowledge and training to demonstrate how to use Augmented Reality Tools*
- *Q9: The STEM/Augmented Reality Professional Development prepared me to effectively integrate Augmented Reality Tools into chapter lessons.*
- *Q10: I am comfortable implementing new technologies such as Augmented Reality in future lessons.*
- *Q11: Augmented Reality Apps are effective learning tools.*

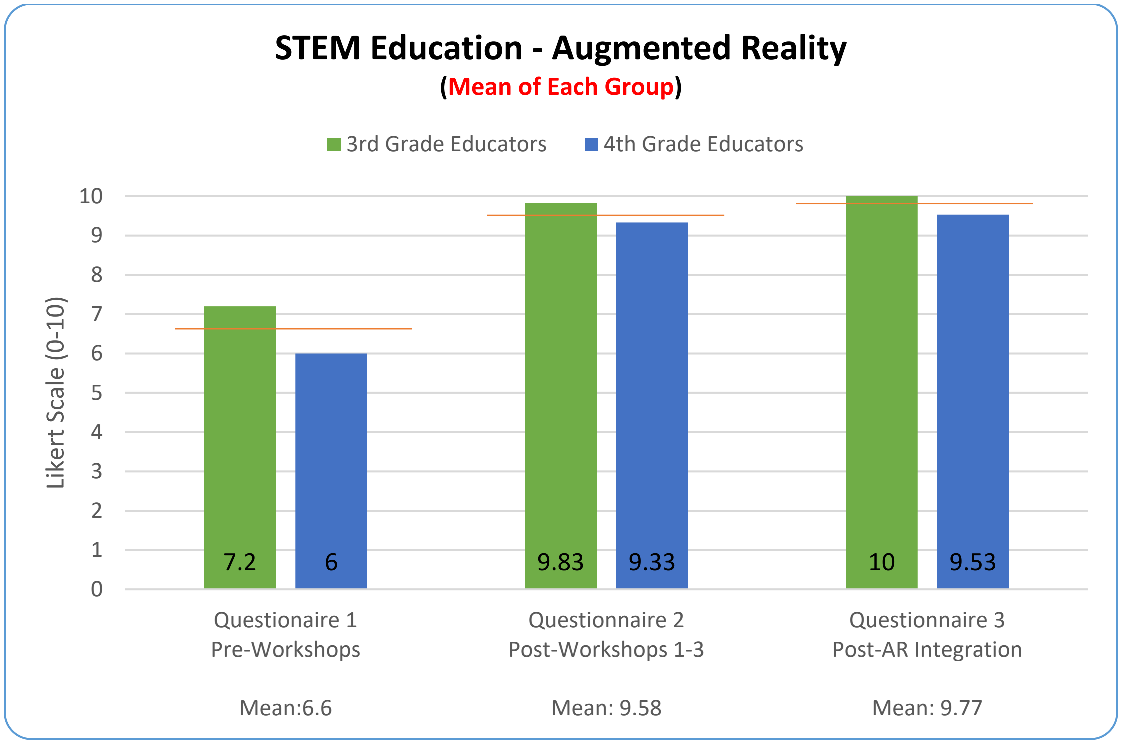


Figure 12: AR Mean Score Analysis

As depicted above, the results from the questionnaires showed positive increases in mean scores from questions relating to Augmented Reality. The educators indicated that the workshops, and classroom integration provided them valuable experience with the AR tools.

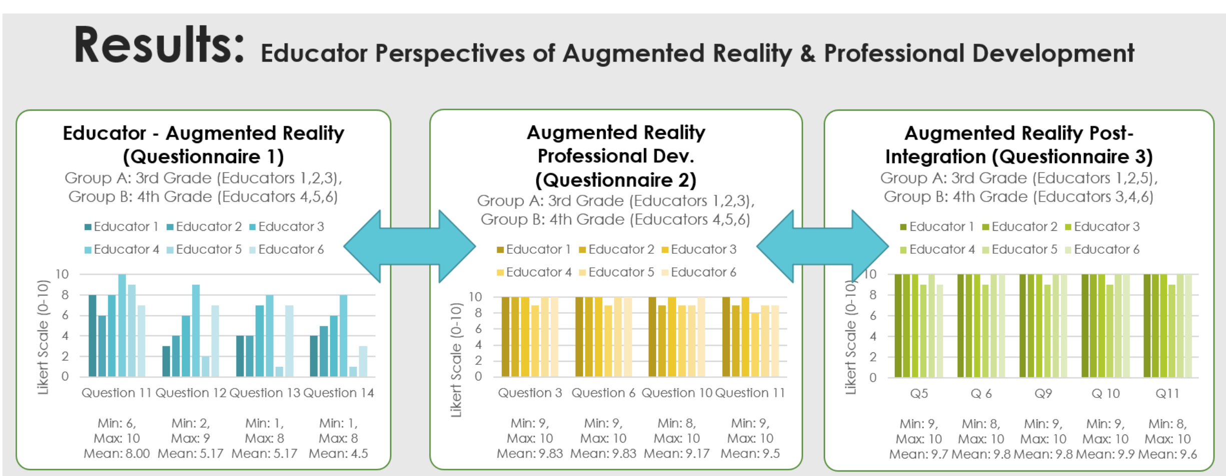


Figure 13: Augmented Reality Data Comparison

The data above in *Figure. 13* displays the educators overall understanding of Augmented Reality increased across each of the data results. The questionnaires indicated the educators had a positive evaluation of the professional development workshops, and both teacher groups indicated that the professional development prepared them to analyze AR apps for instruction. This answers the guiding question regarding the workshops effectiveness at preparing educators to integrate AR. The educators responded that they were prepared for the AR integration and the overall application of the tools into classroom learning was successful.

Based on the cross-section of data as seen in Appendix C, the questionnaires and discussion groups, the major themes and trends noted above emerged. The emerging themes were constructed into three main categories: Perspectives of STEM Education, Effective STEM/Augmented Reality Professional Development, Integration of New Technologies such as Augmented Reality. The following section provides the analysis that identified each of the themes for AR integration.

3.5.1 Augmented Reality - Educator Observations

During the integration phase of the workshop, educators used the selected AR apps and introduced them to the students. The teachers provided directions on how to use the AR apps and demonstrated the apps. Below is the contents of Questionnaire 4, which displays the teacher's feedback from each section of AR implementation. Third Grade teachers recorded the implementation of the AR apps a total of 11 times and Fourth grade teachers, six times.

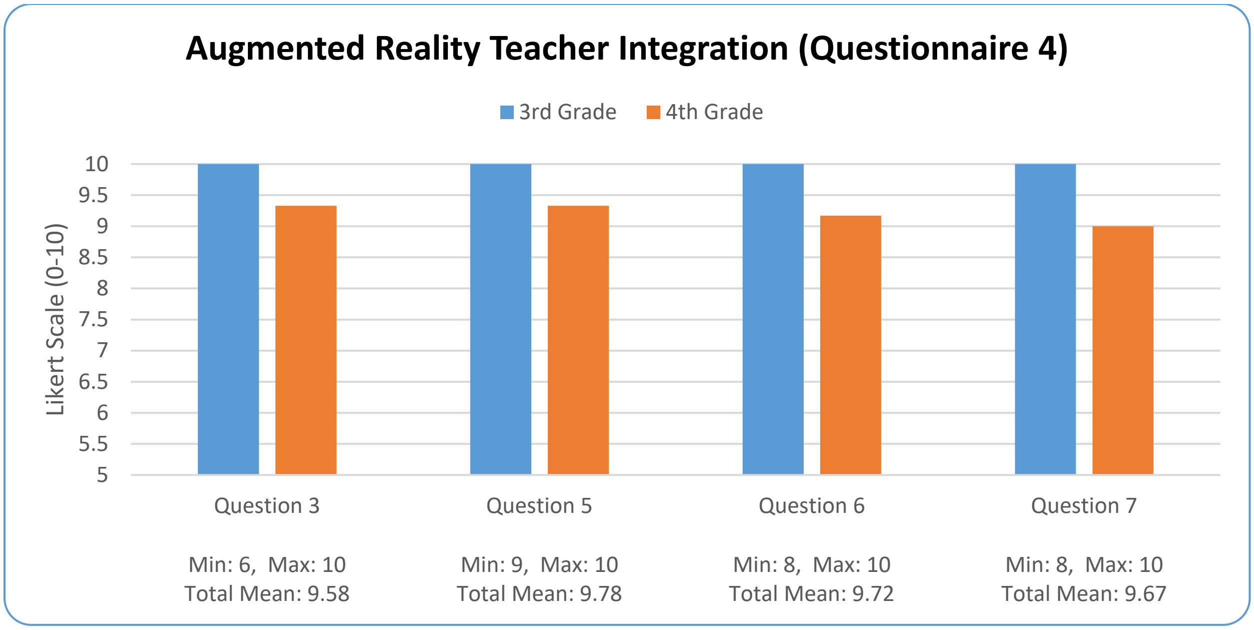


Figure 14: Observation Table: Teacher Integration

- *Q3: I was confident in my knowledge and training to demonstrate how to use the AR App*
- *Q5: I was comfortable teaching students how to work in the AR App*
- *Q6: I was able to problem solve technical issues with the AR App*
- *Q7: I was able to effectively integrate the AR App into my lesson*

Figure. 11 demonstrates that the educators in both groups felt comfortable integrating the AR apps into the lesson. Standard mean for the groups were all above the 95th percentile, indicating a high level of confidence.

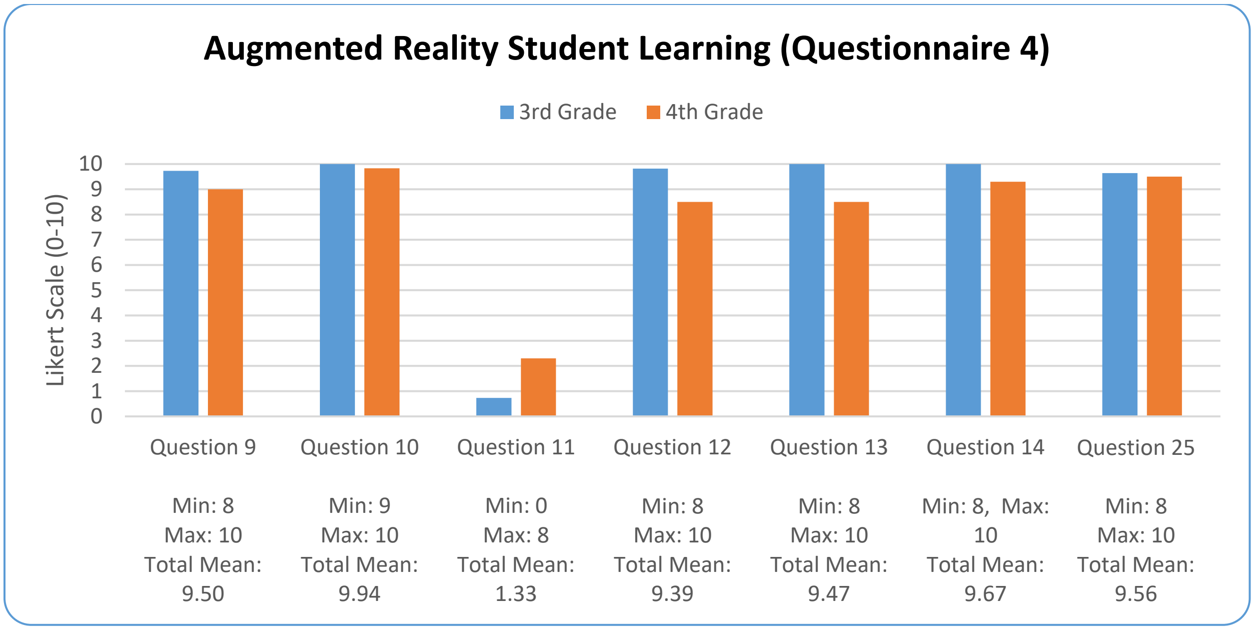


Figure 15: Observation Table: Student Learning

- *Q9: My students demonstrated a clear understanding of content from using the AR App*
- *Q10: My students were engaged in using the AR App*
- *Q11: My students were frustrated when using the AR App*
- *Q12: The AR App was an effective tool in delivering chapter content:*
- *Q13: The AR integration developed student STEM skills. (Ex. Creativity, Problem-solving)*
- *Q14: The integration of the AR App was a positive experience*
- *Q25: My students understood how to use the AR App*

Data sets from *Figure. 15* indicate educators observed a very high level of AR application among the students during AR lessons. As referenced in the literature, AR is an engaging and immersive experience that can increase student involvement, as well as retention of content knowledge, Chin, K. Y., Wang, C. S., & Chen, Y. L. (2019). Question 11 indicates low levels of student frustration when using the AR apps. This is a good indicator that the learning tools is not causing additional stress to the student or learning environment. The Augmented Reality workshops were effective at preparing the educators to implement the AR tools into classroom learning. The questionnaires indicated the educators had a positive evaluations of the professional development workshops, and both teacher groups indicated that the professional development prepared them to integrate AR tools.

