EFFECTS OF ELEARNING AND BLENDED INSTRUCTION ON STUDENT LEARNING

by

CHRISTIE PRATT SCHMITT

(Under the Direction of Jay W. Rojewski)

ABSTRACT

This study used action research to determine the best blend of instruction for achieving deeper learning of a VEX Robotics curriculum at a suburban high school. Activities/lessons used to teach the LearnMate VEX Robotics REC curriculum included the eLearning content from LearnMate, an online curriculum and class management system, and teacher-prepared lessons utilizing traditional instruction. Action research was used to complete three cycles with the curriculum. The research found that students' scores increased and deeper learning was achieved when the content based lessons were taught using teacher-led instruction with class discussions and the programming activities we taught using LearnMate as an eLearning tool. Students found the content easier to understand and ask questions when taught in the blended instructional method.

INDEX WORDS: blended instruction, deeper learning, surface learning, eLearning, action research

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DOCTOR OF EDUCATION

ATHENS, GEORGIA

2016

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DEDICATION

This dissertation is dedicated to my mom and dad, Doug and Donna Pratt, who have supported me in everything I have done since birth. You instilled the value of education and pushed me to be the best version of myself. Mom, thank you for your long walks while I edited my papers, worked on statistics, writing papers, and sat through nightly class meetings. Dad, thank you for telling me I am crazy, you always make light of my stress, and might have been right. Together your faith, belief, and guidance make me forever grateful. I only hope Tim and I do as well raising Carson and Nathan. I love you.

I also dedicate my dissertation to my best friend and husband, Tim Schmitt. Who would have thought that we would be graduating together with doctorate degrees from the school we first met and earned our bachelor's? The day we finally walk across the stage will be a moment to treasure forever. While the process was hard, having your love and support as we pushed through it, made the difference. Thank you for supporting me through the tear and stress and helping me have the strength to keep going all the times I wanted to quit.

Carson and Nathan, my two sons, thank you for dealing with the trips to Athens, the days spent writing papers, weekend's mommy and daddy were in class, and the craziness of two parents working on a doctorate. Hopefully we have taught you the value of education throughout this process.

ACKNOWLEDGEMENTS

I give thanks to my committee members for all of your support throughout the process, Dr. Jay Rojewski, Dr. Roger Hill, and Dr. John Mativo, together we made it through my tears and stress. Thank you for your continuous support and uplifting spirts.

Dr. Hill, who would have thought that 15 years after graduating from my undergraduate, I would be finishing another program at UGA under your direction. Thank you for all your guidance over my college years in undergraduate and now doctorate. It is an honor for me to be able to complete another degree with you.

Dr. Jay, in my undergrad at UGA, you were “that teacher” for me; fun, exciting, and engaged. After our first class in the doctorate program and the writing of my purpose statement I knew you were the advisor for me. You have guided me, pushed me, supported me, and motivated me. You have seen my ups and downs throughout the process and always have words of encouragement and support to give. I do not know that I could have made it through this process without you. Thank you for changing me as a person, researcher, student, and teacher. I will forever be grateful of the impact you have made on me.

To my family, mom and dad, Robin and Jule Strickland, Kathy and Don Schmitt, Grandma, and Granny, and my two boys Carson and Nathan, thank you for your endless love and support.

Thank you to my work family for all your love and support. You helped with research questions, statistics problems, and provided guidance and love when it was needed; it is the small things that make all the difference.

To my TSA students, thank you for your understanding when things were busy and tough or when I just needed to research or write. Thank you for encouraging me and being excited about the end and "Dr. Schmitt." Thank you to Mrs. Lori Law and Mr. Brad Crawford for being available me to my defenses to help relieve my stress! The parents and students that surround me are a blessing and a second family.

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CHAPTER I

INTRODUCTION

This action research study determined how different blended instruction strategies influenced the achievement of students in secondary Engineering and Technology Education classes taught at a suburban high school in Georgia consisting of approximately 1500 students; middle/upper class. Instructional strategies were applied within the delivery of VEX robotics curriculum. Activities/lessons used to teach the LearnMate VEX Robotics REC curriculum used eLearning content provided by LearnMate, an online curriculum and class management system, and teacher-prepared lessons utilizing traditional instruction (Intelitek, 2008). A combination of eLearning and traditional instruction created a blended instruction model. This chapter describes the history of Engineering and Technology Education, curriculum, VEX robotics, teaching strategies, and the purpose of this study.

Technology Education in Modular Format

Engineering and Technology Education is one of Georgia’s Career Technology Education pathways taught in secondary public schools (Georgia Department of Education, 2013). Pathways consist of a three sequenced courses related to a specific vocational content area. In the late 1990s money was invested on a new lab design for secondary Engineering and Technology Education (Weymer, 2002). This resulted in the development of modular technology education (MTE) classrooms, where content was delivered through a computer-based course management system. Students answered questions and performed tasks. The teacher's role, as facilitator, was to assist students when they had questions. MTE was a vendor-provided curriculum that offered students opportunities to learn about technology by (a) participating in interactive media presentations, (b) following instructions in workbooks, (c) writing responses in student journals, and (d) experimenting and building projects. Personal computers replaced classroom teachers as disseminators of technological content and processes in modular labs formats. MTE was a self-contained instruction system defined by program learning theory, technological devices, and equipment (Petrina, 1993).

Despite a lack of research on its effectiveness, modular laboratories were installed by numerous school districts around the country. The MTE approach received mixed reviews by teachers, as to whether or not the curriculum method and delivery were a goo option for the classroom. Pullias (1997) referred to MTE as recipe-driven activities not connecting individual units of content to the entire curriculum.

The MTE format has changed slightly over the years from a classroom of students doing multiple, different modules to a whole group modular format with entire classes working on the same module. Reading from a notebook has been replaced with reading off a computer, but the overall method is the same. When I began teaching in 2001, the MTE format was the accepted method. Students sat at computers throughout the classroom and read from notebooks, did activities on training boards or the computer, and answered quiz questions. The teacher served as a facilitator throughout the process. Now in 2016, the MTE format has changed to an online format, students can use virtual trainers, and the entire class works on the same module in a whole group instruction method.

In the 1990s and even early 2000s computers were not a common household item and were exciting for students. Now, we carry computers in our pockets, in the form of smartphones, and can use them everywhere. In my classroom, the novelty and excitement of computers no longer exists and we have a generation of students who have answers at their fingertips through Google and the internet. My students struggle with reading and following directions, causing them to become disengaged, often asking for me to teach the content. Students often skip content to search for answers and take quizzes to quickly move to activities. Students in my Engineering and Technology courses are hands-on learners who grasp and retain content through doing. When students complete an MTE module, they often retain the hands-on activity, but do not remember factual/content information. As the teacher in a school system and where LearnMate MTE has been adopted, it is my job to facilitate student learning through modular education, that reflects the 1990s MTE format.

Elements of Learning

Three Domains of Learning

As a teacher, it is important to understand the domains of learning when creating effective lessons for students. The three domains of learning are affective (feeling, emotions, and attitudes), cognitive (thinking), and psychomotor (doing) (Emenike, Danielson, & Bretz, 2011). In this research study, I examined student learning using all three domains of learning, while teaching a hands-on unit involving robotics. Affective learning involves student's feelings toward blended and traditional instruction methods. Cognitive learning was demonstrated by students' ability to recall the process of performing a learned task with a robot and express it through words. Psychomotor learning was introduced by students performing a hands-on task with robots, such as programming an obstacle course.

Deeper Versus Surface Learning

This study examined students' depth of knowledge, from surface learning through deeper learning using different delivery methods for the VEX Robotics curriculum. Surface learning is defined as accepting new facts and ideas and storing them as isolated unconnected, bits of information. Gholson and Craig (2006) said that deeper learning occurs when a learner actively explores, reflects, and produces knowledge, not just recalls and regurgitates it. Students who experience deeper learning master a set of skills and develop an understanding of the academic content that allows the application of knowledge both within and outside the classroom. Deeper learning allows students to learn new facts and ideas and make links between content to other subject areas (Biggs, 1999; Entwistle, 1988; Ramsden, 1992). Carmean and Haefner (2002) noted that deeper learning allows for concepts to be applied beyond the classroom.

eLearning and Blended Instruction

This study used a combination of eLearning and blended instruction to determine the best combination to deliver the LearnMate VEX Robotics curriculum. While the curriculum was written in an eLearning format, as the researcher, I observed my students to determine if parts of the content would be better taught and understood by teacher-taught lessons in place of the eLearning content. This section will define eLearning and blended instruction.

eLearning

Electronic learning (eLearning) began to be applied in educational settings in the late 1990s and was viewed as a replacement to traditional classroom approaches. Jethro, Grace, and Thomas (2012) described eLearning as a technology that offers learners control over their content, learning sequence, and pace of learning, allowing students to tailor their learning process. Virtual worlds are established through simulations, role-play, and remote control of real-world tools and devices allowing students to gain hands-on experience through the Internet or virtual delivery mode. Jethro et al. (2012) suggested that eLearning is more efficient than traditional instructor-led content because learners gain knowledge and skills faster leading to a more positive attitude, improved motivation, and higher performance yielding higher results for students. However, Singh (2003) criticized eLearning as an often dry, page-turner format with point-and-click content and quizzes.

Liao and She (2009) suggested that web-based content, or eLearning, can be successful if content design is based on pedagogical theory. In their study, eLearning students outperformed conventionally taught students on scientific reasoning on both a post-test and retention quiz. The pedagogical theory and combination of instructional methods is a continuous change based on the learners.

In New Zealand, to assist with accessibility and replace traditional teaching methods, modules, prepared self-paced content, were used to teach content in a classroom (Cantrell, Pekan, Itani, and Velazquez-Bryant, 2006). Within the vocational areas, low and middle achievement scores increased modular instruction, while high-achieving students remained the same.

Blended Learning

Blended learning is a multifaceted combination of online or computer-based instruction and face-to-face classroom instruction (Massoud, Iqbal, Stockley, & Noureldin, 2011). Massoud et al. (2011) suggested that there is not a formula to determine the amount of face-to-face instruction versus e-learning. Lee and Dashew (2011) focused blended learning on three areas of interaction; learner-content, learner-instructor, and learner-learner. Learner-content interaction overrides resources such as modules or virtual simulations, so that students can teach themselves. Learner-instructor interactions involve instructor feedback, verbal and nonverbal, to help facilitate a comfortable learning environment. Learner-learner interaction helps establish a learning community where learners interact with one another and move the classroom from teacher-centered to student-centered. Massoud et al. (2011) suggested that finding the right blend of traditional lecture and eLearning is important to the overall success of a lesson and the interaction between student, teacher, and content.

Several studies have looked at the effect of a hybrid classroom (one that uses blended instruction) versus a traditional classroom on student learning. A study by Kenny and Newcombe (2011) produced high results for a hybrid classroom. Napier, Dekhane, and Smith (2011) tested computer literacy students on a final exam and found no significant differences between blended and traditional instruction. Ashby, Sadera, and McNary (2011) found students in a blended class did not perform as well on assessments as students in traditional classrooms and eLearning courses. Based on these studies, there is evidence supporting and not supporting the effect of blended instruction on student learning.

Need for the Study

There is limited research on modular technology education curricula. Rogers (2004) found little increase in knowledge gained by students from MTE labs when compared to traditional classrooms. A study by Gloeckner and Adamson (1996) identified both advantages and disadvantages of MTE. Advantages included (a) flexibility without changing the curriculum, (b) minimal cost for activities, (c) ability to meet the needs of individual students, (d) exposure to technical concepts, and (e) clear and concise testing. Disadvantages included (a) limited time to explore concepts, (b) higher-order thinking skills are not encouraged, (c) teach-by-number – too prescriptive, (d) boring repetitive, and (e) lack of teacher input. The advantages and disadvantages have led to mixed opinions about MTE and its success in the classroom. As technology has evolved, MTE has taken a new form of modular style, called eLearning. However, it remains a vendor-driven solution without research on its effectiveness or the effectiveness of its teaching of content.

Purpose of the Study

The purpose of this action research study was to determine the best blend of instruction for secondary Engineering and Technology Education students when taught through a computer-based system where students learn through individual or group activities and readings. Instruction incorporated a variety of instructional delivery methods ranging from pure eLearning to a blended instruction model that combined eLearning and teacher-infused instruction. Jethro et al. (2012) described e-learning as a computer-based technology that offers learners control over their content, learning sequence, and pace of learning allowing a learner to tailor their learning process.

Picciano (2006) described blended instruction as lessons planned in a pedagogically valuable way where face-to-face and eLearning time is mixed. Teacher-infused instruction involves a combination of LearnMate content and teacher-led lessons of both lecture format and hands-on activities. LearnMate is a vendor-developed curriculum that consists of modular-based instruction where students follow computer guides to learn about robotics and construct a robot. LearnMate content was infused with teacher-led activities/lessons focused on the VEX Robotics REC curriculum Unit 1: Introduction to Robotics that lasted 15 hours (Intelitek, 2008). The study consisted of three cycles consisting of four phases each; study and plan, take action, collect and analyze evidence, and reflect (Riel, 2010). Student learning and deeper understanding of learned content was examined in each action research cycle as changes to instruction were developed and implemented.

Research Questions

1. How does the blending of LearnMate and teacher-led instruction influence overall student learning in my Engineering Applications course?
2. Did students in my Engineering Applications course gain deeper learning about factual content and concepts about robotics differently through LearnMate or teacher-led instruction?
3. When students perform hands-on practice activities with robotics in my Engineering Applications course, was deeper learning gained through LearnMate or teacher-led instruction?

Theoretical Framework

For my study, I chose Carmean and Haefner's (2002) deeper learning principles as a framework to understand the concept. According to these principles, deeper learning occurs when learning is social, active, contextual, engaging, and student-owned. Social learning offers timely and rich feedback and promotes reciprocity and cooperation among students. Students should have an understanding of the learning process and be involved with teachers and classmates. Active learning is engagement in real-world problem-solving that incorporates judgment and exploration. Practice and reinforcement are enforced and learning involves action. Contextual learning builds on existing knowledge and is integrated into the learner's world. New knowledge is demonstrated and students show a deep foundation of factual knowledge. When students are engaged in learning, they respect diverse talents and ways of learning and communicate high expectations while maintaining a high-challenge, low-threat environment. Students are motived to learn and feel free to take risks to achieve new depths of knowledge. Deeper learning is gained when students take ownership of the knowledge learned and apply it to their lives. Students organize knowledge by taking control of their learning, noting failures, planning ahead, and appropriating time and memory to tasks. Students reflect and use higher-order thinking skills to apply knowledge from different sources to accomplish a task or assignment.

The five deeper learning principles of Carmean and Haefner (2002) do not all have to be present at one time for deeper learning to occur, but provide a framework for elements that provide deeper learning opportunities. Deeper learning can occur with one or more of the deeper learning principles present. In my action research study, the five principles of deeper learning-social, active, contextual, engaging, and student-owned- were used as a focus in the design of each action research cycle by ensuring that lessons met the criteria for deeper learning.

Importance of the Study

This action research study helped me determine which method and blend of instruction was more effective for deeper student learning in an Engineering and Technology classroom (ETE) for the VEX Robotics LearnMate curriculum. Results of provide insight into my teaching practices and ways to address deeper learning principles, and future curriculum development for Engineering and Technology Education courses.

Ramsden (1992) and Carmean and Haefner (2002) identified teaching practices that lead to deeper learning by students. Modifications to suit the needs of learners of eLearning curriculum and traditional lecture-based classroom teaching can help better prepare students to take ownership of their learning and become lifelong learners. Carmean and Haefner (2002) defined deeper learning as learning that results in a meaningful understanding of material and content that allows for the concepts to be applied beyond the regular classroom. Results of this study can help with future development and modification of curriculum that utilizes a blend of instructional modes to better suit the needs of the student learning styles.

Finally, the action research process has advantages for teachers including helping improve educational practices and the process educators' use in their own practice; encourages collaboration and is participative; is practical and relevant; is a planned, systematic approach to understanding the learning process; is open-minded; and is a justification of one's teaching practices (Mertler, 2012). While action research has its advantages researchers are closely involved in the treatment and reflections in the study, which can limit research validity as false theories may be established. However, action research is a practitioner-based method in which teachers have an opportunity to gain valuable professional development and transformation (Coghlan & Brannick, 2010).

CHAPTER 2

REVIEW OF LITERATURE

This chapter examines the history of modular instruction that was developed as a vendor-driven curriculum for Technology Education. The chapter also defines deeper versus surface learning, applies three domains of learning to learning taxonomies, and examines eLearning and blended instruction and analyzing the positives and negatives of both types of instruction as it applies to this action research study.

Deeper Learning in Student Understanding of Lessons

This section examines how students gain a deeper understanding of information being taught. Montgomery, Larsen, and Hale (2011) defined deeper learning as the experiences that lead students to understand and retain knowledge that can be used at school and in future careers. Gholson and Craig (2006) said deeper learning engages learners who actively explore, reflect, and produce knowledge, not just recall and regurgitate it, or apply surface learning, a basic recall of information. Students experiencing deeper learning master a set of skills and develop an understanding of the academic content that allows the application of knowledge both within and outside the classroom. Deeper learning allows students to learn new facts and ideas and make links to other subject areas (Biggs, 1989; Entwistle, 1988; Ramsden, 1992). Carmean and Haefner (2002) defined deeper learning as a meaningful understanding of material and content that allows concepts to be applied beyond the classroom. Based on these definitions, a student with a deeper understanding and mastery of content can implement it outside the classroom, unlike a student who learns surface learning and basic recall.

Surface versus Deeper Learning

Ramsden (1992) noted distinct differences in deep and surface learning by defining and comparing characteristics of each (see Table 1). For example, on a project, the deeper learning student will relate previous and new knowledge to solve a task, whereas the surface learning student will focus on completing the task using basic knowledge. According to Ramsden (2003), students with a greater depth of knowledge can apply the learning experiences to world-wide situations beyond the classroom.

Table 1.

Characteristics of Deep and Surface Learning Approaches

Deep learning	Surface learning
Intention is to understand and the student maintains the structure of the task.	Intention is to only complete the task for that project.
Focus on the arguments and concepts for solving the problem.	Focus on the signs (worlds of the text and application of the formula to solve the problem.
Relate previous and new knowledge.	Associate facts and concepts without reflection.
Relate theories to everyday experiences.	Treat tasks as external and unimportant.
Organize content and structure into a whole idea	Focus on unrelated parts of tasks.

