# EXPERIENCES OF SECONDARY MATH TEACHERS IMPLEMENTING AN ADAPTIVE PERSONALIZED LEARNING TOOL

A Record of Study

by

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ABSTRACT

The role of the teacher has become increasingly crucial in the effective implementation of personalized learning with technology.  Teachers are the program facilitators in the classroom. However, research is limited in regard to understanding teachers' lived experiences as they relate to technology integration practices and the particular use of personalized learning adaptive programs.  This qualitative study was conducted to understand high school teachers' experiences in implementing adaptive personalized resources by allowing the teachers' voices to be heard concerning their insights into implementation.  Specifically, this phenomenological study was an exploration of three high school teachers' perceptions of implementing a personalized learning resource to increase academic knowledge.  These three teachers were purposefully selected to participate in unstructured interviews and classroom observations.  The analytical focus was on finding patterns of similarities and differences to understand their perceptions and experiences of the adaptive personalized learning resource. The findings showed that the three teachers' lived experiences with the personalized adaptive resource included three main conclusions. These were (a) teachers experienced buy-in to the mathematics adaptive learning tool; (b) teachers experienced realization of student knowledge, and (c) teachers experienced realization that the use of ALEKS in their teaching supported student self-regulation. The changes in teaching and learning included two main conclusions: (a) teachers experienced shifts in instruction, and (b) teachers experienced a change in culture.

## DEDICATION

To my husband, Richard, whose support and unshakeable faith in me has helped me turn my dream of a doctorate into a reality. Thank you for making me laugh when I often wanted to cry. I want you to know how much it means to me that you always believe in me. I could not have done this without your love, support, and gourmet dinners. You mean the world to me. I love you madly!

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"You're braver than you believe, stronger than you seem and smarter than you think."

~Christopher Robin

## NOMENCLATURE

| | |
|---|---|
| ACT | American College Testing |
| ALEKS | Assessment and Learning in Knowledge Spaces |
| CAI | Computer-assisted instruction |
| ESEA | Elementary and Secondary Education Act |
| ESSA | Every Student Succeeds Act |
| ICT | Information and communication technology |
| ITS | Intelligent tutoring system |
| NCLB | No Child Left Behind |
| NETP | National Education Technology Plan |
| PD | Professional development |
| PL | Personalized learning |
| TAM | Technology acceptance model |
| TPACK | Technological pedagogical content knowledge |

# CONTRIBUTORS AND FUNDING SOURCES

## Contributors

This work was supervised by a record-of-study committee consisting of Rhadika Viruru (chair), Monica Neshyba (cochair), and Emily Cantrell (committee member) of the department of teaching, learning, and culture of Texas A&M University. Noelle Sweany of the department of educational psychology of Texas A&M University also served as a committee member. All the research and development of this record of study was completed by the student.

## Funding Sources

McGraw Hill Education funded the digital adaptive resource related to this research.

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# CHAPTER I

## INTRODUCTION: LEADERSHIP CONTEXT AND PURPOSE OF THE ACTION

A severe disruption in education occurred in the 1980s and 1990s due to the introduction of computer and internet technologies into society. For the past 30 years, since that new wave of technological advancement began, U.S. education performance has steadily declined (Fullan, 2012). Additionally, the worldwide movement from a print to a digital society has changed the workforce demands for certain occupations in the fields of science, technology, engineering, and mathematics (Bahng & Lee, 2017). In 2019, the National Assessment of Education Progress reported that only 33% of eighth graders were proficient in math. Moreover, eighth-grade mathematics scores in the United States have not significantly changed since 2007. The stagnant and below-proficiency rate of eighth-grade students is problematic (National Center for Education Statistics, 2018). Students below proficiency have a difficult time applying mathematical concepts and procedures and successfully participating in high school mathematics classrooms. Comparatively, the mathematics performance of American teenagers still significantly lags behind other industrialized international counterparts (Mullis, Martin, Foy, & Arora, 2012). These reports highlight a significant issue in both education and society.

These issues were highlighted in Bybee and Stage's (2005) landmark article "No Country Left Behind," which focused on international comparisons and was based on the results of two high-stakes tests (i.e., Trends in International Mathematics and Science Study and Program for International Student Assessment). These assessments showed the United States ranked 24th out of 29 member nations. The United States continues to rank low in math in comparison to other industrialized nations, ranking 38th out of 71 on the 2015 Program for International Student Assessment. In addition, American College Testing (ACT, 2018) reported that high school graduates were not prepared for higher education and readiness levels in math had steadily declined since 2014. The declining scores highlighted in these reports have garnered much attention and have fostered movements by administrators, teachers, and policy makers toward the reformation of math instruction and learning to ensure the success of every student regardless of race, ethnicity, or socioeconomic status.

## Defining the Problem

Reform has been a popular topic in the American school system for several decades. Specifically, discussion has centered on restructuring the century-old classroom model in order to free teachers of habitual methods. Traditionally, teachers lecture or model concepts in front of a class of diverse learners. Andreas Schleicher (2018), director of education and skills at the Organization for Economic Cooperation and Development, posited that low math proficiency rates point to the method by which math is taught in the United States. Higher ranking countries, he noted, teach fewer learning targets but teach them with increased depth. Increased depth leads to greater retention and application of math knowledge. However, teaching deeper with fewer learning targets fails to impart the varied skills and motivation levels required by the diverse needs of today's learners. Many secondary students in the U.S. enter higher level math classes lacking confidence in math and are hampered by gaps in basic whole number arithmetic and mathematical reasoning (Arroyo, Woolf, Burleson, Muldner, Rai, & Tai, 2014). The researchers argued that varied skill levels and gaps in mathematical foundations create ongoing challenges for high school teachers attempting to meet individual needs. Targeting students' individual mathematical differences, strengths, and gaps requires more than the one-size-fits-all traditional schooling model. Moreover, new technology is now available to individually assist students at a pace that works for them. In 2010, former U.S. Secretary of Education Arne Duncan stated:

> Our K–12 system largely still adheres to the century-old, industrial-age factory model of education. A century ago, maybe it made sense to adopt seat-time requirements for graduation and pay teachers based on their educational credentials and seniority. Educators were right to fear the large class sizes that prevailed in many schools. However, the factory model of education is the wrong model for the 21st century. Today, our schools must prepare all students for college and careers—and do far more to personalize instruction and employ the smart use of technology. (para. 22)

In rethinking the status quo, educational institutions have turned to technology as a resource to enhance teaching and learning (Anderson & Maninger, 2007). The National Council of Teachers of Mathematics (2011) stated, "Technology is essential in teaching and learning mathematics; it influences the mathematics that is taught and enhances students' learning" (p. 24). However, supplying schools with technology, online programs, and applications will not transform or positively change teaching and learning in and of itself (Tucker, Wycoff, & Green, 2017). A need exists to move beyond using technology to merely mimic the way in which math has always been taught. By incorporating innovative pedagogies and new technologies, teachers have the potential to instruct, assess, and engage students in new education models.

**National Context**

Eliminating the problem of merely mimicking teaching techniques with technology in the United States requires innovative solutions and reframing (Cuban, 2001) to meet the diverse needs of an interdependent and technologically integrated nation (Pletka, 2007). To address the various levels of students' mathematical academic needs, growing empirical evidence has supported using adaptive tutoring software to enhance personalized learning (PL) experiences and alter attitudes toward mathematics (Arroyo, Burleson, Tai, Muldner, & Woolf, 2013).

**Personalized learning using adaptive technology as a solution**. Adaptive technology and educational legislation have generated alternate pathways for teaching mathematics. Adaptive technology supports learner-centered instruction and is being used to target individual students' mathematical differences and provide instruction based on the needs of each learner (DeWitte, Haelermans, & Rogge, 2015). Using adaptive technology, students work at their own pace, utilize the resources available to take control of their learning, and receive frequent and individualized feedback on their progress (Horn & Staker, 2011). Significantly, a comprehensive review of research on K–12 classrooms across the country over the past 2 decades showed an increased use of adaptive technology to raise academic performance in mathematics (Cheung & Slavin, 2013).

PL, which relies heavily on adaptive technology, is a student-centered approach to learning that results in a fundamental shift in how education is delivered by a teacher. The emergence of PL, based on its use of computer-based adaptive learning systems, has changed the underlying processes for teaching and learning in the 21st century. As Bingham (2017) noted, "In recent years, there has been an increase in the popularity of personalized learning (PL) and educational technology in American K–12 schools" (p. 521). Instead of class consumption of content through a lecture, students have more opportunity to learn at their own pace, more control over how they receive instruction, and more relational connections to peers and teachers.

PL that utilizes technology in education is not new. In 1958, Skinner successfully demonstrated how "teaching machines" could be used to provide students with individual instruction. Since then, computer-assisted instruction (CAI) has been studied. As a model for learning in the 21st century, personalized adaptive learning, an updated version of CAI, is intended to provide adaptive instruction tailored to "students' [unique] strengths, needs and interests through the use of interactive digital resources and frequent and varied use of student data" (Bingham, 2017, p. 523). The dynamic technological learner-centered approach empowers teachers and students with valuable, timely student data that can be used to set individual progress goals, monitor learning, and target instruction (Abawi, 2015). Those educators who support PL claim it improves learning for all students, whether below, on, or above level (U.S. Department of Education, 2015). However, to reach the full potential of every learner, teachers must promote innovative PL opportunities aimed at creating an environment that fosters learning for all students.

PL using computer-based adaptive learning systems is now an option for schools and provides new opportunity for diminishing gaps and accelerating learning. Many of the math adaptive software initiatives are specifically focused on tackling low mathematics algebra skills (Pane, Griffin, McCaffrey, & Karam, 2014). Low algebra skills and high failure rates are a concern in ninth-grade classrooms nationwide (Nomi & Allensworth, 2013). Most importantly, Algebra 1, a standard requisite ninth-grade class, is considered a gateway to advanced mathematics, science courses, and success in higher education, college-bearing courses (Paul, 2005). To enhance mathematical knowledge, it is important for teachers to understand how to effectively leverage technology to deliver PL and transform the experience for all learners. When making learning pathway decisions for individual learners, teachers should use data analytics from the digital resources, consider the social and emotional development of learners, and rely on hands-on, problem-solving experiences.

**Redesigning the education model with technology**. The role of the teacher is increasingly critical in the effective implementation of PL with technology. According to a study by Hanover Research (2014), when implementing PL, the traditional role of the teacher must expand to include the role of instructional facilitator. As the instructional facilitator, a teacher coaches and advises. The teacher as coach helps students develop metacognitive skills. The teacher as adviser in matters beyond academics also assists with social matters (Hanover Research, 2014).

Gross and DeArmond (2018) identified a gap in information on how to best support K–12 teachers implementing innovative PL models in the classroom. Ultimately, teachers decide when and how to use technology for effective implementation and instruction (Kim, Kim, Lee, Spector, & DeMeester, 2013). According to Tondeur, Van Braak, Ertmer, and Ottenbreit-Leftwich (2017), an instructor's pedagogical beliefs form the foundation of technology use in classroom practices and need to be addressed to understand the critical role teachers play in technology integration. Use of technology may challenge existing beliefs and require an instructor to embrace a second order change— "change that confronts teachers' fundamental beliefs and thus, requires new ways of both seeing and doing things" (Ertmer, 2005). Many teachers have not accumulated enough technological expertise within PL, so changing practice is difficult. The examination of teacher beliefs and the link to implementation of information technology seemed critical to explore as new policies redefine good teaching (i.e., U.S. Department of Education, Office of Educational Technology, 1996, 2016, 2017). Cultivating educational views favorable to increased technology use must begin with understanding the nature of teachers' beliefs. If educators have a strong belief that knowledge is grounded in authority, they will have a difficult time promoting adaptive PL environments (Kim et al., 2013).

Technology in teacher-centered classrooms inevitably ends with augmentation of the traditional model of mathematics instruction. Therefore, to support use of PL, researchers must better understand how teachers use personalized adaptive resources to target student needs.

Research on teachers' lived experiences related to technology integration practices and the particular use of PL adaptive programs was limited. Although it is the teachers themselves who typically decide to adopt or deny classroom technology, very little research existed that highlighted PL and the impact it has on teachers (Courcier, 2007; Fisher & White, 2017; Jenkins, Williams, Moyer, George, & Foster, 2016). The few studies that did examine teacher experiences were conducted by researchers whose organizations promote PL. In one such study, Jenkins et al. (2016) explored the voices and perceptions of teachers, administrators, and coaches across the nation who implemented PL. Prior to delivery of PL, teachers without formal training in PL researched best practices. Jenkins et al. (2016) found that, within their local contexts, teachers created a relevant PL model. Overwhelmingly, educators within the study emphasized that PL environments would be impossible without technology, individualized support, and flexibility. As demonstrated in the interviews, Jenkins et al. (2016) highlighted the power of teachers to transform teaching and learning when given parameters and support. The study also demonstrated that as the drivers of innovative ideas in their classrooms, teachers can create classrooms to help all students succeed.

In another study, Fisher and White (2017) identified six themes that emerged from 150 teacher and leader conversations over the course of one day: (a) embrace not knowing; (b) codesign; (c) cultivate early adopters; (d) open doors; (e) rethink roles; (f) make time. The themes highlighted how to engage and manage change in blended learning and PL environments. Technology was mentioned as a tool used in implementing blended and PL environments;

however, it was not the most important element. Instead, the core of the next-generation environments related to managing human resources across the entire school community. A similar study, "Personalized Learning at a Crossroads," was funded by the Bill and Melinda Gates Foundation, which has demonstrated an interest in technology integration (Gross & DeArmond, 2018). The 2-year study was conducted by Gross and DeArmond (2018), who examined both the Next Generation Systems Initiative and the Regional Funds for Breakthrough Schools Initiative. The study consisted of interviews, observations, and focus groups across the nation and involved 39 schools and 17 cities. The aim was to understand the early stages of implementing a PL initiative. Gross and DeArmond (2018) showed that very few schools successfully transformed teaching and learning because the school systems involved were not designed for innovation. In order to truly facilitate change in teaching and learning, significantly more research was necessary to understand both teacher experiences in adaptive personalized environments and the designing systems for innovation.

**Situational Context**

In an effort to increase mathematical achievement and support diverse mathematical learning needs, the math faculty and administration at a high school with the pseudonym St. Francis High School piloted the Assessment and Learning in Knowledge Spaces (ALEKS) platform, a web-based intelligent tutoring system (ITS). A pseudonym was used for the high school and teachers to protect the privacy of those who participated. The pilot took place during the 2018–2019 school year. At that time, St. Francis High School's math department consisted of three experienced math teachers, all of whom were the focus of the study.

The pilot goal was for students to use the personalized adaptive resource to meet individual learning needs, fill knowledge gaps, and allow students to work at their own pace.

Using artificial intelligence in a cycle of assessment and learning, ALEKS assesses students' current knowledge and areas for growth in a particular math course. ALEKS delivers students a personalized pathway on the exact topics where they are most ready to learn. Students will not start on the same topic. The program is predicated on the notion that there are multiple pathways to accomplish a series of learning objectives. Additionally, the use of ALEKS can aid in building conceptual understanding and increase higher order thinking and competence. By setting learning and progress goals for students to monitor, the school leaders hoped to empower students to take responsibility for their own learning, create math confidence, and increase student achievement as measured by the ACT Aspire Test.

Established in 2003, St. Francis was a catholic high school located in Southern Arizona and comprised of a diverse student population. As of 2019–2020, enrollment at the 4-year college preparatory high school was 281 students in Grades 9 through 12. Of the 281 students, 210 identified as Hispanic/Latino (74%). About 90% of the student population received some sort of tuition assistance—mostly through Arizona's tax credit program. Students came from a variety of educational institutions throughout the greater Tucson area. More than half of the student body transferred from catholic elementary schools (52%). The remainder of the student body arrived from public schools (30%), charter schools (12%), Christian schools (4%), and home schools (2%). Consequently, students came to St. Francis High School with varying levels of mathematical readiness and experience.

St. Francis' college preparatory vision was to provide a challenging academic environment that encouraged Christian growth. In math, students had the option of college preparatory classes or honor classes. All math courses were designed to be college preparatory in nature to ensure the preparedness for credit-bearing college or university math courses.

However, some students had gaps in their mathematical knowledge and were not ready for the rigorous college preparatory work offered at the high school. Based on the variety of schools that feed into St. Francis, students entered the school with varying degrees of math competency and knowledge gaps.

## The Problem

Traditional teaching and learning strategies have not been sufficient enough to tackle individual students' math differences at St. Francis High School. Personalized student-centered learning using digital technology appeared promising. This phenomenological qualitative study was undertaken to understand teachers' experiences and insights in implementing an adaptive personalized mathematical resource and to allow their insights into implementation to be heard. Teachers are the program facilitators in the classroom, so if classroom reforms are to be successful, teacher participation is critical (Davis, 1989; Hart, 1995).

PL requires more than the addition of adaptive technology and digital resources (Basham Hall, Carter Jr., & Stahl, 2016). Personalized, adaptive student-centered learning requires a change in pedagogy—the way individual students learn within a culture (Fullan & Edwards, 2017). This change in the process of teaching and learning places an "enormous pedagogical and procedural burden on the students—as well as the teacher" (Basham et al., 2016, p. 128).

In successful PL environments, the role of the student shifts from receiving information to interacting with the teacher and the technology to regulate learning. Developing self-regulation is critical in PL environments. Students need tools to foster their own agency (Dabbagh & Kitsantas, 2005). This modification requires educators to effectively use technology in their practice to make instructional decisions that maximize the full benefits available to all digital learners (U.S. Department of Education, Office of Educational Technology, 2017).

However, pedagogical approaches to technology integration are often channeled by old paradigms within a traditional school model. Many traditional teachers assign a low value to technology use for student learning, lack self-efficacy in using technology for learning, and worry about standardized tests. Sadeck and Cronjé (2017) found that teachers were using technology for learners in more traditional activities that aligned with their teaching style rather than engaging learners with the technology for learning. If school systems do not redefine teaching and learning through the effective use of technology, today's youth will be continually challenged as they try to succeed in higher level math and science classes and in a global economy. For the implementation of new information and communication technologies (ICTs) to be effective, instructors must move away from the outmoded mentality of the traditional educator who teaches textbook knowledge through step-by-step demonstration of procedures and instead adopt the roles of coordinator and moderator (Tomczyk et al., 2017). Redesigned teacher and student roles should focus on individual learner outcomes.

One size does not fit all. Adaptive technology does not eliminate the necessity of teachers; rather, it redefines their role. Because technology alone does not motivate students, the teacher is vital in the learning design (Basham et al., 2016). The methods by which teachers utilize tools and apply data to enhance instruction is crucial. Teachers use the data to provide frequent feedback, mentoring, counseling, and evaluation in order to reach every student. Using personalized tools and data, teachers become engagers, advisers, and coaches.

In PL classrooms, students are at the center of the learning environment and have some control over their learning. Instead of waiting for the teacher to present an all-encompassing curriculum, students can use adaptive technology with differentiated instruction to fill learning gaps and extend learning to higher levels. Intelligent tutoring systems are computer-assisted learning environments that are created using computational models (Steenbergen-Hu & Cooper, 2013). Educators can personalize intelligent tutoring systems to provide students individualized learning instruction with space and time to think critically and deeply about what they are learning. As students respond with information, an ITS adapts and adjusts to assist and meet the needs of the individual learner (Shute & Zapata-Rivera, 2007). Immediate guidance is provided on demand in the form of feedback, hints, and error messages for each student. Thus, the self-paced experience is personalized with electronic support (VanLehn, 2006). Steenbergen-Hu and Cooper's (2013) meta-analysis of empirical research on the effectiveness of ITSs provided further evidence that educational technology might be best used to support teaching and learning.

The classroom requires adequate space for students to learn with and without adult intervention and support. In PL environments, control over learning shifts to the students who have some choice of lesson and some control over how they learn. Research has indicated that students achieve higher levels when research-based, student-centered instruction is implemented (Odom & Bell, 2015; Polly et al., 2015; Wright, 2011).

**Relevant History of the Problem**

During the 2018–2019 school year, St. Francis High School's incoming ninth graders' standardized test scores were well below the state average. Moreover, these ninth-grade students underperformed on the ACT Aspire Test in mathematics as compared to the rest of Arizona. The freshman math teacher spent the first 3 months of the school year reviewing prerequisite knowledge and skills with all students utilizing a traditional mathematics approach. After spending 3 months reviewing skills, the teacher and students were unable to fully cover required course content. Use of direct instruction associated with content coverage did not meet the academic needs of all students because several students had significant knowledge gaps.

The administration and the mathematics department sought to find a technology-based tool to make learning more effective and allow for individualized student learning. At the beginning of the second semester of the 2018–2019 school year, the administration and high school math teachers decided to pilot ALEKS, an adaptive personalized mathematics resource designed to ensure mastery and aid to increase student achievement. The corporation that developed ALEKS provided a free pilot for the initial introduction and for summer school program use. During spring 2019, the staff spent time training, implementing, and enhancing familiarity with ALEKS. The school continued to use the resource throughout the summer of 2019 to target the unique learning needs of incoming freshmen. The summer school program for incoming freshmen was implemented by the Algebra 1 teacher and a parent volunteer. The knowledge gained during the 4-week summer program through the use of ALEKS was expected to accelerate learning and create momentum as freshmen entered the 2019–2020 school year.

At the start of the 2019–2020 school year, all students in Algebra 1, Algebra 2, Geometry, and Precalculus began using ALEKS in their grade-level courses. To create a PL pathway, students completed an initial knowledge check to assess their current mastery knowledge of a course. Using knowledge space theory, ALEKS's artificial intelligence engine pinpoints knowledge gaps and refines the way topics are uniquely related, creating a learning pathway for each student on the topics where he or she is most ready to learn. The artificial intelligence program continuously assesses a student's abilities, ensuring a mastery rate of more than 90%. The student data populated in ALEKS empower teachers to easily and effectively differentiate instruction for students with diverse academic needs.

**Significance of the Problem**

During the Spring of 2019, two of the three high school math teachers at St. Francis High School piloted the adaptive personalized mathematics resource. In the fall of 2019, a third teacher, new to the school, expressed interest in participating. The purpose of this phenomenological qualitative study was to explore and understand the professional learning and practice of these high school math teachers who implemented an adaptive PL resource in their mathematics classroom to support all learners—from intervention to enrichment. The participants in this study were three high school math teachers at the same high school. Two of the teachers were in their second year of implementing the digital resource as part of the pilot program. One of the teachers, new to St. Francis, joined the pilot in the fall of 2019. The participants were suitable for this study because of their experiences and because they self-initiated the use of the adaptive resource. A phenomenological research design was appropriate for this study because it supported understanding teachers' experiences, feelings, beliefs, and convictions about adaptive learning technologies. To better understand the teachers' lived experiences with ALEKS, classroom observations with debriefing sessions and teacher interviews were conducted.

## Research Questions

The following research questions guided the study at St. Francis High School.

1. What are the lived experiences (i.e., instruction, practice, and learning) of high school teachers using the mathematics adaptive personalized learning tool?
2. What changes in teaching and learning have high school teachers experienced through the use of the mathematics adaptive personalized learning tool in their classrooms?

## Personal Context

To maintain anonymity, the teachers and the selected school were given pseudonyms. The personalized mathematics program in this study was referred to as ALEKS. The potential for bias in this study existed since I am an employee of the company that promotes ALEKS, and I am acquainted with the principal at St. Francis. The high school teachers and administrators at St. Francis selected ALEKS to target the low math skills and standardized test scores of incoming ninth graders. As a PL specialist for the education company that promotes ALEKS, I set up the pilot program for St. Francis. My relationship with the principal at St. Francis provided me easy access to the participants. Prior to the study, I met with the principal, vice principal, and other participants to explain ALEKS, set up the pilot, and provide initial training. Training consisted of one 3-hr after-school session for two high school teachers, the vice principal, and the principal. Because of my relationship with the principal and the previous selection of an adaptive digital resource to pilot, I invited the administrators and teachers to participate in this study. The administrators and specific teachers were selected because they were already utilizing ALEKS.