3.5.2 Discussion Group

During the discussion group educators were given the opportunity to respond to the pre-formatted questions. The educators received the questions in advance to allow them to prepare their ideas ahead of time. Grade level teacher groups participated in the discussions separately to allow for increased feedback. The discussion group was transcribed and coded using provisional coding, which is an exploratory coding method (Saldaña, 2021).

Provisional coding allowed for the utilization of themes developed from the scope of the quantitative data gathered from the questionnaires. Once the initial coding was completed, thematic (concept) coding was applied to identify the themes and trends in the data. The inquiry questions were used as the guide to the coding and emerging theme development. The themes have then been displayed in a table to identify the most impactful trends in the data (Saldaña, 2021). Teachers identified areas of STEM projects where cross-curricular activities could be integrated.

Table 4: Emerging Themes - Workshop

Inquiry Question	Sub-categories	Description	Feedback
What are the educator's perspectives of STEM education? **Theme:** **Educator Perspective of STEM Education**	Instruction	Involves active student learning, teaching pedagogy and standardized curriculum implementation.	Utilize new AR tools, and technologies to engage students and deliver content effectively.
	STEM Skills	Knowledge of STEM and Industry based skills demonstrated and integrated into the learning environment.	Teachers suggested increasing STEM activities to allow for greater student skill development. Implementing cross-curricular activities.
	Definition	Define the STEM acronym and terms among the organization and teacher groups.	Educator refined district level interpretation of STEM education.
Based on the professional development workshops, what is the educators understanding of STEM principles and 21st century skills after completing the modules? **Theme:** **STEM Professional Development**	Collaboration	Educators working together to establish learning pathways, curriculum demonstrations and planning.	Educators indicated the positive effects of multiple grade levels participating in professional development together.
	Preparation & Planning	Teachers design lessons, presentation materials and assessments for student learning. The application of a framework to develop lessons content, and assessments for student learning.	Teachers collaborated as teams to plan for the AR integration. The workshops provided a framework for evaluating AR tools and lesson design.
	Time	The teaching teams need the allocated time to prepare, plan, and test new technologies to implement into leaning.	The teachers indicated in multiple workshops and the discussion group that time is a critical component to the entire process of planning, preparation, instruction and the student experience while learning.
Based on the professional	Technology	The use of devices that aid in the student learning, research	Educators displayed their comfort with technology and

development workshops, how are educators able/prepared to effectively integrate augmented reality tools into STEM-based instruction? **Theme:** **AR Integration**		and application of digital tools.	indicated that they use it as a teaching tool on a regular basis. New technologies can be challenging, but they had a very positive AR experience.
	Observation	Educators observing students utilizing the AR tools in classroom learning	The educators reported that they observed students displaying great STEM and technology skills during the AR app integration.
	Integration	Educators using the AR tools in classroom learning, specifically to promote STEM based learning.	The teacher teams indicated that the AR integration was successful, and each time the use the tools they will grow in the expertise and implementation.
	Engagement	The interaction between students, teachers, and the content or technologies used for learning.	The teachers reported that students were very engaged in the AR app integration. Students were immersed into the content and utilized self-learning and exploration skills while participating in the AR activities.

The teachers indicated that the AR integration was a very successful activity in the classroom setting. Students were engaged and enjoyed the learning process. The apps provided the students with the opportunity to explore and self-paced their learning.

The discussion group helped address each of the guiding questions, allowing the educators to give personal experiences and perspectives of the professional development workshops and the AR tools and integration. Regarding the question, GQ1. What are the educator's perspectives of STEM education? The educators discussed their initial ideas of STEM education, which at times seemed broad, since so many facets of education could be corralled into STEM. The educators indicated that introducing some parts of STEM, such as engineering and technology might not be at the fore front of their educational pedagogy. It is sometimes difficult to develop cross-curricular activities and projects.

Since the initial workshops focused on providing information and experiences for the educators, answering the guiding question, GQ2. Based on the professional development workshops, what is the educators understanding of STEM principles and 21st century skills after completing the workshops, can be addressed? The educators indicated that the workshops provided them with a vision of the districts overarching principles of STEM, as well as the states' emphasis on STEM education. The teachers discussed that they felt comfortable and prepared to teach the STEM based lessons in the classrooms. There was a consensus among both teacher groups that smaller projects could help them actively address specific STEM skills. One of the most important aspects of the professional development workshops was providing time and collaboration among the groups, which increased their collective knowledge and understanding of STEM learning.

The educators indicated that they enjoyed implementing the AR, and felt well prepared to use the AR tools in the classroom. The group's responses helped answer the AR guiding question, GQ2. Based on the professional development workshops, how are educators prepared and adept to effectively integrate augmented reality tools into STEM-based instruction? The educators noted that using the AR and VR tools during the workshops as well as during their collaborative planning helped them to understand the AR tools and prepare for implementation. The teachers discussed how engaged the students were during the activities and how the AR tools supported self-paced learning and discovery. All indicators suggest that the workshops were effective in preparing the educators for STEM and AR based instruction and learning.

3.5.3 Results from NASA Task Load Indexes

The NASA Task Load Index (TLX) was utilized to enrich the data sets with additional educator indicators as they experienced the professional development workshops and the AR integration. Based on the review of the NASA Task Load Index by Hart (2006) the TLX is still considered a valuable tool in determining stress and work load factors of a given task.

The TLX is a 21 point gradation scale that looks at six main factors: TLX 1 – Mental, TLX 2 – Physical, TLX 3 – Temporal, TLX 4- Performance, TLX 5 – Effort, TLX 6 – Frustration. During the STEM/AR study, two NASA Task Load Index questionnaires were administered, one after the professional development workshops, and the second after educators implemented augmented reality tools in the classroom environment.

During the professional development workshops 1-3, educators participated in lesson planning, collaborative team discussions, VR / AR testing, and hands on AR app review. The teacher groups completed a task load index survey at the end of Questionnaire 2, which was distributed after the first three workshops were completed. Below are the results of the TLX survey. The results were calculated with the raw scores only, no weighting. The data has been normalized. Examples of the questions relating to the two different TLX surveys collected follow the format: *Question 1: Mental Demand - How mentally demanding were the professional development workshops? Question 1: Mental Demand - How mentally demanding was the integration of AR into student learning?*

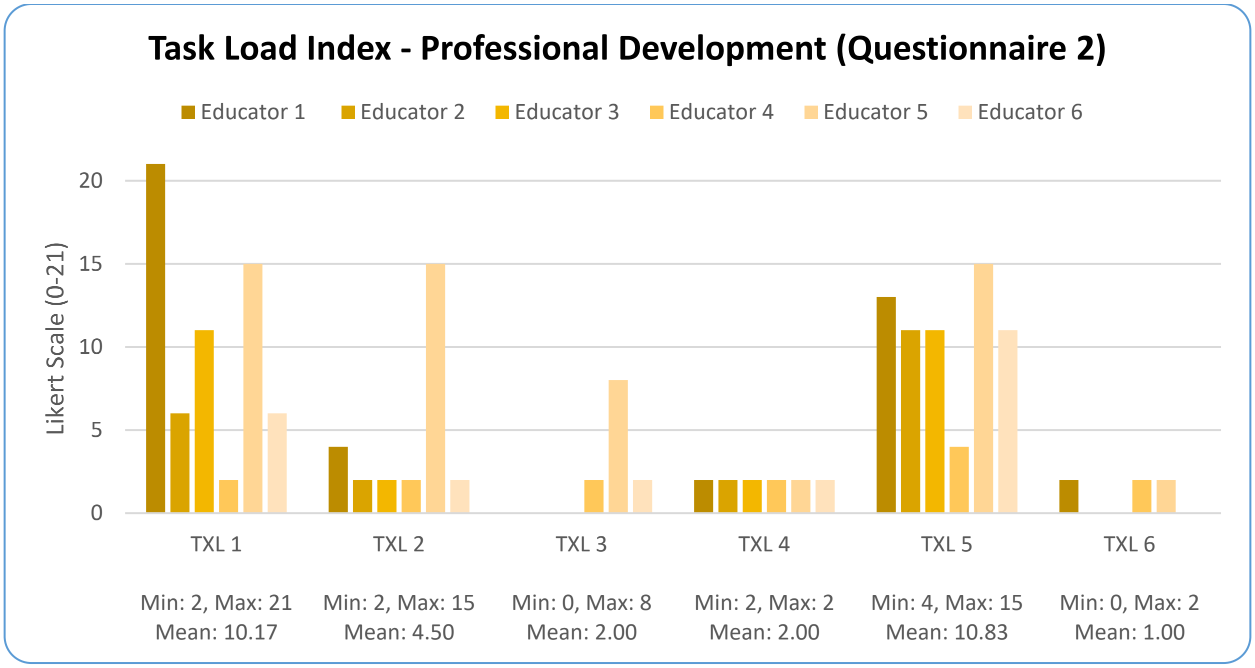


Figure 16: Task Load Index: Professioanl Development

Rate each of the six types of demands and factors from the professional development workshops:

TLX 1 – Mental, TLX 2 – Physical, TLX 3 – Temporal, TLX 4- Performance, TLX 5 – Effort, TLX 6 – Frustration

Figure. 16 indicates that the majority of educators experienced very small amounts of stress during the professional development workshops. Spike in data regarding TLX 1 – Mental, could indicate that some of the group felt the professional development was challenging and strained their attention. All verbal indicators during and after the workshops testified of a pleasant experience. The TLX 5 – Effort level were also elevated, indicating the educators applied a reasonable amount of effort in participating in the workshop series.