Deeper Learning Taxonomies

Educational models are key components in the design and implementation of eLearning and blended instruction. The models are derived from views about cognition and knowledge and form the basis for learning, which link theory to practice. Constructivism views the learner as an active participant in the learning experience requiring the learner to develop knowledge through situations, activities, and social interactions the challenge the learner to make new meanings rather than acquire concepts as abstract of individual entities (Dabbagh, 2005). Dabbagh (2005) compared deeper learning theories and constructivist views and found similarities including (a) promoting and supporting authentic activities, (b) facilitating problem solving and exploration, (c) promoting collaboration and social negotiation, (d) supporting role-playing activities, (e) promoting articulation and reflection, (f) supporting multiple perspectives, (g) supporting modeling and explanations, and (h) providing scaffolding. McLoughlin and Oliver (1999) explained that the role of instructional strategies in the classroom is a way to create a learning culture where collaboration, self-awareness, different perspectives, and self-management are promoted. In the instructional model of McLoughlin and Oliver (1999) teacher assumes a role that is supportive and communicative while addressing the needs of the student as the student works through content.

Deeper learning principles of Carmean and Haefner, (2002) Dabbagh (2005), and Weigal (2002) can be compared to the educational pedagogy of Bloom's (2002) taxonomy and student learning strategies (see Table 2). While the vocabulary is different in each of the deeper learning taxonomies, the progression of learning is similar.

Like the deeper learning theories of Carmean and Haefner, (2002) Dabbagh (2005), and Weigal (2002), Webb's (2002) Depth of Knowledge (DOK) is another way of arranging assessments to meet the criteria for deeper learning. DOK levels are (a) Level 1: Recall, (b) Level 2: Skill/concept, (c) Level 3: Strategic thinking, and (d) Level

4: Extended thinking. Students learn to hypothesize, critique, analyze, synthesize, compare, connect, prove, or explain their ideas (Webb, 2002). During assessments, the deeper the knowledge gained, the higher DOK level assessments that can be completed (Ramsden, 2003).

Table 2.

Bloom's Taxonomy and the Deeper Learning Principles (DLP)

Bloom's taxonomy (2002)	Carmean and Haefner (2002)	Dabbagh (2005)	Weigel (2002)
Remembering	Contextual: build on knowledge	Authentic: assessments using multiple knowledge areas	Relate learning to previous knowledge and experience
Understanding	Contextual: knowledge is demonstrated and concrete Ownership: organized for retrieval of knowledge		Aware of understanding that develops while learning occurs
Applying	Active: knowledge is demonstrated	Exploration: role playing that is complex	Look for patterns and underlying principles
Analyzing	Active: real world problems	Authentic: real-world situations and a variety of resources	Look for patterns and underlying principles
Evaluating	Active: judgment and exploration are used together Ownership: higher order thinking	Exploration: hypothesizing	Examine logic and look for relatable conclusions
Creating	Ownership: failures, planning ahead, higher order thinking	Exploration: problem solving	Problem solving and exploration

DOK level 1 reflects a surface depth of knowledge with recall of information such as a name or date of an event, but as each DOK level progresses, the synthesis and application of knowledge required increases. DOK level 2 requires the student to recall information for a specific task or situation like the providing a description and the steps of the engineering design process. On a level 3 DOK task, students would be given a problem and have to implement a solution using the engineering design process. DOK level 4 would further the level 3 task by having students develop their own problem and solve it. The ability of a student to apply knowledge on different DOK levels is an indication of deeper learning (Stanford Center for Opportunity Policy in Education, 2013).

Bloom's (2000) taxonomy, Webb's (2002) DOK, and the other deeper learning principles can be aligned with each other; however, the deeper learning principles do not address the basic knowledge that must be learned before deeper learning tasks can occur. Principles of deep learning are derived from research and build on learner's prior knowledge and experiences. Deeper learning principles of Carmean and Haefner (2002), Dabbagh (2005), and Weigal (2002) were examined to determine the most appropriate theory for this action research study.

Carmean and Haefner (2002) analyzed and combined the research to develop principles of deeper learning to determine the elements of instruction that should be included in an effective course management system. According to their principles, deeper learning occurs when one or more of these five elements are present (a) social, (b) active, (c) contextual, (d) engaging, and (e) student-owned and can be described when the following are present for teachers and students:

1. Social learning offers timely and rich feedback and promotes reciprocity and cooperation among students. Students should have an understanding of the learning process and be involved with the teacher and classmates.
2. Active learning is engagement in real-world problem solving that incorporates judgment and exploration. Practice and reinforcement are enforced and learning involves action.
3. Contextual learning builds on existing knowledge and is integrated into the learner's world. New knowledge is demonstrated and students show a deep foundation of factual knowledge.
4. When students are engaged in learning, they respect diverse talents and ways of learning and communicate high expectations while maintaining a high-challenge, low-threat environment. Students are motived to learn and feel free to take risks to achieve new depths of knowledge.
5. Deeper learning is gained when students own their knowledge. Students organize knowledge by taking control of their learning, noting failures, planning ahead, and appropriating time and memory to tasks. Students reflect and use higher-order thinking skills to apply knowledge from different sources.

While all five elements of the deeper learning principles of Carmean and Haefner (2002) do not all have to be present at one time for deeper learning to occur, they provide a framework for successful deeper learning situations. In my study, the principles of deeper learning were used when reflecting on the action research phases. Changes in the structure of teaching, moving away from self-directed learning towards teacher led instruction will be incorporated during each phase of the study based on data, to promote the most understanding and depth of knowledge from the participants.

Conditions for Deeper Learning

For deeper learning to occur through both eLearning and traditional classroom instruction, there must be a shift in the roles of students and teacher. Ramsden (1992) outlined the characteristics of the learning context that would encourage conditions and deeper knowledge by students and teachers (see Table 3). Information in Table 3 was used as a checklist throughout my study to guide the teaching conditions towards deep learning and ensure I met the criteria for a deeper learning approach.

Table 3.

Conditions Associated with Deeper and Surface Learning Approaches

Deep approaches	Surface approaches
Teacher demonstrates commitment to and enthusiasm about the subject	Teach demonstrates a lack of enthusiasm for the subject
Teacher demonstrate an interest in and knowledge of subject	Teacher demonstrates a lack of interest in and knowledge of the subject
Academic expectations are clearly stated	Conflicting messages about the subject and rewards
Subject content is meaningful and relevance is stressed to the student	Excessive amount of material in the curriculum with little feedback on student progress
Teaching and assessment methods foster active and long term engagement of learning tasks	Assessment methods focus on recall
Students have the opportunity to exercise choice in the method and content studied	Few opportunities to demonstrate independent student learning
Student have previously experienced educational contexts with deeper approaches to learning	Students have previously experienced education contexts with surface approaches to learning

Fullan and Langsworthy (2014) identified three core components that enable deep learning; (a) new learning partnerships between teachers and students, (b) deep learning tasks that restructure the learning process to give it purpose, and (c) digital tools and resources to accelerate the learning process. Building a partnership creates trust between teachers and the students allowing students to share interests and become engaged in the learning process. This relationship can be formed from the shared excitement between the teacher and student in the content (Ramsden, 1992). When students take an active role in the learning process, they become leaders of their learning process. Assigning deep learning tasks that relate to a student's life, allows criticism and work through familiar problems and situations while applying knowledge learned. Finally, accelerating the learning process with digital tools keeps the content exciting and allows the student to become a leader and explore the content (Ramsden, 2002).

Crick (2011) developed a set of design principles to create classrooms that promote deep learning including a language for learning, authenticity, active engagement, enquiry, coaching and mentoring, and authentic assessment. A language for learning is a language in which we can talk about ourselves as learners and develop our own story. Authenticity is personal involvement in learning that has meaning and relevance to their life beyond the classroom. Active engagement involves products and performance outside that classroom that require active learning that is more than repetition or retrieval of memorized facts. Inquiry is using communication to build on prior knowledge and inquire to obtain a more in-depth understanding. Coaching and mentoring involves creating relationships that empower the learner to take responsibility of their own learning. Using these elements, learning can become connected beyond the classroom doors and into the lives of students creating a world where content is beyond rote memorization, but instead applied to life situations.

Assessments and Transfer of Knowledge in Deeper Learning

Surface learning is, at best, about quantity without quality, and deep learning is about quality and quantity (Ramsden, 2003).

> Knowing facts and how to carry out operations may well be part of the means for understanding and interpreting the world, but the quantitative conceptions stops at the facts and skills. A quantitative change in knowledge does not in itself change understanding. Rote learning scientific formulae may be one of the things scientists do, but it is not the way scientists think. (Biggs, 1989, p. 10)

According to Ramsden (2003), deeper learning requires students to take knowledge further than surface learning by doing the following; (a) focus on what is signified, (b) relate previous knowledge to new knowledge, (c) relate knowledge from different courses, (d) relate theoretical ideas to everyday experience, (e) relate and distinguish evidence and argument, (f) organize and structure content into a coherent whole, and (g) internalized emphasis where reality becomes visible. When provided a deeper learning task, students must recall previous knowledge and apply it, organize multiple types of information into a whole concept, and provide evidence or an argument to support their decisions.

Assessments of learning should have a balance between evaluating basic knowledge and transferring knowledge to other contexts. Webb’s (2002) Depth of Knowledge (DOK) is one way of arranging assessments to meet the criteria for deeper learning. Table 4 shows the difficulty progression of activities as the depth of knowledge and DOK level increase. A DOK level 1 task focuses on basic recall, while a DOK level 4 task focuses on using prior knowledge to solve a problem or complete a task. The ability of a student to answer questions on the different DOK levels is an indication of deeper learning (Stanford Center for Opportunity Policy in Education, 2013).

Table 4.

Webb's (2002) Depth of Knowledge Examples

Level 1	Level 2	Level 3	Level 4
Recall elements and details of story structure, such as sequence of events, character, plot and setting.	Identify and summarize the major events in the narrative.	Support ideas with details and examples.	Conduct a project that requires specifying a problem, designing and conducting an experiment, analyzing its data, and reporting results/solutions.
Conduct basic mathematical calculations.	Use context cues to identify the meaning of unfamiliar words.	Use voice appropriate to the purpose and audience.	Apply mathematical model to illuminate a problem or situation.
Label locations on a map.	Solve routine multiple-step problems.	Identify research questions and design investigations for a scientific problem.	Analyze and synthesize information from multiple sources.
Represent in words or diagrams a scientific concepts or relationship.	Describe the cause/effect of a particular event.	Develop a scientific model for a complex situation.	Describe and illustrate how common themes are found across texts from different cultures.
Perform routine procedures like measuring length or using punctuation marks correctly.	Identify patterns in events or behavior.	Determine the author's purpose and describe how it affects the interpretation of a reading selection.	Design a mathematical model to inform and solve a practical or abstract situation.
Describe the features of a place or people.	Formulate a routine problem given data and conditions.	Apply a concept in other contexts.	
	Organize, represent, and interpret data.		

Examining the depth of knowledge and thoroughness of answers to tasks, in this study, was done using Biggs (1989) SOLO (Structure for Observed Learning) taxonomy which was designed to assess the structural complexity of student responses. The levels of the SOLO taxonomy are not content specific and can therefore be modified and used with any subject matter (see Table 5). For my action research study, rubrics using the SOLO taxonomy rating scale shown in Table 5 were used to help identify the depth of knowledge gained throughout each cycle and unit. Table 5 shows a rubric from evidence of student work. The more evidence of knowledge a student can demonstrate the better the understanding of the content.

Table 5.

Levels of Biggs' (1989) SOLO Taxonomy

Depth of knowledge		Evidence of knowledge
1	Pre-structural	Use of irrelevant information, or no meaningful response.
2	Uni-structural	Answer focuses on one relevant aspect only.
3	Multi-structural	Answer focuses on several relevant features, but they are not coordinated together.
4	Relational	The several parts are integrated into a coherent whole: details are lined to conclusions; meaning is understood.
5	Extended abstract	Answer generalizes the structure beyond the information given: higher-order principles are used to bring in a new and broader set of issues.

Deeper learning can also be assessed through interviews and questionnaires. Svensson (1977), Prosser and Millar (1989) and Ramsden (1981) asked students in interviews questions such as: (a) How did you read the books set for the course? (b) What sorts of things do you usually do when studying for this course and why? and (c) What kinds of things do you do in tutorials and seminars? Answers to these questions help examine a student's motivation and quest for knowledge. One of the best known questionnaires for accessing depth of knowledge was developed by Biggs (1999). Based on results from the surveys Biggs (1999), teachers can determine whether students are usually surface or deep learners (see Table 6).

Student's answers to a questionnaire like that of Biggs (1999) can help provide direct information about mastery of content and depth of knowledge on a topic. If a student answers with primarily surface answers, the method of teaching needs to be changed to help students better understand.

Table 6.

Examples Questions from the Biggs (1989) Study Process Questionnaires

Deep learning meaning orientation	Surface learning reproducing orientation
I try to relate ideas in one subject to those in others, whenever possible.	I find I have to concentrate on memorizing a good deal of what we have to learn.
I usually set out to understand thoroughly the meaning of what I am asked to read.	I usually don't have time to think about the implications of what I have read.
I try to understand new ideas; I often try to relate them to real life situations to which they might apply.	Although I generally memorize facts and details, I find it difficult to fit them together into an overall picture.
When I'm tackling a new topic, I often ask myself questions about it which the new information should answer.	I find I tend to remember things best if I concentrate on the order in which the lecturer presented them.
In reading new material I often find that I'm continually reminded of material I already know and see the latter in a new light.	I tend to choose subjects with a lot of factual content rather than theoretical kinds of subjects.

Three Domains of Learning

Effective teaching is modeled from taxonomies such as Bloom's taxonomy based off of the three domains of learning: cognitive, affective, and psychomotor (Bloom, Engelhart, Furst, Hill, & Krathwohl, 1956). When trying to obtain a deeper learning, it is important to understand the three domains of learning. This section will outline the three domains of learning and their application to Carmean and Haefner's (2002) deeper learning principles.

Cognitive Learning

The cognitive domain deals with recall and recognition of knowledge and the development of intellectual abilities and skills. The cognitive domain can be demonstrated using six classifications including knowledge, comprehension, application, analysis, synthesis, and evaluation (Bloom et al., 1956). Cognitive understanding occurs when a student decodes, conceptualizes and applies content followed by reflection (Zollman, 2012). Piaget and Beth (1966) stated that a student constructs knowledge during the reflective abstraction including internalization, coordination, encapsulation, and generalization. Research has shown that measuring a student's belief of his or her own cognitive learning is important in determining the amount of instructional mastery (Richmond, Lane, & McCroskey, 2006).

Affective Learning

Krathwohl, Bloom, and Basia (1964) explained the affective domain of learning in which affective learning which they defined as emphasizing one's feelings, emotions, or degree of acceptance or rejection for the situation. Affective learning is about "interests, attitudes, appreciations, values, emotional sets or biases" (p. 7). Krathwohl et al. (1964) created a taxonomy of objectives for the affective domain that included receiving a certain stimuli, responding to a stimuli, valuing the worth of the stimuli, organizing based on importance, and characterization of one's values. Mottet and Beebe (2006) noted that affective learning occurs when learners "take ownership of their learning and is manifested when students enact behaviors that demonstrate that they respect, appreciate, and value the knowledge and skills they are acquiring" (p. 8). Students develop a personal identity and self-understanding that is the fundamental development task of their psychological maturity in adolescent years (Erickson, 1968). Classroom teachers create appropriate classroom conditions for this identity to flourish including fostering self-determination, cultivating self-regulation, capitalizing on collaborative social goals, and establishing an engaging classroom environment (Zollman, Smith, & ReiSDorf, 2011). Teachers create classroom conditions that foster self-determination by providing opportunities for students to make choices, demonstrate competency, and participate in peer relationships. Self-regulation is taught by allowing students to evaluate their progress towards goals and reflection on how learning connects to their future lives. Cooperative and authentic learning enables students to work and learn together enhancing collaborative social goals. Creating an engaging classroom environment allows learners to feel confident (Zollman et al., 2011). Research has shown that affective learning can predict cognitive learning and is one of the most important domains of learning that leads to behavior change (Christophel, 1990).

Psychomotor Learning

The final domain of learning discussed by Bloom et al. (1956) is psychomotor learning, the motor-skill aspect of learning, Psychomotor learning requires manipulation of material objects to perform a task and is demonstrated by physical skills such as movement, coordination, manipulation, dexterity, grace, strength, and actions that define fine motor skills (Zollman, 2011). There are three stages in the psychomotor domain: thinking (cognitive), linking (associative), and autonomic (physical dexterity) (Dave, 1970; Romiszowski, 1999). The thinking stage involves awkward slow movements where the learner is trying to control actions. Frustration in this stage can be high, but with practice, the student can improve, for example, driving a robot. In the linking stage, the student associates one movement with another known movement. While the student still has to think, the movement becomes easier, for example, comparing driving a robot and playing a video game with similar controls. The autonomic state happens when the student no longer needs to depend on the teacher for feedback and the motions and movements are spontaneous and the mind and body are one. This state can be achieved with practice (Dave, 1970; Romiszowski, 1999).

Traditionally there is less emphasis on the psychomotor domain than the cognitive and affective domains in education, but with technological advances the psychomotor domain is becoming increasingly important (Zollman, 2012).

Domains of Learning / Carmean and Haefner's (2002) Deeper Learning Principles

All three domains of learning were assessed during this study, as they relate to Carmean and Haefner's (2002) deeper learning principles (see Figure 1). The five elements for deeper learning are social, active, contextual, engaging, and student-owned.

Social learning is exhibited when it involves prompt feedback, encourages contact between students and faculty, and involves cognitive apprenticeship (Carmean & Haefner, 2002). Prompt feedback and encouraging contact among students and faculty represent the affective domain, while the cognitive apprenticeship represents the cognitive domain of learning.

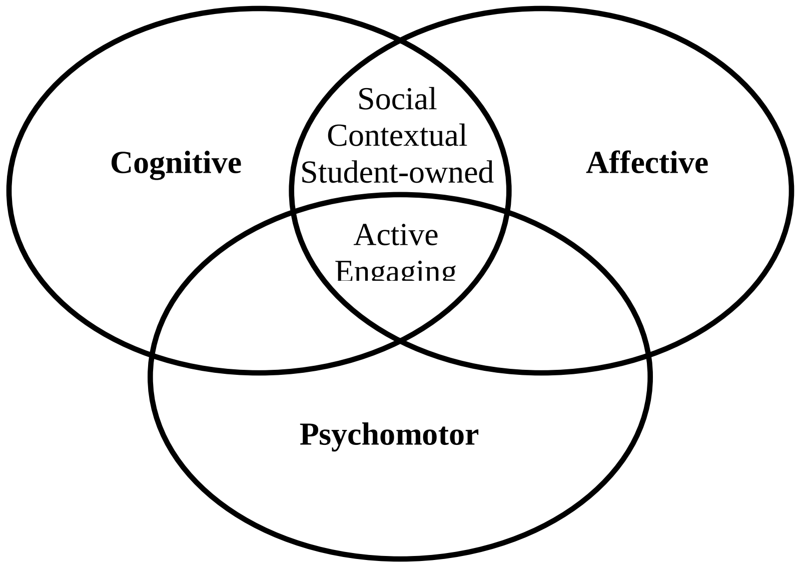

Figure 1. Domains of Learning and Deeper Learning Principles

Active learning is engagement in real-world problem solving, using active learning techniques and involved in practice and reinforcement (Carmean & Haefner, 2002). The active learning involves the cognitive ability of the student to recall the knowledge, the affective learning in the participation of the assigned task, and the psychomotor domain in the hands-on, active engagement of the learning assignment, for example, programming a robot.