### Personal History

After 15 years of teaching, I left the classroom in 2008 and began a journey into the digital landscape. I spent a great deal of time helping educators and administrators understand why there was a need to shift the art of education away from the 20th-century factory model to a 21st-century blended learning model. My first stop on this journey was employment with Promethean, a global interactive education technology company. I was extremely excited about an opportunity to share new and innovative technology with teachers. I felt like a magician with a wand that mysteriously made things move, appear, and disappear. With a few clicks and a few steps—voilà! Magic! The Promethean active classroom is used to actively engage students with interactive whiteboards, sound systems, and clickers. Training sessions focused on sharing the resources, using the pen, highlighter, textboxes, sound, images, and the layers (e.g., magic ink, translucency slider, restrictors) to engross the students. Teachers embraced the innovation, collaboration, and learning. Students loved the engaging lessons and the atmosphere of an interactive classroom. Often, I would get enthusiastic celebrations and praise from the students. "I love what you did in my class today! When are you coming back?" I remember teaching a glow-in-the-dark math lesson using a black background and colored text. The students were engaged and excited about doing glow-in-the-dark math, but, in retrospect, it was still a traditional lesson—a modified 20th-century lesson—that simply incorporated engaging techniques.

Reflection on those first 4 years, coupled with my growing understanding of technology integration, led me to realize that Promethean's tools allowed teachers a starting point for rationalizing technology in education. The Promethean tools were simply substitutions for other tools in the classroom, with no functional change in the actual teaching and learning methodology. The level of student engagement increased, but students still received information passively. For the most part, teachers expressed enthusiasm about using the Promethean board and associated software products because it did not challenge or change their existing teaching and learning methodology.

I quickly realized this new technology represented only the beginning of a transformation in education. The shift was exciting, and I was eager to be a part of that change. As my mindset shifted, so did my place of employment. I enthusiastically joined a different education company as a member of the technology integration team. This change felt a bit like stepping back into the Wild West. I worked with various districts and spirited teachers who were willing to be challenged and aspired to be better. During the first year, goals and outcomes encouraged the creation of technology-rich lessons and the exploration of options using innovative technology tools. Professional development (PD) sessions opened the door to collaborative conversations. Teachers shared their successes and failures, reflected on personal practices, and examined the blending of educational technology using Puentedura's (2014) substitution, augmentation, modification, and redefinition. This dialogue led to a synergistic balance between technology tools and effective teaching practices using those tools. Teachers in various grade levels worked to design technology-rich lessons to be shared with students and actively engaged with in-depth discussions about effective technology integration and how to advance beyond their current skill level. These sessions gave teachers a space to rethink teaching and learning. Lessons reflected the teacher's technological skills and willingness to take risks. My workdays in PD were filled with energy and excitement, but instruction and learning environments saw minimal change. Teachers piloted the idea of technology integration, but only to modify and augment the traditional classroom. Unfortunately, many had not entered the zone of transformation.

The varied levels of technology use forced me to question why some teachers were becoming more adept at the integral use of technology in the classroom but were not altering actual teaching practices. Despite several half or full days of technology integration collaboration, planning, and coaching, most teachers reverted back to traditional 20th-century methods. After 5 years at the education company, I struggled with the question of why some organizations were bubbling with innovative energy while others felt worn out and in need of a jump start. I felt like a rock star in one setting, but like an alien dragging teachers into the 21st century in others. I did not know if the problem related to leadership, definition of roles, expectations, resources, support, time, beliefs, or implementation. After 5 years grappling with these questions, I decided to move on. I signed on to another education company as a PL specialist and continued the journey of collaborating with districts, administrators, and teachers who are integrating technology into education. The last 10 years have spawned much reflection regarding my education technology journey. Taking the time to work through the questions of where we were going with technology use and how we planned to get there was important to understanding the path forward and the learning transformation required for each individual school district, school, teacher, and student.

**Journey to the Problem**

My lifelong learning journey led me to the doctoral program at Texas A&M University. The crossroads of my professional, military, and student journey moved me to explore the complexity of teaching and learning in the 21st century. How to support in-service teachers in their practice to create student-centered environments through blended learning and PL was a problem that I wanted to solve. I understood this kind of change required a paradigm shift that would move educators from delivering passive to active learning and challenge the system to examine digital learning in the classroom, while at the same time developing an understanding that the nature of knowledge, learning, and effective classroom practice with technology varies from teacher to teacher (Ertmer & Ottenbreit-Leftwich, 2010). Ertmer and Ottenbreit-Leftwich (2010) found teachers are critical change agents in the use of technology for instruction. To support the premise that a “teacher is not effective without the appropriate use of information technology,” the need for continuous observation, practice, reflection, and collaborative cultural support are critical (Ertmer, 2005).

## Significant Stakeholders

The participants in this study were two high school administrators and three high school math teachers from a Catholic high school in southern Arizona. The participants sought to adopt a personalized adaptive mathematics resource that would provide a successful learning path for all students to achieve academic success. As the researcher, I collaborated with the teachers and administrators to support, guide, facilitate, and scaffold their professional learning. The intent of my involvement was to troubleshoot problems as they arose and answer questions. I shared the findings of my study with the administrative team and the high school math teachers.

## Definition of Terms

Terms relevant to this research are defined below.

- Adaptive learning—Strategies, instruction, and content modified on the data generated from student engagement with technology at any time. Individual pathways to a student's mastery of a particular learning topic are developed and adjusted based on student responses (Waters, 2014).
- Blended learning—A combination of online learning with face-to-face instruction to personalize learning (Horn & Fisher, 2017).
- Differentiated instruction—To support all students, educators plan for student differences. All students have the same learning goal, but the teaching methods vary by what is best or preferred for each student (U.S. Department of Education, Office of Educational Technology, 2010).
- Information and communication technology (ICT)—Tools that shape the three dimensions of a teacher's practice (i.e., curriculum, strategies, and context; Loveless, 2011).

- Institutional barriers— "Barriers created by schools and administrators of schools" (Levin & Wadmany, 2006 p. 256). These may include a weak Wi-Fi connection, inadequate access to technology, lack of sufficient technological tools, and ineffective PD.
- Intelligent tutoring system (ITS)—A computer-assisted learning environment created using computational models (Steenbergen-Hu & Cooper, 2013).
- Internal barriers—Deeply rooted mindsets that are difficult to change (e.g., pedagogical beliefs, teacher beliefs about the role of technology, and beliefs about the nature of knowledge).
- Pedagogy—The art, science, or philosophy of teaching practiced by an instructor and incorporating the following elements:
    - any "relationship, conversation, reflection and action between teachers, learners, subjects and tools" (Loveless, 2011, p. 301) and
    - "any conscious activity by one person designed to enhance learning in another" (Watkins & Mortimore, 1999, p. 17).
- Personalized learning (PL)— "An approach through which students work collaboratively with their teachers to design educational experiences that are responsive to their unique learning interests, needs, and aspirations" (Netcoh & Bishop, 2017, p. 35).
- Self-efficacy—An individual's belief concerning his or her capability to achieve a desired outcome or behavioral change (Bandura, 1977).
- Technology integration—Implementation of computers for effective and efficient use in meaningful curriculum-driven enhancement of student learning. Methods should

allow for flexibility, creativity, and collaboration while making real-world connections (Dockstader, 1999).

- Technological Pedagogical Content Knowledge (TPACK)—Framework for supporting effective teaching with technology. According to Koehler, Mishra, and Cain (2013):

  > TPACK is the basis of effective teaching with technology, requiring an understanding of the representation of concepts using technologies; pedagogical techniques that use technologies in constructive ways to teach content; knowledge of what makes concepts difficult or easy to learn and how technology can help redress some of the problems that students face; knowledge of students' prior knowledge and theories of epistemology, and knowledge of how technologies can be used to build on existing knowledge to develop new epistemologies or strengthen old one. (p. 16)

## Closing Thoughts on Chapter I

Eighth-grade math performance rates across the nation continue to fall below proficiency (National Center for Education Statistics, 2019). High school teachers have struggled to fill the mathematical skills gaps of each individual student, which has led to a lack of conceptual understanding in Algebra 1 and higher level secondary math and science classes. The appropriate use of technology combined with good teaching is essential to successful performance outcomes (Ertmer & Ottenbreit-Leftwich, 2010) and PL experiences. Different adaptive PL models have been successfully placed into practice to address mathematical academic performance gaps. To address the below-proficiency math scores and gaps in mathematical knowledge at St. Francis High School, an adaptive personalized mathematics resource was introduced for all incoming ninth-grade students. The adaptive PL resources may support all students, from intervention to acceleration. This study was undertaken to better understand the lived experiences of three high school math teachers in Southern Arizona who self-initiated and integrated a digital PL resource to achieve academic success for all students.

Chapter I highlighted the significance of the research study regarding adaptive PL, poor math skills, and the methods by which math is taught in schools across the nation. Research has shown that in the 21st-century classroom, "effective teaching requires effective technology use" (Ertmer & Ottenbreit-Leftwich, 2010, p. 2). Teachers and administrators must rethink and challenge the factory model of education and explore ways to improve mathematics education at a pace that allows each student to build confidence, independence, and proficiency. Otherwise, students will continue to demonstrate below-proficiency math knowledge. If educators fail to address poor math skills, students will not only continue to underperform and struggle in high school math and science classes, they will also inevitably struggle to apply their knowledge to new and different situations after high school.

# CHAPTER II

# REVIEW OF SUPPORTING SCHOLARSHIP

The use technology to significantly change K–12 teaching and learning first appeared in the literature around the turn of the 21st century. These reform efforts proposed student-centered practices as the most effective way to prepare students for the 21st century workplace (Voogt, Knezek, Christensen, & Lai, 2018). Consequently, this study focused on teachers who were using adaptive technology as a tool to meet the individual academic needs of every student, a shift from traditional teacher-centered math instruction to PL. In many K–12 learning environments, especially because of the publication of the Every Student Succeeds Act (2015) and the National Education Technology Plan (NETP; U.S. Department of Education, Office of Educational Technology, 2016), PL became the new instructional focus intended to meet the diverse needs of learners (Basham et al., 2016). The adoption and utilization of instructional technology provided more opportunities for PL to meet individual student needs (U.S. Department of Education, 2018).

The purpose of this qualitative study was to understand the experiences of secondary math teachers during the implementation of a PL adaptive resource designed to support all learners in mathematics—from intervention to enrichment. Implementing PL requires more than technology and digital resources (Basham et al., 2016). It requires a change in pedagogy (i.e., the way students learn within a culture; Fullan & Edwards, 2017). This modification requires educators to effectively use technology in their practice to realize the full benefits available to all digital learners (U.S. Department of Education, Office of Educational Technology, 2017). Multiple general studies into the importance of ICT in education have been conducted, but little empirical research has examined this phenomenon from the teacher’s perspective and practice.

Chapter II shares the relevant literature for this study's research questions in relation to teachers' experiences in implementing adaptive PL resources. The review begins with a historical context and development of the use of PL and adaptive technology in education. The next section continues with details about the action research method used to generate thick descriptions and explanations of the phenomenon, followed by a discussion of the theoretical frameworks that guided the study. The chapter concludes with an examination of the most significant literature on implementing educational technology and PL and practice in order to achieve a deep understanding of this phenomenon from the teacher's perspective. The following key points are addressed: effective digital leadership, digital learning, educator's beliefs and e-learning practices, professional learning in the digital age, and professional learning pathways.

## Relevant Historical Background

Giving all students access to quality education is a responsibility for all educators. Ultimately, the goal is to empower learners by giving them the tools and support they need to be successful in an information age. As a result, the education system continues to grapple with methods of instructional practices to improve and enhance teaching and learning for all students—regardless of economic status—to enable more options for their future (Hardiman, 2012). In 1984, Bloom compared and contrasted three methods of instructional practice: conventional classroom, mastery learning, and tutoring. In his study, Bloom (1984) found that students who received instruction through one-on-one tutoring with formative assessment and feedback outperformed students in conventional instructional practices by two standard deviations, otherwise known as the 2 sigma problem (Paiva, Ferreira, & Frade, 2017). For generations, teachers have sought to meet individual student needs—a goal that can be traced back to Confucius' idea of "teaching students according to their aptitude" (Peng, Ma, & Spector, 2019, p. 2). Peng et al. (2019) further explained that traditional student-centered learning is a manageable challenge when working with a relatively small group that primarily uses special teaching systems. Understanding that one-on-one tutoring and mastery learning leads to stronger individual student growth, district personnel have looked to educational resources to answer the 2 sigma problem in Bloom's (1984) study. Personalized adaptive technology offers a powerful tool for achieving the goal for every student and every classroom.

In the technology sector, various innovations prompted shifts in the practice of education. Skinner's (1958) teaching machines established a vision to increase learner independence by allowing students to complete tasks independently and at their own pace (Peng et al., 2019). The initial technology charted a PL pathway toward adaptability. Since then, technology-enhanced learning has gradually entered classrooms. The first computerized adaptive testing systems were limited by the level of technology because their adaptive nature was mainly based on simple rules of analytics and not on growth patterns (Weiss & Kingsbury, 1984). Based on students' responses, the computerized adaptive testing system placed students on a predetermined learning continuum with very little accuracy or flexibility. As systems gradually became more complex, CAI, developed in 1960, showed proof of academic benefits. In a decade-long study by Kulik, Kulik, and Bangert-Drowns (1985), students who used CAI outperformed their peers by an average of 30%. Even though CAI did not account for students' strengths or weaknesses, it showed a potential to change the way teaching and learning were carried out in the classroom. During the mid-1970s, software engineers aspired to apply artificial intelligence techniques to create personal ITSs. Tutor-like technology models used PL for individual struggling students (Keefe & Jenkins, 2002). ITSs were designed to simulate a human tutor's guidance by offering customized instruction. Thus, the use of technology to personalize learning is not new. It was once a tutor-like model for individual struggling students. Now, though, PL provided through advanced technology offers a way to effectively meet the needs of all students on a larger scale.

Today's PL is slightly more complex due to the advancement of information communication technology. Information communication technology can now "provide more opportunities to personalize the learning experience for many more students" (Project Tomorrow, 2012, p. 1). The new development of current technologies can provide learners more flexibility, effectiveness, adaption, engagement, motivation, and feedback to promote the development of PL (Spector, 2014). Currently, the new PL approach, a student-centered ideology, has developed into an automatic learners' real-time experience to accommodate self-paced learning content and activities to meet students' needs on a larger scale (Peng et al., 2019). Learners have greater independence to choose what they want to learn and when and where they want to learn it (Cradler & Bridgforth, 2002; United Nations Education, Scientific and Cultural Organization, 2004). The real-time experience promotes learning skills such as self-regulation and self-monitoring (Inan, Yukselturk, Kurucay, & Flores, 2017; Nikolaki, Koutsouba, Lykesas, Venetsanou, & Savidou, 2017). These researchers found self-regulation and self-monitoring to be integral factors in student success. Moreover, skills such as self-regulation and self-monitoring are behaviors and traits of lifelong learning. In summary, the integration of adaptive technology has created new pathways and opportunities to personalize learning.

Adaptive PL has gradually become more complicated and extremely disruptive to the traditional classroom. An example of this is the ALEKS platform. It encompasses the notion that there are multiple pathways to accomplish a series of learning objectives. Based on knowledge space theory, ALEKS uses artificial intelligence to assess a student's current knowledge and areas for growth in a particular course. The initial knowledge check determines what a student knows, does not know, and, most importantly, what he or she is ready to learn (ALEKS Corporation, 2017). Students do not start on the same topic. ALEKS delivers students a personalized pathway on the exact topics he or she is most ready to learn. The ready-to-learn pathway allows students to skip around and work on different concepts within their pathway. It also allows a student to take a linear approach and work on specific modules or domains if that is the way the student learns best. A corporate synopsis pointed out that, "ALEKS is based on the understanding that students learn math in different ways, and at differing speeds" (ALEKS Corporation, 2017, p. 1). According to one group of researchers, "Findings indicate that personalized learning environments require more than technology, that the technology itself is simply a tool to support implementation" (Basham et al., 2016, p. 126). It is important to note that PL is not defined by technology and can be implemented with or without technology as a tool. However, all of the teachers in this study used an adaptive personalized resource to open the door to a student-centered environment.

New educational approaches that improve and enhance the learning process are possible through the adoption and integration of ICT (United Nations Education, Scientific and Cultural Organization, 2004). This method of personalized adaptive practice does not perpetuate the traditional factory model of education that characterized the industrial age. Adaptive learning resources can be used to raise all students' achievements by meeting each individual's learning needs, tailoring instruction, and ensuring that all responses subscribe to a sound pedagogy (Fu, 2013). If designed with the idea of promoting meaningful and effective learning, each learner can progress at a different pace based on preferences, strengths and weaknesses, and self-regulation.

According to Bransford, Brown, and Cocking (2000), several studies on ICT and learning showed that technology can assist students in becoming more knowledgeable, reduce the amount of direct instruction, and give teachers an opportunity to coach students and target their needs. Chang, Chen, Chen, Lu, and Fang (2016) conducted an 8-week study of an e-learning Visual Basics programming course. Participants with similar skills were randomly divided into two groups. Both groups attended the normal e-learning sessions. In addition to the e-learning sessions, the experimental group engaged in adaptive learning to assist with their e-learning sessions. According to Chang et al. (2016), adaptive learning was found to be more effective than traditional teaching methods for increasing learners' interest. Additionally, Sabo, Atkinson, Barrus, Joseph, and Perez (2013) studied the effectiveness of two adaptive learning programs used exclusively to deliver high school algebra instruction. Thirty students were evenly divided and randomly assigned to one adaptive learning program for 14 days. Evaluations of the two adaptive learning programs, Carnegie Learning's Cognitive Tutor and ALEKS, indicated that both groups made significant gains in algebra within the 14-day time frame.

In the policy sector, changes in legislation have gradually created pathways to PL. Curriculum policies pivotally changed in 1983 due to concerns raised by the federal report *A Nation at Risk* and the demands of a globalizing economy (National Commission on Excellence in Education, 1983). The education crisis identified in the report called for every student to acquire computer literacy to avoid falling prey to the global economy. Governing bodies responded with policies to meet the challenge of expanding technology to support e-learning practices.

President Reagan's administration increased federal involvement to more systematically address curriculum and education technology, which transformed the failing school system into a government priority. In 1993, the Clinton administration created the Office of Educational Technology and passed the Improving America's Schools Act (1994), which reauthorized the Elementary and Secondary Education Act (ESEA) of 1965. This act provided funding to states, districts, and schools for programs and resources to ensure that all children met rigorous academic standards, to develop a technologically literate citizenry, and to produce an internationally competitive workforce (Improving America's School Act, 1994).

In 1996, the first NETP, titled *Getting American Students Ready for the 21st Century: Meeting the Technology Literacy Challenge*, was released by the secretary of education (Roumell & Salajan, 2016). The document set the vision at the federal level for improving teaching and learning through the effective use of technology. The core theme of the plan was technology literacy to ensure the nation's continued success in a global economic environment. The 2004 NETP education technology call for action continued in cadence with the two previous NETPs (1996, 2000), which promoted technology as a vehicle for general educational reform. It also drew attention to the disconnect between teachers' limited capabilities to meet the expectations of technology-savvy students.

President Bush's No Child Left Behind (NCLB, 2001) mandate, a controversial federal policy, redirected reform efforts toward accountability, standards, and accreditation. The 2001 NCLB Act overshadowed the 2004 NETP mandates. The NCLB policy emerged out of concern that schools were failing to educate all children (U.S. Department of Education, 2001). NCLB updated the ESEA, giving more authority to the federal government to hold schools accountable for student outcomes. It included a new federal system of testing and accountability, not only for the entire population, but also for subgroups (i.e., race, ethnicity, first language classification, and socioeconomic status). In addition, Title I provided federal funds to students at risk of failure and living at or below the poverty level (U.S. Department of Education, 2001). It was rewritten to level the playing field for students living and learning in poverty, with the goal of closing the achievement gap between low-income students and other students. To receive federal funding, schools were required to meet adequate yearly progress on state tests and focus on best teaching practices. NCLB increased the federal footprint with an overreliance on accountability (Forte, 2010). However, at the center of its reform, it provided minimal flexibility for effective teaching and learning with technology.

National influence continued with the American Recovery and Reinvestment Act of 2009. Designed to stimulate the economy after the economic downtown, it laid the foundation for systemwide improvement and innovation. Once again, the legislation raised standards and expanded the emphasis on what students needed (U.S. Department of Education, Office of Educational Technology, 2017). In 2015, when the 50-year old ESEA was reauthorized, it became known as the Every Student Succeeds Act (ESSA; ESSA, 2015–2016). ESSA introduced new levels of autonomy. It provided flexibility, courage, and creativity at the state level to expand on effective and innovative practices within the local context, thereby opening the door for effective technology integration. With ESSA, legislators acknowledged the importance of collaboration to ensure a more holistic approach to education to improve outcomes for every child. In addition, the Race to the Top initiative called for an interconnected systemwide improvement for all students and teachers in these four core areas:

- establishing high, challenging learning standards aligned with readiness for college and careers and transforming instructional practices to enable students to meet the more challenging expectations,
- developing and supporting effective teachers and leaders,

- creating data systems and using technology to inform and enhance instruction, and
- turning around the lowest performing schools (U.S. Department of Education, 2015, p. vii).

With the creation of ESSA, unprecedented funds were made available to 12 Race to the Top grantees (i.e., 11 states and the District of Columbia).

Each previous policy built upon the other in moving toward the PL goals identified in the 2017 NETP (U.S. Department of Education, Office of Educational Technology, 2017). In addition to aligning to the goals of PL, NETP aligned to ESSA's effective use of technology activities. The 2017 NETP vision presented an updated course of action to support systematic changes in learning and teaching through technology. The five overarching goals for transforming learning experiences together provided the conditions for all learners of all ages. The goals related to (a) learning, (b) teaching, (c) leadership, (d) assessment, and (e) infrastructure. Significantly, the content, examples, and recommendations presented in the 2017 NETP goals call on all stakeholders who work in education to engage in the important work of shifting practices to increase the use of technology in order to improve student learning for personal growth (U.S. Department of Education, Office of Educational Technology, 2017).

## Alignment with Action Research Traditions

Change is more likely to occur if a community of practitioners is personally involved in the research process. Carl Glickman (1992) noted that *action research* in education is research conducted by colleagues in a school setting to improve a particular practice. Action research is a problem-focused cycle of continuous movement aimed at improving instruction (Anderson, Herr, & Nihlen, 1994). Inspired by Kurt Lewin's work, it is composed of a cycle involving planning, acting, observing, and reflecting (Kemmis, McTaggart, & Nixon, 2014). It requires participation and generates greater commitment, thereby increasing the likelihood of action (Royer, 2002). Action research is a reflective study that is accomplished through immersion within the study; thus, the researcher maintains ownership of the study and the problem that is being reflected upon. However, permanent change cannot be made on a campus or in a school district solely by one researcher.

For a change or improvement to actually result from the action research, collaboration among all stakeholders must take place. Anderson et al. (1994) stated that "[action research] is a larger social movement that challenges dominant research and development approaches that emphasize an outside-in, top-down approach to educational change" (p. 7). In order for the research to be relevant and the results implemented, the change and movement must occur at all levels.

Teaching and learning math are complex processes. Because no one single correct teaching and learning approach exists, I used the action research framework in this study to encourage ownership, collaboration, and reflection in practice with teachers to gain a holistic approach to the local phenomenon. Moreover, the implementation of an adaptive mathematics resource in this study most aligned with collaborative action research. Collaboration among practitioners regarding good teaching and understanding of past and current practices are likely to improve teaching and learning outcomes (Levin & Rock, 2003). The teachers made a commitment to improve students' math skills. Action research was used as a tool to promote the study. Anderson et al. (1994) found that if teachers are involved in testing and exploring how an adaptive program can improve student achievement, they are more likely to develop a better understanding of their own teaching using computer technology and take responsibility for their own professional growth (Ming, Hall, Azman, & Joyes, 2010). Because the researcher is typically invested in action research, the researcher is continuously trying to improve upon the research solution by studying, taking action, collecting and analyzing data, reflecting on the research, and repeating the cycle continuously. This cycle promotes more understanding at the beginning of each step and provides opportunities for other stakeholders and participants to allow improvements to be made. Although action research using technology to improve student achievement takes time (Royer, 2002), the value in continuous reflection is what made collaborative action research such a useful tool for this study.