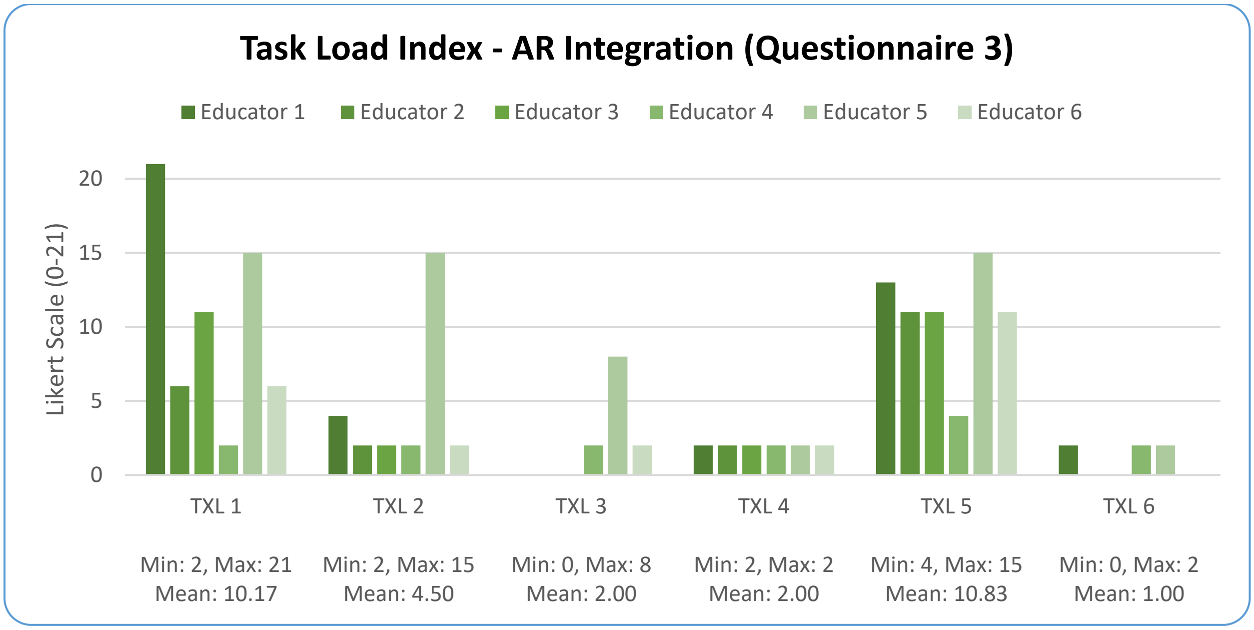


Figure 17: Task Load Index: Augmented Reality Integration

Rate each of the six types of demands and factors from the AR app Integration:

TLX 1 – Mental, TLX 2 – Physical, TLX 3 – Temporal, TLX 4- Performance, TLX 5 – Effort, TLX 6 – Frustration

Similar to *Figure. 17*, the TLX for augmented reality indicates that Mental and Effort are the two categories that show much elevation in data. There is a possibility that the level of mental elevation is related to the introduction of new technologies, as noted in the literature review.

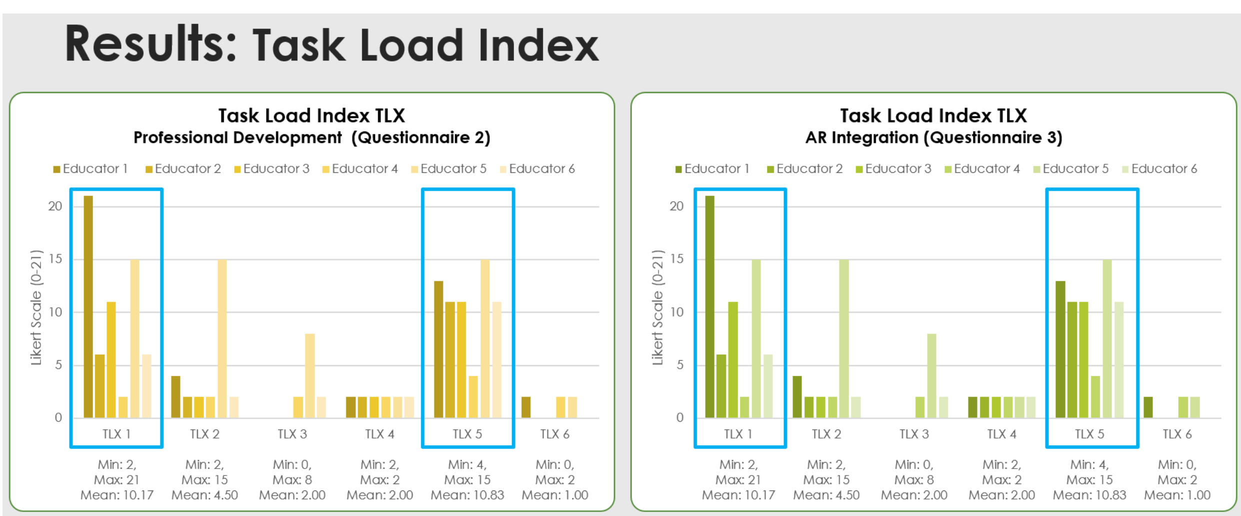


Figure 18: Task Load Index Highlights

The higher level noted in the TLX 5 – effort column indicate that teachers put forth effort during the AR Integration with their students. This is understandable as the educator is integrating the technology into the classroom, and demonstrating a new tool.

The results from the questionnaires, TLX surveys and discussion groups imply that the educators benefited from the professional development workshop. There was an expectation for the workshops to assist the teachers in understanding and skill development, yet one of the outcomes that was significant is the collaboration and team work among the grade levels.

4.0 Learning and Actions

4.1 Discussion

The scholarly research sought to qualify two areas of investigation, first, the inherent value of STEM skills in the educational environment, and second, educators' integration of new technologies such as Augmented Reality into 21st century learning pedagogies. The integration of new technologies in the educational environment supports STEM initiatives aimed at preparing youth for future careers. English (2016), suggested that individual need STEM skills to be successful in the future. The study seeks to understand if the professional development workshops can assist in preparing educators to deliver STEM based skills and principles in the classroom. Framing the data within the context of the guiding inquiry questions addresses the driving influences of the study. The inquiry questions for the study:

1. GQ1. What are the educator's perspectives of STEM education?
2. GQ2. Based on the professional development workshops, what is the educators understanding of STEM principles and 21st century skills after completing the workshops?
3. GQ3. Based on the professional development workshops, how are educators prepared and adept to effectively integrate augmented reality tools into STEM-based instruction?

The objectives of the study are to understand how educators perceive STEM education, and implement new technologies such as Augmented Reality that transposes STEM principles and skill development. STEM based education should provide students the opportunities to learn the interdisciplinary STEM skills as stated by Bybee (2013). The study investigates the local context of AR integration to support the continued application of technologies in the educational environment.

4.1.1 Key Findings

Figure 19: Impact Word Cloud

Based on the study, the word cloud above highlights the terms and phrases most commonly used by the educators during the discussion groups and professional development workshops. The key findings of the study revolved around the perpetual need to improve the delivery and instruction of STEM education. The study indicated that the workshop series was able to enhance the educators understanding and comfort with STEM education principles and concepts. Educators were able to identify district level curriculum and programming needs that will improve the integration of STEM skills into grade level learning. During the discussion group, one educator mentioned what would work well for next time, and next year, already investing and planning for future integrations of STEM and AR tools.

Planning, research, and preparation time was a central theme, indicating teachers needed to have the professional planning and collaboration time to effectively design STEM and AR lessons into curriculum areas. The workshops prepared educators to explore and identify AR apps that could be appropriately used in current grade level instruction.

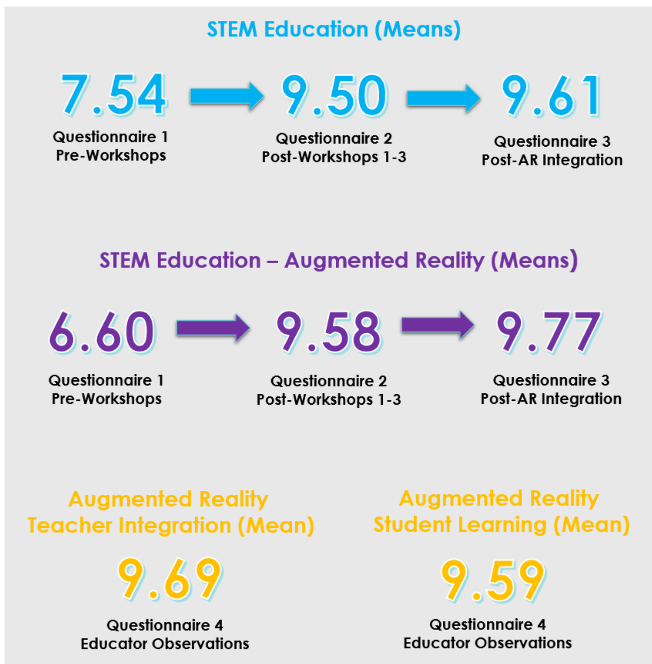


Figure 20: STEM / AR Mean Data Analysis

As indicated in *Figure. 20*, the mean score increased at each stage of the professional development. Educators at both grade levels effectively integrated the AR apps, creating an engaging learning environment for students. The key findings pointed to an effective professional development series that prepared teachers to integrate new technologies that effectively delivered STEM based learning and principles to students. Three significant findings were:

1. The professional development workshops, teacher collaboration, and professional planning were effective in providing the educators the understanding and strategies needed to deliver STEM principles and skills through AR integration and learning.
2. The educators have participated in improving the educational organization, STEM programming, technology integration, and district system by partaking as leaders in the professional development.
3. Educators provided an engaging environment for students to become immersed in learning, exploration, and the development of STEM skills that can benefit their future academic avenues, and careers.

The workshops have aligned the goals of the study to the district goals of building an environment for all students to learn and prosper academically and individually.

4.1.2 Professional Development Workshops

The professional development workshops played an intricate role in providing educators the tools and information necessary for AR integration. Educators participated in professional development workshops, utilizing Darling-Hammonds *Seven Design Elements of Effective Teacher Professional Development*, which was focused on the "Design Principles for Effective Teacher Professional Development in Integrated STEM Education: A Systematic Review" research by Chung Kwan Lo in Hong Kong. Workshops one and two of this study, were conducted in a single morning with a break between each workshop. Six educators from the elementary school participated in the workshops. Prior to the workshops, questionnaire one was completed, this was a pre-workshop questionnaire designed to gather baseline data from the educators before they were exposed to the concepts and principles of STEM education during the professional development.

To effectively measure the success of the workshops, data was collected using Likert scales. Awan, Afthanorhan, & Mamat (2016) found the Likert scale effective in their research stating that:

> Finally, recent research confirms that 10 points of Likert scale serves a promising scale under parametric based SEM. Both measurement and structural models can be assessed with 10 point of Likert scale that is expected more success in determining the construct validity. (p.21)

The questionnaires proved to be an effective tool in identifying the educators' perspectives on STEM Education, the PD workshops and Augmented Reality integration.

The workshops lasted around three and a half hours in total. Workshop one reviewed STEM education in the school district as well as the current trends, industry initiatives, and state and federal guidance impacting the STEM field. During the second portion of the workshops educators learned about virtual and Augmented Reality systems and technologies. Demonstrations of each of the technologies, followed by hands-on experiences with the devices using VR and AR applications.

Darling-Hammond has had a profound influence on the design of professional development. Darling-Hammond et al. (2017), discusses in *Elements of Effective Professional Development* a framework methodology, "we found seven widely shared features of effective professional development." (p.4). The table below aligns the principles of Darling Hammond to the STEM and augmented reality professional development. Chung Kwan Lo (2021) displayed the left two columns in her study of TPD. The right hand column lists the application of these design elements into the STEM/ AR professional development workshops. Please see the figure below:

Table 5: DH Model Professional Development Workshops

Design Element:	Description:	STEM / AR Professional Development Workshops
Content Focused	TPD activities focus on the content that teachers teach in their classroom and context.	Teachers aligned their lessons to augmented reality apps that enriched the current curriculum. The professional development focused on the integration of STEM principles into classroom instruction.
Incorporates active learning utilizing adult learning theory	Teacher participants are provided with instructional models (e.g., demonstration lessons and sample materials) as a vision of practice	Teachers were provided with a framework for evaluating AR technologies. Demonstration of the technologies and group lesson planning.
Supports collaboration, typically in job-embedded contexts	Teacher participants are directly engaged in the practices which are connected to their classrooms and students.	The teachers participated in using the AR apps. Learning how the students would be immersed in the content and developing lessons and assignments based on their experience with the technology.
Uses models and modeling of effective practice	Teacher collaboration is facilitated at the teacher, department, school, and/or district levels.	During PD, the AR apps were demonstrated, and then the teacher groups investigated various AR apps to identify effective content.
Provides coaching and expert support	Coaching and expert scaffolding support teacher participants' implementation of new curricula, tools, and instructional approaches.	The professional development was facilitated by experienced educators with a background in technology, virtual and augmented reality systems. Teachers were given the opportunity to learn and explore the instructional tools.
Offers opportunities for feedback and reflection	Teacher participants are provided with time to think about, received input on, and make changes to their practice.	During each of the workshops there was a discussion session to address curricular and instructional needs. Educators set goals for STEM education within the grade and building levels.
Is of sustained duration	Teacher participants are offered multiple opportunities to engage in learning.	The workshop series was 4 specific opportunities for educators. Additional PD will be provided to sustain and grow the STEM and AR programming.