Contextual learning principle is knowledge that builds on existing knowledge and is applied and demonstrated by the learner (Carmean & Haefner, 2002). In this research study, students were required to learn to program a robot for a specific task. The content taught the basics of programming, but required students to take ownership in the learning and complete the task by using previous knowledge of programming, therefore incorporating the cognitive and affective domains of learning.

Engaging means communicating high expectations, emphasizing intrinsic motivators, and involves a high-challenge, low-treat environment (Carmean & Haefner, 2002). In this study, students had tasks they had to accomplish on a specific timeline that allowed flexibility based on their learning, while incorporating extra challenges to students who perform well on tasks and do the best. Students worked with psychomotor skills for programing of the robot, applying cognitive knowledge to build a program, and have extra incentives to do their best incorporating the affective domain of learning.

Student-owned learning emphasizes time on task, allows for reflection and emphasizes higher order thinking skills making it a part of the cognitive and affective domains of learning (Carmean & Haefner, 2002). In this study, students worked at their own pace to complete their activities.

Throughout the research study the domains of learning were assessed as they relate to each of the elements of the deeper learning principles and the unit of instruction the students completed on robotics and programming.

eLearning and Blended Instruction

This action research study focused on lessons taught using a combination of eLearning and blended instruction. This section will define eLearning and blended instruction and look at research studies involving each method.

eLearning

Jethro, Grace, and Thomas (2012) described eLearning as a method of teaching using computers that offer learners control over their content, learning sequence, and pace of learning, allowing learners to tailor the learning process to meet the learners needs. Jethro et al. (2012) identified two common eLearning modes; distance learning and computer-based instruction. Distance learning is a method of delivering information to learners at remote locations that uses computers. Computer-assisted instruction or computer-based learning uses computer technology to aid in the delivery of content through multimedia packages.

Electronic learning (eLearning) began to be applied in educational settings in the late 1990s and was viewed as a replacement to traditional classrooms. Virtual worlds can be established through simulations, role-play, and remote control of real world tools and devices allowing learners to gain hands-on experience through the internet or virtual delivery mode. Jethro et al. (2012) suggested that eLearning is more efficient than a traditional classroom with teacher-led instruction because learners have the ability to work at their own pace and gain knowledge and skills faster leading to a more positive attitude and improved motivation and performance yielding higher results. However, Singh (2003) disagreed with Jethro et al. (2012) criticizing eLearning as often a dry, page-turner format with point and click content and quizzes allowing students to easily recite information and continue in the content without gaining a deeper understanding.

Studies were researched involving computer-based instruction and student retention of information. These studies were (a) web-based instruction compared to teacher led instruction and their scientific reasoning, (b) modular education, or computer-based education, as a third-year secondary school program for students in New Zealand, and (c) engineering module activities as a method for teaching the design process to middle school science students in Nevada. Each of these studies examined the effectiveness of eLearning and students ability to learn the material (see Table 7).

8th grade scientific reasoning. Liao and She (2009) suggested that web-based content or e-learning can be successful if content is design based using pedagogical theory. "Adaptive learning can offer flexible solutions that dynamically adapt content to fit individual real-time learning needs," (Liao & She, 2009, p. 233). ELearning allows for flexibility and change of pace in content delivery based on the individual learner. This study utilized e-learning to teach scientific reasoning. The eLearning students outperformed the conventional students on scientific reasoning on both a post-test and retention performance.

Form five – third year secondary schooling. New Zealand operates on a two-tier educational system that places elite students on a higher educational level than other students. The Form Five educational model aims to integrate all secondary and tertiary qualifications and divide them into eight levels or courses, much like the subject areas in the United States (McGee & Hampton, 1996). To replace traditional teaching, modules were used to teach content and at the completion of each module students were given an examination. Within vocational content areas, low and middle-achievement student's scores increased when taught with modular instruction while high achieving students' scores remained the same as with traditional classroom instruction. The self-pacing of the modular instruction helps students in low and middle achievement levels progress at their own pace. The study showed no variations with achievement and modular instruction based on gender where in the study by Cantrell, Pekan, Itani, and Velazquez-Bryant (2006) a variation was evident.

In the Form Five study learners could choose their own learning modules based on their interest which may be why all subgroups showed an increase in achievement. Overall, vocational teachers favored modular instruction more than the academic teachers and had more favorable results.

Engineering Design in Science. Teachers in Nevada were brought together with a grant through the National Science Foundation to establish modules to teach the engineering design process through science classes to incorporate STEM; science, technology, engineering, and math (Cantrell et al., 2006). Teachers used a blended teaching method utilizing computer-based simulators for students to design projects, while utilizing class discussions and hands-on projects to reinforce content. Throughout the process students focused on the engineering design process. All but two groups of students increased the scores on the assessments. The girls in the study had less gain which may be due to the nontraditional career focus of engineering. Students with learning disabilities reduced their achievement gap because of the hands-on nature of teaching the engineering design process allowing for multiple learning domains. Teachers in the study observed that students who were not generally interested in science content were more engaged due to the hands-on nature of the assignment.

After looking at the research, it appears as though eLearning is a favorable teaching method that produces positive results. Average students and students with disabilities performed better using the eLearning. There was also evidence of improved student interest due to the self-pacing of the content.

Table 7.

Comparison of the Research Studies

Researcher	Purpose	Participants	Method	Statistical analysis	Results
Liao & She (2009)	Do students who receive web-based instruction outperform conventionally educated students in scientific reasoning	211 8th graders recruited from six average-achievement classes in a middle school in Taiwan	1. E-learning group – teachers facilitated as the students went through self-paced e-learning content 2. Conventional group – used textbook, lectures, lab experiments.	Comparison of post-test scores between the e-learning and conventional groups	Web-based group outperformed conventional group on both a post-test performance and achievement
McGee & Hampton (1996)	Prepare students for the Form Five national examination through e-learning or modular instruction.	15-year-old students in Form Five school in their third year	Each module was 30 hours over a 6-7 week semester. Students took modules over six semesters and did a four week exam preparation.	Scores on the school certificate marks were collected over three years and compared with the modular prep. scores	1. Low and middle students were higher achieving with modular instruction 2. High ability students had no change 3. Technical drawing and technology results improved
Cantrell, et al, (2006)	Engineering design activities were created to help integrate science, technology, math, and engineering	434 students in Nevada middle schools	1. Blended instruction was used beginning with class discussion introducing the concept, 2. e-learning simulation to design the project that produced data, 3. construction of the model based on data from the e-learning simulation	Score on the blended assessment were compared with science CRCT scores	1. Males benefited but gaps increased for females. 2. Achievement gap for students from low income families remained same 3. Achievement gap for American Indians & Whites increased, gaps for Blacks & Hispanics diminished. 4. Asians showed most improvement

Blended Learning

Blended learning is a mixture of online or computer-based instruction incorporated with face-to-face classroom instruction (& Graham, 2006 & Massoud, Iqbal, Stockley, & Noureldin, 2011). Ross and Gage (2006) differentiated between web-based instruction and technology-enhanced courses by defining web online instruction as supplementary without taking away the traditional in-class time. Piccano (2006) described blended instruction as lessons planned in a pedagogically valuable way where face-to-face and eLearning time is mixed. Blended instruction increases student knowledge and interaction utilizing traditional teaching with contemporary multimedia or internet learning environments. In my study, I used a blended instruction approach to incorporate teacher-led instruction with modular content to enhance the learning process and clarify topics of confusion and difficulty. Massoud et al. (2011) suggested there is not a formula for the amount of face-to-face time versus eLearning needed to reach success, rather the blend of the instruction needed is based on the needs of the individual learners on the topic being studied. The depth of knowledge questions and levels helped determine the correct blend of instruction, assessing areas of weakness with in the eLearning content and student understanding through answers to student interviews, observations, and performance tasks.

Blended learning research studies. Blended learning studies were examined including (a) academic achievement of students in traditional and hybrid classrooms, (b) student attitudes toward blended instruction, and (c) the impact of blended learning on student's critical thinking dispositions and levels. Based on these studies, there is varying evidence of blended instruction on the depth of student learning. However, course content, the teacher, and the method of blended instruction can affect the students' learning (see Table 8).

Kenny and Newcombe (2011) reported favorable results in a hybrid classroom that involved a blend of teacher-lecture and computer based tasks, but results were minimal. On a unit test, students in the blended section, teacher-lecture and online assignments, had a slightly higher average score (47.46 out of 60) than both the large, non-blended section (44.34) and the small, non-blended section (47.40). Napier, Dekhane, and Smith (2011) studied a computer literacy course with one class of traditional instruction and one using traditional and computer based instruction. Both groups where given the same final exam but no differences between blended and traditional instruction were found.

Ashby, Sadera, and McNary (2011) found that students in a blended class did not perform as well on a math assessment compared to the traditional classroom and eLearning courses. However, while results did not support blended instruction, the content was math, which is difficult to teacher online, so depending on the implementation process of the blended instruction and the motivation of the learner, these scores could be accurate.

Based on these studies, there is varying evidence of blended instruction on student learning. However, all of the researches noted that the course content, the teacher, and the method of blended instruction can affect the students' depth of knowledge gained.

Table 8.

Comparison of Research Studies on Student Achievement in the Classroom

Researcher	Purpose	Participants	Methodology	Statistical Analysis	Results
Ashby, Sadera, & McNary (2011)	Success in a Developmental Math course offered in three different learning environments (online, blended, and face-to-face)	167 participants math students – randomly selected	2 classes were tested on each learning environment (online, blended, and face-to-face) and final tests compared	Comparison of scores from each learning environment with a one way ANOVA	Significant differences between learning environments with the students in the blended courses having the least success and lowest scores
Kenny & Newcombe (2011)	Blended learning effect on student learning	3 classes of 60/60/30 students	Half the class alternated once a week with online assignments while the remainder did teacher lecture	Exam score compared between blended and non-blended classes	Blended learning had a slightly higher score than non-blended
Korkmaz, & Karakus (2009)	Impact of blended learning on student's critical thinking dispositions and skills	57 students – 28 in the experiment group and 29 in the control group	Experimental pattern with a pre-test and post-test control group. The experiment group was subject to hybrid learning and the control group was taught through traditional instruction	Geog. Attitude Scale and CA Critical Thinking Disposition Inventory with Cronbach Alpha values of 0.92 and 0.88. The data was subject to percentage, arithmetic mean, t-test, ANOVA< Scheffe' and Pearson correlation tests.	Blended learning contributed more to student critical thinking dispositions and levels
Napier, Dekhane, & Smith (2011)	What do students perceive as the benefits and challenges of taking blended learning courses?	Introductory computer literacy course – specific number of participants unknown	Blended instruction and traditional instruction were taught and the same exam given to both classes	Performance on the final exam was compared in traditional and blended learning sections	Differences between the traditional and blended learning groups were not strong

Design and implementation of blended learning. Finding the right blend of traditional instruction and eLearning is important to the overall success of any lesson being taught. Shea (2007) thought that blended instruction must reflect the four conditions of adult learning as described by Brown and Cocking (2000). These conditions are *learner-centeredness* or meeting the goals and interests of the learner; *knowledge-centeredness* or using active relevant learning experiences; *assessment-centeredness* or finding ways to effectively measure learning so that formative and constructive feedback can be provided; and *community centeredness* or creating a sense of connectedness and collaboration among learners. These conditions are an important part of the instructional course design.

Hong (2006) described blended instruction as incorporating the "Seven Principles of Good Practice in Undergraduate Education" developed by Chickering and Ehrmann in 1987 and updated in 1996. These principles are (a) promoting interaction among faculty and students, (b) enhancing reciprocity and cooperation among students, (c) promoting active learning, (d) providing prompt feedback and increasing time on task, (e) setting high expectations, and (f) recognizing diversity in learning (Hong, 2006). The principles help establish guidelines for effective teaching.

Redesign of content to a blended learning approach should focus on three areas according to Lee and Dashew (2011) including *learner-content* where students learn the content on their own, *learner-instructor content* where learner and instructors work together, and *learner-learner interactions* where learners work with each other to learn the content. Blended approaches to learning guide instructors away from the traditional classroom approaches and allow for more constructivist methods of exploratory learning and hands-on experiences (Lee & Dashew, 2011).

Research of Hong (2006), Shea (2007), and Lee and Dashew (2011) has outlined elements that create the foundation for strong instruction including positive teacher student relationships, prompt and meaningful feedback, cooperation and a sense of community among the students, and promoting active learners utilizing relevant information. Balanced instruction requires that people learn to emphasize the importance in the learning process and become active participants rather than passible observers (Olgun, 2009).

History of Engineering and Technology Education

Middle and high school Georgia Career and Technical Education focuses on career-based courses that emphasize work place skills. Students have the opportunity to take a series of three courses relating to career areas, these courses form a career pathway. One of pathways students can choose is the Engineering and Technology (ETE) pathway, consisting of courses that focus on the engineering design process and related engineering skills. The Georgia Department of Education's Engineering and Technology pathway has undergone many changes. In 2006, the Engineering and Technology pathway began its movement toward the incorporation of engineering and engineering design process (Wicklein, 2006). Many iterations and changes have led to this point in its history. This section outlines the history of the Engineering and Technology pathway, the introduction of robotics, and how engineering-related courses encourage deeper learning.

The Beginning of Industrial Arts

In 1904, Richards noted that industrial arts has influenced directly from industry, which inspired educators who became influential in implementing industrial arts (Smith, 1981). Through this inspiration, Russell (1909) published *The School and Industrial Life* in 1909 and suggested that elementary education include economic, humanistic, and scientific studies as part of the general curriculum replacing fine arts, domestic art, and domestic science. Russell defined economic as “the study of industries for the sake of a better perspective on man’s achievement in controlling the production, distribution, and consumption of the things which constitute his natural wealth” (Smith, 1981, p. 187). The work of Russell defined industrial arts and its purpose in education.

Bonser and Mossman (1923) furthered the definition of industrial arts to be an area which creates changes in raw materials to increase their value for human usage. While Bonser is often credited as the founder of industrial arts, his untimely death left Russell, Mossman, and Erikson as pioneers to develop applications and best practices for teachers to implement the instruction of industrial arts content in classrooms (Bartow, Foster, & Kirdwood, 1994).

In 1929, Mossman redefined Bonser’s definition of industrial arts to include: (a) procuring and producing raw materials, (b) manufacturing these raw materials, and (c) distributing these materials and commodities to people who consume them. Mossman established the first general shop, in which students’ experienced wood-working, drawing, and home economics.

Wilber, in 1948, defined industrial arts as “those phases of general education which deal with industry, its organization, materials, occupations, processes, and products, and with the problems of life resulting from the industrial and technological nature of society" (p. 2). Wilber replaced the industry concept with technology (Foster, 1995). Wilber's change from industry to technology was based on a more technologically-driven society and needs.

Despite earlier efforts, debate remained about the focus and direction of industrial arts, thus leading to the curriculum development project called *A Curriculum to Reflect Technology* created by Warner and his students at Ohio State University in 1947. This project divided the study of industrial arts into five areas: communication, construction, power, transportation, and manufacturing. Many curriculum development projects were conducted based on Warner's ideas, such as *The American Industry Project, The Maryland Plan,* and the *Industrial Arts Curriculum Project*, thus making Warner one of the most influential people in industrial arts. Industrial arts, as a part of vocational education from the 1950s through the 1970s was based on one of three areas: (a) industry - as exemplified by the Industrial Arts Curriculum Project and the American Industry Project, (b) technology - as promulgated by Olson and DeVore, and (c) the needs of the child - as found in Maley's work (Wright, 1992). Vocational curriculum was taught to children based on needs of society as reflected in industry and technology.

In 1973, Maley published *The Maryland Plan* in which industrial arts, as a curriculum area, included "those phases of general education which deal with technology, its evolution, utilization, and significance; with industry, its organization, materials, occupations, processes, and products; and with the problems and benefits resulting from the technological nature of society" (p. 2). While the work of Maley involved technology, it was the release of *Jackson's Mill Industrial Arts Curriculum Theory* which was a major step in a unified focus of industrial arts (Snyder & Hales, 1981). This work is associated with the acceptance of the universal systems model (input, process, output, feedback) and four systems: transportation, construction, manufacturing and communication. The Jackson's Mill Project became the foundation and conceptualization of the technology education curriculum and change from industrial arts (International Technology Education Association [ITEA], 1996).

Societal influences on Industrial Arts

One of the most significant problems with describing the historical background of industrial arts is that the terms industrial arts, manual arts, and manual training were used interchangeably and, therefore, there are no particular dates marking the start and end of each curriculum period (Barlow, 1967). Instead, the progression of the curriculum can be traced through history and societal changes.

The industrial revolution, between 1759 and 1975, helped shape the development of industrial arts. During this time, people worked in factories processing raw materials and doing physical labor. One of the main products of the Industrial Age was the automobile. The cost of the automobile was derived from the raw materials and physical labor needed for production. Production of the automobile had a direct correlation to Vocational Education and Industrial Arts in the industrial age.

World War I, the Great Depression, World War II, and the Space Age also helped change the industrial arts curriculum for over half a century. The demand was high for people with mechanical skills, technical skills, and scientific knowledge. This led to an educational focus on automotive, machining, metal fabrication, forging, electrical, building, and drafting. Legislation such as the Morrill act of 1862, the Carl D. Perkins

Act, and the Smith Hughes Act of 1917 were major influencers in the development of industrial arts and made it possible and a requirement to fund vocational education (Barlow, 1967).

Industrial Arts and Deeper Learning

Industrial Arts content followed the deeper learning criteria established today with hands-on implementation of content. A student might learn about welding in class, and then practice the application of welding in a real-world situation. This activity combined with the instruction on safety and operation of a welding tool is an example of deeper learning. According to the deeper learning principles of Gholson and Craig (2006), when provided real-life application and hands-on experiences, students gain a greater depth of knowledge.

Technology Education

Technology Education began to emerge in the 1960s as a result of curriculum innovations in industrial arts and federal funding. *The American Industry Project* (Face, Flug, & Swanson, 1966) and the *Industrial Arts Curriculum Project* (Towers, Lux, & Ray, 1966) stressed societal needs in a curriculum that teaches technology. DeVore (1980) also had a plan that stressed hierarchical subject matter and provided a foundation for curriculum. The innovation, experimentation, and professional discourse improved the curriculum and prompted the inclusion of technology with industrial arts in schools (Cochran, 1970). The inclusion of technology began to change the industrial arts curriculum from a manual trade to a technology-based focus.