This record of study was undertaken to utilize action research to understand the practices of three high school math teachers as they implemented a digital adaptive learning resource in their classroom to support all learners—from intervention to enrichment. The school had students who were entering high school with a wide disparity of math skills and skill gaps and who were ultimately not ready for rigorous college preparatory Algebra 1 content. As students continued their secondary math journey, skill gaps increased, leaving them unprepared for the rigor of upper-level mathematics and sciences. The value of mathematical preparation extends beyond high school into college, career, and income, so the teachers and administration decided to select ALEKS (i.e., an ITS) to supplement and fill gaps for all high school students in Algebra 1, Geometry, and Algebra 2.

## Theoretical Framework

The theoretical frameworks that aligned with this action research into the use of adaptive technologies in mathematics education were TPACK and the technology acceptance model (TAM). TPACK emerged over the past decade to assist teachers in navigating technology usage (Mishra & Koehler, 2006). TPACK researchers examined the alignment between the three types of knowledge educators need to successfully combine content (i.e., subject matter), pedagogy (i.e., methods of teaching), and technology (i.e., understanding various technologies). The basis of this model is that effective technology integration requires both the content and the instructional method to align with the technology in use (Mishra & Koehler, 2006). Koehler et al. (2013) defined TPACK as follows:

> TPACK is the basis of effective teaching with technology, requiring an understanding of the representation of concepts using technologies; pedagogical techniques that use technologies in constructive ways to teach content; knowledge of what makes concepts difficult or easy to learn and how technology can help redress some of the problems that students face; knowledge of students' prior knowledge and theories of epistemology, and knowledge of how technologies can be used to build on existing knowledge to develop new epistemologies or strengthen old ones. (p. 16)

The alignment and relationship of technology, pedagogy, and content leads to enhanced student experiences. When teachers learn how to blend and apply TPACK, they are more likely to be confident and to use technology in their instruction in appropriate ways (Maeng, Mulvey, Smetana, & Bell, 2013). Some educators might find it easy to think that adding a great technology tool will enhance mathematics learning. But technology is not a silver bullet to the challenges in education. If an educator lacks in one area, he or she will not have the understanding to teach via technology effectively.

Practitioners need support to effectively develop digital pedagogies. Poitras, Doleck, Huang, Li, and Lajoie (2017) studied preservice teachers as they became competent at learning with technology using an open-ended learning environment. They found that the open-ended learning environment fostered teacher acquisition of TPACK and helped them regulate their learning. In a comparative case study, Lee and Kim (2017) presented a third version of the

TPACK-based instructional design model for improving teachers' ability to create student-centered instruction with technology. The focus was on developing preservice teachers' TPACK learning using the three-step TPACK-based instructional design (ID) model. Specifically, the researchers wanted to examine whether the three steps of understanding, experiencing, and practicing maximized the application of TPACK knowledge and improved preservice teachers' understanding of student centeredness and transferred into lesson design and implementation. Ongoing support should deliberately address the purpose, pedagogy, and organization around technology and provide options for real-time support, collaboration, and examination of the instructional design models.

Through a review of the literature, Loveless (2011) offered three theoretical frameworks for teaching with ICT aimed at addressing the questions of digital pedagogy. The study found that learning effective instructional methods came not from a standard approach to modeling pedagogy but from an opportunity for educators to collaboratively engage and adapt their practice with others in their discipline. Integrating technology effectively into learning requires educators to be comfortable and knowledgeable with digital resources while understanding how to apply them seamlessly into the learning process (Levin-Goldberg, 2012). Consequently, a need exists for contextualized and personalized training programs that scaffold learning and support teachers in the transition to digital teaching and learning.

Another theory that underpins the understanding of teachers' use of digital technologies in mathematics education is Davis's (1989) TAM. This information technology acceptance theory provides an explanation of why teachers reject technology and how they come to accept and use technology, such as an adaptive PL tool, in teaching and learning (Davis, Bagozzi, &

Warshaw, 1989). According to the theory, technology integration practices are influenced by two factors: *perceived usefulness* and *perceived ease of use* (Davis, 1989; Rogers, 1995).

The first factor that may contribute to a teacher's use of personalized adaptive technology (i.e., ICT) is perceived usefulness. Perceived usefulness means the degree to which individual users recognize the new technology will improve achievement. If teachers perceive that PL through technology is useful to teaching and learning outcomes, they are more likely to implement ICT. Researchers have shown that the level of adoption will increase when individuals perceive a new technology as useful in the teaching and learning of mathematics (Pierce & Ball, 2009; Reed, Drijvers, & Kirschner, 2010; Teo & Milutinovic, 2015; Wong, 2015). Although there were several studies that used TAM as a theoretical framework with different technologies, most researchers looked at the relationship between the TAM factors in quantitative studies through self-report survey instruments (Ibili, Resnyansky, & Billinghurst, 2019; Okumuş, Lewis, Wiebe, & Hollebrands, 2016; Wong, 2015). The second factor, perceived ease of use, refers to the perceived degree of ease with which users can apply the new technology (Davis, 1989). The relationship between both factors explains the acceptance or rejection of technological innovations in schools. In *Second Life*, a 3D virtual environment, 206 nursing students perceived the new learning system as being useful because they were able to use it easily (Chow, Herold, Choo, & Chan, 2012).

Both theoretical frameworks, TPACK and TAM, offer differing but overlapping ways of examining the factors that influence teachers' practice in the integration of ICT in teaching and learning. Teacher knowledge of TPACK and beliefs about pedagogy and technology are intertwined, and both determine the decision of teachers to use technology (Tondeur, Roblin, van Braak, Fisser, & Voogt, 2013). Used properly, ICT can enhance higher order thinking skills, lifelong learning habits, and communication skills. However, when trying to understand the lived experiences of teachers as they implement a PL resource (e.g., ICT), it is important to be aware of the perceptions of teachers, factors that influence teacher adoption and integration, and teaching methodologies pertaining to ICT.

## Most Significant Research and Practice Studies

*You can't buy personalized learning.*

—Richard Culatta (2012)

The researchers considering adaptive PL reviewed many factors that influence teachers' adoption and integration of ICT in the teaching and learning process. Leadership support is critical. Implementing PL requires administrators to set the vision and direction. District and building administrators communicate goals and prioritize instructional practices they believe will impact student growth (Mirzajani, Mahmud, Ayub, & Wong, 2016). In the changing technology landscape, the role of the school leader is to adapt to change while promoting organizational goals and vision within the changing environment. Fullan (2012) noted that in the everchanging field of technology and education, effective leaders are change knowledge leaders. They motivate, support, and understand the change process while moving the vision forward. They promote this vision in teachers by "fostering the capacity to focus, to innovate, to empathize, to learn, to collaborate, to relish transparency, to shed non-essentials, and to develop leadership in themselves and others" (Fullan, 2012, p. 70). If administrators implementing PL lack a clear vision as to its real purpose, it becomes superficial, and teaching does not change the educational system (Ertmer & Ottenbreit-Leftwich, 2013). Teachers need leaders who work on their behalf and pave the way for change.

Shifting paradigms from industrialized learning to PL requires time, trust, and support from administration. Leaders who cultivate a well-executed change process foster trust and value in teachers, parents, and students within the spirit of volunteerism (Fullan & Edwards, 2017). Fu (2013) noted that school leaders should ensure that teachers understand that the goal of technology is not to replace teaching and learning but to advance the process. Administrators promote this advancement by building trusting relationships, collaborating, setting clear expectations, encouraging risk-taking, and providing a model for support (Hughes, Boklage, & Ok, 2016). Most important to the change process is providing teachers with PD opportunities designed to foster technology utilization and deepen individual learning (U.S. Department of Education, Office of Educational Technology, 2017). Without leaders acting as strong advocates for transformation, the field of education will continue to struggle to fully implement technology and PL across school systems nationwide.

**Leadership and Organizational Culture**

Successful change in the classroom must be supported at the building and district levels within a coconstructed culture of continuous improvement. According to Somekh (2008), "Teachers are not 'free agents,' (there is indeed no such thing) and their use of ICT for teaching and learning depends on the interlocking cultural, social and organisational context in which they live and work" (p. 450). Ertmer and Ottenbreit-Leftwich (2013) pinpointed leadership as a critical factor in shaping organizational norms by looking at the juncture between leadership and culture. An example of this can be found in Cho's (2017) study. Cho maintained that in the mission-driven organizational environment of catholic schools, environment mattered when planning and implementing software programs. In another study, Imbriale, Schiner, and Elmendorf (2017) considered a district implementation pilot with one-to-one devices. In this study, administrators and teachers were involved in systematic planning, conversations, and professional learning rooted in theory, practice, and learned experiences. These conversations focused on a unique understanding of how the technology related to the curriculum in creating student-centered learning and developing 21st-century skills (Imbriale et al., 2017). The collaborative work and technology discussions represented a significant shift in the top-down leadership approach and empowered leaders at multiple levels (Imbriale et al., 2017). However, McLeod and Richardson (2011), in an analysis of literature and conference records, found that school technology leadership lagged in recognizing the importance of digital technologies and technology leaders. In fact, schools with principals who lacked technology leadership exhibited less effective technology implementation for enhancing student learning outcomes (Anderson & Dexter, 2005; Creighton, 2003). However, over the last 15 years, there has been an increased emphasis within the study of educational leadership and technology on more shared forms of leadership (Hughes et al., 2016). Thus, in order to reap the benefits of technological leadership, there is a need for technology-adept individuals at all levels to undertake leadership roles and promote technology for educational purposes.

**Digital Learners**

Learners are key stakeholders in the learning process. In order to embark on a new digital initiative to personalize learning, administrators, coaches, and teachers should have a good understanding of the digital learners in their schools and classrooms (Csorba, 2016). Twenty-first-century digital learners are labeled by researchers as Generation Y, Generation Z, Postmillennials, the iGeneration, Digital Natives, and the Net Generation (Pletka, 2007). These designations apply to students born after 1980 and raised in the digital age. According to Csorba (2016), “Technology is like the air you breathe” (p. 60), and these students appreciate the choices it offers. Csorba (2016) further explained that this new crop of learners prefer conversation over lecture, are more tolerant of diversity, and can manage and foster virtually formed relationships. Technology has connected them to an entire planet beyond their neighborhood, thus making them the first generation of globally born citizens.

The term *digital learners* is not based on age or generation. Gallardo-Echenique, Marqués-Molías, Bullen, and Strijbos (2015) offered a more global vision of the 21st-century student. They proposed a unified concept of digital learners who learn through ICTs in the knowledge society. These learners:

- focus on learners rather than persons, who should realize the possibilities and potentials of digital technologies in their environments and recognize the value of technology and the opportunities it presents learners in their daily life;
- argue that learners are not merely users or consumers of technology;
- highlight the complexities of learners' technology experiences;
- rejects the generational boundary and any chronological generations that exclude other types of actors who share similar practices (i.e., accept all learners);
- does not assume any predefined learner characteristics; and
- adopts a sociocultural, anthropological, communicational, and pedagogical approach from the learners' perspective. (p. 172)

Accessing information, experts, and people is easier with technology. Digital learning is characterized by nonlinear processing, social learning, collaboration (Rosen & Beck-Hill, 2012), and multitasking (Teo, 2013). According to Bennett and Maton (2010), digital learners communicate and socialize in vastly different ways. Using phones, digital learners connect socially, play video games with others around the world, and design their own virtual worlds in which to explore and communicate (Downes & Bishop, 2012). Mobile learning places learners in the center of the experience and emphasizes the portable way digital learners engage with and access information (Cochrane, 2010). Kincey, Farmer, Wiltsher, McKenzie, and Mbiza (2019) found that mobile learning also happens outside the traditional four walls of the classroom and the classroom schedule. Digital learners experience the individual freedom of learning whatever they choose, whenever they choose.

Digital learners unplug when they enter a 20th-century factory-style classroom. The traditional environment promotes extreme boredom, leaving about one third of students involved in their schoolwork by the time they reach ninth or 10th grade (Sheninger & Murray, 2017). Teaching bored students is not fun and puts teachers in a difficult predicament (Fullan & Edwards, 2017). Similarly, researchers have found that when children encounter screen and multimodal learning through technology, it conflicts with current curriculum and existing teaching methods (Hashemi & Cederlund, 2017). Heidi Hayes Jacobs (2010) described students' conflicting learning environments in the following way:

> I often wonder if many of our students feel like they are time traveling as they walk through the school door each morning. As they cross the threshold, do they feel as if they are entering a simulation of life in the 1980s? Then, at the end of the school day, do they feel that they have returned to the 21st century? (p. 7)

Imbriale et al. (2017) found that although digital learners are comfortable with technology and are assumed to be sophisticated users of technologies, their use of it for educational purposes needs to be developed. According to researchers, digital learners appear to have superficial skills for seeking and analyzing information and limited understanding on using new technology for specific purposes (Brown & Czerniewicz, 2010). Previous studies have also shown that students improperly regulate their learning; they may not appreciate what rigorous learning entails, hindering their ability to diagnose their own level of learning or have the ability to extend learning using new strategies (Baumeister & Heatherton 1996; Taminiau et al. 2013). Although some digital learners share these characteristics, not all young people engage in the same level of technology use (Bennett & Maton, 2010). The role of the teacher is increasingly critical in the effective implementation of adaptive technology (Hoyles, 2018). Teachers in the digital age should be prepared to foster learning circles based on the diverse technology experience of learners.

Teachers should support all students in developing learning through digital technologies in authentic contexts (Sheffield, Blackley, & Moro, 2018). According to Tezci (2011), technology should not only enhance traditional teaching and learning, it should also develop both content and technology to improve student-centered learning. Students need to develop the skills to thrive in a progressively complex and data-rich society in order to problem solve effectively (International Society for Technology in Education, 2016). Digital technology is ubiquitous, and educators have no choice but to discover a way to effectively use digital resources to move the instructional process (West, 2012) toward deep, authentic application of skills, knowledge, and concepts (Imbriale et al., 2017). The focus for learners in the digital age should be on student-centered practices and support in regulation of students' own learning.

**Educators' Beliefs and e-Learning Practices**

Traditional educational methods produce a learning void in the age of prevalent digitization because teacher-centered practices are associated with low-level technology use. The learning void produced by technology creates a challenge for educators at all levels by disrupting the teacher's vocation developmental process (Sadeck & Cronjé, 2017). Sadeck and

Cronjé (2017) found that teachers were using technology for learners in more traditional activities that aligned with their teaching style rather than engaging learners with the technology for learning. The traditional routine of teaching and planning may inhibit their ability to revise their craft (Callahan, 2014). Having a better understanding of what teachers' educational theories are will help explain the low-level use of technology and identify what makes teachers use computers (Marcinkiewicz, 1993).

Teachers' beliefs affect how technology is used in the classroom. An exploratory mixed methods study by Kim et al. (2013) examined the relationship between teacher beliefs and their technology integration in the classroom. The researchers looked at teachers' beliefs about the nature of knowledge and learning as well as beliefs about effective ways of teaching, and they investigated how these beliefs related to the teachers' integration of technology. Specifically, the researchers explored the fundamental beliefs that teachers had about teaching and how these beliefs aided in decision-making. In their study, they focused on teachers who had relevant knowledge on the use of the technology but integrated technology differently than expected into individual teaching practices. The primary goal was to identify teachers' beliefs in order to improve technology use in poorly performing schools. The explicit focus was on the fundamental belief "about what is important in student learning and thus teaching" and the way those beliefs translated to technology integration practice in the classroom (Kim et al., 2013, p. 77). Their findings implied that beliefs affect the level of technology use.

PL is student-centered learning. However, if teachers have a strong belief that the source of knowledge is based in authority, technology use will be teacher centered. Some suggestions for changing teacher beliefs are rooted in Kagan (1992) and Pajares' (1992) recognition that beliefs are difficult to change because beliefs come from past experiences that influence teachers' beliefs. Based on this fact, the authors suggested using experiences that challenge teachers' current beliefs.

Tondeur et al. (2017) explained that pedagogical beliefs need to be addressed to understand technology integration in the classroom. However, Buzzard, Crittenden, Crittenden, and McCarty (2011) discovered that technology integration is perceived to be a challenging task due to vast preferences and usage across disciplines, which further obscures the idea of utilizing digital technologies to enhance learning. Benjamin Rush, an early American education reformer, pointed out that individuals must create new habits of the mind to change old ways of thinking (Gutek, 2013). In fact, in today's digital society, educators should adopt the mindset that teaching is not sufficient without ICT (Ertmer & Ottenbreit-Leftwich, 2013). Changing mindsets is an individual process, but it can be accomplished using experiences that challenge teachers' current beliefs.

In addition to teachers' educational beliefs, Levin and Wadmany (2006) studied teachers' beliefs about the role of technology and technology use in the classroom. The researchers used a longitudinal study to examine teachers' beliefs by integrating information-rich tasks into school curricula to determine whether a change in teachers' educational views occurred. The study provided a greater understanding of the unique learning of every teacher. Change in educational beliefs is an individual process because teachers have a wide variety of educational beliefs. Levin and Wadmany's (2006) study supported Guskey's (2002) assertion that change in beliefs can occur after a change in practice. Levin and Wadmany (2006) also implied that professional learning through a constructivist approach allowed teachers to "construct their knowledge in unique and meaningful ways" (p. 173). Similar to findings in other studies, this study also confirmed that changes in beliefs are difficult to alter and may be slow to materialize.

Most importantly, Levin and Wadmany (2006) described a comprehensive, actionable framework to improve teacher beliefs and technology integration. Ongoing support should deliberately address the "purpose, pedagogy, and organization around technology" (Hashemi & Cederlund, 2017, p. 222) and provide options for real-time support. For the implementation of new ICTs to be effective, teachers need ongoing support to move away from the old-style mentality of the traditional educator who teaches textbook knowledge (Tomczyk et al., 2017). Nonetheless, acquiring the skills to undo and unlearn traditional teaching is complex. Teachers respond differently to similar education technology initiatives, despite working in the same community. As more and more schools seek to change the professional learning environment to create technology-based PL experiences, teachers must be given room to experiment and innovate (Ertmer & Ottenbreit-Leftwich, 2010). Unlike the traditional context of PD support, educators require continuous, quality PD with significant support to enhance the learning experience and make it more student centered (Sheffield et al., 2018). Fullan (2012) advocated that change begins with stealthy interventions. However, no matter the method of implementation, understanding teacher beliefs, knowledge, and self-efficacy are essential elements in building PD interventions to move technology integration and PL forward.

Teachers are agents of change. In *Teacher Technology Change: How Knowledge, Confidence, Beliefs, and Culture Intersect,* Ertmer and Ottenbreit-Leftwich (2010) focused on Fisher's (2006) notion of the individual as an agent and examined technology integration through the lens of the teacher as the agent of change. To effectively leverage technology resources, the authors examined four essential characteristics for teacher agency in preservice and in-service teachers: (a) knowledge, (b) self-efficacy, (c) pedagogical beliefs, and (d) subject and school culture.

Ertmer and Ottenbreit-Leftwich (2010) focused on redirecting the mindset of teachers away from traditional ideas of teaching and learning and redefining teaching and learning through effective technology use. The technology resource used by teachers in this study was a tool the teachers selected. Digital tools play an important role in transforming mathematical practices of learners and teachers (Hoyles, 2018). The authors Ertmer and Ottenbreit-Leftwich (2010) cautioned that technology should not be viewed as an agent of change, consequently, the participants were intimately involved in the process and were the agents of their own learning. As has been noted, technology knowledge and efficacy are not the only variables needed to modify teaching practice. There was also an essential correlation attributed to educational beliefs and understanding that pedagogical beliefs and value beliefs existed. Teacher beliefs contribute in understanding how teaching and learning is processed with the digital resource to support PL experiences in the classroom. Teacher experiences are relevant to affecting belief change. In attempting to broaden the concept of good teaching, it must be recognized that "the idea is effective only when combined with relevant ICT tools and resources" (Ertmer & Ottenbreit-Leftwich, 2010, p. 259). All these factors should be considered and integrated when reforming and understanding teacher practice with technology use.

In summary, for technology integration in today's classrooms to effect change, educational reform efforts should consider how knowledge and beliefs translate into practice. If teachers are to act on developing and implementing student-centered technology to help students learn content, then ongoing PD, support, and collaboration should address the purpose of technology integration.

**Professional Learning in the Digital Age**

PL is a new innovative practice that requires a mind shift from the traditional definition of teaching. Teaching, according to Shulman (1986), includes knowledge of subject, teaching methods, classroom management strategies, and how to teach particular content. Shulman's definition of good teaching should be broadened to include the idea that "teaching is effective only when combined with relevant ICT tools" (Ertmer & Ottenbreit-Leftwich, 2010, p. 259). Teachers are key to implementing PL, so their perceptions of the innovation are essential to the process. Moreover, in order to "adopt educational innovation, teachers require extensive learning and training opportunities" (Karmeshu, Raman, & Nedungadi, 2012, p. 586). The overarching goal of most current professional learning involves cultivating self-efficacy through digital literacy (Cullen & Greene, 2011). Digital literacy is developed through "communal communication" of technology integration into instructional curricula (Richardson, Sales, & Sentocnik, 2015, p. 20).

A vibrant professional community plays an essential role in adopting and sustaining an innovation by providing teacher support. Colleagues and peers can aid in creating a familiarity with technology, cultivating self-efficacy, and enabling exposure to multiple levels of targeted expertise and support. Within a community of professional learners, teachers can learn and develop new approaches to learner-centered teaching and change their practice (Goodnough & Murphy, 2017). Community beyond individual classrooms provides a space to learn, discuss possible strategies for improvement, build relationships, and collaborate in reshaping policy at school and district levels to improve educational practices (Luetkemeyer, 2016; Palaigeorgiou & Grammatikopoulou, 2016). In addition, community provides stability while reducing isolation in a rapidly changing landscape of technology (Twining, Raffaghelli, Albion, & Knezek, 2013). In a community, practice becomes public (i.e., transparent), offering ways to explore and reflect on the use of ICT in teaching and learning.

Professional learning provides opportunities for teachers to obtain greater theoretical and practical knowledge of instructional technology, which can be used to improve PL and shift teacher thinking. Research has indicated that teachers' professional learning is most successful when it is spread out over time. Continuous support allows teachers to reflect and make meaningful connections to the learning (Bransford et al., 2000). The key to continuous improvement within the framework of learning is the cycle of reflection and action. Critical self-reflection and action help to improve the constantly change in teaching and learning. To support the continuous development of teachers, Postholm (2012) recognized the critical importance of active and social participation in practice and the importance of ongoing PD. She advocated that schools should support educators in lifelong learning in order to help them prepare students for the 21st-century workforce. Sheffield et al. (2018) cited decades of research that showed "transformative learning occurs when instruction and support is over time, onsite, reflective and has identifiable links to the curriculum" (p. 489). Their research supported the recent professional reform movement focused on authentic, collaborative partnerships within schools and communities built around professional learning opportunities for teachers on student-centered learning and assessment. Yoon, Duncan, Lee, Scarloss, and Shapley (2007) indicated time allocation for professional learning should be from 30–100 hours every 6–12 months. Unfortunately, supporting teachers in a cycle of continuous, collaborative development is a big challenge for today's districts and schools.

Despite the investment in training programs focused on educating teachers on how to integrate technology, purposeful integration of technology continues to be a struggle

(Timotheou, Christodoulou, & Angeli, 2017). Some authors referred to a gap between the traditional and innovative professional learning models relating to technology integration practices in the classrooms (U.S. Department of Education, Office of Educational Technology, 2017). Fu (2013) identified several unique challenges that contribute to this dilemma. A lack of technical competencies in the area of new education technologies stems directly from the wide variance of undergraduate teacher training, generation gaps, and ineffective PD. The lack of technical skills necessary to handle essential digital resources is due to resource constraints at all levels and a general lack of technology exposure. Finally, the lack of pedagogy in technology use is a systemic issue across the profession of teaching. Tomczyk et al. (2017) looked at the challenges of including new information technologies through a didactic lens that could help stimulate a methodological search and develop competencies. Hashemi and Cederlund (2017) dissected pedagogical context and its influence on changes in education. Blundell, Lee, and Nykvist (2016) suggested a tri-theory framework to help teachers conceptualize these challenges and influences (i.e., extrinsic and intrinsic) as they collaboratively transferred their practices through digital learning in schools. Although there may be hurdles to implementing innovative change, such as PL, it was clear from the literature that today's teachers should have opportunities for continuous support with an emphasis on PL in order to expedite the transition from traditional to digital learning methods.