The third workshop addressed teachers concerns about the technology as well as helping them plan for their upcoming augmented reality integration. The third workshop was two separate sessions, one for the third grade educators and one for the fourth grade educators. The two groupings allowed for each to discuss and focus on their upcoming curriculums integrations as well as and what apps might be possible for their integration into lessons. Teachers were provided with a list of various augmented reality apps that they could explore, as well they had the freedom to research and find additional AR apps independently or as a group. During workshops three, educators were given a frameworks to assist them in evaluating the apps to evaluate effective implementation into their lessons. After the three workshops were concluded, the educators completed questionnaire two, which included a NASA Task Load Index.

The teachers groups worked as teams to plan for the AR integrations. Each team selected the content, timing and materials that they would be using to integrate and assess the curriculum content. After each implementation with students the teacher recorded an observation questionnaire 3. Due to the nature of instruction at the elementary school, each grade level teacher had a morning and afternoon student group. The teachers were able to record data about the integration regarding each group. As well, the third grade teachers utilized two separate AR apps, and were able to collect observation data on both. Once AR Integration was completed with the grade levels, the educators completed a questionnaire 4, which included a NASA Task Load Index.

The final stage of the workshop is a reflection and discussion group to allow the educators to give personal feedback regarding the professional development and AR integration. The discuss groups were separated into the two grade level teams to allow for increased feedback from each group. Following all of the workshop sessions, data from the questionnaires and discussion groups have been analyzed to identify themes and trends within the data.

4.1.3 STEM Education

Educators from the third and fourth grades participated in providing feedback to the STEM/AR professional development workshops. One of the main inquiry questions was formed to identify educators understanding and perspectives of STEM education. The word STEM means, Science, Technology, Engineering and Math, and yet, there are many interpretations of the term. Based on the initial questionnaires, workshops and discussion groups, the educators reflected on what the term STEM means to each of the individually and as an organization. The group understood the districts term of STEM being an interdisciplinary process of learning, based in the STEM curriculums, but defining STEM as a group of educators was important for each of the team members to understand how STEM concepts and skills can be honed and utilized in student learning. STEM education can be thought of as a process, a set of skills, and different disciplines. Industry and education often refer to STEM as the jobs and careers that come from STEM fields. The plan "Charting a course for success: America's strategy for STEM Education" (2018), states:

> STEM skills are increasingly important for all career paths and for all people to succeed throughout their lives. STEM skills such as computational thinking, problem-finding and solving, and innovation are crucial for people working to manufacture smarter products, improve healthcare, and safeguard the Nation, and these skills are valuable assets across many other fields and job categories. The success of the Nation demands a STEM-literate modern workforce and Americans adept at navigating an increasingly high-tech, digital, and connected world.

It was important to understand how the educators viewed STEM education with the context of the local educational environment. During the first workshop session, the teachers collaborated to STEM goals for the school year. The first goal was to implement smaller STEM activities on a regular basis. The second goals was to identify where STEM and AR/VR could be integrated into the curriculums, and determine what tools and strategies. The final goals was for educators to integrate elements of STEM on a daily basis, to ensure the development of STEM skills needed for success in larger STEM projects. The reflections of the teachers during this session define the innovative educators within the school district.

4.1.4 Impact of STEM / AR Professional Development Workshops

The educators indicated that the collaborative nature of the workshops greatly benefitted each grade level group. Workshop presentations provided the teachers with a background knowledge of STEM education and its implications to industry and future work forces. Mohr-Schroeder, Bush, Maiorca, & Nickels (2020), stated that STEM literacy is critically important for students to be able to apply advanced problem solving methods. Educators also suggested that STEM activities span across curriculums, specifically into the math activities.

During the second workshop the group was introduced to the foundational knowledge of augmented and virtual realities, a technology which has been transforming digital applications within entertainment, industry, and education. The educators had the opportunity to use AR and VR tools to help them understand the learning process and interactivity students would experience from the technologies. Throughout this workshop, educators needed to have the opportunity to explore the technologies as both a teacher and student, allowing them to prepare for the engaging and immersive learning tools. During the second workshop the educators were provided with a list of AR apps and a framework to help them analyze what types of apps might be useful within their curriculums.

The teachers then met for a third workshop where they reviewed their apps, discussed strategies for implementation, and addressed concerns about the integration process. This was an opportunity for the teachers to reveal their findings, discuss the possible apps and how they related to the curriculums. Teachers mentioned during this workshop they found multiple apps that would work for other chapters of the text, but not the current section of the text. The teachers did find a weather based app that addressed water cycles and some of the main concepts they had recently reviewed. Due to the inconsistencies in curriculum alignment, the educators chose to integrate the AR app as an extension to the chapter content, building it onto the curriculum as an enrichment and review activity. The teachers reported that the students enjoyed the AR apps so much that they did not want to stop learning using the tools and asked when they could do it again. The educators' observations of their own integration of AR apps proved that the teachers became very comfortable using the AR tools. They also noted the successes of the students, recording very few frustrations, and in contrast, strong levels of enjoyment and engagement with the content.

4.1.5 Student Engagement

During the discussion group workshop, the educators discussed student engagement and investment into the AR learning apps. One teacher was quoted stating, "I would say, their overall excitement level of engagement, was high. The retention of skills, I think, was good and for some of them, especially yourself started learners their acquisition of new knowledge and new skills was strong." Research by Cheng & Tsai, (2013) indicates that AR technologies develop a positive learning environment that is engaging and motivating to students. A fourth grade teacher mentioned that while using the AR apps, student had to become good problem solvers, as they navigate the app, and try to resolve any small issues with the apps, such as losing the objects on the screen or resizing objects.

As stated in the literature review, one of the main goals of introducing AR into the STEM/Science based learning is to increase engagement which can correlate increased academic achievement. Chen C.H. (2020) described AR technologies as having a positive effect on the learning environment, providing immersive experiences for the learners that can increase their knowledge of content.

Technology tools such as Augmented Reality apps have the ability to immerse the user into the content, game, or environment. Students at the elementary school level where able to explore educational content using AR apps on a digital tablet device. Each student was able to independently examine, explore and learn at their own pace and level of interest. A third grade teacher mentioned, “I think an advantage was, it was student led discovery”. As noted by the teachers during the discussion groups, the students greatly enjoyed using the AR apps. The educators across both groups mentioned that students were deeply engaged in the content. On the educator observation questionnaires, teachers rated student engagement at a mean of 9.98 of 10pts scale, with a variance of only 0.05.Another teacher stated that, “They were able to do the exploration and the kids just thrive on things like that, they're happy with technology, so it was a good experience.”

4.1.6 Limitations of the Study

Although the professional development yielded positive results, there were limitations to the study. The educators were able to implement the augmented reality tools within a one and a half month time frame. The time frame limited the content that the teachers were able to use when searching for the AR apps. This constraint caused the educators to be very limited on apps that aligned to their curriculums. The teachers tried to be flexible with the content they were covering, but it was difficult to find AR apps that could directly replace direct instruction. The apps were used more in the form of enrichment and review of content that had already been previously taught.

The educators discussed the prep work that needed to take place before the students could use the apps effectively. The time required to teach students how to effectively use the apps prior to the execution of this study proved to be cumbersome at times. Educators also indicated that students having to conduct research while simultaneously using the apps on the same device became difficult. The study did not address all of the flaws with the instruction and delivery of the AR tools, but more of the educators' experience.

4.2 Next Steps and Implications

The STEM and Augmented Reality Professional Development Workshops granted educators a foundational knowledge of STEM education and AR systems. Teacher AR integration provided applications of new learning tools into the classroom environment, allowing the educators to develop learning strategies to demonstrate advanced technologies. Implementing organizational changes takes the support of the administration, school board, and educational staff. There is an opportunity to have all educators at the elementary school level prepared to understand and integrate STEM based learning, either through more traditional instruction, or advanced technologies such as augmented reality. Based on all of the data collected, the workshop series and AR integration gave the teachers new tools to invest into their classrooms.

Based on the study and its findings this researcher has three recommendations:

1. **Sustain and Grow:** The first objective is to sustain what has already been created through the STEM / AR professional development workshops. Starting with the school district's administrative team and onward to the professional teaching staff. It is critical that the school leaders continue to support the STEM programming established in the district on a yearly basis. Specifically from the study, supporting the third and fourth grade teachers in their current application of STEM projects, activities and students skill development is essential to the growth of the STEM programming. As noted by the educators during the study, giving teachers with the time to test, plan, and research the new learning tools really helps to prepare them appropriately for integration into student learning. The teacher teams felt that the collaborative interaction with the other grade levels gave them a better understanding of curriculums and application of STEM.
2. **Building STEM Educators:** Create buy-in form educators. Empower them through professional development, allocation of resources and planning time. The school district must continue to analyze the current STEM programming, identify the growing trends in industry and careers to provide students the most beneficial opportunities for employment in the future. It is critical that the educators have the time to participate in professional development that facilitates collaboration, and a planning framework for their future instruction. The school district is committed to providing teachers and students the technologies needed for instruction, learning and future growth.
3. **Student Engagement:** The district must continue to find ways to reach all students within the district. Providing various methods of instruction and learning so that every student can be successful academically and personally.

In future research, it would be good to reflect further into the limitation of instruction, pedagogy, and standards alignment within STEM education. As presented in the theory of improvement and literature, STEM literacy, skills and learning are vitally important to the success of students' future careers. Augmented reality tools proved to be an effective way to engage students in STEM based learning. The teacher groups demonstrated exceptional professionalism, flexibility, and desire to refine their craft, and grow as educators. The problem of practice for this research study focused on existing instructional pedagogies at the elementary school level which lack integrated technologies to support and engage students in Science and STEM based learning. Both the qualitative and quantitative data indicate a change in the organizations ability to infuse technology integration with STEM based learning. The positive results yielded from the study indicate a prerequisite for future research, professional development and technology integration that supports educators and student learning.

5.0 Reflections

This study demonstrates the complexity and advantages of STEM based learning through the integration of technologies such as augmented reality. As a leader within my system, I seek to empower members of the organization, engaging in collaborate change. The study provided me an opportunity to be a guidepost for the educators, focusing on improvement throughout the workshops. I will apply this transformational process into the next stages of my career as I continue to develop and learn as a change agent.

The first step to improving the system is learning to identify the challenges within the organization. Some issues are policy based, and often practice based. Unwritten rules of an organization can get mottled or muted over time. As a leader within the organization it is my goal to identify and clarify the challenges within the system. As studied by Lawlor and Hornyak (2012), developing a scope of improvement and using SMART goals which was attributed to Peter Drucker, can make positive changes within the organization. Lawlor and Hornyak (2012) note, "SMART goals are written using the following guidelines being: 1) Specific – define exactly what is being pursued? 2) Measurable – is there a number to track completion? 3) Attainable - can the goal be achieved? 4) Realistic – doable from a business perspective, and 5) Timely – can it be completed in reasonable amount of time? " (Williams, 2012). In order to lead well in parts of a system, SMART goals need to be developed to provide a vision and objects for the members.