Different curriculum plans and ideas in the 1980s led to confusion among teachers leading industrial arts supervisors from West Virginia to bring together curriculum specialists to synthesize a plan of ideas (Lewis & Zuga, 2005). This plan developed into *The Jackson's Mill Curriculum Theory*, which became a national compromise and ended experimentation by teachers in the field and led to a unified curriculum model (Snyder & Hales, 1981). The Jackson's Mill document became the direction of technology education in the United States and was embraced by the American Industrial Arts Association (AIAA). In 1986, AIAA adopted a name change to the International Technology Education Association (ITEA) and focused on teaching technology education following the Jackson's Mill compromise (Lewis & Zuga, 2005).

In 1991, Sterry and Savage updated the Jackson's Mill project and created *A Conceptual Framework for Technology Education.* The new framework kept many of DeVore's ideas from the Jackson's Mill curriculum, which defined technology as "a body of knowledge and the systematic application of resources to produce outcomes in response to human needs and wants" (Sterry & Savage, 1990, p. 7). The framework used problem-solving as a means of teaching technology and listed content areas of bio-related, communication, production, and transportation technologies (Lewis & Zuga, 2005).

In conjunction with ITEA, William Dugger sought funding from the National Science Foundation to create standards that would outline the content to be taught. The project emphasized the importance of technological literacy and the study of technology for children. Major publications of this project include; *Technology for All Americans: A Rationale and Structure for the Study of Technology* (ITEA, 1996), *Standards for Technological Literacy: Content for the Study of Technology* (ITEA, 2000), and *Advancing Excellence in Technological Literacy: Students Assessment, Professional*

Development, and Program Standards (ITEA, 2003). These documents contained a set of standards that helped define technological literacy, influencing the *Technology for All Americans Project*, which promotes technological literacy and provides a clear and defined curriculum for instruction (Lewis & Zuga, 2005).

The *Technology for All Americans* document has three parts: the need for technological literacy, the universals of technology, and integrating technology into the curriculum (ITEA, 1996). In 2000, the *Standards for Technological Literacy* (ITEA) were published based on the *Technology for All American*s document and established 20 content standards that link curricular goals from grades K-12 for technological literacy (ITEA, 2000). In 2003, ITEA produced the document *Advancing Excellence in Technological Literacy: Professional Development, and Program Standards*, further explaining how teachers, administrators, and others can promote technological literacy for all students.

The Information Age, known as the beginning of the computer era, began in 1975 and placed value on information and removed the focus on raw materials and physical labor causing a movement way from industrial arts curriculum. The amount of knowledge continued to grow exponentially and new innovations broadened the gap between the classroom content and the technological era (Daider, 1986). This gap created a rationale for Technology Education curriculum to be realigned with modern technology. The Standards for Technological Literacy were created and consisted of five sections: (a) The Nature of Technology, (b) Technology and Society, (c) Design, (d) Abilities for a Technological World, and (e) The Designed World (ITEA, 2003). These categories define criteria for technological literacy and formed the beginning of the

Technology Education curriculum structure. Technology Education was introduced into schools during a conservative restoration when the Reagan administration set out to reform education with a reduction in taxes, school choice, curriculum change, and the beginning of standardized testing (Hershback, 1997). While leaders in Technology Education tried to merge the curriculum with changes, reductions in funding and courses were inevitable, thus making curriculum and content changes difficult.

Technology Education and Deeper Learning

Activities in a Technology Education course changed the focus from a direct correlation to a real-world occupational skill as in Industrial Arts to a more general overview of different engineering and technology areas. Students in a Technology Education course would complete modular based assignments where they may simulate a circuit by plugging in cords in the specific holes in an electronics trainer based on instructions and see a circuit work. While students learn the basics about circuity, the depth of knowledge is not enough to expand beyond the module trainer. This experience is different than that an Industrial Arts student who would use electrical components to connect a similar circuit that could be found in industry.

Engineering and Technology

A change in the focus of Technology Education began when Foster (1995) found that technology education leaders believed that the most appropriate curriculum approach in technology education was engineering systems including; (a) math/science/technology integration, (b) design/problem solving, (c) tech prep, and (d) engineering systems. Bensen and Bensen (1993) believed it was imperative to engage in the engineering profession to bring Technology Education into the 21st century. The National Academy of Engineering produced a document, *Technically Speaking: Why All Americans Need to Know More about Technology*, which defined a technologically literate person as a person who is familiar with the nature and limitations of the engineering design process (Pearson & Young, 2002). The document promoted the use of math, science and social studies while teaching technology curriculum and the engineering design method. While there was a lack of research for the movement to Engineering and Technology, the Georgia Department of Education (2007) adopted Engineering and Technology standards that reflected the national concerns of low student performance in math and science and in 2010, on the second attempt, the professional organization ITEA became the International Technology and Engineering Educators Association (ITEEA). This changed the focus of what was Industrial Arts and Technology Education to Engineering and Technology, with focus on the Engineering Design Process.

Curriculum and Instruction Strategies

The Georgia Department of Education (2013), in 2012-2013, aligned and rewrote the Engineering and Technology Georgia Performance Standards, content taught in all Georgia Engineering and Technology courses, to align with the ITEEA *Standards for Technological Literacy*. Alignment of the standards helped teachers better prepare students in the Engineering and Technology pathway for the national End of Pathway Assessments. End of Pathway Assessments are given after a student has completed three years of coursework to determine if the student has gained the necessary knowledge of the pathway.

Even though program standards across the state are the same, the curriculum and instruction resources are different from classroom to classroom leading to a different experience based on each classroom. This section outlines several different types of curriculum and instructional strategies currently used in Engineering and Technology programs including: Engineering by Design, Engineering the Future, and LearnMate. For the purpose of this action research study the vendor-driven curriculum LearnMate, was examined to determine its effectiveness in my classroom as a standalone teaching resource and modified with blended instruction including teacher-led instruction based on student feedback and results throughout study.

Engineering the Future

The Boston Museum of Science developed the *Engineering the Future: Science, Technology, and the Design Process* (ETF) curriculum. The ETF curriculum is a yearlong high school engineering or science course based on the Standards for Technological Literacy (ITEA, 2000) that teaches students about engineering in the everyday world while incorporating math and science. This curriculum incorporates traditional lecture with hands-on projects as students learn about four different areas; (a) manufacturing and design, (b) construction and thermal systems, (c) fluid systems, and (d) electronic and communication systems. The curriculum includes a traditional textbook, an engineering design workbook for each project that guides students through the design process, and a teacher guide. Throughout the curriculum, students learn content by applying the information through hands-on application including building circuits, designing products, reverse engineering a putt-putt boat, and testing strengths of materials. This curriculum is hands-on for the teacher and requires the teacher to have knowledge of the content area, thus making some teachers uncomfortable teaching it.

Engineering by Design

Engineering by Design, like the Engineering the Future curriculum uses a constructivist model that focuses on classroom lectures incorporated with problem-based projects. The constructivist learning approach teaches students through application and discovery of the knowledge. ITEEA created the Engineering by Design content based on the ITEEA Standards for Technological Literacy, Common Core State Science Standards, Principles and Standards for School Mathematics (NCTM), and Project 2061 Benchmarks for Science Literacy (AAAS). The program is organized around 10 principles that organize the content: (a) engineering through design improves life; (b) technology and engineering have affected, and continues to affect everyday life; (c) technology drives invention and innovation and is a thinking and doing process; (d) technologies are combined to make technological systems; (e) technology creates issues and impacts that change the way people live and interact; (f) engineering and technology are the basis for improving on the past and creating the future; (g) technology and engineering solve problems; (h) technology and engineering use inquiry, design and systems thinking to produce solutions; (i) technological and engineering design is a process used to develop solutions for human wants and needs; and (j) technological applications create the designed world. Applying these strategies, the Engineering by Design curriculum is based on yearlong courses including Foundations of Engineering, Technology and Society, Technological Design, Advanced Design Applications, Advanced Technological Applications, and Engineering Design.

Georgia CTAERN Curriculum

CTAERN is a network that contains curriculum units written by teachers in the Engineering and Technology programs in Georgia. These units are designed to be implemented with minimal equipment requirements and contain teacher-led discussions, lectures, and projects. There is a lack of resources for this curriculum and it is not as comprehensive as vendor-based curriculum, but it can be accessed and used by all Georgia teachers without any fees, and is a good resource (CTAE Resource Network, 2014).

LearnMate (A Modular-Based Curriculum)

LearnMate is a vendor-developed Learning Management System (LMS) for a modular-based curriculum that involves having students follow a guide on the computer to learn about different engineering-based curriculum. While there is a lack of research on modular-based curriculum, this curriculum was developed and sold by vendors as the new instructional method, and therefore was accepted and introduced into classrooms. The modular style curriculum consists of online multimedia presentations including directions for completing hands-on tasks and built-in assessment questions. Students can work through the curriculum at their own learning pace. Units of instruction vary based on the content selected. The curriculum contains built in software programs, videos, reading content, a glossary, animations, and questions to check for understanding. The instruction is led by the LearnMate module and the teacher helps as a facilitator of the content.

My test scores and projects, show that students do not learn the information beyond each activity and cannot apply the information on future projects. The purpose of this action research study was to determine which blend of instruction is more effective for secondary Engineering and Technology Education students when being taught using a computer-based modular curriculum. A variety of instructional delivery methods were used, ranging from pure eLearning, Modular Technology Education (MTE) curriculum, to a blended instruction model that combines eLearning and teacher-led instruction. Teacher-led instruction involved a combination of the LearnMate REC Robotics content and traditional classroom instruction involving lectures and hands-on demonstrations.

The History of Technology Education in the Modular Format

In the late 1990s, although there was a lack of research, resources were invested on a new lab design for secondary Engineering and Technology Education classrooms as the traditional Industrial Arts program changed to a Technology Education classroom. This change involved the development of a modular technology education (MTE) classroom. Despite a lack of research, modular laboratories were installed by numerous school districts. Pullias (1997) referred to MTE as recipe-driven activities not connecting individual units of content. Weymer (2002) defined MTE as vendor-provided curriculum that allowed students opportunities to learn about areas of technology by (a) participating in interactive media presentations, (b) following instructions in workbooks, (c) writing responses in student journals, and (d) experimenting and building projects. Personal computers replaced classroom teachers as disseminators of technological content and processes in modular labs. MTE is a self-contained instruction system defined by program learning theory, technological devices, and equipment (Petrina, 1993).

Experiences with the MTE Format

There is still minimal research on the MTE format in what was formerly known as Technology Education, now Engineering and Technology classrooms. The MTE format has changed slightly over the years from a classroom of students doing different modules at the same time by reading from a notebook and rotating through each curriculum unit, to a whole group modular format where the notebook of content has been moved to a computer, but the overall method remains the same. When I began teaching in 2001, the MTE format, was the accepted method. Students sat at computers throughout the room and read from notebooks, did activities on training boards or the computer, and answered quiz questions. The teacher served as the facilitator throughout the process. Now in 2014, the MTE format has changed to an online format, students can use virtual trainers, and the entire class works on the same module in a whole group instruction method.

While the packaging has changed from a notebook and equipment, the delivery and methodology is still the same, however, in the 1990s and even early 2000s computers were not a household item and were exciting for students to work with. Now we carry computers in our pockets, in the form of a smartphone, and can use them everywhere. The novelty and excitement of computers has worn off and we have a generation of kids who have answers at their fingertips through Google and the internet. The computer and technology used to be exciting, but no longer is today. My students struggle with reading and following directions, causing them to become disengaged, often asking for me to teach the content. While working through the content, students skip information to search for the answer and take the quiz to quickly move on to the activity. The students in my Engineering and Technology courses are hands-on learners who grasp and retain content through doing. When they complete an MTE module, they often maintain the hands-on activity, but do not remember the other information. As the teacher, it is still my job, as designed in the 1990s MTE format, to facilitate the learning experience, regardless of its effectiveness for my students; however, is this really effective?

Role of Robotics in Engineering and Technology Education

Researchers have found that robotics curriculum excites and motivates students to learn about science, technology, engineering, and math (Kolberg & Orlev, 2001; Mclntyre, 2002; Nourbakhsh et al., 2005; Nugent, Barker, Grandgenett, & Adarnchuk, 2010; Robinson, 2005; Sklar, Johnson, & Lund, 2000). Hands-on experiments provide students a concrete application of the abstract math and science concepts learned. Carnegie Mellon Robotics Academy (2008) conducted a study of the implementation of robotics curriculum in an eighth-grade technology classroom to assess the mathematics concepts and found that when prompted through robotics, a wide range of formal math ideas such as measurement, algebra, statistics, and geometry were mentioned by students. Students incorporate science and engineering through experimentation and modification of designs. According to the Vex Robotics website, “The study of robotics, by its very nature, captures all four legs of STEM very well, while a competitive environment increases motivation and desire to succeed” (VEX Robotics, 2010).

Robotics competitions allow students to apply their curriculum knowledge by using the engineering design process to create a robot that will perform a specific task. The application of knowledge leads to a deeper learning of the content as students interpret a problem and design their robots to solve it. There are a number of robotics competitions available for high school students including: BEST, Botball, FIRST

Robotics Challenge, FIRST LEGO League, FIRST Tech Challenge, Trinity, and VEX Robotics. Each robotics competition is slightly different, but all of the competitions create a game with specific tasks students are to accomplish using a robot. The games change each year and provide students with a new challenge.

Currently there are five curriculum resources for the competition robotics platform known as VEX Robotics: Autodesk's VEX Robotics Curriculum, Project Lead the Way (PLTW), Analytical Integrated Math (AIM), Intelitek's Robotics Education Curriculum (REC), and Carnegie Mellon's Robotics Academy (Georgia Department of Education, 2007). At Ola High School, the study location, the Intelitek Robotics Engineering Curriculum (REC) is used through the LearnMate Management System. REC is a comprehensive study of engineering concepts including physics, programming, mechanical systems, electrical and electronics systems, and relevant activities. This curriculum is aligned with ITEEA's Engineering by Design program. The REC curriculum is used throughout the year in the Engineering Applications third year class.

Deep Learning in Engineering and Technology Education

Montgomery, Larsen, and Hale (2011) defined deeper learning as a term used for the experiences that lead students to understand and retain knowledge they can use in school and future careers. Gholson and Craig (2006) said deeper learning engages the learner who actively explores, reflects, and produces knowledge, not just recall and regurgitate it, or apply surface learning. Students master a set of skills and develop an understanding of the academic content that allows the application of knowledge both within and outside the classroom. Deeper learning allows students to learn new facts and ideas and make links between content to other subject areas (Biggs, 1999, Entwistle, 1988, Ramsden, 1992). Carmean and Haefner (2002) defined deeper learning as learning that results in a meaningful understanding of material and content that allows for the concepts to be applied beyond the regular classroom.

The hands-on application of knowledge makes Engineering and Technology classrooms the ideal setting for deeper learning to occur. The use of the engineering design process allows students to take ownership of their learning, build on previous knowledge, work with a team, and solve a design problem. Engineering design experiences provide environments for students to become engaged and use their concept knowledge for synthesis and analysis of design problems (Cantrell, Pekcan, Itani, & Velasquez-Bryant, 2006).

The Intelitek REC curriculum is setup with mini-projects and content lessons that finish with a culminating project. Based on the deeper learning principles of Carmean and Haefner (2002), the REC content should help students establish a deeper grasp of the material. The culminating project encourages students to use the material learned throughout the unit to solve a real-world problem. For example, using knowledge from a previous programming lesson about gears, students have to navigate an obstacle course using basic programming. The recall of the previous knowledge allows students to take the project to the next level by applying what they have learned in a previous lesson and continuing to grow on that knowledge by practicing the skill of programming a robot that could be found in industry.

CHAPTER 3

METHOD

This study determined how different teaching strategies influenced student achievement at Ola High School in Engineering and Technology Education classes. The study used a blend of eLearning content from the LearnMate VEX Robotics REC curriculum combined with teacher-prepared lessons using traditional instruction (Intelitek, 2008). The study focused on the following research questions:

1. How did the blending of LearnMate and teacher-led instruction influence overall student learning in my Engineering Application course?
2. Did students in my Engineering Applications course gain deeper learning about factual content and concepts about robotics differently through LearnMate or teacher-led instruction?
3. When students did hands-on practice activities with robotics in my Engineering Applications course, was deeper learning gained through LearnMate or teacher-led instruction?

This chapter will outline the research process for the study, identify participants, and explain the procedures and layout for data collection and analysis used during each of the action research cycles.

Research Design

Action research was used to structure of my study. Schoen (2007) defined action research as a professional research tool that empowers teachers to monitor and analyze their professional practice with the intent to expand their knowledge base and enhance instructional practice. Action research has achieved a level of respect and legitimacy in education because it improves teaching practices (Volk, 2010). Action research is a process that improves education by incorporating change and is practical and relevant to classroom teachers, allowing teachers to research within their own classrooms. Teachers in public education in the United States are encouraged to be reflective in their practice and to engage in action research to improve instruction and classroom learning (Sigler, 2009). Action research empowers teachers to monitor and analyze their own professional practices to expand their knowledge base (Schoen, 2007, Volk 2010). During action research, a teacher participates in a direct reflection and analysis of their own classroom, hoping to improve instruction (Mertler, 2012).

Design of the Study

The process of action research was first conceptualized by Lewin (1952) and further developed by Carr and Kemmis (2003). Action research is a cycle of action and research consisting of four major components; plan, act, observe, and reflect. The planning phase includes problem analysis and development of a strategic plan; the action phase refers to the implementation of the strategic plan; the collect and analyze phase includes an evaluation of the action by collecting and analyzing data; and reflection means thinking about the results and the action research process, which may lead to the identification of a new problem or problems and hence a new cycle of planning, acting, observing, and reflecting.

Action research is about examining one’s own practice using a systematic design (McLean, 1995). This action research study used the design of Riel (2010) in which four key processes take place including study and plan, take action, collect and analyze evidence, and reflect (see Figure 2). Teachers utilize reflective teaching in developing lessons, assessing student learning, and incorporating practical experiences, while implementing educational theory, research, experiences, and the lesson's effect on students (Parsons & Brown, 2002). Through action research, a minimum of three cycles are implemented and reviewed.