**Professional Learning Pathways**

The literature reflected the complexity and importance of continuous, transformative, teacher professional learning and the "issues of purpose, pedagogy, and organization around technology" (Hashemi & Cederlund, 2017, p. 222). For the most part, researchers agreed regarding the skills needed to be a 21st-century educator. The modern teacher should master the use of digital learning, collaboration, communication, creativity, critical thinking, problem-solving, and choice (Partnership for 21st-Century Skills, 2007), and professional learning practices with specific reference to ICT are needed to better prepare educators to promote 21st-century learning. To overcome challenges and develop digital technical competencies for the enhancement of instructional technologies, Qasem and Viswanathappa (2016) considered utilizing a blended learning approach to help teachers conceptualize digital literacy learning. The online and blended learning practices that have emerged in education and technology sectors were designed to implement more effective environments and transform contemporary schools (Basham et al., 2016).

**Blended learning**. Blended learning offers an environment of collaboration and flexibility to meet the expectations of the Net Generation. The Clayton Christensen Institute (2018) defined blended learning as follows:

> A formal education program in which a student learns: (1) at least in part through online learning, with some element of student control over time, place, path, and/or pace; (2) at least in part in a supervised brick-and-mortar location away from home; (3) and the modalities along each student's learning path within a course or subject are connected to provide an integrated learning experience. (para. 2)

In this definition, the Clayton Christensen Institute (2018) acknowledged that both the computer-generated environment and the physical setting impact change as it pertains to various teaching and learning methodologies—a point made a decade earlier by Owston, Wideman, Murphy, & Lupshenyuk (2008). These researchers discovered that when educators were supplied with opportunities for on-the-job learning and peer collaboration, program success rates increased, thereby demonstrating that blended learning is a valuable method for productive PD. Similarly, Qasem and Viswanathappa (2016) discovered that teachers coached within a blended learning instructional approach showed greater improvement in the depth of their ICT knowledge than those teachers trained through an e-course design. Adopting a blended learning culture is a significant shift and may be the bridge that leads teaching and learning into a new world of education (Tucker et al., 2017). The dynamic interplay between having some control over learning and peer collaborative interactions allows educators space to examine their instruction, student learning, and the learning environment in relation to technology integration for student learning.

**Community of practice (professional learning networks)**. Due to rapid change in the technology landscape, technology PD through a blended learning approach must be continuous so that technology is successfully integrated into education. One way that teachers have taken control over their learning is by joining professional learning networks to gain new knowledge and reflect on their practice (Krutka, Carpenter, & Trust, 2017). Online communities of practice create professional learning networks that allow learning anytime and anywhere (Bostancioglu, 2018), thereby fostering continuous development. Bostancioglu (2018) studied an online community of practice of foreign language teachers and found that the teachers perceived that they developed a deeper understanding and awareness of teaching and learning with technology, which provided evidence of TPACK. E-TPACK, a self-regulating online professional learning platform, was designed to teach teachers how to utilize technology to promote and measure ongoing TPACK development (Timotheou et al., 2017). These researchers pointed out that central to the system's adaptive feature is identifying and purposefully employing technology within a subject-matter topic and the curriculum. Online communities of learners provide a flexible foundation of PD by creating an engaging and collaborative learning environment that is unique for each participant.

**Job-embedded support.** In the past, teachers relied heavily on staff development sessions to introduce new procedures or techniques, a process which resulted in very little change in practice. Margolis, Durbin, and Doring (2017) addressed the need to change teacher PD by providing a framework that simultaneously addresses both cultural and structural changes. This action moves staff development from the boardroom to the classroom and directly ties PD to active participation with students. According to Darling-Hammond, Hyler, and Gardner (2017), job-embedded PD entrenches learning in a day-to-day setting that creates shared responsibility to improve teacher and student learning through content-specific instructional practices. Althauser (2015) called attention to job-embedded PD as a method of allowing teacher application of emerging practices in the classroom and increasing the probability that reform-based actions will continue.

Professional development that is conducted in the classrooms during the regular school day, in contrast to nights and weekends, provides an authentic platform to transform practice. Teachers collaboratively construct knowledge and reflect with colleagues with the intention of producing focused student-centered approaches. Achterman and Loertscher (2008) indicated that collaboration stimulates the brain, allowing for deeper individual and group learning. Researchers have suggested that teachers who engage in frequent and continuous conversations about teaching and learning will create a motivated culture of shared practice and build stronger self-efficacy (Altinay, Dagli, & Altinay, 2016). According to Darling-Hammond and McLaughlin (2011), collaboration in communities of practice can offer various opportunities for PD; teachers can implement problem-solving teaching and learning practices tailored to the unique needs of students and actively explore and evaluate new ideas and techniques with students' responses. Both methods give teachers more academic freedom, while providing real-time feedback on the PD itself. Therefore, educators should work together to improve teacher pedagogy for effective technology use.

Teaching content focused on teacher knowledge, classroom instruction, and student achievement is more likely to improve with sustained, job-embedded PD (Darling-Hammond et al., 2017). Authentic, intensive coaching over time gives educators the opportunity to learn, observe, and reflect (Speck, 2002). Teachers practice, learn, problem solve, and collaborate as part of a continuous improvement cycle without leaving their setting.

**Personalized learning**. Supporting teachers in continuous development that creates a positive shift presents a significant challenge for today's school districts. As education professionals, teachers can actively shape their practice in creating student-centered environments (Felton & Koestler, 2015) through PL. Hallman (2018) studied the challenges of PL through a middle school teacher's implementation of one-to-one iPads in her classroom. The teacher struggled with the fundamental shift in the relationship between the way knowledge was conceptualized and repositioned. Eventually, through her constant reflection, she became aware of the need for teacher agency, which allowed her to reposition knowledge toward technology and student learning. In a different study, Buzzard et al. (2011) found that technology did not play an essential role in the act of teaching. The process of learning new technology was seen as a challenging task. However, although challenging, researchers found that instructors and students recognized the inherent link between technology usage and increased knowledge and were very receptive to the idea of teaching and learning via digital technology (Buzzard et al., 2011). A pilot project conducted by Sheffield et al. (2018) helped teachers develop their digital competencies through collaboration on a digital professional learning network. The reflections made by teachers in the pilot (i.e., data) showed that enduring, rooted PD programs improve teacher confidence and preparedness to scaffold student learning of digital technologies successfully.

## Closing Thoughts on Chapter II

Technology is a tool that resides in the very fabric of everyday living. However, all of the benefits of technology usage as they pertain to teaching and learning in practice for PL were not yet evident in the literature. The paradigm shift moves education from teacher-centered to student-centered learning and challenges educators to incorporate digital learning into new pedagogic designs. However, school administrators and faculty who do not value technology may likely prove counterproductive to implementing change despite all efforts at developing and implementing best practices (Machado & Chung, 2015). Researchers have concluded that effective teacher professional learning requires changes at the political, instructional, and individual level (Twining et al., 2013). Although researchers have highlighted many challenges, they suggest that ICTs should be seen as an opportunity for exploring new goals, structures, and roles. The interactions of these factors are important in understanding change from teacher-centered to student-centered learning.

Technology-based reform or transformation represent much more than the use of technology ad nauseam. Increases in device volume and screen time are not the answer to modern education reform. The real goal involves shifting the focus of technology integration toward how educators use pedagogy to support technology-enabled learning (Ertmer & Ottenbreit-Leftwich, 2013). According to Koehler et al. (2013), technology-enabled learning requires educators to grow continually in the three frames of knowledge: content knowledge, pedagogy knowledge, and technology knowledge.  Based on today's advanced technology, teachers should be engaged in professional learning conversations and social networks about blended learning and PL with a goal of harmonizing students of differing knowledge status and interests and differing racial, religious, ethnic, and economic backgrounds.  The discussions and actions should focus on understanding how children learn and on moving education into the digital age.  Conversation and collaboration around understanding teachers' experiences are critical components in the many facets of the local learning environment because no educational model is one-size-fits-all.  The ingredients to redefine teaching and learning are all present, but the creative recipe is lacking.

Researchers, leaders, and practitioners need to continue to question, explore, and challenge the pedagogy, content, and knowledge needed to transform education.  Leaders must be able to understand and adapt to changing technologies and guide learning organizations toward accepting and implanting the change.  Darling-Hammond and McLaughlin (2011) stated that there must be regular occasions for active learning opportunities over an extended period with a connection to curriculum and standards.  Collaborative professional learning communities can create change within a district, school, and the classroom.

In this literature review, it was recognized that a technological revolution has drastically changed the education environment and the very profession of teaching.  Traditional teaching practices and PD models do not adequately cater to the technological needs of the modern student.  Furthermore, the existing pedagogy does not address the needs of teachers who are responsible for digital learning in a global learning environment.  Until educational leaders, from national to local settings, provide advocacy, technological resources, and effective PD, the traditional education landscape cannot evolve to meet the needs of the digital age.  Leadership is essential in shaping organizational norms and creating pathways for teacher learning. The technology revolution has started and understanding educators' experiences as they navigate the revolution is important to changing the learning experience in the 21st century.

# CHAPTER III

## SOLUTION AND METHOD

Students enter high school with varying levels of mathematical skill, confidence, and motivation. Teachers in secondary classes engage with students who may lack knowledge and skill in foundational mathematical reasoning or basic whole number arithmetic. This continuum of skill level presents teachers with many challenges when trying to close academic gaps in knowledge and meet the needs of all students. Attempts to diminish the skill gaps using traditional teacher-directed whole class instruction has not fully succeeded. Technology, when applied to decreasing these gaps and meeting the needs of every student, provides new opportunities to efficiently manage this level of differentiation. As Wolf (2010) pointed out: "Technology dramatically increases a teacher's ability to identify and manage the needs of many students, and for students to access a large variety of interventions, content, resources, and learning opportunities everywhere at any time" (p. 10). Personalized adaptive resources are implemented and maintained through the effort of the teacher acting as an agent of change. Given the still difficult process of adapting to a PL environment that incorporates technology-assisted learning, this qualitative study examined the implementation of a particular technological device in secondary math classes in order to provide educators and administrators with relevant insights that can be considered when applying such practices to their own classrooms and schools.

This chapter includes the following elements of the research methodology: an outline of the solution, justification of the solution, study context and participants, research paradigm, data collection methods, justification of use of instruments in context, data analysis strategy, and timeline.  Additionally, this chapter provides information about the procedures that were followed to ensure trustworthiness, and it concludes with a brief summary.

**Outline of Solution**

The purpose of this phenomenological study was to acquire a better understanding of the lived experiences of three high school math teachers in Southern Arizona who self-initiated and integrated ALEKS, a digital PL resource, to close academic gaps in knowledge for intervention and acceleration.  ALEKS is a personalized, adaptive technology-based mathematics resource. The use of ALEKS allows students to work at their own pace to meet individual needs.  Students work on a particular skill at the level appropriate for them.  McGraw Hill Education funded the digital adaptive resource, ALEKS, related to this research. The technology-based resource was implemented by the math teachers with administrative support. The solution for this study was expected to produce a qualitative record of teachers' lived experiences.

To fully understand the essence of teachers' experiences with a specific PL resource, semistructured interviews and classroom observations with debriefing sessions were used to explore the teachers views of the adaptive PL program; the impact of the PL resource toward their goal; and the effect on instruction, practice, and learning.  The research questions, interviews, and observations helped draw out individual experiences on instruction, practice and learning and how these personal practices aligned with the teachers' own educational beliefs regarding teaching and learning.  The intent was to fully understand the teachers' experiences with the math adaptive resource in their classroom.  If PL with adaptive technology is meant to make learning more personal for a student, then understanding teachers' perspectives, beliefs, and classroom practices can shed light on the role of information technology in the classroom. Few studies have provided empirical research on these effects in the context of a technology-enhanced learning environment. According to the literature, if reforms are to be successful, teachers need to be committed to implementing the program (Hanover Research, 2014; Marcinkiewicz, 1993). A better understanding of teachers' experiences using the adaptive resources can inform policies and decisions at national, state, and district levels that can transform the learning of all students.

Open-ended tools were used to obtain a rich and comprehensive description of each teachers' experience with the digital resource. The entirety of data for this study consisted of three open-ended teacher interviews, three classroom observations with debriefs, metaphors describing their experiences with teaching and learning with ICT, and autoethnographic journaling focused on my personal technology integration experience with educators. Through this unique use of journaling, the self-reflections also became data.

The interviews lasted approximately one hour and began with an open-ended question intended to elicit responses that moved toward questions that probed for in-depth responses. This technique allowed participants to describe their practices, beliefs, and feelings about their experiences fully and honestly, and the method allowed for a flexible, open-ended interview. I originally set up the pilot program at the catholic high school, so I had cultivated a relationship with three of the teachers and the administration team. I believed that I had instilled enough trust and confidence with the teachers and administration to honestly solicit ideas, celebrations, and frustrations.

**Justification of Solution**

St. Francis High School implemented a PL resource to meet the diverse academic needs of incoming ninth graders enrolled in Algebra 1. School leaders were concerned about the low math standardized test scores of incoming freshmen and their ability to be successful in Algebra

1, advanced high school math, and high school science courses. Low algebra skills and high failure rates were a concern in ninth-grade classrooms nationwide (Nomi & Allensworth, 2013). Most importantly, Algebra 1 was considered a gateway to advanced mathematics, science courses, and success in higher education, college-bearing courses (Paul, 2005). The standardized test scores of freshmen at St. Francis were well below the state average. Teachers spent the first 3 months of the school year reviewing prerequisite knowledge and skills with all freshman students in a traditional mathematics behaviorist approach. Because the teachers and students spent 3 months reviewing skills, they were unable to fully cover the content in the current courses. Use of direct instruction associated with content coverage was not meeting the academic needs of all students.

After the initial meeting with the teachers and administrators in January 2018, it was decided that adaptive resources would be implemented in Algebra 1 and Algebra 2 to address the various individual levels of students' mathematical academic needs. This step was taken based on growing empirical evidence that supports adaptive tutoring software to enhance the PL experiences and alter attitudes toward mathematics (Arroyo et al., 2013).

Teachers have a strong role to play in school reform efforts. To enhance mathematical knowledge with ICT, it is important to understand how teachers leverage technology to deliver PL and transform the learning experience for students. Having a strong knowledge base for teaching with technology will not necessarily translate to effective use of technology. Understanding teachers' educational beliefs and how they support technology use is equally, if not more, valuable. Consistent findings in the literature supported an association between teaching styles and teacher beliefs (Kagan, 1992). In order to explore that association, this phenomenological qualitative study was undertaken to investigate the professional learning and practice of high school math teachers as they implemented a digital adaptive learning resource in their classroom to support all learners, from intervention to enrichment.

## Study Context and Participants

Established in 2003, St. Francis Catholic high school was located in Southern Arizona where it served a diverse student population. In 2018–2019, 210 of the 282 students identified as Hispanic/Latino (74%). As of 2019–2020, the enrollment of the 4-year college preparatory high school was 281 students, Grades 9 through 12. Of the 281 students, 210 identified as Hispanic/Latino (74%). About 90% of the student population received some sort of tuition assistance—mostly through Arizona's tax credit program. Students came from a variety of educational institutions throughout the greater area. More than half of the student body transferred from catholic elementary schools (52%). The remainder of the student body arrived from public schools (30%), charter schools (12%), Christian schools (4%), and home schools (2%). Consequently, students came to St. Francis High School with varying levels of mathematical readiness and experience.

St. Francis' college preparatory vision was to provide a challenging academic environment and encourage Christian growth. In math, students had the option of college preparatory classes or honor classes. All math courses were designed to ensure the preparedness for credit-bearing college or university math courses. However, some students had gaps in their mathematical knowledge and were not ready for the rigorous college preparatory work offered at the high school. A variety of schools fed into St. Francis High School, so students entered into school with varying degrees of math competency and knowledge gaps.

The St. Francis High School math department consisted of three experienced math teachers, all of whom were the focus of the study. This study opportunity naturally unfolded due to the nature of my employment as a PL specialist and my recent move to Arizona. The selection of the three high school teachers also seemed logical based on their personal initiative and my work-related position. Thus, I relied on purposeful sampling, which is a qualitative research method that involves "selecting information-rich cases for in-depth study" (Patton, 2015, p. 264).

## Research Paradigm

Given the purpose of the research, I used qualitative research methods, as described by Lincoln and Guba (2000), to develop this study. Qualitative research is appropriate for qualifying a social or human problem (Marshall & Rossman, 2015). A qualitative method was designed to identify a phenomenon from the lived experiences of selected participants (Moustakas, 1994). The following questions guided this research:

1. What are the lived experiences (i.e., instruction, practice, and learning) of high school teachers using the mathematics adaptive personalized learning tool?
2. What changes in teaching and learning have high school teachers experienced through the use of the mathematics adaptive personalized learning tool in their classrooms?

This research was conducted through qualitative methods using a phenomenological approach. A phenomenological approach is suitable for developing phenomena and provides opportunities to gain insight and a deeper understanding regarding the experiences which are not perceived through quantitative research methodology (Moustakas, 1994). Patton (2015) stated that this approach carefully and thoroughly captures and describes "how people experience some phenomenon—how they perceive it, describe it, feel about it, judge it, remember it, make sense of it, and talk about it with others" (p. 115). In describing phenomenological research, Creswell

(2013) identified, "the type of problem best suited for this form of research is one in which it is important to understand several individuals' common or shared experiences of a phenomenon" (p. 81). As the researcher, I was allowed to study the phenomena in an environment that was familiar to the study participants (Marshall & Rossman, 2015). The phenomenological approach allowed me to examine the practices and philosophies of the teachers regarding the implementation of the digital resource and how it supported PL in their classrooms without imposing expectations of best practices on teachers (Ottenbreit-Leftwich et al., 2010).

## Data Collection Methods

To obtain a rich and comprehensive description of each teachers' experience with the digital resource, open-ended tools were used. The entirety of data for this study consisted of open-ended teacher interviews, classroom observations with debriefing sessions, metaphors reflecting participant's experiences describing teaching and learning with ICT, and autoethnographic journaling focused on my personal technology integration experience with educators. Through this unique use of journaling, the reflections also became data.

Prior to the data collection, I provided each participant with an explanation of the research, the purpose behind the research, and a reasonable expectation of what to expect in terms of time, questioning, and participants' rights. All three math teachers volunteered to participate in the study and signed a consent form (Appendix A) in accordance with the Institutional Review Board. Participants were advised that 45 minutes to 1 hour should be allocated for each data collection session (i.e., observation with debriefing session and one-on-one interview). Additionally, I ensured that their interests and rights as participants would be guarded and appreciated. I respected their right to participate as well as their right to withdraw from the study, if desired. To protect their anonymity, the participants and the high school were given pseudonyms. After voluntary consent, I began the data collection process.

Because I set up the pilot at St. Francis and assisted with initial implementation of ALEKS, I cultivated a relationship with the math teachers as well as the administration team. Importantly, "ultimately engaging in research requires building trusting relationships with the people in the setting being studied" (Patton, 2015, p. 355), and the relationship between the researcher and the participants in a study develops as knowledge is coconstructed (Bryman, 2003; Denzin & Lincoln, 1994; Gelo, Braakmann, & Benetka, 2008). Building trusting relationships allows the researcher access to all necessary environments, while also instilling trust and confidence in the research subjects. If the subjects have confidence and trust in the researcher, they are more likely to provide accurate and substantial information. As confidence grows among both parties, the researcher can cultivate an insider's point of view, thereby allowing him or her to be highly intuitive (Krauss, 2005), flexible, empathetic, and understanding. Significantly, I believed that I had instilled enough trust and confidence to solicit honest ideas, celebrations, and frustrations from the participants.

Several factors were considered before beginning the study and answering the research questions (Malterud, 2001). As the research tool, I was committed to reflexivity. I considered how my perspectives, my beliefs, and my presence affected the study and adequately accounted for the effects of my position (Malterud, 2001). Heath (2017) identified this commitment as the first step in phenomenological research methodology. To free oneself from presuppositions, she suggested the practice of *epoche* (Moustakas, 1994), which encourages a naïve approach to data. To nurture this mindset, Heath suggested creating a journaling process that spans the research period and commented: "This process demands thoughtful attention and a concentrated awareness of internal and external influences in order to create a mindset of receptiveness" (p. 94). Another important factor that was considered was data collection, which often includes large amounts of data and requires a well-documented analysis.

**Observations**

A mutually agreed upon date and time was set for each participant's observation and debriefing session. The observation was conducted with each teacher and lasted about 45 min to 1 hr. The observations provided evidence about how the teachers were using ALEKS in their teaching practices. Field notes were carefully taken in the back of the room using an observation sheet (Appendix B). The observation sheet included the teacher's name, date, and start and finish time. The observation sheet provided space to describe the setting, behavior, and activities of the participants. After each observation, I debriefed with each teacher and then found a quiet place to add my initial reactions and interpretations of the data.

**Interviews**

After the observations, a one-time interview was scheduled. The one-on-one sessions were conducted in the classrooms between the researcher and the research study participant. The one-on-one interview is commonly used as a valuable method of collecting insight of perceptions, experiences, and understanding of a given phenomenon (Ryan, Couglan, & Cronin, 2009). Kemple, Segeritz, and Cole (2011) recommended seeking teacher feedback as educators adapt to personalized technology-enhanced programs. Each interview lasted approximately one hour and began with an open-ended question intended to move toward questions that probed for in-depth responses (Appendix C). Creswell and Creswell (2018) noted that semistructured interviews are used to bring about a conversation that achieves an improved comprehension of the contextual and descriptive experience of participants. Notes were taken during the interview, and the interview was recorded with permission from the interviewee. A digital recorder was used in conjunction with the face-to-face interview to ensure the accuracy of the interview transcript. Interviews were recorded and transcribed in accordance with the Institutional Review Board procedures. The recordings permitted me to concentrate on the interview rather than on writing notes. The ability to go back and replay the interview provided more accuracy in transcribing for key information (Merriam & Tisdell, 2016). To remain as true to the facts as possible, prior to transcription, I listened repeatedly to the audio recordings of each debrief and semistructured interview to become familiar with the words of each participant.

For interview and observation notes to be useful, they should be extremely detailed, with facts from the field and the participants. Everything needs to be included, even the information that seems inconsequential or unnecessary. For comprehensive, timely, and accurate field notes, a researcher needs to be mentally focused and physically prepared. Detailed field notes require the researcher to stay locked in on the purpose of the research and avoid unnecessary distractions. This type of data collection can be physically and mentally draining, so the researcher should be cognizant of his or her limits (Patton, 2015).

The observations and open-ended interviews created a flexible format and allowed participants to describe their practices, beliefs, and feelings about their experiences with a personalized adaptive resource fully and honestly. After each data collection session, I wrote reflexive memos and recorded initial impressions to make sense of the data. Themes from the interviews were juxtaposed with my own reflective dialogue.

The qualitative approach of this study helped illuminate a deeper understanding of the teachers' perceptions and attitudes, while offering an opportunity to explore differences in implementation of the program by individual teachers on the same campus (Creswell &

Creswell, 2018). Conversely, quantitative research would not be able to focus on an in-depth understanding of the human experience within the context (Krauss, 2005) or the multiple realities of the participants in this situation (Glesne & Peshkin, 1992; Lincoln & Guba, 1985). The qualitative methods helped the teachers openly share their experiences with a personalized adaptive resource.

All collected data generated during this study were locked in a file cabinet throughout the duration of the study and then destroyed upon the confirmation of the researcher's EdD. The key to the cabinet remained in the researcher's possession during the period of study. The file cabinet was located in my home office. No one other than myself was permitted to access the locked file cabinet for any reason.

## Data Analysis Strategy

Data from the observations, interviews, metaphors on the concept of teaching and learning with ICT, and autoethnographic journaling were analyzed through a phenomenological lens. According to Creswell (2012), phenomenology is used to describe personal experiences and the essence of a phenomenon, which in this study was the experiences of teachers who implemented a personalized adaptive resource. Data can provide pathways to more detailed information and insights into individual experiences (Yilmaz, 2013).