When developing educational objectives for the school district these SMART goals provide an outline for committees or teacher teams to analyze and measure the effectiveness of their efforts. SMART goals can help create a shared vision among the organization members, and deliver timelines that guide progress in reaching community goals. As a leader I want to build an environment of team-work, collaboration, and shared visions. During the professional development series with the educators, I was reminded of how invested these professionals are at refining their craft and finding new ways to engage and connect with their students.

When designing the professional development workshop I reviewed the basics of STEM education with the grade level teams. We looked at the current trends, policies/guidelines, and attributes that are defining STEM education. The team then considered the district's current terminology for STEM education and discussed what STEM really was in the district and what it could become. This collaborative workshop presented the educators an opportunity to express their ideas of STEM and invest in the districts vision for the programming. Creating this type of buy-in is critical to being a good leader, and making organizational change. Members of the organization must have a voice, and be valued within the educational community. As a leader I look for opportunities to empower the district staff, developing teacher agency. Providing teachers the opportunity to invest in their professional learning pathway.

My goal as a leader within the district is to set a yearly vision of the STEM programming that provides the staff and administration a progressive pathway towards STEM literacy and integration throughout the district levels. Using the lessons from this study, I will continue to develop STEM learning experiences for the staff to assist in their personal and professional growth. This study was the first step in achieving my aim, and I make the following recommendation to make positive changes and improvements in a school system:

1. **Build a Vision:** Develop a vision that is clear, concise, and measurable. If possible, allow others, in my case educators to help define that vision. As the ship starts to sail, be flexible in adapting the vision, measuring your failures, and making the necessary adjustments to keep forward progress. If possible, build a brand around

your vision, a culture and identity regarding your program or professional development. Communicate your vision with your team, community and other leaders in the organization so that you build support and networking for future planning. When developing STEM programming I come to teacher teams and administrators with a vision of what we can build together, to benefit our school, the students, and the community at large.

2. **Build Teams:** No one can accomplish systems level change alone. Providing others within the organization opportunities to lead and invest in the change goals is important for organizational transformation. Collaboration and communication are key to reaching the teams goals, and implementing significant structure for change.
3. **Be Realistic and be positive:** Change takes time and it is an iterative process. Identify the step-by-step manner in which you can move from small systems change to an organizational change. Know that you will encounter speed bumps, road blocks and even others within the organization that will combat your ideas and efforts. Developing your leadership skills as a problem solver will help you navigate through the issues and individuals who might deter you from your path. Try your best to encourage your teams, identify each member's skills and allocate work that makes each individual successful in the process. Be humble about the failures and excited about the success.
4. **Brevity:** Improvement science is important work that takes committed practitioners who invest in their organizations. Developing a rigor to your work, holding yourself and your team to a high set of attainable standards is critical in making transformational changes.

I have tried to integrate all of the principles above into the development and application of the STEM professional development series. To the best of my knowledge, the educators in the study were collaborators in the process who invested in the vision of STEM education. The improvements to the STEM programming at the elementary school level can only be measured in time, but the educators have now received additional tools to engage students in STEM based skills and learning. I have improved as a leader, and scholarly practitioner through the development and application of this study. It is my desire to see the results, suggestions, and scope of this research positively impact other practitioners in their place of practice.

Appendix A : Email - Educator Communication

Educational Study: STEM in Elementary School Education:
Evaluating a STEM and Augmented Reality Professional Development Workshop for Educators
Primary Investigator: Ryan Bookhamer

Dear Educators,

I am conducting an educational research study to examine a STEM (Science, Technology, Engineering, and Math) and Augmented Reality Professional Development Workshop for educators. The study seeks to understand the effects of technologies in education, specifically augmented reality (AR). This study is part of my doctoral work at the University of Pittsburgh. The study seeks to understand educator's familiarity with STEM Literacy, 21st century STEM skills, and augmented reality tools. The research focuses on the alignment of AR applications to curriculums, and effectiveness of implementation. The study consists of an educator professional development workshop consisting of four modules, and AR implementation into Science/ STEM Curriculums within the grade level.

Participation in the study has no bearing on your employment or standing within the school district and is completely voluntary.

Participants will be involved in four professional development workshops to review STEM principles, learn about AR/VR, and develop an integrated learning plan for AR technologies within the classroom.

Module 1: STEM Literacy and 21st Century Skills
Module 2: Technology in STEM Learning: Augmented Reality Applications
Teachers will review the following materials within the module:
Module 3: Augmented Reality within Curriculums: Integrating Augmented Reality Tools Teachers will review the following materials within the module:
Module 4: Reflection of Augmented Reality Integration

The study will align within the current grade level curriculums and will utilize technology tools (digital tablets) that are already in place within your classrooms. The study seeks to understand the professional development modules effectiveness in preparing teachers to select, plan, and implement AR applications into the curriculums. The modules benefit the teachers by providing an understanding of STEM principles, 21st Century Skills, and new technologies such as AR to effectively integrate into classroom learning. Through a collaborative group workshop model, the team will develop positive learning experiences that will hopefully increase academic achievement in the long term.

Participating teachers will be given the opportunity to test VR apps using the Oculus Quest 2 Headset (Manufacturer). The teachers will be able to test the Tilt Brush painting app in the virtual world. Because VR headsets can cause individuals to feel imbalanced or disoriented, participation in the VR headset experience is completely voluntary and participants can choose to skip this activity.

Data will be collected through questionnaires and focus groups. A participant can withdraw from the study at any time. If a participant withdraws from the study, data collected prior to withdrawal may be used. Identifiable data will be stored in a separate file from identifiable data. Data will be collected and stored on secure devices that are password protected. Risk of the study may include a rare breach of data.

The study has been approved by the District Superintendent and all data relating to the study will be kept in a secure manner.

I am inviting you to participate in this educational study that helps measure the implementation of Augmented Reality (AR) applications into grade level curriculums.

If you are willing to participate in the study please contact me directly via email. As well, if you have any questions about the study I would be happy to answer them.

Thank you for your time and consideration.
Ryan Bookhamer

Appendix B : Professional Development Workshop Overview

Module 1: STEM Literacy and 21st Century Skills

a. Pre-workshop Questionnaire

b. STEM – Science, Technology, Engineering, and Math

   i. What are STEM Fields and Careers?

   ii. What is STEM Literacy?

   iii. What is STEM Education?

   iv. Current Trends in STEM Education

c. 21st Century STEM Skills

   i. What are the skills?

   ii. Who needs them?

   iii. How do we understand them and teach them to students?

d. Elementary School STEM Trends and Practices

   i. Discussion

   ii. Reflect on the District's Elementary STEM Programming

   iii. Review STEM integration in the current grade levels

Module 2: Technology in STEM Learning: Augmented Reality Applications

a. Virtual Reality (VR) and Augmented Reality (AR)

   i. What is VR and AR

   ii. How is AR/VR used in the world?

   - Industry
   - Education

- Research (Medical, Military, Industry)
- Entertainment

b. A Reality Experience

   i. Testing AR and VR tools

   ii. Science base AR App

   iii. Physical block that activates AR tools

c. VR/AR Experience Discussion

Module 3: Augmented Reality within Curriculums: Integrating Augmented Reality Tools

Teacher collaboration and team work in the following areas:

a. Teachers developing AR app criteria for integration and alignment to curriculum

b. Teacher selecting multiple science chapters and content to implement AR tools

c. Teacher Reviewing AR Apps

d. Lesson Planning – How will the Apps be integrated into the chapter, what content, what topics? How does the AR app enhance learning through either engagement, content, new learning?

e. Teachers create instructions, activities and assessments for App integration

f. Instruction and Pedagogy Discussion

Integration: Teachers integrate the AR app into classroom learning.

Module 4: Reflection of Augmented Reality Integration

Collect the following data resources from the teachers:

a. Teacher Observation Questionnaire

b. Record - Focus Group Questions/ Discussion

c. Complete Post-workshop questionnaire

Appendix C : Data Collection Sheets - Teacher Pre-Workshop Questionnaire 1

DATA COLLECTION SHEETS

Educational Study: STEM in Elementary School Education:

Evaluating a STEM and Augmented Reality Professional Development Workshop for

Educators

Primary Investigator: Ryan Bookhamer

Teacher Pre-Workshop Questionnaire 1

Thank you for participating in the STEM/Augmented Reality Professional Development (ARPD) workshop. The questionnaire is designed to gain a baseline understanding of teachers experience with STEM education concepts and augmented reality tools. Participating in this study is completely voluntary. When participating in the study, participants will complete questionnaires that seek to understand the individual's knowledge and experiences with STEM and Technology education.

Defined Terms:

STEM - Science, Technology, Engineering, Math
STEM Project or Activity - An interdisciplinary activity that focuses on teaching, Science, Technology, Engineering or Math skills/principles with inquiry and design Based learning.
AR - Augmented Reality (Usually in the form of an APP)

Please complete the following questions regarding STEM Education.

1. What Grade Level do you teach? (Asked in all Questionnaires)
    a. Third Grade
    b. Fourth Grade

2. How many years of teaching experience do you have?
    a. 0-3 years
    b. 4-6 years
    c. 7-9 years
    d. Above 10 years
    e. Above 15 years
    f. Above 20 years

3. I have a strong understanding of STEM Education Principles.

(10 = Strongly Agree, 1 = Strongly Disagree)

4. When you hear the words STEM education, what do you think about??? Please select the following options:
   - ☐ Science
   - ☐ Technology
   - ☐ Engineering
   - ☐ Math
   - ☐ ELA
   - ☐ Complex Problem Solving
   - ☐ Computer Science
   - ☐ Engineering and Design Process
   - ☐ Robotics
   - ☐ Innovative Thinking
   - ☐ Communication Skills
   - ☐ Active Learning
   - ☐ Soft Skills
   - ☐ Industry Skills
   - ☐ Interdisciplinary Learning
   - ☐ Critical Analysis
   - ☐ Project Based Learning
   - ☐ Hands on Learning
   - ☐ Integrated Content
   - ☐ Field Trips
   - ☐ Outdoor Learning

5. I am comfortable integrating STEM concepts into my lessons.
   (10 = Strongly Agree, 1 = Strongly Disagree)

6. The development of STEM skills is an important part of my curriculum.
   (10 = Strongly Agree, 1 = Strongly Disagree)

7. I use all disciplines of STEM (Science, Technology, Engineering, and Math) in my instructional pedagogy.
   (10 = Strongly Agree, 1 = Strongly Disagree).

8. I have integrated STEM projects and activities into my classroom curriculum?
   a. Often - Integrating STEM on a weekly basis.
   b. Sometimes - Integrating STEM on a Monthly basis.
   c. Not very often - Integrating STEM on a Semester basis.
   d. NO STEM Integration at this time.

9. My students demonstrate strong STEM skills (Ex. Creativity, Problem Solving, and Technology Literacy.)
   (10 = Strongly Agree, 1 = Strongly Disagree)

10. My students demonstrate how to apply STEM skills to solve complex problems.
    (10 = Strongly Agree, 1 = Strongly Disagree)

11. I am comfortable integrating technology tools (Ex. Digital tablets) into my lessons.
    (10 = Strongly Agree, 1 = Strongly Disagree)

12. I am familiar with Augmented Reality tools and applications.
    (10 = Strongly Agree, 1 = Strongly Disagree)

13. I am comfortable integrating Augmented Reality tools into my lessons.
    (10 = Strongly Agree, 1 = Strongly Disagree)

14. Augmented Reality is an important teaching tool in my classroom.
    (10 = Strongly Agree, 1 = Strongly Disagree)

15. Have you integrated Augmented Reality apps or activities into your classroom curriculum?
    a. Often - Integrating STEM on a weekly basis.
    b. Sometimes - Integrating STEM on a Monthly basis.
    c. Not very often - Integrating STEM on a Semester basis.
    d. NO STEM Integration at this time.