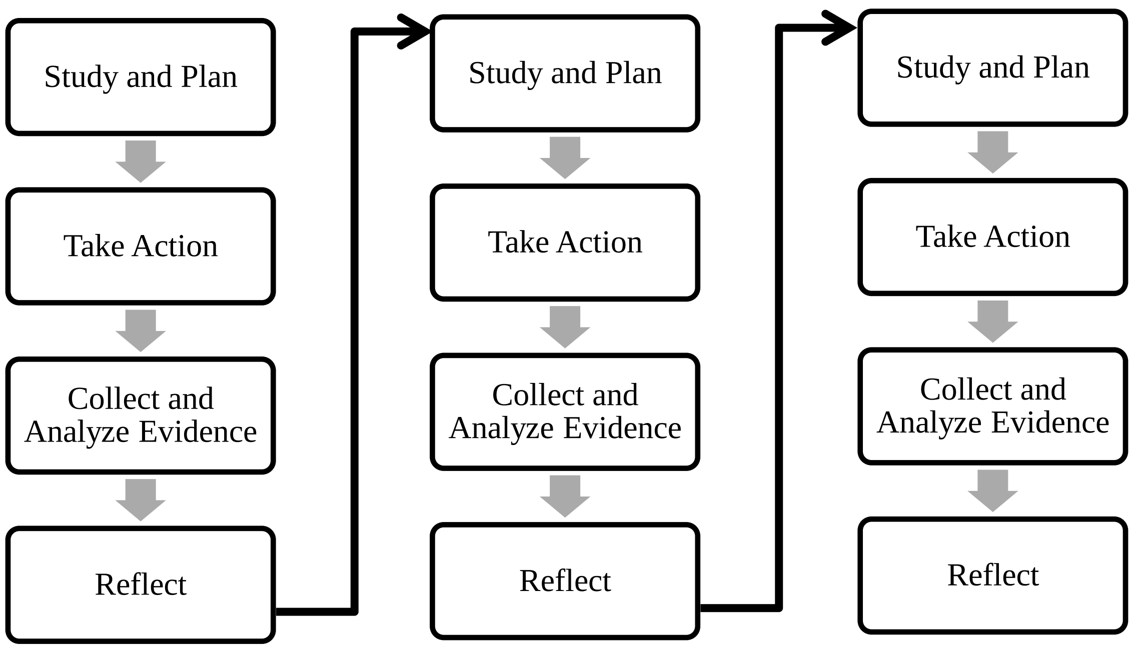

Figure 2. Riel's (2010) action research cycles

Action research should be carried out by a single teacher who tries to better understand his or her own behaviors, attitudes, or practices (Kapachtsi & Kakana, 2012). A variety of methods including data gathering, interviews, portfolios, dairies, field notes, audio and video tapes, photos, memos, questionnaires, focus groups, checklists, logs of meetings, case studies, surveys, self-assessments, samples of student work, and more are examples of data collection in action research (Sigler, 2009). My study consisted of three action research cycles and progressed through the four stages of planning, completing the action, analyzing, and reflecting in each cycle.

Study and Plan. During the planning phase, a lesson plan along with clear descriptions, expectations, and responsibilities is established (Hansen & Borden, 2006). For the first cycle, I worked with my action research team, a group of professionals in education that reviewed my research throughout the process, to establish my criteria and expectations for each action research cycle with the goal for determining what combination of blended instruction is most efficient and the overall achievement level acceptable. The first action research cycle consisted of a model with the teacher as the facilitator while students used the eLearning content. This delivery method was chosen for the first action research cycle because it is the expected delivery method of the content being taught and it established a baseline. In the second and third action research cycles, lessons were altered based on results of the previous cycle to a more blended model, in which the teacher taught portions of the content as students worked through LearnMate. The amount of teacher-led versus eLearning was determined based on results from the previous cycle.

Take Action. Throughout the implementation phase, the study involved qualitative and quantitative data collection. Scores were taken on quizzes, short answer questions, and programming activities. This will be discussed further in the data collection section of this chapter.

Collect and Analyze Evidence. At the conclusion of each action research cycle, I analyzed the data and meet with the action research team to help limit the bias from me as the teacher and my personal attitude towards the content. Hansen and Borden (2006) stressed that when researchers act as facilitators and become intimately involved in the program roles can become blurred and cause a threat to the research. A research journal (see Appendix A) was used to establish a clearer picture of the happenings during each action research phase and notes were reviewed with the action research team to help limit bias. Data was examined in each cycle to determine the depth of knowledge students gained in that cycle.

Reflection. During the reflection phase, analysis of the data and the instructional process was reviewed. Interviews and observations were reviewed to determine methods of instruction students prefer. All reflections were recorded in the researcher journal and used in the planning phase for the next cycle.

Advantages and Disadvantages of Action Research

Action research has both its advantages and disadvantages. Advantages of action research include helping improve educational practices and the process educators use in their own practice; encourages collaboration and is participative; is practical and relevant; is a planned, systematic approach to understanding the learning process; is open-minded; and is a justification of one's teaching practices (Mertler, 2012). While action research has advantages results are never conclusive. In action research, the researcher is closely involved in the treatment and reflections in the study, which can limit the validity of the research as false theories may be established. However, action research is a practitioner-based method in which teachers have the opportunity to gain valuable professional development and transformation (Coghlan & Brannick, 2010).

There was a potential for bias in this study, as the researcher and practitioner are the same person. Coghlan and Brannick (2010) observed that "you as the researcher are yourself an instrument" (p. 31). Action research requires the researcher to act as a facilitator and become intimately involved in the study and process to understand and evaluate each phase of the research (Hansen & Borden, 2006). As the researcher assumes both roles, stress can form as role ambiguity, role conflict, and role overload become part of the study. Role ambiguity was minimized by establishing clear expectations and role descriptions while establishing trust and open communication among participants, the researcher, and the action research team.

Participants

This study used convenience group comprised third year students in my Engineering Applications class, who were learning the VEX Robotics curriculum. These students attend a school medium-sized suburban high school near Atlanta, Georgia consisting of approximately 1500 students. This sample was chosen because it is the researcher's student population in the course that utilizes the content being assessed through this study. The entire class participated and consisted of 21 students, 19 adolescent men and 2 adolescent women. There were 7 students identified as gifted or high functioning, 1 student with special needs, and 13 general education students in the population. Students enrolled in the course chose the class due to future career interests. The students were currently completing their final course in the engineering pathway and have had the researcher's class the past two school years; however, this was their first opportunity to work with the LearnMate curriculum.

As a teacher in the engineering program, I conducted the research and taught the lessons throughout the process. It was important for me to limit bias that may have altered my results. Therefore, I established an action research team, comprised of three individuals within the profession, which reviewed my notes, data, and research cycles to help limit bias during the study. The team included teachers chosen based on the following criteria: (1) knowledge in the area of Career, Technology, and Agricultural Education, (2) experience with modular-based instruction, (3) knowledgeable about teaching methods. Participants on the action research team were my department chair, a Family and Consumer Science teacher with an Educational Specialist degree in curriculum and instruction; a former Engineering and Technology teacher who is now a CTAE Director and has used the LearnMate curriculum; and a former engineer who now is an architecture teacher and has experience with the LearnMate curriculum.

Procedure

Several steps had to be completed to receive approval for the action research study (see Table 9). This section outlines the procedures that were followed to complete the research process. A research application to the principal of the school and the school system of the study location were submitted. Once approval was received from the school system, an IRB application was submitted through the University of Georgia (see Appendix G). Participant names were not used, thus giving students confidentiality.

This study was completed during the fall 2015 semester. The University of Georgia IRB and school system's research applications were submitted in August. Once approval was received by both institutions, parents and students received a letter stating information about the study and requesting permission. The action research cycles began in November and finished in December. Three cycles of action research were completed taking approximately four to five days per cycle with reflections between each cycle.

Table 9

Action Research Study Timeline

Time	**Procedural step**
August 2015	Prospectus defense
August 2015	IRB application submitted to the University of Georgia.
August 2015	Research application submitted to the school system.
September 2015	Research permission letter sent to parents.
November 2015	Action research cycles are completed and reviewed.
Spring 2016	Results of study are reported.

Data Collection

This section outlines the data collection methods used during the study. Students were taught various teaching methods. Results were analyzed to identify where deeper learning occurred. The process was a mixed design of qualitative and quantitative research approaches that varied between action research cycles. During the planning phase of each cycle, the process and changes for that cycle's implementation were laid out. Table 10 lists each type of data including observations, interviews, and artifacts (Mertler, 2012).

Table 10

Data Collection Methods

Data collection method	Purpose of Data
Observations	Used to gain insight into student perceptions, comments made by students, interest levels expressed by students, and difficulties experienced (see Appendix A and B)
Informal interviews	Used to ask questions when necessary to help clarify observations.
Formal interviews	Used to further verify the data collected through observations and informal interviews. (see Appendix C)
Artifacts	Student work samples used to determine the level of understanding of the content. (see Appendix B)

Qualitative data. Observations, interviews, and notes were taken as students progressed through each lesson to reflect upon with the action research team. These artifacts allowed me to examine what students thought about the delivery of the content. As students worked through the lesson, a daily journal was kept to note my reflections (see appendix A).

Students representing low, middle, and high level achievement scores in each section were interviewed to gather feedback to help with the reflection phase of the action research process. These students were selected based on observations. The entire class was also interviewed as a group. The following questions were asked during the interviews:

1. What did you like about the lesson?
2. What items were confusing during the lesson?
3. Do you think the content be easier to understand by having a teacher lead a demonstration or did the LearnMate content explain the content with enough clarity?

Quizzes, programming activities, and short answer questions were used to help determine the mastery of content, using programming activities in the VEX LearnMate curriculum. The action research team met to ensure the information gathered from the artifacts was correctly interpreted and valid. Having the criticism of a team ensures that data is being interpreted correctly (Kapachtsi & Kakana, 2012).

Quantitative data. Quizzes built into the LearnMate curriculum and extended response questions were used to determine the depth of student knowledge and mastery of content. The same quizzes and short answer questions were used with teacher-led lessons and LearnMate lessons. All data collected on each action research cycle was analyzed and applied to the planning for the next cycle. A spreadsheet was created to record all of the data per lesson and the length of time spent. This allowed me to look at the average of the data and distribution of scores. I also examined the distribution of scores using a scatter plot of scores and time spent on the lesson. I looked at the following: students who scored well and spent little time, students scored low and took no time, students took time and scored high, and students that spent longer took than normal, but scored low. Throughout each cycle, a plan was developed by the action research team to determine the data needed based on modifications to the curriculum unit being taught.

Data Collection Procedures for Each Action Research Cycle

This section outlines the details of the action research cycles and the specific data collected per lesson and action research cycle (see Table 11). Each action research cycle was designed with at least one of each of the following: quizzes, written robotics programs, and short answer questions. Each cycle also included a content based lesson and hands-on programming lesson. The lessons in throughout the research process, progressed in difficulty and scaffold off of the previous lessons.

Table 11

Data Collected Per Lesson

Cycle	Lesson	Overview	Quiz	Program	Questions
1	2.2 Block programming, syntax, motor control	Using waits and basic motor commands to create a program.	X		X
1	2.3 Programming the VEX controller	Writing a basic program to drive and loading the program.		X	X
1	2.4 Open-loop driving exercises; optimization	Calculating and programing the robot to go a specific distance.		X	X
2	2.5 Variables and constants	Incorporating variables and constants into programs.	X		
2	2.6 Apply constants, variables, and comments	Write a program using constants, variables, and comments		X	X
3	2.7 Precedence, tests, and loops	If-then statements and expressions with the order of operations	X		
3	2.8 Tests and loops	Use loops to write programs.		X	X

Action research Cycle One. During Cycle One, students learned about process control and the steps for programming a VEX controller using wait commands and basic motor commands while completing lessons 2.2-2.4. Students completed one quiz, short answer discussion questions including drawing a map of a basic program to make a robot drive forward, and wrote 1 basic optimized driving program. Amount of time spent reading the content and the quiz score were examined. I looked to identify if students read the content for mastery or skimmed the content to get answers to the quiz questions. LearnMate provided time spent on lessons and scores on quizzes electronically. The short answer discussion questions were assessed using the LearnMate answer key and Biggs (1989) SOLO Taxonomy (see Table 12) to determine the depth of answers provided. An observation report was also kept each day. Follow-up interviews were conducted with a sampling of low-level, medium-level, and high-level students on to clarify observations and data and determine changes for the second cycle.

Table 12

Levels of Biggs' (1989) SOLO Taxonomy

Depth of knowledge		Evidence of knowledge
1	Pre-structural	Use of irrelevant information, or no meaningful response.
2	Uni-structural	Answer focuses on one relevant aspect only.
3	Multi-structural	Answer focuses on several relevant features, but they are not coordinated together.
4	Relational	The several parts are integrated into a coherent whole: details are lined to conclusions; meaning is understood.
5	Extended abstract	Answer generalizes the structure beyond the information given: higher-order principles are used to bring in a new and broader set of issues.

Action research Cycle Two. In the second action research cycle, students completed lessons 2.5 and 2.6. Students created a program, completed short answer discussion questions, and took a quiz over content. Data was collected on the success of student's program and the amount of time taken to write the program. Programming times were assessed to determine where students had difficulty or performed very well by providing an average class time. Data was recorded in a spreadsheet in Microsoft Excel. The short-answer discussion questions were assessed the same way as in Cycle One and observation logs were completed daily. Interviews were conducted to clarify the data.

Action research Cycle Three. During this cycle, students continued to build on knowledge from the previous lessons and completed lessons 2.7 and 2.8 to learn about if-then statements and write program loops. Students wrote a program to make a robot react when using a bumper switch. A quiz, a program, and short answer discussion questions will be completed.   Data was collected from each of the items and assessed as in the previous cycles.

Data Analysis and Reflection

A plan for modifying each of the three cycles is presented in Table 13. Each cycle took approximately one week to complete. The first cycle consisted of LearnMate being delivered in its designed format with the teacher as facilitator. This delivery method was chosen because it is the expected delivery method when using LearnMate. At the end of the cycle, quiz scores and time taken on each quiz section were recorded in Excel and reviewed to check student performance. Depth of understanding was checked through the short answer responses using Biggs (1989) SOLO Taxonomy to grade the depth of student answers. A level 4 or 5, defined by Biggs (1989) as relational or extended abstract, was the response level expected. Relational refers to several parts integrated into a coherent whole where meaning is understood. Biggs (1989) defines extended abstract is structure beyond give information the displays higher-order thinking and can be used to examine a new set of issues.

Based on results, subsequent lessons were modified to incorporate a blended instruction approach. For example, if students had difficulty with quizzes or answered quickly and did not read the answers, and interviews showed that students were not interested or didn't like the delivery or understand the delivery of the content, the teaching method for the next lesson was changed. Content-based lessons in the next cycle would become teacher-led while using the information and content in the LearnMate curriculum. Students wrote a program for a robot to perform a specified task.

The accuracy of the program and time taken to write the program was assessed for each student and compared to the class as a whole. Short answer questions reviewed using the Biggs (1989) SOLO taxonomy. The same steps and adjustments to delivery as in Cycle One followed through the remaining cycles. In between each cycle, I met with my action research team to discuss my data and conclusions in preparation for the next cycle.

Table 13

Action Research Cycles

Action research steps	Cycle 1	Cycle 2	Cycle 3
Study and plan	Traditional eLearning through the LearnMate curriculum.	Based on Cycle 1 results, one of the plans below will be implemented: 1. If reading and retention of content did not meet the standard score of 70 for the average of the class, the teacher will modify this lesson to teach the content in a traditional classroom lecture format. 2. If the activities were not performed accurately due to understanding (interviews), the teacher will modify the lesson and teach the activities through whole group instruction and use LearnMate as a resource.	Based on the results of Cycle 2, Cycle 3 will: 1. Continue with the same format as Cycle 2 2. Revert back to the format of Cycle 1 3. Incorporate more blended instruction where needed based on the evidence.
Take action	Students will complete LearnMate REC 2.2-2.4 and the teacher will act as a facilitator of the information.	Students completed LearnMate REC 2.5-2.6 which will be a blend of eLearning and teacher led instruction.	Students completed LearnMate REC 2.7-2.8 which will be a blend of eLearning and teacher led instruction based on the plan above.
Collect and analyze evidence	Quizzes, programs, questions, interviews, and observations	Quizzes, programs, questions, interviews, and observations	Quizzes, programs, questions, interviews, and observations
Reflect	What activities did students like? Where did students struggle? Did they maintain the information they learned and read?	What activities did students like? Where did students struggle? Did they maintain the information they learned and read?	What activities did students like? Where did students struggle? Did they maintain the information they learned and read?

CHAPTER 4

RESULTS

This chapter describes the results of an action research study in a high school engineering and technology classroom using the LearnMate VEX Robotics curriculum. The study was designed to determine the best blend of learning methods, using LearnMate and teacher-led instruction, to provide students with a deeper understanding of course content. Each action research cycle and step—study and plan, take action, collect and analyze evidence, and reflect—is explained. Findings that answer each research question are presented. The VEX Robotics curriculum is divided into lessons as a part of a prescribed unit that teaches programming and is a mixture of content-based reading-learning and hands-on programming that require students to perform hands-on activities. The content-based and hands-on units are intertwined. The action research cycles were divided to allow each cycle to have content reading lessons and hands-on programming lessons included to ensure consistency during successive cycles. Table 14 shows each of the action research cycles, an overview of lessons taught during each cycle, and data collected.

An action research team was formed to help guide the action research cycles and limit bias that could have influenced decisions in each cycle. Based on feedback from the action research team, a spreadsheet was created to chart scores on quizzes, questions, and time taken on each lesson. While the quiz and question scores were my primary, the time students took on each assignment was used as a tool to help determine struggling students and exceling students when looking at the scores on a scatter plot.

Table 14

LearnMate Lessons and Data Collected Per Lesson

Cycle	Lesson[a]	Overview	Quiz	Program	Questions
1	2.2 Block programming, syntax, motor control	Using waits and basic motor commands to create a program.	X		X
1	2.3 Programming the VEX controller	Writing a basic program to drive and loading the program.		X	X
1	2.4 Open-loop driving exercises; optimization	Calculating and programing the robot to go a specific distance.		X	X
2	2.5 Variables and constants	Incorporating variables and constants into programs.	X		
2	2.6 Apply constants, variables, and comments	Write a program using constants, variables, and comments		X	X
3	2.7 Precedence, tests, and loops	If-then statements and expressions with the order of operations	X		
3	2.8 Tests and loops	Use loops to write programs.		X	X

[a]Numbers (e.g., 2.2) refer to the actual component included in the prescribed LearnMate unit on robotics.