All interviews and debriefs were transcribed. When complete, the study participants were encouraged to review the interview transcripts to validate the findings and ensure the accuracy of the data. The collected data was organized into data sets. Each data set included three digital files, one interview, one classroom observation with a debrief session and metaphors. The coding process began by carefully reading through all the data in the data set. All data sets were read thoroughly and in sequence from each participant. I examined each individual participant's interview, observation, and metaphor separately but also looked at all the data together to search for common threads. In the second phase of the process, open coding began with the rereading of one participant's entire data set and assigning a short summary code to every complete statement. This task was completed for each participant. In the third phase, common trends in the data sets were noted and grouped according to individual themes to establish measurements of relative frequency (Moustakas, 1994). Charmaz (2010) described coding as a critical link between the data collection and the explanation of meaning. In this study, coding was conducted line by line in each debriefing and interview transcript. During the coding process, broad themes were captured to better understand the lived experiences of each teacher's experience with ALEKS. Emergent themes from the interview questions, observations, and metaphors were juxtaposed with my own reflective dialogue. After all three data sets were analyzed and coded separately, a validity member check was conducted by asking each participant to determine whether or not the essence of each observation, debrief, and interview was correctly captured. The aim of this process, known as member checking, was established to ensure researcher bias had not interfered with the results (Lincoln & Guba, 1985). The participants agreed that the essence of their experiences had been captured, so no modifications or additional themes were presented to the researcher as a result of the check. Member checking enhanced the accuracy, credibility, and trustworthiness of the findings (Newman & Hitchcock, 2011). A collective list of topics was created, and similar topics were clustered based on common themes that emerged from the semi-structured interviews, observations with debriefing sessions, and metaphors. These were juxtaposed with my own reflective dialogue. The emerged themes were abbreviated as codes. Data analysis continued by cycling back through the 72 pages of transcribed data multiple times looking for descriptive wording from the topics. Descriptive wording was turned into categories.

For this study, data analysis involved looking for similarities and differences in perceptions, experiences, and relationships. I used first- and second-cycle coding methods to search for common themes from the interview questions, observations, and the metaphors on the concept of teaching and learning with the adaptive resource (i.e., similarities, differences, and complements). Themes from my interview questions, observations, and metaphors were juxtaposed with my own reflective dialogue. The goal was to fully understand the essence of the teachers' experiences and perceptions with the adaptive PL resource. Public documents from the school website were also collected to enhance my understanding of the experiences, relationships, and behaviors being discussed. Results were compiled and reported in table and narrative format.

## Timeline

Data for this study was collected over approximately two months, from February 2020 to March 2020. The observations began at the beginning of February and the interviews took place at the end of February and continued through the beginning of March. During the interviews, data from the conception of the pilot in January 2019 were captured. Once the data were collected, analysis immediately commenced in March, and results and findings were determined in April. The study was finalized in May of 2020.

## Triangulation

The study results were internally validated by the triangulation of data (Merriam & Tisdell, 2016). Triangulation is a "validity procedure where researchers look for any convergence among multiple and different sources of information to form themes" (Creswell &

Miller, 2000, p. 126). Supporting the findings through multiple sources (i.e., classroom observations, interviews with teachers, metaphors on the concept of teaching and learning with the adaptive resource, and autoethnographic journaling) were compared and contrasted to strengthen themes (Yin, 2014). The convergence of evidence and member checking ensured the participants were understood.

## Limitations

Limitations of this study were based on the design. The study was conducted in one high school instead of a school district or in multiple schools across the country, so the information gathered cannot be used to make predictions or control a situation. The data also cannot be used to generalize to a broader educational system or provide causal explanations (Yilmaz, 2013). This phenomenological study relied on a purposeful sample, which was a limitation that decreased the generalization of the findings. It may not have been the most productive sample for answering the research questions because the school and teachers were chosen based on my professional connections. Another limitation of the study was my role as the researcher. In addition to working for the company that supports ALEKS, I was the research instrument and could not be separated from the study. No one is truly objective, and researchers encompass different knowledge states and interests and come from diverse racial, religious, ethnic, and economic backgrounds. Each brings his or her experiences, ideas, and prejudices into the role of a researcher (Patton, 2015). Hence, bias may have been a factor because it was difficult to separate experiences from the research, but having some effect is unavoidable (Patton, 2015).

## Closing Thoughts on Chapter III

To develop the record of study, phenomenological qualitative research methods were used to help answer the following questions: What are the lived experiences (i.e., instruction, practice, and learning) of high school teachers using the mathematics adaptive personalized learning tool? What changes in teaching and learning have high school teachers experienced through the use of the mathematics adaptive personalized learning tool in their classrooms? Data analyzed were collected through teacher interviews, classroom observations, metaphors on the participant's experiences with teaching and learning with ICT, and autoethnographic journaling to illuminate teachers' perspectives and insights. The results of the qualitative phenomenological study will allow educators and administrators to understand the experiences of teachers implementing a personalized adaptive resource.

# CHAPTER IV

# ANALYSIS, RESULTS, AND FINDINGS

During the 2018–2019 school year, St. Francis High School's incoming ninth-graders' standardized test scores were well below the state average. Ninth-grade students underperformed on the ACT Aspire Test in mathematics as compared to the rest of Arizona. Students below proficiency had a difficult time applying mathematical concepts and procedures and successfully participating in high school mathematics and science classrooms. The participant teachers believed that the use of direct instruction associated with content coverage was not meeting the mathematical academic needs of all students because several students had significant knowledge gaps. The goal of this phenomenological research was to understand as accurately as possible the lived experiences of three high school mathematics teachers who implemented an adaptive personalized resource to improve mathematical skills and close academic knowledge gaps.

The data collected and examined focused on the following research questions:

1. What are the lived experiences (i.e., instruction, practice, and learning) of high school teachers using the mathematics adaptive personalized learning tool?
2. What changes in teaching and learning have high school teachers experienced through the use of the mathematics adaptive personalized learning tool in their classrooms?

After the presentation of data collection and analysis processes, the following sections are presented: (a) a participant overview and participant profiles, (b) a description of the context with relevant details, and (c) the findings related to the two research questions. Each participant took part in the study under a pseudonym to allow their responses to be authentic.

## Introducing the Analysis

Data for this study was collected from the perspectives of three participants who participated in one classroom observation with a debriefing session and one semi-structured interview, including their metaphors on the concepts of teaching and learning with ALEKS. For each observation, I completed an observation form (Appendix B), which included categories of setting, behavior, and activities of the participants. Observational data resulted in seven to eight pages of notes per participant. Teachers were given the opportunity in observation debriefing sessions and the semi-structured interviews to share their experiences using the PL resource with their students. The one-on-one sessions were conducted in their classrooms, in person, between the researcher and the research study participant.

A digital voice recorder was used in conjunction with the face-to-face interview to ensure the accurate transcription of the interviewee's responses. The timeframe of the debriefing sessions ranged from 15–25 min and the timeframe of the interviews ranged from 45–50 min. To remain as true to the participants' words as possible, prior to transcription, I listened repeatedly to the audio recordings of each debrief and semi-structured interview to become familiar with the words of each participant. When the transcription of the debriefs and interviews was complete, collected data was organized into data sets. Each participant's data set included three digital files: one interview with metaphors, one classroom observation, and one debrief session.

The coding process began with the careful reading of all the data in a data set. All data sets were read thoroughly and in sequence from each participant. In the second phase of the process, open coding began with the rereading of one participant's entire data set and the assignment of a short summary code to every complete statement. This task was completed for each participant.  After all three data sets had been analyzed and coded separately, trustworthiness was addressed by implementing a member check that involved reaching out to each participant by email to determine if the themes had captured the essence of their experiences.  Participants validated the themes, so no modifications were made as a result of the member check.  A collective list of codes was created from the data sets.  In the third phase, common codes were grouped together and one theme with five subthemes emerged.  Data analysis continued by cycling back through the data multiple times looking for descriptive wording related to the themes.

## Presentation of Data

This study took place in a small 4-year college preparatory catholic high school in Southern Arizona.  St. Francis' vision was to provide a challenging academic environment that encouraged Christian growth.  Established in 2003, St. Francis comprised a diverse student population.  As of 2019–2020, enrollment was 281 students in Grades 9 through 12.  Of the 281 students, 210 identified as Hispanic/Latino (74%) with quite a few immigrant families and some refugees from Africa.  About 90% of the student population received some sort of tuition assistance, mostly through Arizona's tax credit program.

A former seminary, the school was housed in a Mediterranean-style building that boasted over 44 acres of pristine desert.  The exterior was comprised of a red brick rectangular floor plan with an enclosed lush, green courtyard.  The facade's grand white arch protruded above the two-story building.  The arch was topped with a sky-blue dome and centered on top of the arch was a white cross.  Cascading terracotta steps led through the arch to the double, glass door entrance. Above the front door of the school and below the arch stood a statue of the Virgin Mary.

Walking through the front door, I saw two students in uniforms wearing solid color khaki pants and blue polos opened the back doors, directly across from the front doors, into the courtyard.

The mathematics department was located through the courtyard and to the right of the entrance on the second floor in the mathematics wing. This wing was composed of three adjacent rooms and was located down a narrow hallway, just passed the girls and boys bathrooms. The average mathematics class size was 16 students. In mathematics, students had the option of college preparatory classes or honor classes. All mathematics courses were designed to be college preparatory in nature to ensure the preparedness for credit-bearing college or university mathematics courses. However, some students had gaps in their mathematical knowledge and were not ready for the rigorous college preparatory work offered at the high school. The variety of schools that fed into St. Francis meant that students entered high school with varying degrees of mathematics competency and knowledge gaps. Varied skill levels and gaps in mathematical foundations created ongoing challenges for the mathematics high school teachers attempting to meet individual student needs.

The teachers in this study used ALEKS to enhance teaching and meet the diverse mathematical needs of all students. ALEKS is an adaptive resource that encompasses the notion that there are multiple pathways to accomplish a series of learning objectives. A corporate synopsis pointed out that "ALEKS is based on the understanding that students learn math in different ways and at differing speeds" (ALEKS Corporation, 2017, p. 1). Adaptive learning resources can be used to raise all students' achievement by meeting each individual's needs, tailoring instruction, and ensuring that all responses subscribe to a sound pedagogy (Fu, 2013). ALEKS uses artificial intelligence to assess a student's current mathematical knowledge and areas for growth in a particular course. The initial knowledge check determines what a student knows, does not know, and, most importantly, what he or she is ready to learn (ALEKS Corporation, 2017). ALEKS delivers students a personalized pathway on the exact topics a student is most ready to learn, keeping students in their zone of proximal development while filling knowledge gaps in understanding. The ready-to-learn pathways allow students to skip around and work on different concepts within their pathway.

## Participants

All of the research study participants were active mathematics teachers who had been teachers for at least 7 years. The three teachers participated voluntarily without compensation or other means of reward for their involvement. There was one female teacher and two male teachers. Observations, debriefing sessions, and interviews were conducted one-on-one, face-to-face, in the classroom that was common among their day-to-day operations. Among the three study participants, the years of teaching ranged from 7 to over 30 years. All three participants had a bachelor of science degree in mathematics and two participants had a master's degree. Table 1 provides a description of each participant identified by their assigned pseudonyms.

Table 1

*Participant Characteristics*

| Participant | Gender | Years of experience | Educational level | Geographical experience |
|---|---|---|---|---|
| Lorraine | Female | 17 | Bachelor of science in mathematics | U.S. (AZ, LA) |
| Carlos | Male | 30+ | Master of science in mathematics<br><br>Bachelor of science in mathematics | U.S. (AZ, OH), United Kingdom, Spain, and Venezuela |
| Alberto | Male | 7 | Master of education in mathematics<br><br>Bachelor of secondary education in physics and mathematics | U.S. and Philippines |

Teachers were asked to share metaphors on their initial and current experiences with teaching and learning with ALEKS. As illustrated in Table 2, teachers' initial experiences evolved as they continued using ALEKS in their classroom.

Table 2

*Metaphors of Teaching and Learning with ALEKS*

| Participant | Initial reaction | Current reaction |
|---|---|---|
| Lorraine | Chaotic. Not sure how to implement it. | Harmony. More balance in my class. The students are more confident, I feel at ease and not worried about getting through the curriculum. |
| Carlos | Paella. Rich in many fruits of the sea that one does not get tired of satisfying hunger. | Infinity. It has no limits. It contains infinite stars, planets, galaxies that are yet to discover and learn more about them. |
| Alberto | Light bulb. Spark of light. | Light bulb. Shining bright. |

**Lorraine**

Lorraine was a caring and enthusiastic educator who greeted her students with a glorious smile. She was highly motivated and committed to the spiritual and academic growth of all students. She created a supportive, collaborative, and challenging academic environment for students that was important for mutual respect, cooperation, and high achievement. Lorraine had a bachelor of science in mathematics and had 17 years of teaching experience in Arizona and Louisiana. She volunteered to pilot ALEKS, but Lorraine was not sure how to implement it. "I don't know if this is going to work. So, in the beginning, it felt a little chaotic." Her biggest struggle was convincing the students that using ALEKS was in their best interest. She continued using it making periodic adjustments. As she reflected on its impact, she began to observe what she perceived as an increase in student academic achievement, mathematical confidence, and student regulation. She felt that ALEKS was bringing more harmony to the learning environment and said:

> There is more harmony in my class. I don't feel like I am worried about getting through the curriculum. I feel like we can do this! In the kids I see more confidence. God created us; we are math inclined by nature. Once we close those gaps, you will be able to do this math.

**Carlos**

Carlos was a compassionate educator with diverse experience. "I am very passionate and very passionate about my subject." A highly enthusiastic, student-centered mathematics teacher, he had more than 30 years of experience teaching at the secondary, undergraduate, and graduate levels in a wide range of environments, including classrooms in the United States, the United Kingdom, Spain, and Venezuela. Carlos had a master of science degree in mathematics and was committed to maintaining high standards in mathematics education. "I am a very firm teacher, but I am a very fair teacher. I am persistent, and I am not going to lower my standards." Carlos found ALEKS very interesting. After watching Lorraine, implement ALEKS with her freshman, he decided to try it with his students. He found ALEKS to be individualized and personalized. Carlos said, "I love it! I love it! It is like Paella; it is rich in many fruits of the sea that one does not get tired of satisfying hunger." He perceived that ALEKS would help all students no matter what their knowledge when they started the mathematics class: "ALEKS is going to create an individualized path for success for each student." He has noticed that some students learned and mastered topics very quickly and some spent more time doing so. He saw a difference in his classes and observed a growth in students' academic achievement, mathematical confidence, and motivation. He described ALEKS as resembling infinity, with no limits. "It contains infinite stars, planets, galaxies and things we have yet to learn."

**Alberto**

Alberto was a gentle and caring teacher who wanted all students to be successful learners. He worked to create a classroom atmosphere that was encouraging to the academic and spiritual needs of all students. He began his class with a reading from the Bible and provided an academic environment that encouraged Christian growth. Originally from the Philippines, he had a master of education degree in mathematics and had taught 6 of his 7 years in the Philippines. This was his first school year in the United States and his fifth year teaching in a catholic school. Even though he did not receive the same initial training as Lorraine and Carlos, he was able to have a positive experience as a whole. His first 4 years of teaching in a technology rich environment prepared him for ALEKS. He said:

> My first 4 years enriched me in how technology affects learning. When I found out about ALEKS, I was excited. It was something I was so happy about. Like a lightbulb that sparked open. I love math. I love technology!

Because of his experience, he believed that technology assisted teaching and learning. Although he was not sure how to use it in the beginning, Alberto was open to using ALEKS to possibly improve his teaching and student learning. He felt supported by his department, the school administrators, and me, the ALEKS specialist. During the study, he described ALEKS as a lightbulb shining bright. He believed it was effective in addressing deficit skills, assisting students in becoming independent learners, creating a love for mathematics, and building self-regulation.

From an observational stance, students entered the classrooms of all three teachers politely and with low voices. Shortly after the bell, all observed environments began class with a prayer. The classrooms transitioned from a buzz to silence. The first 15–20 min of class, students worked independently in ALEKS. Routines appeared to be clearly established and the classroom environments were generally a quiet space. On the wall of each classroom, a typed progress tracker, the size of a piece of paper, showed mastery growth for each student.

Lorraine's classroom featured six groups of four connected desks facing each other. Students entered the classroom talking quietly, laughing, and smiling. Once the bell rang, students took their seats and pulled out their computers, notebooks, or whiteboards. Students bowed their heads, and some folded their hands in prayer as Lorraine shared a prayer with the class that ended with a collective, "Amen." Students logged into the ALEKS website. Lorraine stated, "You have 15 minutes. I'm starting GoGuardian [a software tool to monitor online learning], so there is no shopping or wandering." Lorraine moved around the room answering questions, laughing quietly, and smiling as students worked on the topics in their PL pathway. One student declared, "Ok, I don't know how to do this!" Lorraine walked over to his desk and leaned over his left shoulder. She asked him if he looked at the explain page and watched the video. A collaboration ensued, and the student shared work on his whiteboard. Students wrote out problems in their notebooks or on a whiteboard. Most students worked independently, navigating between their computers and their whiteboards or notebooks with various pockets of students working together. Students were clearly comfortable asking each other and their teacher for help. In the debrief, Lorraine mentioned: "I encourage them to work together, and they know that I am here to help them figure it out. . . . I tell them, in the work force you are out there working with people and you are collaborating and brainstorming together." It appeared everyone was on task and working with ALEKS. I did notice two students on the right side of the room talking and slouching in their chairs. They appeared disengaged. Lorraine walked over to them and asked them how they were doing. She pointed to one of the student's screens and advised that a calculator could be used on a particular problem. Then Lorraine shifted attention to the other student and told him to try an easier topic and pointed to his screen. Lorraine shared: "There're some students that struggle with the benefits of ALEKS, time management and motivation. . . . I do a lot more coaching with those students." At the end of the 18 min, Lorraine asked them to finish up and put their computers away. I noticed a few students toggle to their reports; some declared, "I finished four topics!" or "I finished two topics!"

Carlos and Alberto's classrooms represented a more traditional setup with five to six rows of desks facing the front of the room and an aisle dividing the rows, partitioning three desks on each side of the room. After the prayer in each classroom, Carlos and Alberto introduced me and then asked students to work in ALEKS. Generally, the classrooms were a quiet space with the occasional hum from the air conditioner. Most learners worked individually; some sought support from a neighbor or the teacher.

In Alberto's geometry classroom, students used iPads to independently work on topics in ALEKS. Students worked out problems on paper or worked out problems in their head; they listened to videos and music and input answers on their iPads. Students navigated between reports, their dashboard, and the topics. Some students filtered their learning pathway and selected topics to work on. Three students raised their hands when they needed support and Alberto walked to their desks. Two students were playing a game when Alberto checked on them. He said: "You aren't' able to trust yourself in doing ALEKS on your own, and you haven't reached your goal." At the end of 15 min, Alberto stated: "Time is up for ALEKS." During the debrief, Alberto mentioned that some students really love working in ALEKS and are motivated to work on their topic goals. These students always ask to work in ALEKS. They say: "I'm finished, can I do ALEKS now?" However, he continued:

> Sometimes a few students are not doing ALEKS when they are given time in class and go to other websites [like the games today]. Then they tell me they don't have time to work on ALEKS when they don't reach their goals. Those students are difficult to motivate in general, not just in ALEKS.

He mentioned he was still trying to find ways to motivate all the students, so all students have positive academic results and gain life-long learning skills.

In Carlos's precalculus classroom, students independently used Chromebooks and calculators to work in ALEKS. Learners went to Carlos's desk for assistance; he also called students to his desk to discuss their learning data (i.e., mastery level and topic goals). A few students who were not meeting their goals complained that ALEKS took too much time. During the debrief, Carlos shared:

> I am trying to introduce them to lifelong learning, goal setting, and reflection. I don't want them to see math at the end of the topic. I want them to reflect on their school goals and their life goals. I am always asking students, what do you want to study in college or after high school? I tell them they need to work through this process and find time.

Across all three observations, most students made choices to work towards their goals and assumed responsibility for their learning. Teachers established clear routines and expectations and assisted when students requested support or when they needed redirection.

## Findings of the Research

Data analysis of the interviews, the metaphors on teaching and learning with ALEKS, and the classroom observations with debriefs yielded one broad theme and five subthemes. The main theme that emerged was that the experience using ALEKS was a unique personalized journey. The emerging subthemes were: various entry points, cycles of reflection, changes in instruction, strategic use of data, and student-centered learning (Table 3). In the next sections, I present the data organized by these themes.

Table 3

*Themes with Descriptions*

| Theme and subthemes | Description of theme |
| --- | --- |
| The process with adaptive technology is a unique learning journey for each participant. | The journey as a whole for these three participants started out as an exciting endeavor but they were unsure about different aspects of the process. Each ended up more excited and confident, which led to different actions in their teaching. |
| Various entry points | Participants shared different entry points into this journey with ALEKS, the adaptive resource. |
| Cycles of reflection | Based on the reflective comments, teachers continued their personalized journey adapting to the changes and challenges in their classrooms. |
| Shifts in instruction | An important instructional shift in the journey shared by participants was a shift in planning remedial whole group learning to planning critical thinking activities. |
| Strategic use of data | Learning to strategically use data to plan instruction, set goals, collaborate, and motivate students was another part of the journey shared by participants. |
| Student-centered learning and self-regulation | Along the journey participants recognized student-centered learning experiences related to self-regulation. Teachers provided learners the necessary tools to support self-regulation. Students became active participants, assuming responsibility for their learning. |

**Personalized Journey**

"A flower doesn't think of competing with the flower next to it. It just blooms!" ~Zen Shin

The main theme that surfaced through the teachers' implementation of ALEKS was that the they were on a learning journey that continuously evolved as they worked to meet the diverse needs of the students. ALEKS was implemented to deliver a personalized pathway on the exact topics each student was most ready to learn; it was a student-centered approach to learning. In using this technology, the participants experienced a fundamental shift in how they were targeting mathematical differences, strengths, and gaps.

Prior to using ALEKS, all three teachers would stop and reteach or plan whole group lessons on remedial skills to try to target the mathematical differences and skill gaps of students. Lorraine was the early adopter and started her journey with ALEKS in January of 2019 with the freshman in her Algebra 1 classes. She said:

> In the past, I spent a lot of time trying to identify exactly where the weaknesses were for each student. That was just impossible. I did my best to group them. I did differentiate, but it was very time consuming and I was losing a lot of time outside of the algebra curriculum.

Certain skills are essential to understanding algebra, and Lorraine explained she would have to stop and reteach prerequisite skills:

> We found out that the middle schools were not teaching laws of exponents. It is expected that they know it by the time they start my class. So, in the past, I would have to teach a unit on laws of exponents. So, what I am hoping is that ALEKS will provide targeted instruction for each student's needs and take care of that because they are typically easy topics to learn.

Shortly after Lorraine voluntarily started her journey, Carlos grew very interested and said he willingly took a step into the personalized journey with a few of his Algebra 2 students:

> At the time the 9th grade class was a pilot. I said, let me try to do it with my Algebra 2 students. However, for the 2019–2020 school year, we decided it must be for everybody. I love it! I love it!

Alberto was hired as the third mathematics teacher in July of 2019 and excitedly began implementing ALEKS in August of 2019 as part of the school initiative. He was delighted about using ALEKS even though he had limited understanding of how it worked. As he smiled, he commented: "I know that technology aids in education. The unique feature of ALEKS, which is artificial intelligence, identifies students' knowledge and allows [for] students' independent learning."

Implementing an adaptive resource was a journey unique to each teacher. The three traditional teachers took the brave first steps into the journey with the belief that ALEKS was going to help every student. All three teachers were open to a new way to meet individual student's unique needs and entered the journey at a variety of points.

**Various Entry Points**

The first subtheme that emerged was that all teachers willingly entered the journey at various entry points with the belief that using the adaptive technology resource would address the various levels of students' mathematical academic needs and change the way individual learners practice and understand concepts in mathematics.

Lorraine was the first one to step into the journey with 70 freshman students. Not knowing if it was going to work, she was willing to contend with disorder and confusion. She told the students that this was something they were going to try in mathematics class:

> I love ALEKS, but I wasn't sure how to implement it so that we got the best results out of it. I think the biggest struggle was convincing the students that it was in their best interest. It was going to help them. They looked at it more like something else I have to do.

Lorraine set a 3-hr expectation for students. She gave the students 10–15 min at the beginning of each class to work in ALEKS in place of warm up problems. Therefore, students were responsible for about 1.5–2 hr outside of class. This out-of-class responsibility was a struggle for students. Lorraine explained: "Another struggle was the time commitment that we expected them to be on ALEKS to help make those improvements. We did 3 hours because that is what we were testing out."