Appendix D : Teacher Post-Workshops 1-3 Questionnaire 2

Thank you for participating in the STEM/Augmented Reality Professional Development (ARPD) workshop. The questionnaire is designed to gain a baseline understanding of teachers experience with STEM education concepts and augmented reality tools. Participating in this study is completely voluntary. When participating in the study, participants will complete questionnaires that seek to understand the individual's knowledge and experiences with STEM and Technology education.

1. The STEM/Augmented Reality Professional Development prepared me to effectively integrate AR into chapter lessons.
   (10 = Strongly Agree, 1 = Strongly Disagree)

2. The STEM/Augmented Reality Professional Development gave me a professional understanding of STEM principles and skills.
   (10 = Strongly Agree, 1 = Strongly Disagree)

3. The STEM/Augmented Reality Professional Development prepared me to effectively identify viable AR tools and apps.
   (10 = Strongly Agree, 1 = Strongly Disagree)

4. The STEM/Augmented Reality Professional Development prepared me to effectively integrate STEM skills into chapter lessons.
   (10 = Strongly Agree, 1 = Strongly Disagree)

5. I can identify 21st century STEM skills my students are displaying in their learning.
   (10 = Strongly Agree, 1 = Strongly Disagree)

6. I am comfortable implementing new technologies such as AR in future lessons.
   (10 = Strongly Agree, 1 = Strongly Disagree)

7. AR Apps are effective learning tools.
   (10 Strongly Agree, 1 = Strongly Disagree)

8. When you hear the words STEM education, what do you think about??? Please select the following options:
   - ☐ Science
   - ☐ Technology
   - ☐ Engineering
   - ☐ Math
   - ☐ ELA
   - ☐ Complex Problem Solving
   - ☐ Computer Science
   - ☐ Engineering and Design Process
   - ☐ Robotics
   - ☐ Innovative Thinking
   - ☐ Communication Skills
   - ☐ Active Learning
   - ☐ Soft Skills

- Industry Skills
- Interdisciplinary Learning
- Critical Analysis
- Project Based Learning
- Hands on Learning
- Integrated Content
- Field Trips
- Outdoor Learning

Teacher Perspective: Please complete the following questions in regards to the professional development training:

NASA Task Load Index Hart and Staveland's NASA Task Load Index (TLX) method assesses work load on five 7-point scales. Increments of high, medium and low estimates for each point result in 21 gradations on the scales. (https://humansystems.arc.nasa.gov/groups/tlx/downloads/TLXScale.pdf)

1. Mental Demand - How mentally demanding was the professional development training? (21 = Very High, 1 = Very Low)
2. Physical Demand - How physically demanding was the professional development training? (21 = Very High, 1 = Very Low)
3. Temporal Demand - How hurried or rushed was the pace of the professional development training? (21 = Very High, 1 = Very Low)
4. Performance - How successful were you in accomplishing what you were asked to do during professional development training? (21 = Failure, 1 = Perfect)
5. Effort - How hard did you have to work to accomplish your level of performance during professional development training? (21 = Very High, 1 = Very Low)
6. Frustration - How insecure, discouraged, irritated, stressed, and annoyed were you during professional development training? (21 = Very High, 1 = Very Low)

Appendix E Teacher Post-Workshop 1-3 and Integration Questionnaire 3

Thank you for participating in the STEM/Augmented Reality Professional Development (ARPD) workshop. The questionnaire is designed to gain a baseline understanding of teachers experience with STEM education concepts and augmented reality tools. Participating in this study is completely voluntary. When participating in the study, participants will complete questionnaires that seek to understand the individual's knowledge and experiences with STEM and Technology education.

1. The STEM/AUGMENTED REALITY PROFESSIONAL DEVELOPMENT prepared me to effectively integrate AR into chapter lessons.
   (10 = Strongly Agree, 1 = Strongly Disagree)

2. The STEM/AUGMENTED REALITY PROFESSIONAL DEVELOPMENT gave me a professional understanding of STEM principles and skills.
   (10 = Strongly Agree, 1 = Strongly Disagree)

3. The STEM/AUGMENTED REALITY PROFESSIONAL DEVELOPMENT prepared me to effectively identify viable AR tools and apps.
   (10 = Strongly Agree, 1 = Strongly Disagree)

4. The STEM/AUGMENTED REALITY PROFESSIONAL DEVELOPMENT prepared me to effectively integrate STEM skills into chapter lessons.
   (10 = Strongly Agree, 1 = Strongly Disagree)

5. I was confident in my knowledge and training to demonstrate how to use AR.
   (10 = Strongly Agree, 1 = Strongly Disagree)

6. I can identify 21st century STEM skills my students are displaying in their learning.
   (10 = Strongly Agree, 1 = Strongly Disagree)

7. I am comfortable implementing new technologies such as AR in future lessons.
   (10 = Strongly Agree, 1 = Strongly Disagree)

8. AR Apps are effective learning tools.
   (10 = Strongly Agree, 1 = Strongly Disagree)

9. The AR App increased student engagement in the lesson.
   (10 = Strongly Agree, 1 = Strongly Disagree)

10. My students had a positive learning experience using AR apps.
(10 = Strongly Agree, 1 = Strongly Disagree)

Teacher Perspective: Please complete the following questions in regards to integrating AR tools into STEM Lessons.

NASA Task Load Index Hart and Staveland's NASA Task Load Index (TLX) method assesses work load on five 7-point scales. Increments of high, medium and low estimates for each point result in 21 gradations on the scales. (https://humansystems.arc.nasa.gov/groups/tlx/downloads/TLXScale.pdf)

1. Mental Demand - How mentally demanding was the integration of AR into student learning?
   (21 = Very High, 1 = Very Low)
2. Physical Demand - How physically demanding was the integration of AR into student learning? (21 = Very High, 1 = Very Low)
3. Temporal Demand - How hurried or rushed was the pace of the integration of AR into student learning? (21 = Very High, 1 = Very Low)
4. Performance - How successful were you in accomplishing what you were asked to do during the integration of AR into student learning? (21 = Failure, 1 = Perfect)
5. Effort - How hard did you have to work to accomplish your level of performance during the integration of AR into student learning? (21 = Very High, 1 = Very Low)
6. Frustration - How insecure, discouraged, irritated, stressed, and annoyed were you during the integration of AR into student learning? (21 = Very High, 1 = Very Low)

Appendix F Teacher Observation Questionnaire 4

Complete one questionnaire per science class integration. Each teacher will have completed two observation questionnaires. Thank you

Thank you for participating in the STEM/Augmented Reality Professional Development (ARPD) workshop. The questionnaire is designed to gain a baseline understanding of teachers experience with STEM education concepts and augmented reality tools. Participating in this study is completely voluntary. When participating in the study, participants will complete questionnaires that seek to understand the individual's knowledge and experiences with STEM and Technology education.

Chapter: ______________________________ Lesson: _____________________________

AR App: ______________________________Days of Implementation: _____________

1. I was confident in my knowledge and training to demonstrate how to use the AR App.
   (10 = Strongly Agree, 1 = Strongly Disagree)

2. I was comfortable teaching students how to work in the AR App.
   (10 = Strongly Agree, 1 = Strongly Disagree)

3. I was able to problem solve technical issues with the app.
   (10 = Strongly Agree, 1 = Strongly Disagree)

4. I was able to effectively integrate the AR App into my lesson.
   (10 = Strongly Agree, 1 = Strongly Disagree)

5. My students understood how to use the AR App.
   (10 = Strongly Agree, 1 = Strongly Disagree)

6. My students demonstrated a clear understanding of content form using the AR App
   (10 = Strongly Agree, 1 = Strongly Disagree)

7. My students were engaged in using the AR App
   (10 = Strongly Agree, 1 = Strongly Disagree)

8. My students were frustrated when using the AR App
   (10 = Strongly Agree, 1 = Strongly Disagree)

9. The AR App was an effective tool in delivering chapter content.
   (10 = Strongly Agree, 1 = Strongly Disagree)

10. The AR integration developed student STEM skills. (Ex. Creativity, Problem-solving)
    11. (10 = Strongly Agree, 1 = Strongly Disagree)

12. The integration of the AR App was a positive experience.
    (10 = Strongly Agree, 1 = Strongly Disagree)

Appendix G Teacher Post-Workshop Focus Group

Thank you for participating in the STEM/Augmented Reality Professional Development (ARPD) workshop. The questionnaire is designed to gain a baseline understanding of teachers experience with STEM education concepts and augmented reality tools. Participating in this study is completely voluntary. When participating in the study, participants will complete questionnaires that seek to understand the individual's knowledge and experiences with STEM and Technology education.

1. Thank you being part of the STEM/Augmented Reality Professional Development (ARPD) workshop modules. Can you reflect on your experience from the workshop? What were the positives and negatives of the workshop model?

2. What was the most beneficial part of the STEM/Augmented Reality Professional Development (ARPD) workshop?

3. Which module prepared you the best for AR integration in your classrooms? Did the professional development, and lesson planning framework assist you with AR integration?

4. What were some of the advantages of using the AR Apps in the classroom? What were some of the disadvantages?

5. What 21^{st} century STEM based skills did you see your students demonstrate through the use of the AR apps and activities?

6. Could you tell me about your experience integrating AR into your lessons?

7. Can you describe the student engagement with the AR App and activity?

8. How did the AR App change your instructional practices from your standard lesson planning and instruction?

9. What impact did the AR have on chapter test scores? (Can you compare prior test scores to the AR Chapter Scores?)

10. What feedback have the students given to you about the AR experience and learning?

11. Reflecting on the STEM/Augmented Reality Professional Development (ARPD) workshop and implementation of the AR App into classroom learning, what would you do differently next time?

12. What knowledge do you now have that you would suggest adding to the professional development?

Appendix H STEM Education Questionnaire Cross-section

Questionnaire 1 Pre-workshop	Questionnaire 2 Post-workshop	Questionnaire 3 Post-AR Integration	Compare & Analyze	Analysis & Trends
Q3: I have a strong understanding of STEM Education Principles	**Q5**: The STEM/ Augmented Reality Professional Development gave me a professional understanding of STEM principles and skills.	**Q32**: The STEM/ Augmented Reality Professional Development gave me a professional understanding of STEM principles and skills.	**Questionnaire 1** **Q3:** Mean - 6.67 **Questionnaire 2** **Q5:** Mean - 9.6 **Questionnaire 3** **Q32:** Mean - 9.5	The PD was effective in providing educators a strong understanding of STEM skills and principles. Very strong correlations between 2nd and 3rd data sets
Q5: I am comfortable integrating STEM concepts into my lessons **Q6: The development of STEM skills is an important part of my curriculum** **Q7: I use all disciplines of STEM in my instructional pedagogy**	**Q5**: The STEM/ Augmented Reality Professional Development gave me a professional understanding of STEM principles and skills. **Q7:** The STEM/ Augmented Reality Professional Development prepared me to effectively integrate STEM skills into chapter lessons.	**Q32**: The STEM/ Augmented Reality Professional Development gave me a professional understanding of STEM principles and skills. **Q7:** The STEM/ Augmented Reality Professional Development prepared me to effectively integrate STEM skills into chapter lessons.	**Questionnaire 1** **Q5:** Mean - 7.67 **Q6**: Mean - 8.17 **Q7:** Mean - 7.83 **Questionnaire 2** **Q5:** Mean - 9.67 **Q7:** Mean - 9.83 **Questionnaire 3** **Q32:** Mean - 9.5 **Q7:** Mean - 9.83	The PD was effective in providing educators a strong understanding of STEM skills and principles. The PD was effective in preparing educators to integrate STEM skills into curriculum. Very strong correlations between 2nd and 3rd data sets
Q9: My students demonstrate strong STEM skills (Ex. Creativity, Problem Solving, and Technology Literacy) **Q10: My students demonstrate how to apply STEM skills to solve complex problems**	**Q5:** The STEM/ Augmented Reality Professional Development gave me a professional understanding of STEM principles and skills. **Q9**: I can identify 21st century STEM skills my students are displaying in their learning.	**Q32:** The STEM/ Augmented Reality Professional Development gave me a professional understanding of STEM principles and skills. **Q31**: I can identify 21st century STEM skills my students are displaying in their learning.	**Questionnaire 1** **Q9:** Mean - 7.0 **Q10:** Mean - 6.5 **Questionnaire 2** **Q5:** Mean - 9.67 **Q9:** Mean - 9.0 **Questionnaire 3** **Q32:** Mean - 9.5 **Q31:** Mean - 9.5	The PD was effective in providing educators a strong understanding of STEM skills and principles. The PD effectively increased the educators' ability to identify student application of STEM skills and within the learning environment.