Action Research Cycle 1

Study and Plan

The first action research cycle consisted of three lessons that were taught using LearnMate, an online curriculum and class management system. The first lesson—2.2 Block Programming, Syntax, and Motor Control—had students read about basic motor commands and their functions in programming. The second lesson—2.3 Programming the VEX Controller—involved students writing a basic program to make a robot drive forward, and loading this program on the robot's microcontroller. In the third lesson—2.4 Open-loop Driving Exercises and Optimization—students calculated and programmed a robot to go a specified distance. The action research team, a group of Career, Technology, and Agricultural Education professionals that helped guide my research analysis and interpretation, recommended that I not include lesson 2.1, a content-based lesson, since lesson 2.2 contained content and lessons 2.3 and 2.4 involved hands-on programming. My role as instructor was to facilitate students' learning and answer questions. Using LearnMate as the teaching tool and having the teacher serve as facilitator was the intended method for teaching content contained in this cycle. Implementing Cycle 1 using the presented delivery method for the effectiveness of the LearnMate content, to be examined, helped established a baseline for data.

Take Action

Lesson 2.2 taught students about programming using basic motor commands that directed a robot to drive forward and wait for a specified time. Students read content using computer-aided delivery and answered two sets of quiz questions about the content. During the reading parts of the lesson, I noticed several students had the content read aloud to them using a tool in the LearnMate content. I experienced some difficulty in getting students to stay on task with the reading lessons. In lesson 2.3, students wrote a basic program to get a robot to drive forward and learned how to load the program on the robot's microcontroller. Most students were successful at the program and were able to get the robot to move forward and transfer the program to the microcontroller. Lesson 2.4 required students to program the robot using the skills acquired in the previous lesson to have the robot drive forward a specified distance. The 16 students that were successful with the first hands-on programming lesson were also successful with the distance programing lesson. Four students did not perform the task.

During these lessons, I observed lazy behavior that consisted of students not wanting to work on assignments and having to be redirected to work on LearnMate rather than play on their phones or focus on other work. Students skipped parts of the lesson only looking for answers to the questions and not reading all of the information presented. Based on my previous experiences with the LearnMate content, this was normal behavior.

Collect and Analyze the Evidence

At the conclusion of the first cycle I interviewed students that performed well and worked quickly, students in the middle range of quiz scores, and students on the lower end quiz scores (see Table 15). Words used by students across all three levels to describe Lesson 2.2 included boring, too long, wordy, confusing, and too much information at once. Students also stressed that they could not ask the computer a question like they could ask a teacher. Students also agreed that the hands-on programming lessons, 2.3-2.4, made sense and provided good practice. Lower achieving students that did not finish the quizzes and had difficulty staying on task said that overall the content was overwhelming and they got lost with the amount of content they needed to go through. Table 15 shows statistics for lessons 2.2-2.4.

Table 15

Action Research Cycle 1 Lessons 2.2-2.4 Statistics

	Score		Time	
Lesson	M	*SD*	M	*SD*
2.2 Quiz	72.00	42.14	42.40	23.25
2.3 Programming	80.00	40.00	37.45	26.23
2.3 Questions	2.60	1.43	37.45	26.23
2.4 Programming	80.00	40.00	36.50	26.15
2.4 Questions	2.55	1.40	36.50	26.15

Note. Quiz and programming scores ranged from 0 to 100. Question scores range 0 to5. Time = minutes.

The mean for the quiz scores in Lesson 2.2 was 72 (*SD*=42.14) with the mean time taken to complete the assignment being 42.4 (*SD*=23.25) minutes. Figure 3 shows a scatter plot for the 2.2 quiz scores and amount of time taken on the lesson. The graph shows a majority of students received a score of 80 or above with varying time taken on the lesson. This score is above the passing score set at a 70. Four students received a zero on the quiz and spent varying times from 0 to over 70 minutes. Based on student feedback, these low numbers represent students that were overwhelmed by the amount of information and reading presented.

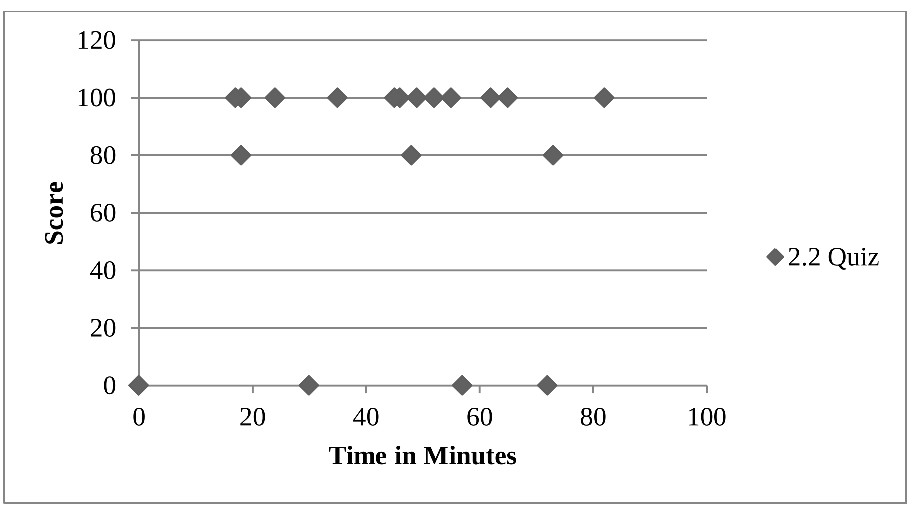

Figure 3. *Content Lesson 2.2: Results of quiz scores and time taken to complete quiz.*

Lesson 2.3 and 2.4 both had a hands-on programming assignments and short answer questions. The mean of the programming scores in the lessons was 80 (*SD*=40) for Lesson 2.3 and 80 (*SD*=40) for Lesson 2.4. These mean scores were above the 70 percent passing score. The mean time taken for each lesson was 37.45 (*SD*=26.23) and 36.5 (*SD*=26.15), respectively. Figure 4 shows two students that spent minimal time on the assignment could not complete the program, while a majority of students performed very well. There was variation in times taken for students to master the programing.

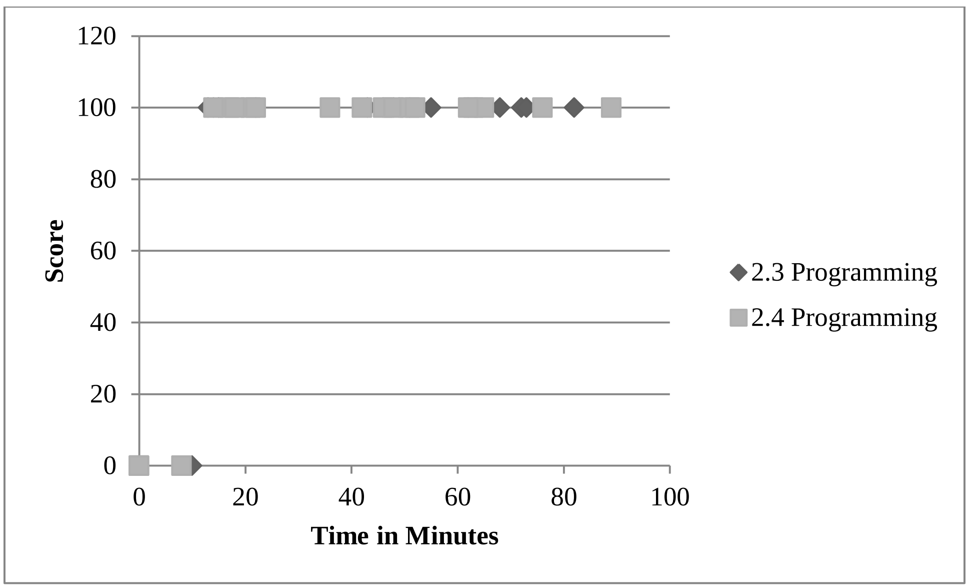

Figure 4. *Hands-on programming Lessons 2.3 and 2.4: Results of programing scores and time taken to complete lessons.*

Lessons 2.3 and 2.4 also had short answer questions that made students reflect on their programming activities and apply their knowledge to different types of questions to demonstrate their understanding. Mean scores were 2.6 (*SD*=1.43) and 2.55 (*SD*=1.4) for Lessons 2.3 and 2.4, respectively, which was below the desired score of 4 or 5 using Biggs' SOLO taxonomy (1989) for depth of answers. Figure 5 shows the distribution of scores. Students that spent more time on the lessons showed higher scores on short answer questions in the 3 to 4 range on Biggs SOLO taxonomy scale.

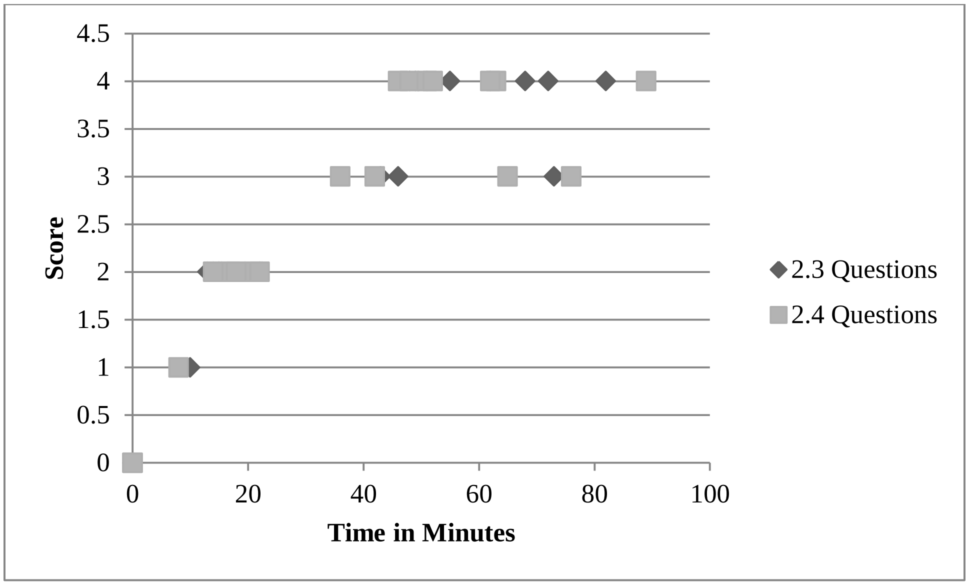

Figure 5. *Hands-on programming Lessons 2.3 and 2.4: Results of questions and time taken to complete the lessons.*

Reflection

Cycle 1 statistics showed mixed results. While most students did well on programming activities, they did not perform as well on quizzes and questions. The mean quiz score of 72 was barely above the 70 percent rate established as a passing score by the school, and scores on the two short answer question sets were low with mean of 2.6(*SD*=1.43) and 2.55(*SD*=1.40) on a 5-point score. Based on Biggs SOLO taxonomy (1989), the short answer scores represented a low depth of learning with unstructured answers that are not coordinating information together. Feedback was given on the short answer questions to help students learn to strengthen their answers. The short answer questions include examples of students creating their own examples of a programming outline based on life activities or calculating how many rotations are needed to make a robot move a set distance.

Overall, students seemed overwhelmed with the amount of reading required in these lessons and struggled with the wording of some content. Students felt the hands-on programming portions of the lessons were easier to follow and not as lengthy in their explanations of content. A lack of structure in the activities and accountability as students progressed through the cycle appeared to overwhelm some students with the overall amount of work, causing them to fall off track, while other students excelled without problems taking it one step at a time.

At the end of the cycle, I met with my action research team and discussed the data, student comments, and my observations. We decided that while quiz scores met the 70% mark for passing, students' comments and my observations showed students did not like and some did not perform well with the content-based lessons provided by LearnMate. The programming lessons were seen as more favorable by students and scores were high, possibly because of the students like for the programming activities and the systematic progression to get the robot to perform the task. The team decided that for Cycle 2, I would teach students the content-based information using LearnMate as my teaching tool and the programming lessons would continue to be taught using LearnMate and myself as a facilitator. Therefore, allowing me to clarify the content information through teaching and helping students who struggled with reading and the amount of content.

Action Research Cycle 2

Study and Plan

Action research Cycle 2 included two lessons, 2.5 Variables and Constants, which taught about incorporating variables, constants, and comments into computer programs, and 2.6 Apply Constants, Variables, and Comments, where students practiced writing programs using constants, variables, and comments. The first lesson was a content-based lesson. Based on decisions and feedback from the action research team, I studied and developed a plan to teach this content using LearnMate as a tool. My plan will be explained in the *Take Action* section. The second lesson involved programming a robot using the variable and constants. During this lesson, used LearnMate as a teaching tool and I acted as a facilitator during the programming lesson, leaving the programming part of the lesson the same as in Cycle 1, where students followed through LearnMate to complete the activity.

Take Action

Together, Cycle 2 took five days to complete. The first two days involved directly teaching the lesson using LearnMate as a tool. I used LearnMate as a presentation tool to teach lesson content, but to eliminate the overwhelming amount of information and wording students struggled with and disliked in Cycle 1, I skipped repetitive slides and summarized information. We also had class discussions on real world examples as they applied to lesson content. Day 3 allowed students to review content and take the quiz through LearnMate. Days 4 and 5 were used for students to complete the programming activities in the hands-on lesson.

Collect and Analyze Evidence

In Cycle 2, there was an increase in scores across all categories. The mean quiz score was 84.75(*SD*=25.80) with a time of 35.75 minutes (*SD*=8.43). The programming mean score was 100(*SD*=0.00) and short answer questions were 3.4(*SD*=1.02) with a time for lesson of 53.35(*SD*=11.76). The quiz and programming scores were above the 70 percent passing score, but the 3.4, for the short answer questions was below the level 4 or 5 on Biggs' SOLO taxonomy, to show deeper learning (see Table 16).

Table 16

Action Research Cycle 2 Lessons 2.5-2.6 Statistics

	Score		Time	
Lesson	*M*	*SD*	*M*	*SD*
2.5 Quiz	84.75	25.80	35.75	8.43
2.6 Programming	100.00	0.00	53.35	11.76
2.6 Questions	3.40	1.02	53.35	11.76

Note. Quiz and programming range 0 to 100. Question scores range 0 to5. Time = minutes.

Students were engaged, asked questions, and took notes, as I taught the lessons. Extra examples were used where students had difficulty. Once the lesson was finished, students completed the quiz on LearnMate and reviewed content. Figure 6 shows that, overall, students did well on the quiz. In this cycle, only one student remained at the 0% level and chose not to take the quiz. In interviews with students, they were more excited to use LearnMate and took their time taking the quiz, as now they did not have to spend the time reading and dissecting content.

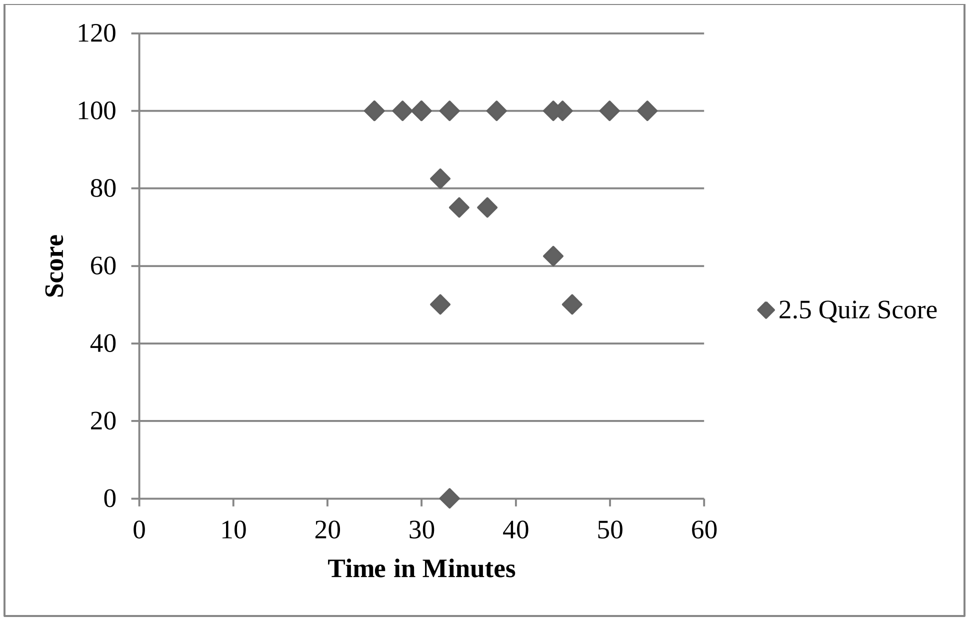

Figure 6. *Content Lesson 2.5 variables and constants: Results of quiz and time taken to complete the lessons.*

The programming lesson was very successful. All students completed the program, even though there was variation in time spent on the lesson. All students were successful, except one (see Figure 6). Short answer scores, while still lower than a 4 or 5, showed deeper learning concepts, through more in depth answers to the questions. There was an increase in scores to 3.4 (*SD*=1.02), which showed more depth of learning than in the previous activity (see Figure 7).