Carlos heard about ALEKS at a previous school and talked to the principal and Lorraine about piloting ALEKS. "I've worked with ALEKS in another school, and I found it very interesting. When I was reading about it, I could see that it is more personalized than MathXL. I loved it!" The initial pilot involved the 9th grade and the freshman teacher. The goal was to fill the gaps. Carlos saw these gaps in his classes:

> The ninth grade had lots of gaps and it was trickling into my Algebra 2 and pre-Calc class. However, I said, let me try it with my Algebra 2 students. The first time my students did the initial knowledge check, I could see the results right away. What is this? It is like an X-ray that I can see through. The pie chart shows me which topics they know, which topics they need to concentrate on, which ones they understand, which ones they need more practice on, and which ones I can reinforce in the future. You can see this immediately. This is beautiful!

Hired in July of 2019, after the initial pilot, Alberto was introduced to ALEKS 1 week before the start of the school year. With a master's in technology education, he said he was excited about using ALEKS:

> I know that technology aids education. I was excited about using ALEKS. Even with the limited time I had to understand what the program had to offer, I was able to have a positive experience as a whole. But I am always wondering about if I am using it effectively. How much more am I able to better understand the reports to monitor my students?

When Alberto started using ALEKS, Lorraine was the teacher for his class in ALEKS, and he was the co-teacher. She wanted to support him. Alberto said: "I had a lot of questions. But because Lorraine, Carlos and you were there, it wasn't as hard as I thought because I had the support. I was able to get through it and explore the possibilities."

Although the teachers entered the journey at different entry points and were uncertain of how it would play out, they continued their journeys. They believed ALEKS was going to meet individual learning needs, fill gaps, and accelerate learning. This belief fueled their interest and the teachers continued forward, adapting to the changes and challenges in their PL classrooms.

**Cycles of Noticing and Reflecting**

The second major subtheme that emerged was that the journey included several cycles of noticing and reflecting. The theme of noticing and reflecting could not be easily identified by using observation only. Several times, all three participants demonstrated their ability to notice and reflect during the follow-up debriefing session and interviews. When they had the opportunity to further elaborate on what they were noticing as students worked in ALEKS, they saw how that knowledge transferred into their teaching and student learning. The cycles of noticing and reflecting helped the teachers navigate their journeys as they rethought their approach to expectations, lesson design, and assessments.

During the initial pilot, Lorraine set a 3-hr-per-week time goal for the ninth graders' time in ALEKS. She said she noticed an improvement for those students who met the weekly time goal: "We did find, [that] those students who committed to working 3 hours per week in ALEKS, their grades did improve. What was holding them back in my class was that they had a lot of deficiencies from prior grades."

That is when she noticed that ALEKS was working. "Thank God! Thank God! It is working!" She perceived that ALEKS was helping to fill those gaps for most students. However, she noticed there were some students who were not progressing. They did not commit to the 3 hours per week, and they were still struggling in algebra. "So," she continued, "we began to think. Is there something else we can do that might motivate them?"

Moving into the 2019–2020 school year, the mathematics department and administration decided to present ALEKS as part of the curriculum. Beginning with the incoming freshman, the school hosted a freshman academy using ALEKS as part of the curriculum. Lorraine presented ALEKS, "just like a textbook" and noticed that more students got on board. "In fact, they whine and cry if I don't give them their 15 minutes of ALEKS," Lorraine laughed. During the second year of implementation, in addition to presenting ALEKS as part of the curriculum, the mathematics department also gave the students more information about the purpose of ALEKS. The teachers felt that students moved into the 2019–2020 year with a good understanding of how ALEKS supported their learning and with a clear understanding of why they were being asked to use ALEKS.

In addition to presenting ALEKS as part of the curriculum, the mathematics department set personalized weekly topic goals and mastery goals for students using a goal tracker. They believed this was a strategic shift from the 3-hr goal during the spring 2019 pilot and hoped it would encourage more participation. They noticed that by focusing on topic goals and mastery goals, more students were inadvertently spending the necessary time working through their ready-to-learn topics, to meet their weekly topic goals. The shift from time goals to topic goals and mastery goals had encouraged more participation, but Alberto observed that some students were not challenged and motivated, so he adjusted the topic goals and mastery goals to be a little more individualized. He said:

> Last semester, I divided the total number of topics students needed to learn over the number of weeks they had in the school year. Over time, I realized that at the beginning of the semester, the students are not as challenged because they were somewhat familiar with the topics. Learning rate slowed as students approached course completion. So, I decided to switch it. I took the chart you recommended, and I tweaked it a little bit. I noticed that students were more motivated when their topic goals decreased as mastery increased. Before it would take them at least 2 weeks to increase mastery depending on their pace. Now, they get it in a week. It is more granular per week, but they have more satisfaction that they have achieved something.

All three teachers commented that they also noticed that through the teacher's expectations, more students managed their learning, valued mastery, and increased mathematical confidence. They believe ALEKS helped students independently learn mathematical skills, monitor their understanding of mathematical knowledge, and alter their attitudes toward mathematics. Some of the following comments by students led participants to believe ALEKS was helping students: “I already learned this in ALEKS;” “This topic is easy because I already did it in ALEKS;” “Finally, we are now on this topic. I’ve been stuck on this topic in ALEKS for quite some time;” “I know how to do this because of ALEKS. May I show my work on the board;” “Can you check if I’m doing this right, I’ve done it in ALEKS before.”

Not only were teachers noticing this shift in learning and motivation during class, but it was also indicated on the ACT Aspire test given in October of each year to all freshman and sophomore students. ACT Aspire is an assessment system used to measure academic achievement. Anchored by the ACT test, it connects students’ performance to college and career readiness standards (ACT, 2020). Teachers compared the 2018 results to the 2019 results. Several of the categories caught their attention, especially the category, probability and statistics, which showed significant academic growth. Interestingly, this topic was not a topic the teachers had covered in class, but students showed considerable growth. The one thing they all considered was that there must be a correlation between the increased scores on the ACT Aspire and work in ALEKS. Intrigued, Carlos looked at the results summarized in the ALEKS Pie Report and noticed that many of the students had achieved mastery in the probability and statistics domain. He stated: “Maybe ALEKS is why, and it is fantastic!”

As teachers noticed differences in students' reactions, learning, and confidence, they also noticed that teaching their core curriculum had become easier. They believed they were spending less time on reteaching lessons and skills. Lorraine shared: “I can quickly review, and I can quickly move.” The cycles of noticing and reflection led to different pathways along their journeys.

**Shifts in Instruction**

The third major subtheme that emerged along the journey related to shifts in the teachers' instruction. As students worked in ALEKS, teachers believed the students gained confidence and motivation, generating alternative pathways for teaching mathematics. Increased knowledge and confidence granted teachers time and flexibility to incorporate justification and modeling activities and created more opportunities for mathematical discourse.

The teachers perceived that the adaptive resource allowed students the time to practice, learn, and master skills at their own pace at their instructional level versus their grade level. As students worked in their PL path, they worked on topics they were ready to learn and had more opportunities to learn at their own pace with a high degree of success. Lorraine mentioned: "Being able to start students at their level, gives students confidence and more motivation." She also indicated that her Spanish speaking students used the Spanish toggle component to switch back and forth from English to Spanish instruction. She said: "Since [work in ALEKS] is at their math level, [Spanish speaking students] are able to read the problems in Spanish and figure out the math. At least their math skills are developing." Lorraine believed ALEKS supported her in meeting the needs of each learner in her class by adapting to each student's individual academic needs. ALEKS provides students immediate and individualized feedback on their progress and detailed explanations to help them building mastery, and teachers can use the data from ALEKS to facilitate individualized learning, motivation, and social and emotional competencies.

All three teachers commented that when using ALEKS, they moved at a faster pace through their course instruction and spent less time on remedial prerequisite activities and skills. As previously mentioned, teachers shared that students often stated: "I learned this in ALEKS!" Carlos elaborated: "Some are very happy when they say to me, 'I've studied that topic already in

ALEKS. I know about logarithms. I know about exponents.'" These teachers believed ALEKS filled in individual knowledge and skill gaps, built student confidence, motivated students to learn, and supported student ownership. After using ALEKS, the teacher participants perceived students quickly figured out mathematical problems and applied the content knowledge to other critical thinking and problem-solving activities.

All three teachers incorporated critical thinking activities into class during the semester when the study occurred. Lorraine incorporated justification and modeling activities. She elaborated at length about how students had risen to the challenge:

> In the beginning it was a struggle, because this type of thinking takes time. Part of it was [the students] being patient with themselves. One of the things I am able to do since using ALEKS is incorporate the CSI packets. Students have to solve a crime. There are six crime scenes and they have to solve them. I don't help them at all with it. They work in groups to figure it out. The math is easy for them. It is figuring out what to do with the math that is hard. Usually it takes a good 30–40 minutes before someone says, "Oh, I get it!" That is the part they don't like because it takes them so long to figure it out. But they are realizing that they can do it. I am trying to get them out of the habit of saying "I don't get it!"

Lorraine believed this shift in instruction and student perseverance was possible based on the knowledge skills and life skills students learned by working in ALEKS:

> ALEKS has helped in creating a growth mindset. In the beginning, [the students] kept raising their hands and saying, "I don't get it!" A lot of them now look at the explain page and the video. I do tell them that if they have tried to understand it, and can't figure it out, that I will help them.

Similarly, Carlos incorporated justification tasks and problem-solving activities into his classroom. He believed students gained the knowledge and confidence to explain and justify problems that require higher level thinking and application since working in ALEKS. Carlos shared a few of the problem-solving activities he used in class:

> Why when you add the angles of any triangle, no matter what triangle, you get 180 degrees? Can you prove it? Can you question it? We need to get them to think and apply. I have asked the students, what happens if you are working with geometry? Let's say you have a cone and you double the height of the cone and keep the same radius. What happens to the volume?

Additionally, Carlos believed students solve problems faster and use academic vocabulary to justify their thinking. He said: "ALEKS helps! It is fantastic!"

These examples illustrated that the teachers' journeys included a shift in their instruction to include personalized adaptive technology and higher level thinking activities. All the teachers believed the shift from planning and teaching below-grade-level remedial tasks to incorporating higher level thinking activities and increased mathematical discourse was possible due to students learning and mastering skills in ALEKS. Prior to using ALEKS, teachers spent a lot of time trying to identify exactly where the weaknesses were for each student. "That was just impossible," Lorraine commented. Because of ALEKS, teachers felt more students were working on grade level and accelerating in mathematics at their own pace with a focus on mastery-based learning. The teachers believed there was a fundamental shift in how mathematics education was being delivered in their classrooms. They believed teaching and learning would further evolve as they continued on their journeys.

**Strategic Use of Data**

The fourth major subtheme identified during the analysis was the strategic use of data. As mentioned in the section on noticing and reflecting, teachers observed changes in learning, confidence, and attitudes in students who were spending at least 3 hours per week learning in ALEKS. During the pilot, Lorraine set time goals and used the Time and Topic Report to monitor students. However, Lorraine perceived that setting time goals was not motivating all students or meeting each student's individual educational needs. She commented: "When the goal was time, it seemed to burden the students." Although Lorraine noticed a positive difference in academics, confidence, and motivation in those students who were spending the 3 hr per week in ALEKS, she wondered what else she could do to motivate all students.

As teachers continued their journey to create PL opportunities for all students, they explored other goal setting opportunities in ALEKS using the data. After consulting with me, their PL specialist, teachers decided to change the weekly time goal expectation and assigned students topic goals and mastery goals for the 2019–2020 school year. To monitor progress on topic and mastery goals, teachers used the Time and Topic Report and the Progress Report. In addition to setting topic and mastery goals, teachers started assigning students grades for weekly completion of topic goals and quarterly progress of mastery goals.

Carlos stated that he began the school year by explaining ALEKS to students and setting topic and mastery goals based on individual mastery after the initial knowledge check. The initial knowledge check determines what a student knows, does not know, and most importantly, what they are most ready to learn in a course. Carlos worked with each student and personalized topic and mastery goals using the ALEKS reports. He said: "Based on your mastery and the number of topics you need to learn this year, this is the number of topics you need to achieve by the end of the year." Carlos also told students that ALEKS was going to be a weekly grade this school year and shared how the grades were going to be calculated. He explained: "Setting expectations and setting goals has helped. Assigning a grade in ALEKS has helped a lot!"

The teachers believed they became more confident interpreters of the data in ALEKS because they tracked students' learning and mastery progress using the ALEKS reports and assigned grades based on students' progress. As a result of setting topic and mastery goals, teachers perceived that students focused on learning the topics and increasing their mastery level. Teachers observed students using their individual reports to monitor topic and mastery goals and collaborating with their teachers about their own learning. Teachers often heard students asking each other, "How many topics did you learn this week? Did your mastery level go up?" Teachers perceived that setting topic and mastery goals had helped students understand why they were using ALEKS and to see their progress in mathematics.

**Real-time data use**. As students work in ALEKS, the adaptive resource captures a plethora of detailed information available in real time for teachers. Teachers mentioned they used the data to provide one-on-one instruction, small group lessons, and whole group instruction to students who had failed or not mastered topics. Carlos shared that he used the data in the Time and Topic Report and Insights Report to identify the learning sequence where students were attempting but not learning in ALEKS to make instructional decisions. He said: "I love it! I can see which ones they understand and which ones they need more practice and which ones I can reinforce in the future. You see this immediately. This is beautiful!"

In addition to the reports generated in ALEKS, a progress bar on the student's learning page captures the student's learning sequence for each topic. The data on the progress bar helped teachers support students' learning in real time. As students worked in ALEKS, teachers walked around during classroom observations. Teachers quickly saw if students were struggling by observing the progress bar. The progress bar changed from green, to yellow, to orange, and then red if a student was struggling.

During Alberto's classroom observation, Alberto walked by a student whose bar was orange. The student shouted out in frustration, "I don't get it!" Alberto asked him if he read the explanation page and watched the video. After the student confirmed that he had attempted to learn the topic with the tools provided, Alberto coached the student through the problem. Alberto leaned over the student's shoulder. He asked the student to explain the problem and how he worked through the problem. Alberto continued to ask him questions, saying, "Why did you do that?" Then he helped the student reflect on and monitor his thinking. Lorraine and Carlos interacted with students in their classes in a similar fashion as the students worked in ALEKS. The data from ALEKS combined with data from the classroom activities and their experiences with students were all factors in building academic learning opportunities.

Strategic data for instruction can also be found in the Pie Report. Carlos and Lorraine mentioned that they used the report to identify groups of students who mastered topics, did not learned topics, and were ready to learn specific topics or standards. The Pie Report along with other formative assessment information was used to target whole group instruction and narrow the focus in creating specific small groups or one-on-one lessons. As teachers described the data in ALEKS, they felt that ALEKS provided opportunities for teaching and learning at all levels that were specific to each individual student's academic and emotional needs. Teachers used the data in the ALEKS reports to pinpoint learning for struggling students and academically advanced students.

In addition to targeting specific topics for learning in ALEKS, the data reports in ALEKS were used to offer a range of tiered support. Lorraine shared how the tiered classes in ALEKS helped students below grade level in Algebra 1. She noticed that there were some students who were struggling and not making any progress in ALEKS or in her Algebra 1 class:

> About half the students in this class had math skills below fifth-grade level, and the other half were at about a sixth or seventh grade level. No one was at an eighth- or ninth-grade level. Their mastery level in ALEKS was below 15% mastery in the on-level algebra course in ALEKS.

Lorraine moved those students into the Math Intervention ALEKS course to build foundational gaps. Using a tiered approach to differentiate learning for students, she was able to help students fill academic gaps. Lorraine continued:

> Using the Tier 3 course, Math Intervention, the math started out easy for students and they were finding success and building confidence. Once students reached about 50% mastery, I moved them into prep for Algebra 1. Five students have been moved into Algebra 1 and are now working on grade level."

In addition, she stressed:

> Being able to start them at the level they were at, gave them confidence and motivation. Students began understanding their strengths and weaknesses through the data and were encouraged by their progress.

As a result, when Lorraine moved a student from one tiered course to the next, a student boasted, After sharing the data that showed their growth, Lorraine perceived an increase in student's confidence and learner self-rated progress and effort.

**Collaboration.** All three teachers commented about feeling more confident interpreting the data and more able to give the students more information about their learning and the purpose of ALEKS. This confidence in using data set the stage for teachers to use the data for collaboration with the students, parents, colleagues, and administrators.

When conferencing with students, teachers helped students understand the reports generated by ALEKS to determine how they could improve their mathematical skills and life skills, such as time management and perseverance. The teachers perceived more students understood how ALEKS was going to help them because the teachers used the data to talk to them about their progress. Lorraine explained:

> Last year, I don't think we did a good job of explaining the purpose of ALEKS and what it is. Telling them why and showing them the evidence [in the Progress Report] how much they have improved from knowledge check to knowledge check, has made a difference.

During one of the debriefing sessions, Lorraine smiled as she mentioned that in her morning class, after a progress knowledge check, two students cheered out, "I've mastered 19 topics!" "I've mastered 14 topics!" "I've mastered 2%!" This type of cheer was echoed in Alberto's and Carlos's classes when students said, "I've got five topics already!" and "I have three topics already!"

Carlos also commented on how sharing reports and data with students had transferred to collaborative conversations around skills and knowledge and regulation of students' own learning. He said: "I did notice that last year students did not look at their reports. This year, students are looking at their Pie Report and Progress Report." As a result, teachers observed students tracking and sharing their progress as they moved through the ALEKS courses.

Teachers witnessed the students collaborating with each other, their teachers, and their parents about their successes and challenges in ALEKS.

During one of the observation debriefing sessions, Lorraine discussed an issue the mathematics teachers were having with students not completing their topic goals. She shared:

> I am trying to explain to them that [post high school] if students place in a remedial course, the course doesn't count. I am trying to give them guidance and telling them that they have control and we're giving them a resource to help build themselves before going to college. So, they are not spending money on classes that don't count towards their degree. We are trying to use ALEKS to prepare you so that your skills are strong, and you are ready.

The teachers believed using data for collaborating with parents reinforced the importance of teacher involvement in using adaptive technology for PL. Lorraine and Carlos shared they engaged students' families by email and phone using the data in ALEKS. Carlos commented on how his collaboration with families helped to engage students, and he shared a comment from one of his students:

> My mom says I am very behind in ALEKS. "Andy, you are 100 topics behind. You are supposed to be working this week on 240 lessons and you've only completed 130 lessons."

Lorraine mentioned, "ALEKS gives me the data I need to collaborate better with parents to show them how they can help their child at home on ALEKS." She continued, "I am also able to collaborate better with my colleagues in the math department and administration to determine changes in curriculum by showing where we have weaknesses and strengths." The ability to collaborate with colleagues and peers was mentioned several times by all three teachers.

**Motivation.** All three participants mentioned the ability to motivate the students using the data. The teachers referenced this point regarding motivation on a deeper level during the observation debriefs and the semistructured interviews. Alberto mentioned: "Some students want to do ALEKS all the time. He reported they would say: "I'm finished! Can I do ALEKS?"

Each of the participants recognized that not all students valued working in ALEKS or were intrinsically motivated by using the adaptive software. They realized that some students were motivated by grades, some students were intrinsically motivated by growth that builds confidence, and some were motivated by purpose. There were also some of the mindset: "I am not going to do anything you tell me."

In an effort to motivate all students, Alberto used the data in ALEKS to display a leaderboard to celebrate students' progress and motivate students. He displayed the top 10 leaders in each class on a chart and stapled it to a bulletin board. The students really enjoyed looking at the leaderboard and one student asked, "Can I take a picture of this and share it with my mom?" Lorraine also used the data from her ALEKS reports to motivate students. She created a friendly group competition in an effort to motivate all students and get them excited about doing math. Lorraine shared that students enjoyed the group activity. Teachers commented that motivation was a challenge, and they continued to search for ways to incentivize, empower, and motivate all students.

As teachers and students became more familiar with the reports and data in ALEKS, teachers became skilled data users. Teachers perceived that their strategic use of data helped to change students' mindsets about mathematics and build mathematical confidence. Teachers also believed the work students did everyday created mathematical confidence, increased academic achievement, and empowered students to take responsibility for their learning. Alberto commented:

> The more they do it, the more they love it! They are learning a lot in ALEKS, and they are really liking it. Many of them say, we haven't done this in Algebra 1, but we have done it in ALEKS.

Using data strategically was a part of the journey that evolved daily as teachers used the data reports in ALEKS and classroom observations for goal setting, collaboration, instruction, and motivation.

**Student-Centered Learning and Self-Regulation**

The fifth major subtheme that emerged during the study was student-centered learning and self-regulation. All study participants mentioned the change in learning and teaching through the adaptive resource from teacher-centered to student-centered learning.

All three participants commented that most students became more responsible and took ownership of their learning. Initially, most students struggled with time management. When students had a weekly time goal, they were given about one hour in class to work in ALEKS per week. Students were responsible for completing about two hours of work in ALEKS outside of the classroom. Most students struggled to meet the latter commitment on their own.

Teachers talked to students about expectations, goals, responsibilities, and study skills. Lorraine indicated: “We were trying to get across to them that if they do a little bit each day, they would meet their goal.” Similarly, Alberto shared that he told his students, “If you divide the goal by five, it becomes small goals. This is what we do in life. Sometimes it requires us to prioritize the important things.” What he found, Alberto continued, was “The more they do it! The more they love it!” These students had become motivated and independent learners.

On the other hand, Carlos mentioned that all the teachers had a few students who saw ALEKS as extra work and were burdened by it. Lorraine pointed out that some of these students had even resorted to cheating by using applications like Photomath and WolframAlpha. She said they told the students that those who really wanted answers could just click on the explanation button in the ALEKS program. She explained that this information solved the problem. In the same vein, students used these applications during knowledge checks, which skewed mastery levels and the learning pathway created by the artificial intelligence. Teachers spent more time explaining learning versus mastery and how the purpose of the knowledge checks was to help build agency. They also moved the knowledge checks into a proctored environment in the classroom. The students who were burdened by ALEKS were the students these teachers continued to try to motivate and foster critical thinking skills through questions and dialogue. Overall, the teachers indicated that their classrooms had become more student centered during ALEKS time and that students were creating their own pathways and learning habits, transforming the role of the teacher from a lecturer into a facilitator in students' academic and personal development.

Teachers believed ALEKS supported the development of student-centered learning and self-regulation. Alberto shared: "It isn't a question of if it works. I've seen so many instances and examples of learning in my classroom by students." The teachers shared their collection of student-centered learning experiences. These experiences became treasures and an intrinsic part of the teachers' lived experience with ALEKS. Teachers' collected what they perceived as successful student-centered learning experiences, which the teachers thought students were self-regulating.

Lorraine shared a story about one boy who was struggling because he had a lot of gaps in knowledge and his mathematical skills were very low. She said:

> He ended up failing my class in the fall, but I told him not to give up. I knew he could do it. He barely failed at about 58%. I told him just keep doing what you are doing, over the Christmas break, keep working in ALEKS. He did and right now at the end of February, he has an A in my class. He is getting a little overconfident and a little cocky. He is working in Algebra 1 level, and he feels good about it. It is nice to hear him say, "Oh, I did that in ALEKS!" and we are barely starting it in class. So, I told him, now you are going to be prepared for this unit. That made him feel good. He scored his first A on an assessment and he felt really good about that too.
>
> Lorraine beamed as she commented:
>
> He says things like "Wow, I get it!" He sees himself as a math student. He even asks me questions about the math honor society. Which is something he probably never would have considered before this semester.

Carlos shared a story about a girl who wanted to be an engineer and was studying to get into college:

> If you look at where she started at the beginning, she was at 13% mastery in August and now in February she is at 71%. This is pre-Cal! She has been working very hard and she looks at her data and the skills she is working on every day. She is very aware of her skills in math and what she needs to work on. She has already worked for about 50 hours in ALEKS. That is fantastic!

Carlos went on to say that his Algebra 2 students had a wide range of mathematical skills and ALEKS was targeting individual differences:

> We inherited many middle school students that didn't have a proper math teacher. If you listen to their stories, you would say, "Oh my goodness! Poor guys!" However, in ALEKS they are progressing. Huge progress!

He pointed to one of his printed custom reports in his hands. "Look, most of them are at 47% mastery. They are progressing!"

Another student experience shared by Alberto were about a student that he and the vice principal thought had learning disabilities because of her many deficiencies in mathematical skills. He said: "Right now, she is getting a high B and she is trying with ALEKS. She boasts that she is a math princess." The student shared with him that she really loves mathematics and if you ask her a mathematical question, she could show you how to do it.