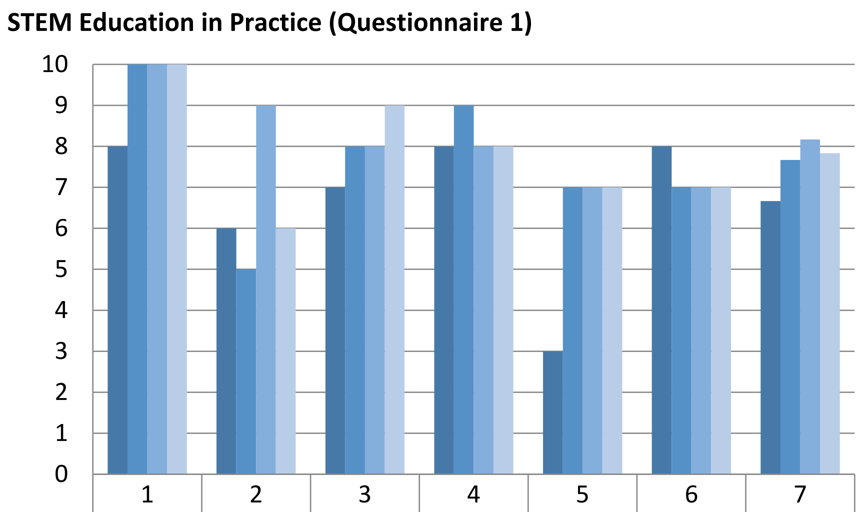
				Very strong correlations between 2nd and 3rd data sets

Appendix I : Augmented Reality - Data Cross-section

Questionnaire 1 Pre-workshop	Questionnaire 2 Post-workshop	Questionnaire 3 Post-AR Integration	Compare & Analyze	Analysis & Trends
Q11: I am comfortable integrating technology tools (Ex. Digital tablets) into my lesson	**Q 10:** I am comfortable implementing new technologies such as Augmented Reality in future lessons.	**Q5:** I was confident in my knowledge and training to demonstrate how to use Augmented Reality Tools? **Q9:** The STEM/Augmented Reality Professional Development prepared me to effectively integrate Augmented Reality Tools into chapter lessons. **Q10:** I am comfortable implementing new technologies such as Augmented Reality in future lessons.	**Questionnaire 1** **Q11:** Mean - 8 **Questionnaire 2** **Q10:** Mean - 9.17 **Questionnaire 3** **Q5:** Mean – 9.67 **Q9:** Mean – 9.83 **Q10:** Mean - 9.83	The Educators are comfortable with Technology. The PD was effective in providing educators a strong understanding of AR tools to implement into lessons. Very strong correlations between 2nd and 3rd data sets
Q12: I am familiar with Augmented Reality tools and applications	**Q6**: The STEM/Augmented Reality Professional Development prepared me to effectively identify viable AR tools and apps.	**Q6:** The STEM/Augmented Reality Professional Development prepared me to effectively identify viable AR tools and apps.	**Questionnaire 1** **Q12:** Mean – 5.17 **Questionnaire 2** **Q6:** Mean - 9.83 **Questionnaire 3** **Q6:** Mean - 9.83	The PD was effective in preparing educators to identify quality AR apps. Very strong correlations between 2nd and 3rd data sets
Q13: I am comfortable integrating Augmented Reality tools into my lessons	**Q3:** The STEM/Augmented Reality Professional Development prepared me to effectively integrate AR into chapter lessons.	**Q3:** The AR App increased student engagement in the lesson. **Q9:** The STEM/Augmented Reality Professional	**Questionnaire 1** **Q13:** Mean – 5.17 **Q14:** Mean – 4.5 **Questionnaire 2** **Q3:** Mean - 9.83 **Q11:** Mean - 9.5	The PD was effective in providing educators a strong understanding of how to use AR tools. The PD effectively prepared educators to

Q14: Augmented Reality is an important teaching tool in my classroom	**Q11**: Augmented Reality Apps are effective learning tools. **Q 10:** I am comfortable implementing new technologies such as Augmented Reality in future lessons.	Development prepared me to effectively integrate Augmented Reality Tools into chapter lessons. **Q11:** Augmented Reality Apps are effective learning tools. **Q5:** I was confident in my knowledge and training to demonstrate how to use Augmented Reality Tools?	**Q10:** Mean - 9.17 **Questionnaire 3** **Q3:** Mean - 9.83 **Q9:** Mean - 9.83 **Q11:** Mean - 9.67 **Q5:** Mean - 9.67	use AR tools in classroom learning and integration. Very strong correlations between 2nd and 3rd data sets

Appendix J : DATA SHEET - STEM Education in Practice



KEY:
0 - 10 Likert Scale

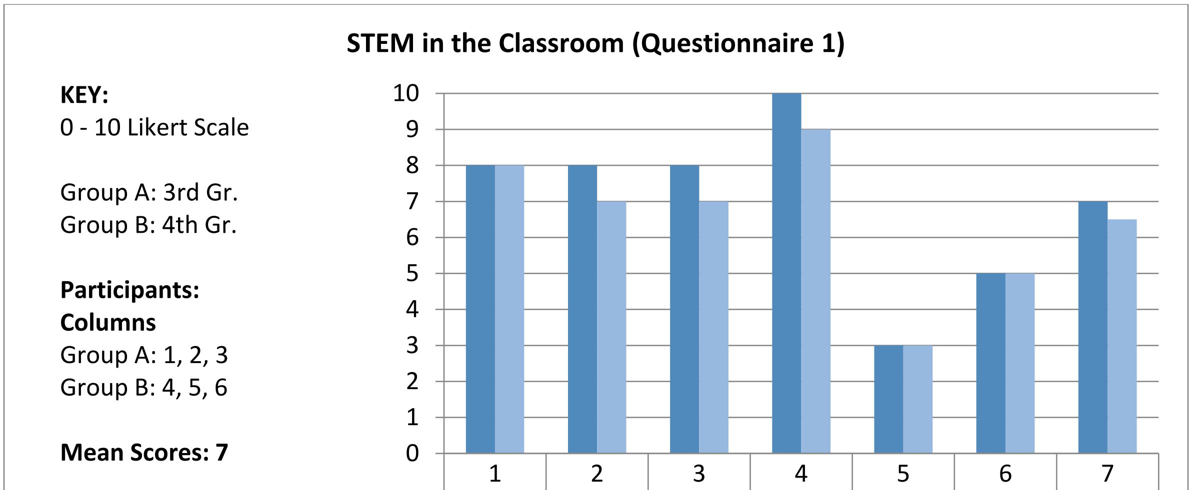
Group A: 3rd Gr.
Group B: 4th Gr.

Participants:
Columns
Group A: 1, 2, 3
Group B: 4, 5, 6

Mean Scores: 7

	1	2	3	4	5	6	7
Q3 - I have a strong understanding of STEM Education Principles	8	6	7	8	3	8	6.67
Q5 - I am comfortable integrating STEM concepts into my lessons	10	5	8	9	7	7	7.67
Q6- The development of STEM skills is an important part of my curriculum	10	9	8	8	7	7	8.17
Q7 - I use all disciplines of STEM (Science, Technology, Engineering, Math) in my instructional pedagogy	10	6	9	8	7	7	7.83

Appendix K : Data Sheet - STEM in the Classroom



	1	2	3	4	5	6	7
Q9 - My students demonstrate strong STEM skills (Ex. Creativity, Problem Solving, and Technology Literacy)	8	8	8	10	3	5	7.00
Q10 - My students demonstrate how to apply STEM skills to solve complex problems	8	7	7	9	3	5	6.50

Appendix L : Data Sheet - Educator Perspectives of STEM Education After Workshops

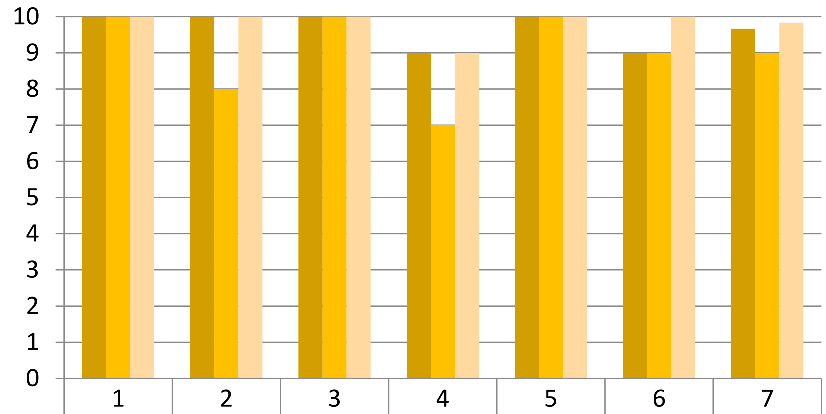
Educator Perspectives of STEM Education After Workshops (Questionnaire 2)

KEY:
0 - 10 Likert Scale

Group A: 3rd Gr.
Group B: 4th Gr.