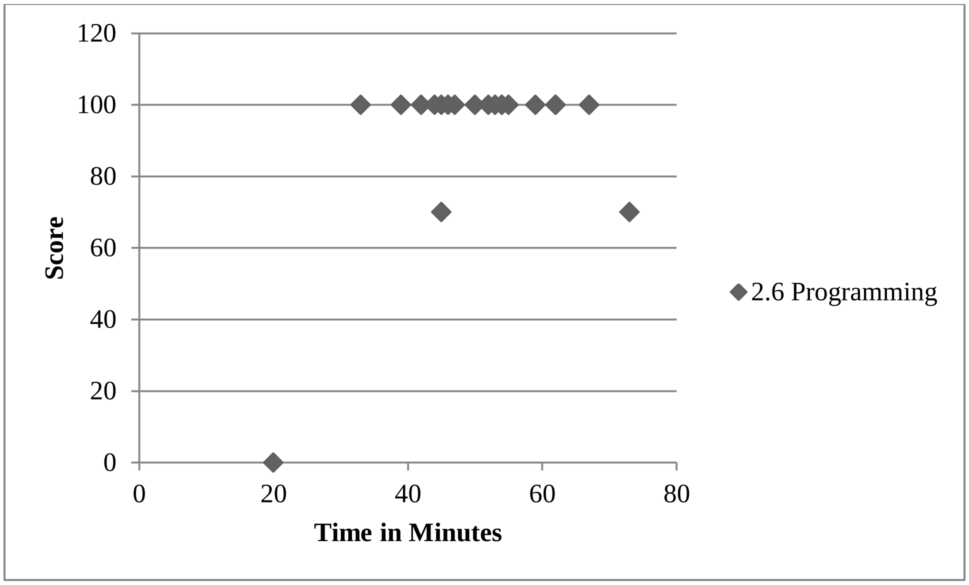

Figure 7. *Programming lesson 2.6 applying constraints, variables, and comments: Results of programming and time taken.*

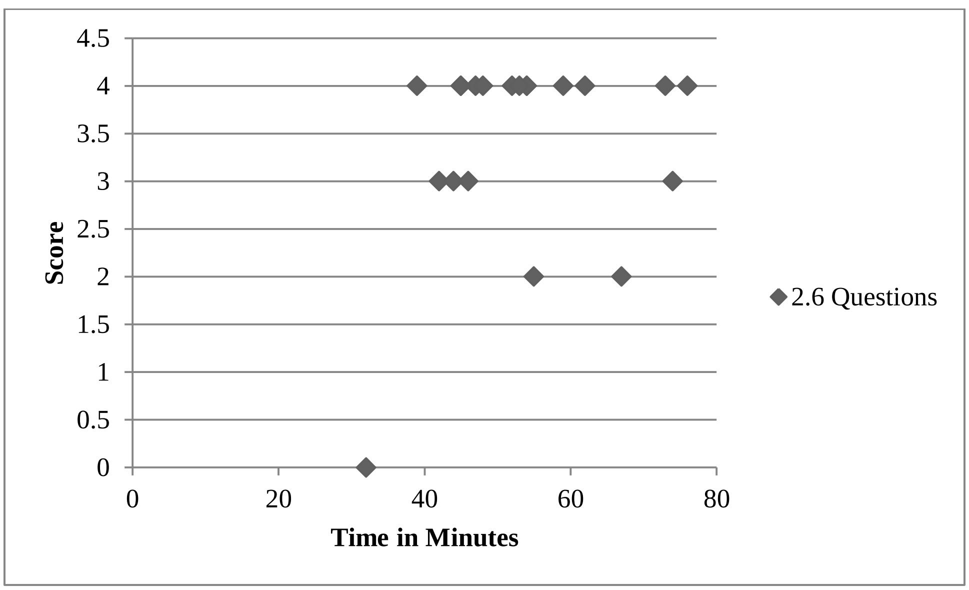

Figure 8. *Lesson 2.6 applying constraints, variables, and comments: Results of programming questions and time taken.*

Reflection

The overall scores from Cycle 1 to Cycle 2 increased across all of the categories (see Table 17). Students were more interested in the teaching of content and participated actively in discussions. During the three days students worked with the LearnMate content to complete quizzes and programming lessons, they seemed more motivated and excited about what they were doing and stayed engaged throughout the class period. Student reflections indicated that the content was easier to follow being taught by a teacher. Getting help from peers was also easier when everyone was working on the same activity. Slower students did not feel like they were getting behind and were able to manage their time. Students that worked faster and had high scores did not have a preference in the delivery of content. These students would complete assignments regardless, but did enjoy classroom discussions. The lessons were easier to manage the progress of students as they worked through the content.

The action research team met to reflect on the data and decided to keep Cycle 3 the same as Cycle 2, but include feedback for students on short answer questions to encourage a deeper level of thinking and more structured answers.

Table 17

Action Research Cycle 1 and 2 Statistics

	M	*SD*
2.2 Quiz	72.00	42.14
2.5 Quiz	84.75	25.80
2.3 Programming	80.00	40.00
2.4 Programming	80.00	40.00
2.6 Programming	100.0	0.00
2.3 Questions	2.60	1.43
2.4 Questions	2.55	1.40
2.6 Questions	3.40	1.02

Note. Quiz and programming range 0 to 100.
Question scores range 0 to #5. Time = minutes.

Action Research Cycle 3

Study and Plan

The third action research cycle was modeled from Cycle 2. Lessons Cycle 3 were 2.7 Precedence, Tests, and Loops, and 2.8 Tests and Loops. In Lesson 2.7, students learned about program loops. In lesson 2.8, students practiced writing program loops to make a robot repeat a process. I taught the first lesson as a lecture using the LearnMate content following the Cycle 2 procedures. The programming lesson was taught using LearnMate, while I acted as a facilitator.

Take Action

Lesson 2.7 was taught using the LearnMate content as a guide, but shortening and summarizing when necessary. Students participated by taking notes and contributing to class discussions. The lesson took two days to complete. Students spent one day taking a quiz and two days to work on the programming lesson using the LearnMate content.

Collect and Analyze Evidence

The mean quiz score in content lesson was 83(*SD*=28.48) and on the hands-on lesson, the median programming score was 92(*SD*=22.93) and questions was 4.55(SD=1.12) (see Table 18). All but three of the students received a score of 100 on the quiz. Two students missed one question and one student did not to complete the quiz (see Figure 9). Students performed well on the programming activity in Lesson 2.8 with only a couple of students not completing the final part of the program (see Figure 9). The short answer questions showed a depth of knowledge on the level 4 to 5 range with a strong understanding of the content and its application beyond the in class activities (see Figure 10).

Table 18

Action Research Cycle 3 Lessons 2.7-2.8 Statistics

	Score		Time	
Lesson	*M*	*SD*	*M*	*SD*
2.7 Quiz	83.00	28.48	33.15	10.45
2.8 Programming	92.00	22.93	50.10	11.71
2.8 Questions	4.55	1.12	50.10	11.71

Note. Quiz and programming range 0 to 100. Question scores range 0 to #5. Time = minutes.

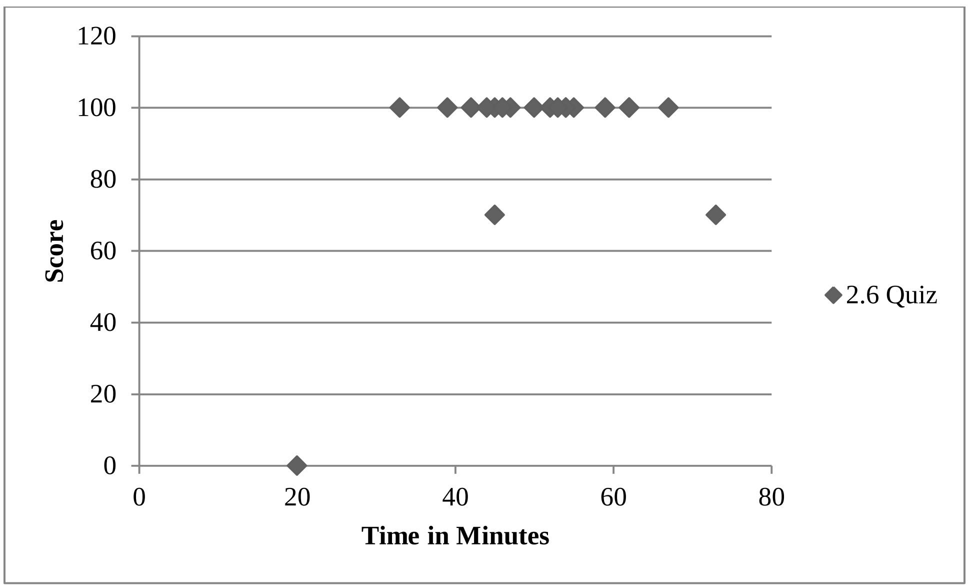

Figure 9. *Content Lesson 2.7 precedence, tests, and loops: Results of quiz scores and time taken to complete quiz.*

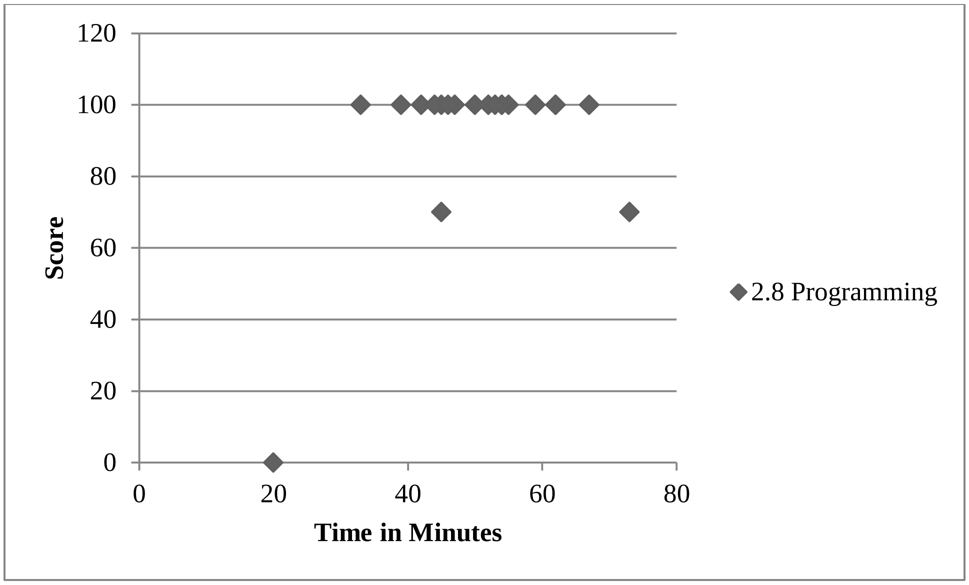

Figure 10. *Programming lesson 2.8 tests and loops: Results of programming and time taken.*

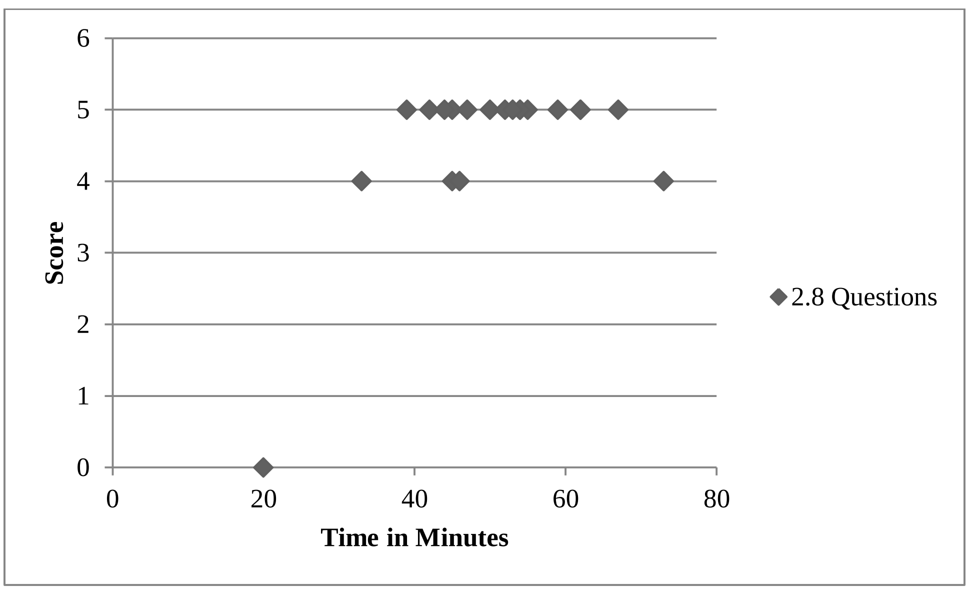

Figure 11. *Lesson 2.8 tests and loops: Results of questions and time taken.*

Reflection

Action research Cycle 3 showed gains in student scores across all three categories (see Table 19). Student comments were positive as in the second action research cycle.

Students that struggled with the first action research cycle continued to make gains in this cycle and improve their scores. The quiz scores stayed about the same, but more students had success with programming and the question scores showed a greater depth of knowledge between Levels 4-5 of Biggs' Solo Taxonomy (1989). In my self-reflection with the action research team, I found it is easier to keep students engaged and moving throughout the content when it is broken up with teacher-led lessons.

Table 19

Statistics for all of the lessons in the action research cycles

Cycle	Assignment	*M*	*SD*
1	2.2 Quiz	72.00	42.14
2	2.5 Quiz	84.75	25.80
3	2.7 Quiz	83.00	28.48
1	2.3 Programming	80.00	40.00
1	2.4 Programming	80.00	40.00
2	2.6 Programming	80.00	40.00
3	2.8 Programming	92.00	22.93
1	2.3 Questions	2.60	1.43
1	2.4 Questions	2.55	1.40
2	2.6 Questions	3.40	1.02
3	2.7 Questions	4.55	1.12

Note. Quiz and programming range 0 to 100. Question scores range 0 to #5. Time = minutes.

Findings

The purpose of this action research study was to find the most favorable combination of blended teaching to allow my students to have deeper knowledge about programming in robotics by reflecting on the three research questions below.

1. How did the blending of LearnMate and teacher-led instruction influence overall student learning in my Engineering Application course?

2. Did students in my Engineering Applications course gain deeper learning about factual content and concepts about robotics through LearnMate or teacher-led instruction?
3. When students did hands-on practice activities with robotics in my Engineering Applications course, was deeper learning gained through LearnMate or teacher-led instruction?

This section examines findings from my study as it relates to each research question. The findings are organized by research question and findings in Table 20.

Table 20

Research Questions and Findings

Research questions	Findings
How does the blending of LearnMate and teacher-led instruction influence overall student learning in my Engineering Applications course?	• Student scores increased with the blended method. • Lower level students were not as overwhelmed by the amount of reading and content. • Easier to manage the progression of student work through the blended approach.
Do students in my Engineering Applications course gain deeper learning about factual content and concepts about robotics through LearnMate or teacher-led instruction?	• Teacher-led instruction produced higher scores. • Students were able to ask questions for clarification. • Class discussions of content allowed for more clarity.
When students do hands-on practice activities with robotics in my Engineering Applications course, is deeper learning gained through LearnMate or teacher-led instruction?	• LearnMate does an adequate job explaining the programming. • There was not a direct need to change the format of the content.

How did the blending of LearnMate and teacher-led instruction influence overall student learning in my Engineering Application course?

Students were more successful with the blended learning method. Using blended learning with teacher-led instruction for the content portion of the lessons allowed students to take a more in depth look at the content, ask questions, and participate in whole class discussions. The content was not as overwhelming for the lower level students. Classroom discussions and feedback helped students improve scores on both quizzes and the questions. Students across the class showed increased motivation on the assignments. The blended method was also a simpler process to monitor the completion of assignments and keep the students together.

Did students in my Engineering Applications course gain deeper learning about factual content and concepts about robotics through LearnMate or teacher-led instruction?

Students gained a deeper understanding and learning when doing the factual content and concepts through the teacher led instruction. Lower level students' scores increased from zeros to scores above 80 over the three cycles. These students felt less overwhelmed by the amount of content and found the lessons easier to understand with the teacher-led instruction and class discussions. The class as a whole participated in the lesson by asking questions and providing real-world examples of the lesson. Students proceeded through the content and took the quizzes quickly after finishing the class lesson. Some students even questioned some of the LearnMate questions, where the questions had multiple answers or not enough information to make a definitive decision, based on their deeper knowledge of the content we had discussed in class. Students also improved their scores with their questions showing a deeper learning through the depth of the answers and examples given. The teacher-led instruction was a more effective method of delivery for the content for my classes.

When students do hands-on practice activities with robotics in my Engineering Applications course, was deeper learning gained through LearnMate or teacher-led instruction?

Students enjoy the programming, hands-on portion of LearnMate. While individual students have questions on some parts of the lessons, as an entire class, they were successful. In the first action research cycle, students performed well, but at different time frames. This may be due to different levels of experience with programming, comfort with the computer, or prior robotics experience. Since there was such a difference in times, but overall good scores, I chose to use LearnMate to teach the content, as it seemed effective for student mastery regardless of a student's background and prior experiences.

CHAPTER 5

SUMMARY, CONCLUSIONS, AND IMPLICATIONS

This action research study determined how the implementation of blended learning effected student achievement in a high school Engineering and Technology classroom in suburban Georgia. Activities/lessons used the LearnMate VEX Robotics REC curriculum, an online curriculum, to incorporate a blend of teacher-prepared lessons using traditional instruction and online lessons (Intellitek, 2008). The guiding questions for the student were:

1. How did the blending of LearnMate and teacher-led instruction influence overall student learning in my Engineering Applications course?
2. Do students in my Engineering Applications course gain deeper learning about factual content and concepts about robotics through LearnMate or teacher-led instruction?
3. When students perform hands-on practice activities with robotics in my Engineering Applications course, was deeper learning gained through LearnMate or teacher-led instruction?

This chapter provides a summary of the study, the findings and conclusions drawn from the study and recommendations for future research.

Summary of the Study

In the 1990s money was invested into Technology Education labs, now known as Engineering and Technology labs, one of Georgia's Career Technology Education pathways taught in secondary public schools. These labs resulted in the development of modular technology education classrooms (Weymer, 2002). Weymer (2002) suggests that the modular technology education facilities were vendor-provided curriculum that provided students learning through interactive media, instructional workbooks, writing responses in journals, and experiments and building activities. MTE was a self-contained instruction system defined by program learning theory, technological devices, and equipment (Petrina, 1993). Teachers were replaced by computers for the delivery of content.

While the format of the content has changed from students doing individual content modules to whole group modular instruction with the entire class working on the same module, and the delivery is now on the computer rather than reading from a notebook, the overall concepts have remained the same. During the 1990s and 2000s computers were not a common household and were exciting and engaging for students, however, now we carry phones in our pockets that have the same basic capabilities as a computer. The excitement of the computers and novelty no longer exists. In my classroom, students skip through the content to search for answers and move quickly through the content. Students gain understanding through hands-on activities and do not remember the factual/content information. As an Engineering and Technology teacher in a school system were LearnMate and the modular lab has been adopted, it is my job to facilitate student learning.as originally designed in the 1990s lab.

Elements of Learning

Three Domains of Learning

In this study I examined student learning using all three of the domains of learning: affective (feelings, emotions, and attitudes), cognitive (thinking), and psychomotor (doing) (Emenike, Danielson, & Bretz, 2011). Affective learning was assessed with the students' feelings towards traditional instruction, LearnMate, and the blended instruction methods. Students demonstrated cognitive learning through the ability to recall the process of performing a learned task with the robot and using words to express the action. Hands-on tasks, such as programming the robot to do an obstacle course, tested the psychomotor learning. Incorporating different learning styles is important to incorporating different learning modalities.

Deeper Versus Surface Learning

This study used Biggs (1989) SOLO Taxonomy to examine the depth of knowledge, surface or deeper learning, gained by students using different delivery methods of VEX Robotics curriculum. Surface learning is defined as accepting new facts and storing them as isolated bits of information, while deeper learning occurs when a learner actively explores, reflects, and produced knowledge, not just recalls it (Gholson and Craig, 2006). When deeper learning occurs, students are able to learn new facts and ideas and make connections between different subject areas (Biggs, 1999; Entwistle, 1998; Ramsden, 1992).