These student experiences empowered teachers along their journey, even when participants found out about the applications some students were using to cheat when learning topics and proving mastery of the topics on knowledge checks. Teachers felt ALEKS could improve learning for all students, whether below level, on level, or above level, but they explained how it was necessary to stay engaged in the learning process.

## Interaction Between the Research and the Context

A small catholic college preparatory high school in Southern Arizona implemented ALEKS, an adaptive mathematics resource, for the past year to increase mathematical achievement and support the diverse mathematical learning needs of all students. St. Francis High School's journey with ALEKS began during the 2018–2019 school year. Teachers and administrators initially looked to fill mathematical knowledge gaps in incoming ninth-grade students who continued to underperform on the ACT Aspire Test in mathematics. As a McGraw-Hill associate, I set up the pilot and served as the ALEKS PL specialist and assisted with initial implementation and ongoing coaching. During the pilot, I cultivated a relationship with the administration team and the mathematics teachers. I functioned in two different roles: the liaison between the company and the teachers and as the researcher. Building trusting relationships during the pilot allowed me access to all necessary environments, while instilling trust and confidence with the research participants.

This study was welcomed by the school's administration and math department. The perceived value of the adaptive resource tool and the important role of the teacher stood out. Associated with this was the importance of the teachers' and students' time commitment and their capacity to devote energy to learning, reflecting, and relearning. Equally as important were the teachers' positive attitudes and beliefs about the use of the adaptive resource, which also stood out. The perception existed that the adaptive tool and the teacher's involvement added value to academic and social growth. The teacher involvement was further perceived as important to contributing to academic, emotional, and personal growth. Another important perspective considered was the administrative support provided to the teachers. Teachers were free to be creative and to adopt approaches compatible with their local context and student population. Although some students continued to struggle academically and lacked motivation to work independently in ALEKS, teachers remained positive in searching for ways to motivate and support them. Regardless of teaching style and use of ALEKS, teachers required various methods to reach all students. From the study, it was evident that the use of an adaptive tool in combination with the role of the teacher was important in meeting learners' needs. This supported the idea that teachers and students should be partners in learning. The insights from this record of study can be used to inform future research about the implementation or promotion of an adaptive resource within a classroom or school. It was clear that an adaptive resource is just a tool without the engagement of the teacher in the one-size-does-not-fit-all approach of the teachers in this study.

**How Did the Context Impact the Results?**

The catholic background did not really come out in the participants' words, but I felt the spiritual immersion was relevant. The teachers' demeanor and interactions with each other and their students felt like that of a family. The community climate was permeated by love, and I believed contributed to the students' motivation to learn. The teachers, by virtue of their role and their community, were given respect. Alberto, Carlos, and Lorraine all started class with a prayer. Lorraine made comments referencing Christian behavior and students smiled and behaved positively. Students also responded positively to their teachers and each other in class. At the beginning of the interview, Alberto mentioned: "St. Francis is a small school, small community, where we check in on each other."

The culture, climate, devices, and digital tools supported the teachers' journey. The undertaking was welcomed by the school administration, which supported the teachers as they worked to boost mathematical skills for all students in Algebra 1, advanced high school mathematics courses, and science courses. Teachers entered at different speeds and in different parts of the journey.

Lorraine jumped into the journey with my support. She noticed that ALEKS was targeting students' individual strengths and skill gaps and that she was able to meet more students' needs when using it. With support from Lorraine and me, Carlos joined her after hearing of her successes. The largest challenge that arose during the ALEKS pilot was motivating the students to meet the 3-hr-per-week expectation.

The school administrators were excited about the opportunity to provide differentiated and individualized instruction despite wide and varying gaps in knowledge, so the freshman spring pilot expanded to the whole school during the 2019–2020 school year. Alberto willingly joined the journey once he was hired in July 2019. Teachers began as novices and with support from administrators, their colleagues, and me, they gained confidence. In essence, they created their own support community as use of ALEKS progressed.

The journey started with one teacher, expanded to the three-teacher mathematics department, and eventually permeated the whole school. Lorraine shared: "You will see students in study hall and in other classes working on ALEKS." She described an ALEKS culture:

> Other teachers in our school are even encouraging students to do ALEKS. If a student finishes something early, the other teachers know that the students have ALEKS and tell them to do their ALEKS. Everybody in the school is working on ALEKS. I tell the other teachers to tell the students they can earn extra credit.

**How Did the Research Impact the Context?**

The teachers reviewed the findings of the study. Based on the feedback and conversations with the teachers, ALEKS broadened their perspective beyond using technology to teach math and fill in the gaps. Alberto shared: "It sparked in me varied ideas to use ALEKS in differentiating instructions and fostering in my students the love for independent learning." The participants and the administration found ALEKS to be helpful and expressed a desire to continue using it to support implementation of PL for intervention and enrichment as they continued to explore tools for developing self-regulated and blended learning. Originally, the teachers emphasized that use of ALEKS was to develop individual skill and promote academic growth. However, their focus appeared to shift to include not only each student's skill growth, but also individual learner growth. This included developing lifelong learning skills, social–emotional skills, and higher level problem-solving as was shared by the details in the individual stories. On a practical level, ALEKS is simply a tool. In this study, it appeared that the various interactions among human and machine altered the learning system within this community. Self-regulatory behavior was not explicitly taught but emerged as a theme. The participants in this study did not necessarily plan to use ALEKS to support student self-regulated learning, social–emotional development, or higher level problem-solving. Rather, they were all working toward improving student achievement. Consistent with Penuel and Johnson's evaluation report (2016), there was little understanding of how to actually design and implement a PL environment appropriate for all learners, yet the participants drew on their self-awareness and the shared experiences of their colleagues and worked creatively to improve motivation by including higher level thinking activities in their classes. Participants will continue their journey with ALEKS, explore classroom practices to support varied learners, and promote higher level thinking.

Within this research, I focused on the teachers' lived experiences as they journeyed from old to new (i.e., traditional to personalized) teaching and learning practices. As the specialist for ALEKS, I believed I had instilled enough trust and confidence in the participants to solicit honest ideas, celebrations, and frustration about the experiences with the adaptive resource. As the research instrument, I tried to consider how my training insights, perspectives, and presence affected the study. Although I kept a journal throughout the research period to free myself from presuppositions and to encourage a naive approach to the data, I wondered if my mindset and insights played a factor in my ability to fully understand the teachers' experiences in the classroom and during the semistructured interviews. I questioned if I was too familiar with ALEKS. When the teachers commented on their experiences, I wondered if I was being receptive to their experiences and wondered if I asked the types of questions needed to fully understand their experiences with their students in their contexts.

Although the findings in this study were encouraging, implementing adaptive technology to support PL environments is complex. Within an adaptive resource to support PL, teachers and students should have the ability to set individual learning goals. Allowing students to self-report is a feature lacking in ALEKS. The system should allow learners to set goals, self-identify strengths and weaknesses, and report comfort level with content and level of effort needed to learn and master topics. The data could be used to identify barriers and provide teachers and learners with information to effectively personalize instruction for all learners. The ability to self-report within ALEKS was not mentioned by the participants, but it was a development idea shared with my manager and the development team.

The results were supposed to be shared in person with the St. Francis administration and teachers in May 2020. Due to the onset of COVID-19 and Governor Ducey's announcement that all school campuses in Arizona would remain closed for the remainder of the 2019–2020 school year, a virtual meeting will be scheduled to share the results. Lorraine also mentioned co-presenting and sharing her experiences at the next principals' Diocese meeting. However, that will have to wait until the fall of 2020. This record of study will be used to share teachers' experiences in implementing a PL tool to advance their journey and provide the basis for a framework to support future professional learning and student learning at St. Francis High School. Future research studies are now needed to examine the design features of both the impact ALEKS has on students' academic performance and human interactions. One research recommendation for future study is to replicate this study with an expanded number of classroom observations and with the addition of focus groups comprised of teachers, administrators, and students.

## Closing Thoughts on Chapter IV

Three teachers from a catholic high school in Southern Arizona were given access to ALEKS, a PL resource, to increase mathematical achievement among their students. Their journey was captured in classroom observations with debriefing sessions and semistructured interviews in the spring of 2020. The school in this study was selected based on their previous use of ALEKS. Data was collected qualitatively. The results of the observations with debriefing sessions, semistructured interviews, and metaphors on teaching and learning were coded and grouped into meaningful themes to provide deeper understanding of the response to the questions being asked. The main theme that emerged was that use of ALEKS created a unique journey for each participant. The emerging subthemes were: various entry points, cycles of reflection, changes in instruction, strategic use of data and student-centered learning and self-regulation.

# CHAPTER V

## DISCUSSION AND CONCLUSION

Low algebra skills and high failure rates are a concern in ninth-grade classrooms nationwide (Nomi & Allensworth, 2013). Paul (2005) argued that Algebra 1 is considered a gateway to advanced mathematics, science courses, and success in higher education, college-credit bearing courses. Many secondary students enter higher level math classes lacking confidence in math and are hampered by knowledge gaps in basic whole number arithmetic and mathematical reasoning (Arroyo et al., 2014). Targeting students' individual mathematical differences requires more than the one-size-fits-all traditional schooling model of the past school years.

In order to address the various levels of students' mathematical needs, growing empirical evidence has supported using adaptive tutoring software to enhance PL experiences and attitudes towards mathematics (Arroyo et al., 2013). PL, which relies heavily on adaptive technology, is a student-centered approach to learning that results in a fundamental shift in how education is delivered by a teacher (Peng et al., 2019). The role of the teacher is increasingly critical in the effective implementation of adaptive technology (Hoyles, 2018).

In this study, PL using adaptive technology was used by three St. Francis High School teachers as a resource to increase the knowledge gaps of students. Standardized test scores for St. Francis High School's incoming ninth graders were well below the state average. Moreover, these ninth-grade students had underperformed on the ACT Aspire Test in mathematics as compared to the rest of Arizona. School leaders and high school math teachers were concerned about these students and their ability to be successful in Algebra 1, advanced high school math courses, and science courses. Traditional teaching and learning strategies had not been sufficient to tackle individual students' math differences. Personalized student-centered learning using digital technology appeared promising. Although it is the teachers themselves who typically decide to either adopt or deny the use of classroom technology, very little research existed that highlighted PL adaptive programs and the impact it has on teachers (Courcier, 2007; Fisher & White, 2017; Jenkins et al., 2016). This phenomenological qualitative study was undertaken to understand three teachers' experiences and perceptions in implementing an adaptive mathematical resource to close academic gaps in knowledge for intervention and acceleration. The findings of the qualitative phenomenological study addressed two research questions:

1. What are the lived experiences (i.e., instruction, practice, and learning) of high school teachers using the mathematics adaptive personalized learning tool?
2. What changes in teaching and learning have high school teachers experienced through the use of the mathematics adaptive personalized learning tool in their classrooms?

The exploratory nature of this phenomenological study permitted a deep understanding of high school teachers' experiences using the mathematics adaptive resource and of changes, if any, in teaching and learning after implementing ALEKS. Patton (2015) stated that this approach carefully and thoroughly captured and described "how people experience some phenomenon—how they perceive it, describe it, feel about it, judge it, remember it, make sense of it, and talk about it with others" (p. 115).

All participants—Lorraine, Alberto, and Carlos—were teachers at the same catholic suburban high school in Southern Arizona. I served as the researcher and the consultant who supported the participating teachers in their use of ALEKS. To obtain a rich and comprehensive description of each teacher's experience with ALEKS, the entirety of data for this study consisted of (a) one open-ended semistructured interview per teacher and metaphors describing teaching and learning with ICT, (b) one classroom observation with debriefing sessions per teacher, and (c) autoethnographic journaling focused on my personal technology integration experience with the educators. The insights from the teachers' in-depth conversations during interviews, classroom observations, and debriefs allowed me to capture their experiences.

Data analysis involved looking for similarities and differences in perceptions and experiences using first- and second-cycle coding methods. During the analysis, conceptual themes emerged from the data to provide deeper understanding to the research questions. The main theme that emerged in this study was that use of ALEKS created a unique journey for each participant. The unique journey pointed to the critical role teachers play in implementing adaptive technology. The significant role of the teacher and the importance of their involvement stood out in the findings. The five emerging subthemes were: various entry points, cycles of noticing and reflecting, changes in instruction, strategic use of data, and student-centered learning and self-regulation.

An important perspective was that teachers willingly entered the journey at various times and in various courses, but they all believed ALEKS would support all learners. Based on the analysis of the theme noticing and reflecting, teachers continued their personalized journey adapting to the changes and challenges in their PL classrooms. When they encountered problems, the teachers tried a number of things until something worked. Another important perspective that emerged from the analysis was the strategic use of data to inform instruction, set goals, collaborate, and motivate students. Although teachers tailored the experience to academic growth, the findings illustrate that the teachers perceived that most students fostered life skills of time management, collaboration, and self-regulation.

## Discussion of Conclusions in Relation to the Extant Literature and Theories

In this section, I present the conclusions to each research question. For each research question, I provide the conclusion, the connection to the findings, and a connection to the research and theory.

The lived experiences of the three teacher participants included three main conclusions (Table 4). These were: (a) teachers experienced buy-in to the mathematics adaptive learning tool; (b) teachers experienced realization of student knowledge, and (c) teachers experienced realization that the use of ALEKS in their teaching supported student self-regulation. The changes in teaching and learning included two main conclusions: (a) teachers experienced shifts in instruction, and (b) teachers experienced a change in culture.

Table 4

*Research Questions with Conclusions*

| Research questions | Conclusions |
|---|---|
| RQ1: What are the lived experiences (i.e., instruction, practice, and learning) of high school teachers using the mathematics adaptive personalized learning tool? | ● Teachers experienced buy-in to the mathematics adaptive learning tool.<br>● Teachers experienced realization of student knowledge.<br>● Teachers experienced realization that the use of ALEKS in their teaching supported student self-regulation. |
| RQ2: What changes in teaching and learning did teachers experience through the use of the mathematics adaptive personalized learning tool in their classroom? | • Teachers experienced shifts in instruction.<br>• Teachers experienced a change in culture. |

*Note.* RQ = research question.

**Research Question 1**

The first research question guiding the study was: What are the lived experiences (i.e., instruction, practice, and learning) of high school teachers using the mathematics adaptive personalized learning tool?

**Experienced buy-in**. The first common lived experience of the three teachers and their use of ALEKS included the teacher's buy-in to using ALEKS in their classrooms. In this research study, the teachers self-selected ALEKS, and believed ALEKS would increase academic knowledge for all students by filling in mathematical knowledge gaps in general and for specific courses. Once they began to implement ALEKS, their personalized journey began to unfold. Although each teacher entered the journey at a different place, they all had similar experiences within the journey. Their experience with the adaptive resource began with uncertainties but was guided by buying into the program based on their belief in the usefulness of ALEKS and the excitement around this potential. What became clear was that teachers entered the journey with the intention of addressing students' mathematical gaps. Teachers immediately saw what students knew and did not know, increasing their buy-in to the program and their willingness to implement it. Teachers' attitudes and beliefs were strong indicators of their engagement in their learning journey. Additionally, the participants found the data useful in expanding on students' learning, further increasing teacher buy-in.

The teachers' buy-in of the adaptive resource (i.e., ALEKS) did not surprise me. According to Tondeur et al. (2017), an instructor's pedagogical beliefs form the foundation of technology use in classroom practices and need to be addressed to understand the critical role teachers play in technology integration. Ertmer and Ottenbreit-Leftwich (2010) focused on the individual as an agent of technology integration and highlighted the teacher as the agent of change.  Technology alone does not motivate students, so the teacher is vital in the learning design (Basham et al., 2016).  Teacher agency was evident in this study through their high level of buy-in (i.e., the teachers were the agents of change).  Participant teachers used the program data to guide frequent feedback, mentoring, counseling, and evaluation in an effort to reach every student.  The participants were actively involved in testing and exploring how the adaptive resource could improve students' achievement.  Kim et al. (2013) mentioned that understanding teachers' beliefs about what is important in student learning and teaching and understanding how those beliefs translate to the integration of the adaptive resource is equally important to the teachers' journey.  For the teachers in this study, it was apparent that their beliefs regarding the usefulness of ALEKS made a difference as to whether or not they used the adaptive resource and to what extent.

The teachers' level of buy-in to the mathematics adaptive resource (i.e., ALEKS), aligned with Davis' (1989) TAM.  According to the model, technology integration practices are influenced by two factors: perceived usefulness and perceived ease of use.  In this two-factor model, perceived usefulness is critical for understanding teachers' use of digital technologies in mathematics education.  Perceived usefulness means the degree to which individual users recognize the new technology will improve achievement.  In this study, it was found that teachers anticipated that ALEKS was useful to teaching and learning outcomes and this perceived usefulness appeared very relevant to their buy-in to the adaptive resource.  Previous researchers have shown that the level of adoption will increase when individuals perceive a new technology as useful in the teaching and learning of mathematics (Pierce & Ball, 2009; Reed et al., 2010; Teo & Milutinovic, 2015; Wong, 2015).  Although there were several studies that used TAM as a theoretical framework with different technologies, most researchers looked at the relationship between the TAM factors in quantitative studies through self-report survey instruments (Ibili et al., 2019; Okumuş et al., 2016; Wong, 2015). However, only in limited studies did researchers apply TAM to educational adaptive resources with high school participants in qualitative studies. In this study, TAM provided a simple framework that helped in understanding the experiences of teachers using ALEKS. TAM is simple; it could be easily adapted to contribute to the literature on the acceptance of technology by mathematics teachers.

**Experienced realizations about student mathematical knowledge.** Another experience of the participants in the study was the teachers' realization about their students' mathematical knowledge and what each student needed. The teachers felt use of ALEKS gave them a stronger understanding of each student's level of math knowledge. ALEKS provided actionable data on students' knowledge to guide instruction, showing teachers what they knew, did not know, and were ready to learn. Carlos recalled his initial realization with the data reports:

> What is this? It is like an X-ray that I can see through. The pie chart shows me which topics they know, which topics they need to concentrate on, which ones they understand, which ones they need more practice on, and which ones I can reinforce in the future. You can see this immediately. This is beautiful!

Prior to using ALEKS, all three teachers would stop and reteach or plan whole group lessons on remedial skills to target mathematical differences and knowledge gaps of students. Lorraine realized that by using ALEKS, she better understood students' current knowledge and learning gaps:

> In the past, I spent a lot of time trying to identify exactly where the weaknesses were for each student. That was just impossible. I did my best to group them. I did differentiate,

> but it was very time consuming and I was losing a lot of time outside of the algebra curriculum. I love it! I love it!

Through the implementation of ALEKS, the teachers realized that there was another way to teach math tailored to the specific knowledge needs of each student. This alternative to teaching was possible because of their use of the adaptive resource.

The participants saw the benefits of instantly seeing students' knowledge level and appreciated their newfound ability to personalize student learning. As was true in this study, Peng et al. (2019) noted that teachers monitored students in real time while using the adaptive resource and adjusted teaching in an adaptive manner suitable for individual students. Although teacher participants in this study monitored students learning to adapt to the needs of their students, the participants mentioned how much they still had to learn to individualize learning for all their students. The adaptive nature of technology provides teachers real-time data to promote education rather than lead education (Peng et al., 2019). As a result, it was essential for teachers in this study to continually review progress by identifying mastery levels (e.g., failed topics, ready-to-learn topics) and academic challenges that might require additional support. The convenience created by the technology in this study was not to augment the traditional classroom but to empower teachers to adopt a pedagogy that promoted human development. It was apparent from the interviews and actions of the teachers in this study that they were using the data about students' knowledge to personalize learning and target whole group instruction. This part of the journey evolved as teachers invested more time learning about the data and collaborating with students and other teachers.

Teachers' realizations with regard to data and identifying students' mathematical knowledge level was described as useful and easy to use when adapting to students' needs. As a result, both factors in TAM (i.e., perceived ease of use and perceived usefulness) were found to have a significant connection to teachers' use of data to support individual and whole group instruction. In this study, it was evident that using data was important in teacher realizations and in personalizing learning for each student to fill in knowledge gaps and improve academic achievement.

**Experienced realizations that ALEKS supported student self-regulation.** The experiences of participants in the study also included the teachers' realization that the adaptive learning tool supported students in goal setting, learning at their own pace, and feeling successful. A spectrum of participants' realizations was found regarding the phenomenon of student regulation. The teachers' observed student-centered learning and self-regulation in this study. Alberto stressed, "It isn't a question of if it works. I've seen so many instances and examples of [student-centered] learning in my classroom by students." Teachers voiced that when students struggled, they were encouraged to watch a video, look at the explanation page, or ask a neighbor for help. The participants experienced students showing increased ownership of time management and goal setting, and their mindset shifted during the semester as they witnessed students becoming engaged and internally motivated. In Lorraine's class, a student who struggled during the fall 2019 semester realized he was able to successfully complete Algebra lessons. Throughout the fall semester and over the winter break, Lorraine encouraged him to keep trying and work in ALEKS. ALEKS presents students with content that is appropriate to their ready-to-learn level of math knowledge and provides immediate feedback and support, so the student became internally motivated, engaged, and confident. Lorraine perceived that her encouragement and personalized support combined with his perseverance led him to regulate his learning and master content. She said:

> I told him just keep doing what you are doing, over the Christmas break, keep working in ALEKS. He did and, right now at the end of February, he has an A in my class. . . . He is now working in Algebra 1, and he feels good about it. It is nice to hear him say, "Oh, I did that in ALEKS!"

Carlos also witnessed students gaining power and motivation through their own goal setting and self-learning in ALEKS. He explained:

> Alana was at 13% mastery in August and now in February she is at 71%. This is pre-Cal! She has been working very hard and she looks at her data and the skills she is working on every day. She is very aware of her [strengths and weaknesses] in math and what she needs to work on.

The participants spoke openly about several stories of transformed students who had become self-regulated learners since using ALEKS.

In this study, ALEKS was perceived by teachers to be an integral component in developing both student knowledge and improving self-regulation. Researchers found self-regulation and self-monitoring to be integral factors in student success (Inan et al., 2017; Nikolaki et al., 2017). The increase in student knowledge and student regulation in this study was perceived to have promoted student learning. Learners had greater independence to choose what they wanted to learn and when and where they wanted to learn it (Cradler & Bridgforth, 2002; United Nations Education, Scientific and Cultural Organization, 2004). Researchers have indicated that students achieve higher levels when research-based, student-centered instruction is implemented (Odom & Bell, 2015; Polly et al., 2015; Wright, 2011). With that said, difficulty was experienced with some students who were not self-directed. As previously mentioned, Basham et al. (2016) noted that technology alone does not motivate students; the teacher is vital in the learning design and teachers continue to explore suitable learning opportunities for all students. In this study, the adaptive technology created new pathways and opportunities for students to interact with the teacher and the technology to regulate their learning.

The perception of student self-regulation provided another explanation of why the teachers' in this study accepted and bought into the use of ALEKS. In accordance with TAM, the participants perceived ALEKS to be useful to students and easy for students to use. Both factors contributed to students' goal setting, life-long learning, and self-regulation skills. Students self-regulation was prevalent in the study, and ALEKS was viewed as useful in creating self-regulation opportunities that led to new pathways. The teachers discovered the usefulness for themselves and saw the usefulness for students.

**Research Question 2**

The second research question guiding the study was: What changes in teaching and learning did teachers experience through the use of the mathematics adaptive personalized learning tool in their classroom?

**Experienced shifts in instruction.** One of the changes the three teachers experienced with their use of ALEKS was a shift in instruction. Shifts in instruction were possible because participants observed an increase in students' mathematical knowledge, a deeper understanding of math concepts, and an increase in student confidence after students began working in ALEKS. Each participant described having more time to cover the course content and shift instruction from review and remedial tasks to critical thinking, creative problem-solving activities, and higher level thinking problems. Lorraine incorporated justification and modeling activities because she no longer had to teach prerequisite lessons. She said: "ALEKS will do that!" Lorraine, Alberto, and Carlos transitioned from remedial activities to incorporating higher level cognitive activities such as justification tasks and problem-solving activities. All three teachers observed students solving mathematical problems faster and using academic vocabulary to justify their thinking.

These teachers shifted instruction from teaching below-level and on-level topics and thinking tasks to incorporating higher level activities and tasks. In this study, the shifts in instruction to include critical thinking and collaboration activities gave students an opportunity to collaborate with other students and articulate their thinking. Digital tools play an important role in transforming mathematical practices of learners and teachers (Hoyles, 2018). The teachers in this study found a way to use the adaptive resource to enhance the instructional process (West, 2012) and move towards deep, authentic application of skills, knowledge, and concepts (Imbriale et al., 2017). Participants promoted learning with the adaptive resource to fill in gaps and helped students elevate their proficiency with opportunities for mathematical discourse through justification and modeling activities.