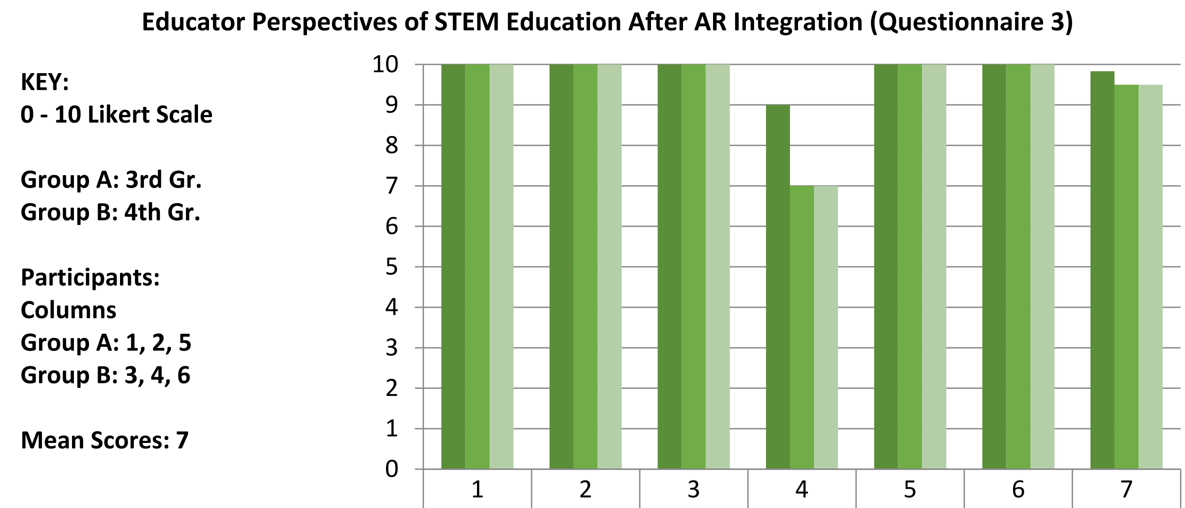
Participants:
Columns
Group A: 1, 2, 3
Group B: 4, 5, 6

Mean Scores: 7



	1	2	3	4	5	6	7
Q5 - The STEM/Augmented Reality Professional Development gave me a professional understanding of STEM principles and skills.	10	10	10	9	10	9	9.67
Q9 - I can identify 21st century STEM skills my students are displaying in their learning.	10	8	10	7	10	9	9.00
Q7 - The STEM/Augmented Reality Professional Development prepared me to effectively integrate STEM skills into chapter lessons.	10	10	10	9	10	10	9.83

Appendix M : Data Sheet - Educator Perspectives of STEM Education After AR Integration



	1	2	3	4	5	6	7
Q7 - The STEM/Augmented Reality Professional Development prepared me to effectively integrate STEM skills into chapter lessons.	10	10	10	9	10	10	9.83
Q32 The STEM/Augmented Reality Professional Development gave me a professional understanding of STEM principles and skills.	10	10	10	7	10	10	9.50
Q31 I can identify 21st century STEM skills my students are displaying in their learning.	10	10	10	7	10	10	9.50

Appendix N : Educator AR

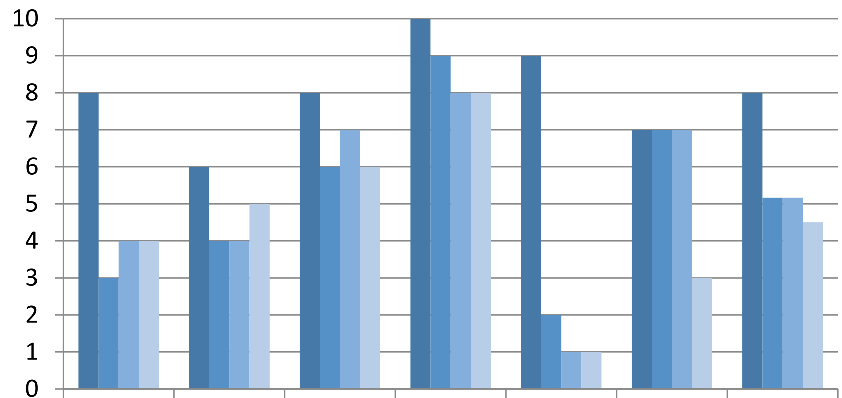
Educator - Augmented Reality (Questionnaire 1)

KEY:
0 - 10 Likert Scale

Group A: 3rd Gr.
Group B: 4th Gr.

Participants:
Columns
Group A: 1, 2, 3
Group B: 4, 5, 6

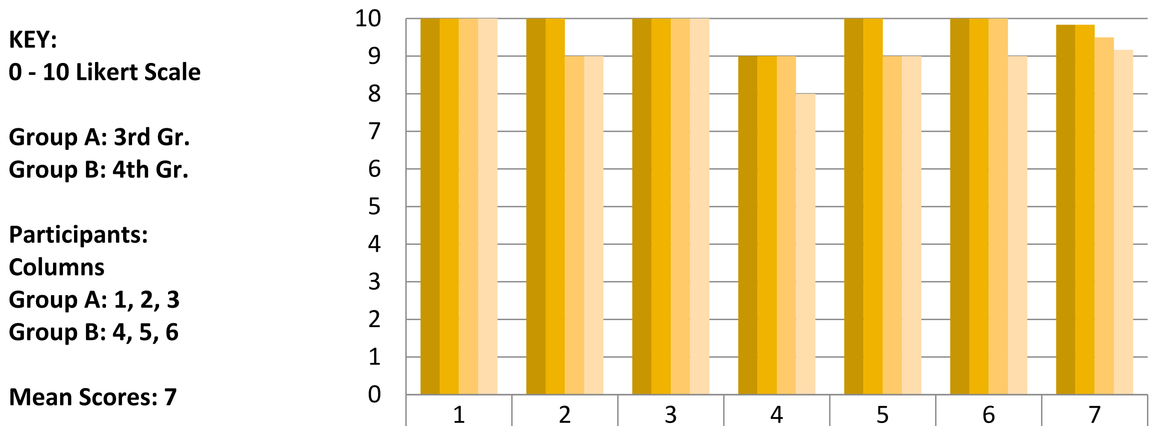
Mean Scores: 7



	1	2	3	4	5	6	7
Q11 I am comfortable integrating technology tools (Ex. I-pads) into my lessons	8	6	8	10	9	7	8.00
Q12 I am familiar with Augmented Reality tools and applications	3	4	6	9	2	7	5.17
Q13 I am comfortable integrating Augmented Reality tools into my lessons	4	4	7	8	1	7	5.17
Q14 Augmented Reality is an important teaching tool in my classroom	4	5	6	8	1	3	4.50

Appendix O : AR Professional Development

Augmented Reality Professional Development (Questionnaire 2)



	1	2	3	4	5	6	7
Q6 - The STEM/Augmented Reality Professional Development prepared me to effectively identify viable AR tools and apps.	10	10	10	9	10	10	9.83
Q3 - The STEM/Augmented Reality Professional Development prepared me to effectively integrate AR into chapter lessons.	10	10	10	9	10	10	9.83
Q11 - Augmented Reality Apps are effective learning tools.	10	9	10	9	9	10	9.50
Q10 - I am comfortable implementing new technologies such as Augmented Reality in future lessons.	10	9	10	8	9	9	9.17

Appendix P : AR Post-Integration

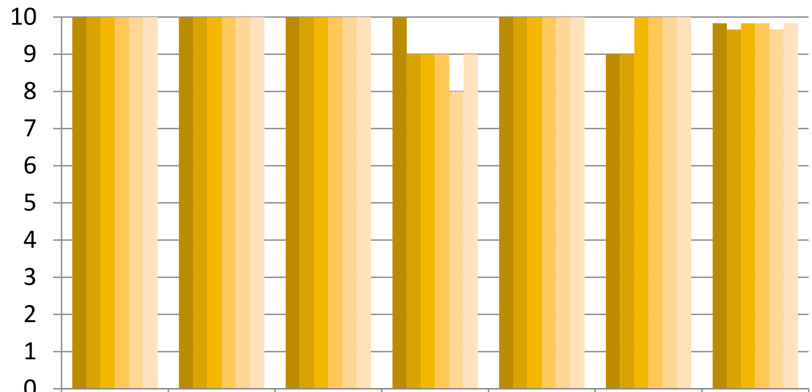
Augmented Reality Post-Integration (Questionnaire 3)

KEY:
0 - 10 Likert Scale

Group A: 3rd Gr.
Group B: 4th Gr.

Participants:
Columns
Group A: 1, 2, 5
Group B: 3, 4, 6

Mean Scores: 7

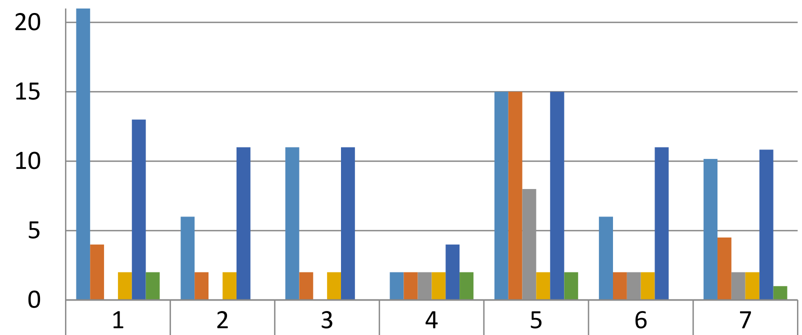


	1	2	3	4	5	6	7
Q3 - The AR App increased student engagement in the lesson.	10	10	10	10	10	9	9.83
Q5 - I was confident in my knowledge and training to demonstrate how to use Augmented Reality Tools?	10	10	10	9	10	9	9.67
Q9 - The STEM/Augmented Reality Professional Development prepared me to effectively integrate Augmented Reality Tools into chapter lessons.	10	10	10	9	10	10	9.83
Q6 - The STEM/Augmented Reality Professional Development prepared me to effectively identify viable AR tools and apps.	10	10	10	9	10	10	9.83
Q11 - Augmented Reality Apps are effective learning tools.	10	10	10	8	10	10	9.67
Q10 - I am comfortable implementing new technologies such as Augmented Reality in future lessons.	10	10	10	9	10	10	9.83

Appendix Q : Task Load Index: Augmented Reality Integration

Task Load Index: Professional Development

KEY:
0 - 21 Point Scale
Group A: 3rd Gr.
Group B: 4th Gr.
Participants: Columns
Group A: 1, 2, 3
Group B: 4, 5, 6
Mean Scores: 7



	1	2	3	4	5	6	7
TLX 1 - Mental Demand - How mentally demanding was the professional development training?	21	6	11	2	15	6	10.17
TLX 2 - Physical Demand - How physically demanding was the professional development training?	4	2	2	2	15	2	4.50
TLX 3 - Temporal Demand - How hurried or rushed was the pace of the professional development training?	0	0	0	2	8	2	2.00
TLX 4 - Performance - How successful were you in accomplishing what you were asked to do during professional development training?	2	2	2	2	2	2	2.00
TLX 5 - Effort - How hard did you have to work to accomplish your level of performance during professional development training?	13	11	11	4	15	11	10.83
TLX 6 - Frustration - How insecure, discouraged, irritated, stressed, and annoyed were you during professional development training?	2	0	0	2	2	0	1.00

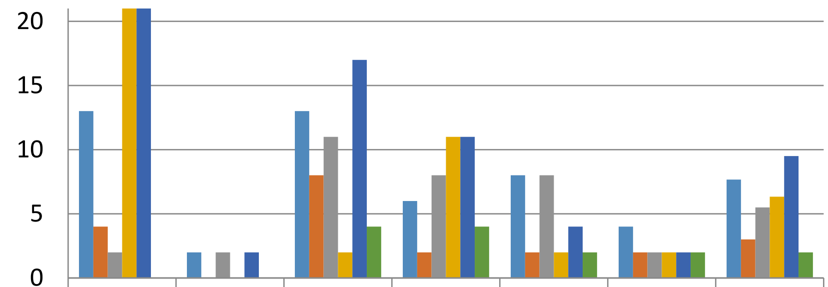
Appendix R : Task Load Index: Augmented Reality Integration

Task Load Index: Augmented Reality Integration

KEY:
0 - 21 Point Scale

Group A: 3rd Gr.
Group B: 4th Gr.

Participants:
Columns
Group A: 1, 2, 3
Group B: 4, 5, 6
Mean Scores: 7



	1	2	3	4	5	6	7
TLX 1 - Mental Demand - How mentally demanding was the integration of AR into student learning?	13	2	13	6	8	4	7.67
TLX 2 - Physical Demand - How physically demanding was the integration of AR into student learning?	4	0	8	2	2	2	3.00
TLX 3 - Temporal Demand - How hurried or rushed was the pace of the integration of AR into student learning?	2	2	11	8	8	2	5.50
TLX 4 - Performance - How successful were you in accomplishing what you were asked to do during the integration of AR into student learning?	21	0	2	11	2	2	6.33
TLX 5 - Effort - How hard did you have to work to accomplish your level of performance during the integration of AR into student learning?	21	2	17	11	4	2	9.50
TLX 6 - Frustration - How insecure, discouraged, irritated, stressed, and annoyed were you during the integration of AR into student learning?	0	0	4	4	2	2	2.00

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