The instructional shift enabled a convergence of the individual concepts students developed while learning mathematics (Sherin, 2002) with the mathematical adaptive tool (Drijvers, Doorman, Boon, Reed, & Gravemeijer, 2010). Good teaching should be broadened to include the idea that "teaching is effective only when combined with relevant ICT tools" (Ertmer & Ottenbreit-Leftwich, 2010, p. 259). The shifts in instruction created by the technology and participants in this study transformed the mathematics classroom. It was apparent from the shared experiences of the teachers that the teachers shifted their practices to incorporate higher order thinking, justification, and collaborative experiences that elevated students' academic engagement, motivation, efficacy, and proficiency with mathematical language.

Shifts in instruction were perceived as possible due to the usefulness of the mathematics adaptive resource. This is consistent with the element of perceived usefulness articulated in TAM. The participants' experience with students increased mathematical knowledge, deeper understanding of math concepts, and increased confidence afforded teachers opportunities to incorporate higher level thinking activities. It was evident that teachers found the adaptive resource useful in filling in knowledge gaps and accelerating learning.

**Experienced a change in culture.** Another change revealed in the analysis of the data was a change in school culture. The teachers described entering the journey to improve mathematical learning at different times. As the participants accepted what they were currently doing was not sufficient to tackle individual students' mathematical differences, they jumped into the journey and began integrating the adaptive PL tool. Once underway, use of ALEKS provided a platform for collaboration among members of the math department, the students, and the administration. Participants mentioned they collaborated with each other about what they were noticing. They felt the collaboration and reflections changed the culture in their classrooms, their department, and the school. When Alberto started using ALEKS, Lorraine taught ALEKS for his class and he was the co-teacher. He felt supported in this culture. "I had a lot of questions. But because Lorraine, Carlos, and you were there, it wasn't as hard as I thought because I had the support. I was able to get through it and explore the possibilities."

Initial discussions in the journey centered around the what ALEKS was and how to use it. As the cultured changed, math department discussions moved into setting goals, increasing student motivation, and emphasizing student accountability. Teachers transformed their practice and culture through the use of the adaptive resource. Lorraine shared the shift in school culture as follows:

> Other teachers in our school are encouraging students to do ALEKS. If a student finishes something early, the other teachers know that the students have ALEKS and tell them to do their ALEKS. Everybody in the school is working on ALEKS. I tell the other teachers to tell the students they can earn extra credit.

The supportive community played an essential role in adopting and sustaining the innovation. As was true in this study, Goodnough and Murphy (2017) discovered that within a community of professional learners, teachers can learn and develop new approaches to learner-centered teaching and change their practice. The participants' culture in this study evolved from one teacher, to two teachers, to their three-teacher math department and then expanded to the whole school. Their conversations focused on the unique understandings of teacher and student learning using the adaptive resource. As Levin and Rock (2003) found, practitioners who collaborate around good teaching and understanding current practices are likely to improve teaching and learning outcomes. It was apparent that the collaborative culture created around the use of the adaptive resource in this study was a critical component in teaching and learning mathematical outcomes for all students in the school.

The cultural support was regarded as useful in direct connection to what the teachers and students were experiencing with the adaptive resource in this study. Cho (2017) maintained that in the mission-driven organizational environment of catholic schools, environment matters when planning and implementing software programs. The collaborative work and discussions around the adaptive resource in this study represented a significant shift in culture. As a result, the idea of perceived usefulness articulated in TAM was found to have a direct connection to the shift in culture. In this study, teachers perceived that ALEKS helped them create a change in the teaching and learning culture of St. Francis High School.

## Discussion of Personal Lessons Learned

A disadvantage of conducting this qualitative study was my dual role as a teacher and a researcher. I was the research instrument and the liaison between McGraw Hill and the school. As a personalized learning specialist for McGraw Hill, I was well versed in the use of ALEKS. I had the responsibility of setting up the pilot, training, and coaching the teachers. As I reflected on this research, I also realized the present study was conducted by a novice researcher, and the design of the study, collection of data and analysis, and findings might reflect my inexperience in understanding the realities of the participants. The objective of the research was to collect enough data from the participants to offer a comprehensive exploration of the lived experiences of teachers using the mathematics adaptive PL resource. Due to my novice research status, I wondered if I was able to observe and capture a rich and comprehensive description of the teachers' experiences as well as capture what was not there (Patton, 2015). Merriam and Tisdell (2016) insinuated that qualitative research is subjective because no one is truly objective. Researchers encompass different knowledge states, interests, and racial, religious, ethnic, and economic backgrounds. Hence, my bias was a factor. It was difficult to separate my experiences and familiarity with ALEKS from the research. Therefore, having an effect was unavoidable (Patton, 2015), but perhaps my bias also enabled me to identify experiences that others might not have seen or known how to address.

In order to reduce the bias as much as possible, I committed to reflexivity to free myself from presuppositions and encourage a naïve approach to data (Malterud, 2001). Heath (2017) identified this commitment as the first step in a phenomenological research methodology. I created a journaling process that spanned the research period. I considered how my perspectives and my presence affected the study and adequately accounted for the effect of my position as a personalized learning specialist and as the researcher. In addition to reflexivity, I regularly reviewed the purpose of the study and considered other possible explanations (Yin, 2014). Objectivity is often difficult to achieve when attempting to capture lived experiences. For this reason, the potential of having research bias did present a level of risk to the research study (Patton, 2015). Despite the potential bias, I felt I cultivated a relationship with the participant teachers as well as with the administrative team. I believe I instilled enough trust and confidence to elicit honest ideas, celebrations, and frustrations from the participants. They welcomed me into their classrooms and spoke freely about their experiences, their students, each other, and ALEKS.

The uniqueness of the teachers and high school selected to participate in this study also threatened transferability. The participant teachers taught at a catholic high school. The study was conducted in one high school instead of a school district or multiple schools across the country, so the findings cannot be used to make predictions or control a situation. The findings also cannot be generalized to a broader educational system or provide causal explanations (Yilmaz, 2013). Each school has their own unique identity. This identity includes shared histories, practices, beliefs, cultures, and it varies widely between schools and districts. However, the participant teachers' experiences and the essence of the phenomenon can be transferred to a context similar to this high school, whether public or private.

## Implications for Practice

The findings for this record of study can be of interest to all potential new users of an adaptive personalized technology tool intended as a resource to enhance mathematics teaching and learning. The National Council of Teachers of Mathematics (2011) stated: "Technology is essential in teaching and learning mathematics; it influences the mathematics that is taught and enhances students' learning" (p. 24). In order to address the stagnant and below-proficiency rates of students in high school math classrooms, growing empirical evidence supports using adaptive tutoring software to enhance PL experiences and alter students' attitudes toward mathematics (Arroyo et al., 2013). However, as was highlighted in this study, supplying schools with technology, online programs, and applications will not transform or positively change teaching and learning in and of itself (Tucker et al., 2017). The role of the teacher is critical in the effective use of personalized adaptive technology to augment mathematics education, especially because teachers can instill higher level thinking practices in their students and assist with social matters.

**Context**

The introduction and continued use of ALEKS made a difference in teaching and learning on the teacher participants in this study and on the school context. From the beginning, participants had a positive feeling about ALEKS and its ability to meet the individual needs of students. Once teachers began implementing ALEKS in their own classrooms, they witnessed its usefulness and the positive impact it had on student learning and teaching. During the first year of implementation, ALEKS helped participant teachers see the concrete nature of students' learning. Teachers could see students' progress through the teacher reports in ALEKS, and teachers could physically see students master skills, extend their learning to higher level thinking activities, and display confidence in math class. Another critical element in the context of the teachers' journeys was that change was not going to happen overnight. Although participants responded positively to this study, educators realized that it took time to notice, reflect, and recalibrate. Implementation of adaptive resources should not be rushed. Based on my own personal experience, I believe the journey takes many years of community collaboration and continuous support to transform teaching and learning practices through adaptive PL in schools. Therefore, schools should make a conscious effort to create a learning environment for teachers and students that provides opportunities to acquire the skills necessary to start and continue such a journey.

The shift in math instruction that occurred at St. Francis High School did not result from the mere presence of ALEKS alone, or even from the ready access to data for student learning outcomes. The journey represented a major shift in the classroom experience, which can be characterized as a combination of the use of the adaptive resource and the support and encouragement offered by the teachers on students' use of ALEKS. In this journey, relationships mattered. The teacher could not be replaced by ALEKS, nor could ALEKS manage the social and emotional interactions needed to build cognitive understanding of concepts with students. The power is in increasing awareness of the importance in human learning with adaptive tools. This study will hopefully lead to further studies focused on engaging and managing change with adaptive personalized resources that include the experiences of administrators, teachers, students, and parents.

**Field of Study**

Although the findings of the study are specific to its context, this study's transferability suggests that implementing adaptive resources like ALEKS should include teacher voice and their experiences in collaborative professional learning activities. Just as Hoyles (2018) argued, "Teachers must be a part of the transformative process as co-designers and teacher researcher's" (p. 223). Technology alone does not motivate students; the teacher is vital in the learning design (Basham et al., 2016). The methods by which teachers utilize tools and apply data to enhance instruction is crucial to understand. Anderson et al. (1994) found that if teachers are involved in testing and exploring how an adaptive program can improve student achievement, they are more likely to develop a better understanding of their own teaching using computer technology and take responsibility for their own professional growth (Ming et al., 2010). Additionally, change is more likely to occur if the members of a community of practitioners are personally involved in the research process. Community provides stability while reducing isolation in a rapidly changing technology landscape (Twining et al., 2013). In order for change or improvement to actually happen, collaboration with all stakeholders at all levels must take place.

Teaching and learning math are complex processes. Teachers are key to implementing PL, so their perceptions of the innovation are essential to the process. In order to "adopt educational innovation, teachers require extensive learning and training opportunities" (Karmeshu et al., 2012, p. 586). Continuous support requires time and allows teachers to reflect and make meaningful connections to the learning (Bransford et al., 2000). No one correct teaching and learning approach exists for moving toward ICT-supported math learning in secondary schools, but the action research framework in this study was one where collaboration, flexibility, and reflection in practice were encouraged for teachers to gain a holistic approach to teaching their students.

## Recommendations

This study was specific to its context, so similar, future studies could be performed to expand on the findings related to what contributed to teachers' positive experiences using adaptive technology to personalize learning. An additional research recommendation for future research involves extending this study by expanding the sample size to include feedback from a more diverse population of teachers, schools, and geographic locations. Additionally, a longer study, to explore teacher changes with professional learning over several years would be beneficial in adding to the body of knowledge around system changes and success.

In addition to replication variations, another modification that could improve the current research involves including the perspectives of students, administrators, and parents to provide insights into creating a shared vision with adaptive technology. Research that draws on qualitative and quantitative data analysis could add additional perspectives and could support teachers so that all students progress in mathematical knowledge and skills to include engagement and social and emotional learning.

**Recommendations for St. Francis**

Clearly, learners are key stakeholders in the mathematics learning process. The analysis and findings for this study showed positive shifts in most students' learning. Those students who did not see the point of learning mathematics and were not engaged needed additional support. Thus, it is important to understand the learners, their unique, individual, and cultural assets so that the learning resonates and supports the learners in meaningful ways. One way to build engagement and build meaning is to engage learners in sharing their ideas about mathematics and share their experiences in learning them. A few recommendations for next year could be to create more opportunities for collaborative experiences (i.e., structural and dynamic) and add a reflection component to students' mathematics journals (see Appendix D for a template). A weekly reflection journal could provide students with opportunities to reflect on their experiences, set goals, and share their ideas and conceptions. Understanding students' experiences, passions, and interests with adaptive technology could help teachers, administrators, and parents increase collaboration, student engagement, student understanding, and student self-regulation. During weekly conferences, the reflection page could be used by students to lead one-on-one conferences with their teachers. In order to embark on a digital initiative to personalize learning, administrators and teachers should have a good understanding of the digital learners in their schools and classrooms (Csorba, 2016).

An additional recommendation for this school is to continue to find time for teachers and administrators to exchange ideas with each other, reflect on their practice, have opportunities for continuous training support, and participate in professional learning networks with an emphasis on PL, collaboration, and student self-regulation. Together, these activities could help teachers continue their journey from teacher-centered to student-centered learning. Digital literacy is developed through "communal communication" of technology integration into instructional curricula (Richardson et al., 2015, p. 20). Within a community of professional learners, teachers can learn and develop new approaches to learner-centered teaching and change their practice (Goodnough & Murphy, 2017). Conversations, collaboration, and professional learning around understanding teachers' experiences are critical components of the local learning environment because no educational model is one-size-fits-all.

**Recommendations for McGraw Hill**

Although the findings in this study are encouraging, implementing adaptive technology to support PL environments is complex. Within an adaptive resource to support PL, teachers and students should have the ability to set individual learning goals. ALEKS does not currently allow students to self-report and shift ownership. Though this was not mentioned by the participants, the system should allow learners to set goals, self-identify strengths and weaknesses, and report comfort level with content and level of effort needed to learn and master topics. The data could be used to identify varying needs, address unique interests, improve engagement, identify barriers, and provide teachers and learners with information to effectively personalize instruction and possible pathways for deeper learning to support all learners.

## Closing Thoughts on Chapter V

The 21st-century workforce demands that people be prepared for certain occupations in the field of science technology, engineering, and mathematics (Bahng & Lee, 2017). The below-proficiency rates of high school students in mathematics is problematic and highlights a significant issue in both education and society. Targeting students' individual mathematical differences, strengths, and gaps requires more than the one-size-fits-all approach that characterizes the traditional school model. Personalized student-centered learning using adaptive technology with teacher engagement appears promising and can provide remediation and acceleration. Technology is available to assist teachers and students at a pace that works for them. Reform or transformation refers to much more than the use of technology ad nauseam. The real aim is to shift the focus of technology integration toward how educators can adapt their pedagogy to support technology-enabled learning (Ertmer & Ottenbreit-Leftwich, 2013).

This investigation focused on the lived experiences of teachers using an adaptive technology resource to learn why it might be useful and on how their actions, thoughts, and hearts impacted learning for students. Many general studies in the area of adaptive technology in education have been conducted. However, I had a difficult time finding empirical research conducted on this phenomenon from the high school mathematics teachers' perspective. Ertmer and Ottenbreit-Leftwich (2010) found teachers are critical change agents in the use of technology for instructions. Teachers have a critical role in the effective implementation of PL with technology, because the teacher coaches and advises. The teacher as coach helps students develop metacognitive skills. The teacher as advisor, in addition to academic matters, also assists with social matters (Hanover Research, 2014). By incorporating innovative pedagogies and new technologies, teachers have the potential to instruct, assess, and engage students in new education models. Instead of consuming content through a class lecture, students using adaptive technology have more opportunity to learn at their own pace, more control over how they receive instruction, and more relational connections to peers and teachers. More research is needed in regard to understanding educators' lived experiences in adaptive personalized environments because the journey is not sequential or linear. There are no shortcuts and there is no silver bullet.

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## APPENDIX A

## INFORMED CONSENT FORM

Texas A&M University Human Research Protection Program

Consent Form

**Project Title:** *Experiences of Secondary Math Teachers Implementing an Adaptive Personalized Learning Tool*

**Principal Investigator**: Darlene Messer

You are invited to take part in a research study being conducted by Darlene Messer a researcher from Texas A&M University. The information in this form is provided to help you decide whether or not to take part. If you decide to take part in the study, you will be asked to sign this consent form. You are free to decide not to participate or to withdraw at any time without adversely affecting your relationship with the researcher or Texas A&M University. I understand that I will not be compensated for my participation.

**Why Is This Study Being Done?**

As a doctoral candidate at Texas A&M University, I am conducting a study for my dissertation which surrounds digital learning in the classroom. The purpose of this study is to better understand and examine the lived experiences of secondary math teachers who integrate mathematics education technology to support intervention, enrichment and personalized learning in their classroom. This study will provide details about what teachers may experience and feel while teaching math using technology (ALEKS) to bring about successful implementation for change.

**Why Am I Being Asked To Be In This Study?**

You are being asked to participate in this study because you are a certified teacher currently employed as a secondary math teacher and integrating mathematics education technology (ALEKS) in your classroom to bring about academic change.

**How Long will the Research Last?**

I will be interviewing secondary math teachers regarding digital learning in their classrooms and conducting classroom observations. Interviews and observations will occur between January 27, 2020, and February 14, 2020. Your participation in this study will be approximately four months.

**If I Say "Yes, I want to be in this research," What Will I Be Asked To Do in This Study?**

If you decide to participate, your participation will include one classroom observation (30–60 minutes) and one interview (60–90 minutes).

**How Many People Will Be Asked to Be in This Study?**

I expect to enroll about 2-3 people in this research study at this site. Criteria for participation requires that the teacher be currently employed in a school setting as a secondary math teacher and integrate mathematics education technology in their classroom.

**Will Photos, Video or Audio Recordings Be Made Of Me during the Study?**

Yes, the researcher will make audio recordings during the interviews so that your perceptions of digital learning with ALEKS (mathematics education technology) can be documented. If you do not give permission of the audio recordings to be obtained, you cannot participate in this study.

______ I give my permission for audio recordings to be made of me during participation in this research study.

______ I do not give my permission for audio recordings to be made of me during participation in this research study.

**What should you know about a research study?**

- Someone will explain this research study to you.
- Whether or not you take part is up to you.
- You can choose not to take part.
- You can agree to take part and later change your mind.
- Your decision will not be held against you.
- You can ask all the questions you want before you decide

**Are There Any Risks To Me?**

The interview and observation are entirely voluntary and do not entail any foreseeable risks. You are free to decide not to participate or to withdraw at any time without adversely affecting your relationship with the researcher or Texas A&M University. All data will be maintained in a locked file in the researcher's home office throughout the duration of the study. Consent forms will be forwarded to the committee chair's office, Dr. Radhika Viruru at Texas A&M University. Every attempt will be made to secure your privacy and confidentiality as you participate in the interviews. Responses will be completely confidential, and no individual names or other identifiable information will be indicated in the course of this study, including St. Augustine Catholic High School. Your name or St. Augustine Catholic High School will not be associated with any research findings and the data will be stored in a secure place. The school and participants will be assigned a pseudonym.

**Are There Any Benefits To Me?**

We cannot promise any benefits to you or others from your part in this research. However, possible benefits of participation may include a contribution to scholarly research and is extremely valuable for building teacher capacity for bringing about change and successful implementation of technology to better serve 21$^{st}$ century learners.

**Will There Be Any Costs To Me?**

Aside from your time, there are no costs for taking part in this study.

**Who Can I Talk to for More Information?**

You may contact the Principal Investigator, Darlene Messer, to tell her about a concern or complaint about this research at 210-872-0803 or dmesser@tamu.edu. You may also contact the faculty advisor, Dr. Radhika Viruru at 979-862-8122 or viruru@tamu.edu.

This research has been reviewed and approved by the Texas A&M Institutional Review Board (IRB). You may talk to them at 1-979-458-4067, toll free at 1-855-795-8636, or by email at irb@tamu.edu.

**Statement of Consent:**

I understand that I am agreeing to participate in this study. The procedures, risks and benefits have been explained to me, and my questions have been answered. I know that new information about this research study will be provided to me as it becomes available. I can ask more questions if I want. A copy of this entire consent form will be given to me.

______________________________ ____________

Signature of participant Date

______________________________

Printed name of participant

______________________________ ____________

Signature of Principal Researcher Date

Printed name of Principal Researcher

# APPENDIX B

# OBSERVATION PROTOCOL FORM

The goal of this observation and debriefing session is to acquire a better understanding of your experiences as a teacher who self-initiated and integrated ALEKS, a digital personalized-learning resource.

## Introduction

Thank you for your willingness to participate in a study that will provide your campus as well as other schools who are implementing personalized learning resources with important information about your experience with ALEKS. As you know, I am a doctoral candidate at Texas A&M University, and I have been collecting data that will provide educators and administrators with relevant insights about your experience to support learner-centered instruction with ALEKS to target individual students' mathematical differences and provide instruction based on the needs of each learner. You signed a consent form to participate in this observation before the study commenced. If you would like to review the consent form, I have it available.

The observation will last approximately 20 min and the debriefing session will last approximately 30–45 min. Everything you discuss with me during this debriefing session and the observation is strictly confidential so please feel free to speak openly. In order for me to accurately record our conversation, I would like to digitally record it so I can later transcribe the debriefing session verbatim. The recordings will not be shared with anyone else. Do you have any questions before we get started?

| | |
|---|---|
| Participant Educator's Name | |
| Pseudonym | |
| Content Area | |
| Date | |
| Time | |

What is the teacher doing?

What are the students doing?

**Debrief:**

Based on the observation data presented, what is the teacher's impression about the experience?

Changes?

Does the teacher think the goals and expectations were met? Planning documents?

Additional comments:

What questions does the teacher have for me?

Action steps: What can I do to provide continued support?

# APPENDIX C

# INTERVIEW PROTOCOL AND QUESTIONS

The goal of this interview is to acquire a better understanding of your experiences as a teacher who self-initiated and integrated ALEKS, a digital personalized-learning resource.

## Introduction

Thank you for your willingness to participate in a study that will provide your campus as well as other schools who are implementing personalized learning resources with important information about your experience with ALEKS. As you know, I am a doctoral candidate at Texas A&M University, and I have been collecting data that will provide educators and administrators with relevant insights about your experience to support learner-centered instruction with ALEKS to target individual students' mathematical differences and provide instruction based on the needs of each learner. You signed a consent form to participate in this interview before the study commenced. If you would like to review the consent form, I have it available.

The interview will last approximately 45 minutes. Everything you discuss with me during this interview is strictly confidential so please feel free to speak openly. In order for me to accurately record our conversation, I would like to digitally record it so I can later transcribe the interview verbatim. The recordings will not be shared with anyone else. Do you have any questions before we get started?

Interview Protocol Guide for the Semistructured Interviews

Time of interview:

Date:

Location:

Interviewee/Pseudonym:

**Potential Questions:**

1. Please describe your school (Demographic Questions)
2. Can you talk a little about your classroom experience before introducing ALEKS to your students? (RQ2)
3. From your experiences, how do you currently use ALEKS in your classroom? (RQ1)

    **Potential follow up questions:**

    What does ALEKS look like in your classroom?

    How do you incorporate mentorship in your classroom?

    How do you use the ALEKS platform?

4. Based on your experiences, how did using ALEKS with your students affect your instruction? (RQ1, RQ2)
5. From your experiences, how would you describe your role (coach, mentor, facilitator, monitor, instructor…) as a teacher in your classroom when using ALEKS with students? (RQ1)
6. From your experiences, how did ALEKS assist you in creating personalized learning for your students? (RQ1)

7. From your experiences, how do you use ALEKS to support intervention and acceleration? All students? (RQ1)
8. Based on your initial experience, can you share a metaphor (word or phrase) that expresses teaching with ALEKS in your classroom?
9. Based on your perception, how do students utilize ALEKS in your classroom? What has their experience with ALEKS been like? (RQ1)
10. From your experiences, have you seen a shift in student ownership of learning since using ALEKS with students? (build student agency, tracking their own learning, setting individual goals…). (RQ2)
11. Based on your current perception, can you share a metaphor (word or phrase) that expresses learning with ALEKS in your classroom?
12. Based on your experiences, what should other teachers know in order to provide digital learning opportunities with ALEKS in and out of the classroom?
13. From your experiences, what type of professional development do you think is needed to prepare educators to utilize ALEKS for intervention, enrichment and personalized learning with 21st century digital learners?

APPENDIX D

STUDENT JOURNAL REFLECTION TEMPLATE

Name: ______________________________

Date: ______________________________

| Knowledge Mastery | Mastery % | Topic Goal |
|---|---|---|
| | | |

1. Look at your weekly Topic Goal, did you meet your goal? Why or Why not?

2. How many topics did you independently learn this week? How? What did you do when you got stuck?

3. This week what topics did you work with a peer, your teacher, or someone else? Why or Why not?

4. What did you discover about yourself, your progress, or the math this week?

5. Where can you use the knowledge learned this week in real life?

6. A priority for next week is?