Deeper learning engages Erikson learners who actively explore, reflect, and produce knowledge (Gholson & Craig, 2006). The LearnMate lessons involve content learning and multiple choice questions, that involve surface learning, but as students' progress into the programming lessons, the depth of knowledge required to execute the program and answer the short answer questions increases. Biggs (1989) SOLO Taxonomy was used as a rubric on the short answer questions to determine the depth of knowledge learned from the activities in each action research cycle, where a level 1 answer is not a meaningful response and contains irrelevant information to a level 5 answer with application and higher-order thinking beyond the basic information in the lesson. Application beyond the fundamentals is a demonstration of deeper learning.

eLearning and Blended Instruction

This study used a blend of eLearning and blended instruction to determine the best combination of delivery for the LearnMate VEX Robotics curriculum through observations and data collected throughout the action research cycles. This section will define eLearning and blended instruction.

eLearning

Electronic learning (eLearning) became a replacement to the traditional classroom and has been described as a technology that offers learners control over their content, learning sequence, and pace of learning, allowing the learning process to be tailored to the student (Jethro, Grace, & Thomas, 2012). Jethro et al. (2012) suggested that eLearning is more efficient than traditional teacher-led instruction because learners move at their own pace and have a more positive attitude and increased motivation that yields higher results for students. eLearning was criticized by Singh (2003) as being a dry, page turner with point and click content and quizzes.

In a study performed by Liao and She (2009) students eLearning students outperformed conventional students on scientific reasoning both on the post-test and retention. Liao and She (2009) suggest that eLearning can be successful if the content is designed following pedagogical theory. In a study conducted in New Zealand, traditional teaching was replaced by self-paced content. Students in vocational areas with low and middle achievement score increased their scores while high achieving students remained the same.

In this action research study, when blended instruction was implemented, high performing students remained the same on the quizzes and programming and increased their scores on the questions throughout the action research cycles. The low and middle level students increased their scores on the quizzes, programming, and the questions using the blended model, but did not do well with the content in the eLearning format.

Blended Learning

Blended learning is a combination of online (computer-based) instruction and face-to-face (traditional) classroom instruction, although there is not an exact formula for the amount of face-to-face versus eLearning and finding the right blend of traditional lecture and eLearning is important to the overall success and interaction of the student, teacher, and the content (Massoud, Iqbal, Stockley, & Noureldin, 2011). The blended learning is focused on three areas of interaction; learner-content, learner-instructor, and learner-learner (Lee & Dashew, 2011). Learner-content allows students to teach themselves using modules and virtual simulations, learner-instruction interactions involve instructor feedback to facilitate a comfortable learning environment, and learner-learner interaction creates a learning community where lessons move from teacher-centered to student-centered. Massoud et al. (2011) suggested that the right blend of traditional lecture and eLearning is important to the overall success of the lesson.

Theoretical Framework

The framework for the study was based off of Carmean and Haefner's (2002) deeper learning principles that believe deeper learning occurs when learning is social, active, contextual, engaging, and student-owned. Students and teachers are involved in a contextual learning process building on existing knowledge and demonstrating a deep foundation of information. Students are encouraged to learn and take risks to achieve new depths of knowledge in a high-challenge, low-threat environment. Deeper learning is gained when a student takes ownership of knowledge and can apply to their lives through reflection and high-order thinking skills.

Carmean and Haefner's (2002) five deeper learning principles do not all have to be present for the deeper learning to occur, but provide a framework for deeper learning opportunities. The deeper learning principles were used as a guide for the action research study to ensure lessons meet the criteria for deeper learning.

Research Design

This study used the action research design, defined by Schoen (2007) as a professional research tool that empowers teacher to monitor and analyze personal practices to expand their knowledge base and improve instructional practice. Throughout the action research process, a teacher participates in direct reflection and analysis of their own classroom and using information gathered to improve instruction (Mertler, 2012).

Design of the Study

Action research is a cycle of action and research consisting of four components; plan, act, observe, and reflect (Carr and Kemmis, 2003). The problem analysis and strategic plan was created during the planning phase; the implementation of the strategic plan occured during the action phase; the collect and analyze phase involved an evaluation of the action, methods, and techniques; during the reflection, the entire action research process was evaluated, which may lead to identification of new problems or current problems and a new action research cycle.

This study used the action research design of Riel (2010) which includes the processes of study and plan, take action, collect and analyze evidence, and reflect for each action research cycle. This study consisted of three cycles performed by a single teacher that progressed through each of the four stages.

Planning Phase. A lesson plan identifying clear descriptions, expectations, and responsibilities is established during the planning phase (Hansen & Borden, 2006). For the first cycle I worked with my action research team, a group of professionals that reviewed my research during each cycle to ensure limited bias, to determine the delivery for the first cycle. The first action research cycle consisted of a model with the teacher as the facilitator while students used the eLearning content. This delivery was chosen for the first action research cycle since it is the expected delivery method for the content being taught. The second and third cycles were changed based on the data collected in each cycle.

Implementation/Action Phase/Data Collection. Throughout the implementation, the study involved qualitative and quantitative data collection including observations, informal interviews of questions throughout the learning, formal interviews at the conclusion of the cycle, and artifacts from the lesson including quizzes, questions, and programming activities

Analysis. At the conclusion of each action research cycle, I analyzed data and met with the action research team to ensure bias was limited. Data in each cycle was examined to determine the depth of knowledge gained in that cycle.

Reflection. During the reflection phase, the analysis of the data and process implemented are reviewed. Interviews and observations are reviewed and used in the planning phase for the next cycle.

Advantages and Disadvantages of Action Research

Action research helps improve education practices and instruction and is a systematic examination of the learning process. The process can be used to justify one's own teaching practices (Mertler, 2012). While action research has its advantages the results are never conclusive. The researcher is closely involved in the treatment and reflections, which can limit the validity of the research and cause false theories to be established.

Participants

This study was done in a medium-sized suburban high school near Atlanta, Georgia consisting of approximately 1500 students that are middle/upper class. The research participants consisted of all the students enrolled in the researcher's third year Engineering Applications course, consisting of 21 participants, 19 male and 2 female. The students have chosen to take the class due to future career goals and are completing the third class in the engineering pathway and have had no experience with the LearnMate curriculum.

An action research team was established to help avoid bias and oversee the process of the study. The team was comprised of teachers chosen based on the following criteria: (1) knowledge in the area of CTAE, (2) experience with modular based instruction, (3) knowledgeable about teaching methodology. Participants on the action research team included my department chair, a Family and Consumer Science teacher with an Educational Specialist in curriculum and instruction; a former Engineering and Technology teacher who is now a CTAE Director and has used the LearnMate curriculum; and a former engineer who now teaches Architecture teacher and has experience with the LearnMate curriculum.

Summary

This section describes the implementation of the action research study using the LearnMate VEX Robotics curriculum. The results, modifications, and decision process for each cycle will be explained.

Action Research Cycle 1

The first cycle consisted of three lessons, the first lesson involved students reading and answering questions. The second and third lessons had students learn how to perform a hands-on task involving programming the robot to drive forward. Based on feedback from the action research team, this cycle was taught using the LearnMate curriculum in the intended method of modular instruction with the teacher as facilitator. During the lessons, it was difficult to keep some students on task, I observed lazy behavior that needed to be redirected, and while most of the students successfully created the program to make the robot drive forward, 4 students never completed the assignments.

At the conclusion of the lessons, I interviewed students, and both high and low achieving students expressed that the content lesson that involved reading and answering questions was boring, too long, wordy, confusing, and too much information. Students said the hands-on programming lessons were early to follow and provided good practice. The data reflected that the lower level students did not complete the lessons. The mean quiz score for the first lesson was a 72 (*SD*=42.14) with the majority of students scoring above an 80. Four students received a zero on the quiz score. The mean of the programming scores in the lessons were 80 (*SD*=40) and 80 (*SD*=40). The passing score was set for a score of 70. The hands-on portion of the lessons included short answer questions that were scored using Biggs' SOLO taxonomy (1989). Mean scores were 2.6 (*SD*=1.43) and 2.55 (*SD*=1.4) for Lessons 2.3 and 2.4, respectively, which was below the desired score of 4 or 5.

Cycle 1 showed mixed results. While most students did well on the programing activities, they did not perform well on the short answer questions and quizzes. The mean quiz score was barely above the 70 percent passing score established by the school and the short answer scores demonstrated a low depth of learning with unstructured answers (Biggs, 1989). Feedback was given on the short answer questions to help strengthen responses on the next cycle. The programming activities were liked more by students and scores were high. After looking at the scores and interview notes, the action research team decided for Cycle 2, to reach the content-based lessons in a traditional lecture and use LearnMate with myself as the facilitator for the programming lessons. Therefore, allowing me to clarify the content information through teaching and helping students who struggled with reading and the amount of content.

Action Research Cycle 2

Action research Cycle 2 included two lessons that taught about variables, constants, and comments in programming. The first lesson involved teacher-led instruction and a quiz. The second lesson was a hands-on programming lesson. During this lesson, I used LearnMate as a teaching tool and I acted as a facilitator during the programming lesson, leaving the programming part of the lesson the same as in Cycle 1.

The first two days of the lessons involved teacher-led lecture using LearnMate as a tool to lead the instruction. While the same content in LearnMate was presented, I was able to eliminate the overwhelming amount of information and wording students struggled with and disliked in Cycle 1; I skipped repetitive slides and summarized information in areas where items were lengthy. Class discussions on real world examples and questions from students were also reviewed. Upon completion of the lecture, students completed the quizzes in LearnMate and worked through the LearnMate activities to complete the programming activities.

During Cycle 2, there was an increase in scores in all categories. The quiz score was an 84.75 (*SD*=25.80), short answer scores were 3.4 (*SD*=1.02), and the programming was a 100 (*SD*=0.00). The quiz and programming scores were above the 70 percent passing score established, but the 3.4 for the short answer questions was below the level 4 or 5 to show deeper learning. Throughout the lecture part of this lesson, students were engaged and asked and answered questions while taking notes. Only one student chose not to take the quiz. My observations showed that students were more excited to use LearnMate and took their time taking the quiz. The programming lesson varied in time spent by students, all of the students were successful and demonstrated a greater depth of learning than in the previous activity.

During Cycle 2, students seemed more motivated and excited about what they were doing and stayed engaged throughout the class period. Student reflections included that the content was easier to understand when taught by a teacher. The slower kids felt they were able to manage their time and were not falling behind. Getting help from peers was easier when everyone was working on the same activity. The faster students had high scores and did not have a preference in the delivery of the content. These students would complete the assignment regardless, but did enjoy the classroom discussions. As a teacher, the lessons were easier to monitor and keep a pace when students worked on the activities together.

The action research team met to reflect on the data and made the decision to keep Cycle 3 the same as Cycle 2. Feedback was included for students on their short answer questions to encourage a deeper level of thinking and more structured answers.

Action Research Cycle 3

Action Research Cycle 3 included two lessons similar to Cycle 2, which involved programming loops to make a robot repeat a process. The format of this cycle followed the same format as Cycle 2. The first lesson was taught using lecture and class discussions with students taking the quiz from LearnMate. The second lesson students used LearnMate to complete a programming challenge.

The mean quiz score for the first lesson was 83 (*SD*=28.48), the programming score was a 92 (*SD*=22.93), and the questions were 4.55 (*SD*=1.12). All but three students received a 100 on the quiz. Two students missed one question and one student did not complete the quiz. The short answer questions showed a depth of knowledge in the level 4 to 5 range with a strong understanding of the content and its application beyond the in class activities.

Action research Cycle 3 showed gains in all three categories and had positive student comments. Students who struggled in the first cycle continued to increase their scores showing a greater depth of knowledge on the short answer questions.

Key Findings

The purpose of this action research study was to find the most favorable blend of instruction to support my students in gaining a deeper understanding of programming in robotics focusing on these research questions:

1. How did the blending of LearnMate and teacher-led instruction influence overall student learning in my Engineering Application course?
2. Did students in my Engineering Applications course gain deeper learning about factual content and concepts about robotics through LearnMate or teacher-led instruction?
3. When students did hands-on practice activities with robotics in my Engineering Applications course, was deeper learning gained through LearnMate or teacher-led instruction?

How did the blending of LearnMate and teacher-led instruction influence overall student learning in my Engineering Application course?

The amount and areas of blended instruction were based on Cycle 1 quiz scores and student feedback. Massoud et al. (2011) suggested there is not a formula for the amount of face-to-face time versus eLearning needed to reach success, rather a blend of instruction should be based on the needs of individual learners. Throughout Cycles 1 and

2, the content part of each lesson was taught using the LearnMate curriculum in a traditional teacher-led lecture with class discussions, and programming lessons were taught using LearnMate in the modular method with myself as the facilitator.

Lee and Dashew (2011) explained that blended learning should focus on three areas including *learner-content* where students learn content on their own, *learner-instructor content* where learner and instructors work together, and *learner-learner interactions* where learners work with each other to learn the content. By incorporating the blended learning approach, students experienced all three interactions throughout the learning process.

During Cycles 2 and 3, scores increased using the blended method of instruction. Lower-level, special education, students were not as overwhelmed by the amount of reading and content presented thus having an easier time staying on pace with classmates. Classroom discussions and real world examples helped further the understanding of content. The blended method also made it easier to monitor completion time for assignments and ensured all students were progressing appropriately. Overall, students seemed to enjoy the assignments and were motivated to complete the work.

Did students in my Engineering Applications course gain deeper learning about factual content and concepts about robotics through LearnMate or teacher-led instruction?

During Cycle 1, factual content and concepts were taught through LearnMate, with me as facilitator. Facilitating lessons puts less focus on teacher interaction and more on student-focused learning. Lower-level students found the amount of content to be overwhelming and because the lesson involved reading content and answering questions, students did not ask for help. In Cycles 2 and 3 the content was taught with teacher-led instruction and class discussion.

Hong (2006) developed a set of seven principles for good practice in teaching. These principles are (a) promoting interaction among faculty and students, (b) enhancing reciprocity and cooperation among students, (c) promoting active learning, (d) providing prompt feedback and increasing time on task, (e) setting high expectations, and (f) recognizing diversity in learning. By incorporating teacher-led instruction in Cycles 2 and 3, I was able to promote interaction among faculty and students, provide prompt feedback with questions students asked during discussions, increase time on task with guided learning and more structured timeframes, and modify content for the diverse population of learners helping to incorporate good teaching practices.

Teaching factual concepts through lecture and classroom discussions led student scores to increase during the three cycles. Students felt less overwhelmed with the amount of content and participated in discussions that helped further the content provided through LearnMate. Some students even questioned the information in LearnMate due to the lack of information presented. Students also improved their scores with their questions showing a deeper learning through the depth of the answers and examples given. The teacher-led instruction was a more effective method of delivery for the content for my classes.

When students did hands-on practice activities with robotics in my Engineering Applications course, was deeper learning gained through LearnMate or teacher-led instruction?

Overall, students enjoyed the hands-on portions of LearnMate. The format of hands-on lessons allowed for learner-learner interaction and learner-content focus. Students interacted with one another as well as explored and learned on their own using LearnMate. Lee and Dashew (2011) outlined these learning approaches as key elements for constructivist methods of exploratory learning and hands-on experiences and as the creation of a strong foundation for deeper learning.

While the programming scores stayed consistent throughout the cycles, scores on questions increased from 2.6(*SD*=1.43) on Cycle 1 to 4.55(*SD*=1.12) on Cycle 3. The short answer questions required students to apply knowledge gained from the programing and content-based lessons. The increase in scores from a level 2 uni-structural answers, that focused on one relevant aspect, to level 4 relational and level 5 extended abstract answers, that put parts together into a coherent whole to bring in new conclusions and higher-order thinking, demonstrated an increase in the depth of knowledge gained (Biggs, 1989).

While some students had questions throughout the activities, students performed well. Some students performed slower on the programming activities. Based on the interviews and observations, this was due to different levels of experience with programming, comfort with the computers, or prior robotics experience. Regardless of these factors all students were successful.

Limitations of the Study

While action research has its advantages in the improvement of teaching practices, results are never conclusive. In action research, the researchers are closely involved in the treatment and reflections of the study. Action research requires the researcher to act as a facilitator and become intimately involved in the study to understand and evaluate each phase of the research (Hansen & Borden, 2006). This can limit the validity of the research and cause false theories to be established, as bias from the researcher may be a factor in decisions made throughout the cycles. Concepts in this study could be used in other classrooms to determine the best teaching methods for a select group of students using LearnMate or another type of online instruction; however one cannot guarantee the treatment will work with all groups of students or individuals and with all teachers due to the interaction of the teacher and researcher.

The content in this action research study had a linear progression of difficulty that scaffolded off of the previous lessons, but maintained the same level of rigor throughout the content. It is important to note that the action research model could change or not produce the same results if the content did not follow a linear pattern of scaffolding or was a concepts students normally experience difficulty with.

Implications for Practice

Through this action research study, I was able to determine the best method for teaching the VEX Robotics curriculum using LearnMate. The reason this study was chosen was because students in my classes have complained about doing the LearnMate activities in a modular format and don't stay engaged. Through this study, I analyzed the effectiveness of the LearnMate curriculum by separating the content into different cycles and completing a systematic action research process of planning, implementation, collecting and analyzing data, and reflection. The in-depth look at course content and delivery allowed me to identify areas where students became disconnected or lacked focus.

By redefining the delivery of content from eLearning to a blended learning method, I was able to implement strategies that encouraged deeper learning. Picciano (2006) described blended instruction as lessons planned in a pedagogically valuable way where face-to-face and eLearning time is mixed. The class discussions and questions that arose from the content being taught in Cycles 2 and 3 allowed for the basic surface knowledge gained through LearnMate to become deeper learning as concepts were applied to everyday experiences, content was reorganized to make it a coherent whole, and content from previous lessons was identified (Ramsden, 2003). The discussions and examples helped to emphasize content and allowed students to ask questions about programming activities.

The blended learning delivery also incorporated all three domains of learning (Bloom, Engelhart, Furst, Hill, & Krathwohl, 1956). Students used cognitive learning to apply knowledge on the multiple choice and short answer questions. The affective domain positively changed, as students struggling in Cycle 1 saw positive changes that adapted content to meet their learning styles, thus improving their attitudes and success. Students incorporated psychomotor skills during the programming of their robots. Therefore, the lesson became a balanced lesson incorporating all three domains of learning.

The study taught me how to reflect on my teaching using a systematic approach and make modifications using research-based strategies to encourage deeper learning. While we often reflect on teaching different units from year-to-year, the process can be used to modify teaching practices from unit-to-unit to help reach different learning styles and achieve the greatest depth of knowledge among activities and lessons that are similar.

Action research is a practitioner-based method in which teachers have opportunities to gain valuable professional development and transformation (Coghlan & Brannick, 2010). While teachers reflect on lessons daily, it is through the action research process, that reflection becomes a formal documentation of teaching. Through this documentation, lessons can be altered and modified to better meet the needs of learners and achieve a greater depth of learning and understanding.

Through reflection, teachers are able to improve their practices and adapt to the learning needs of students in their classrooms. By modifying teaching practices to meet learners' needs, students take ownership of their learning and become lifelong learners (Carmean & Haefner, 2002). The action research practice ensures that content and the practice for teaching the content remains practical and relevant to today's learners (Mertler, 2012). Having students engaged and excited about the learning practice encourages deeper learning to occur. While the formality and documentation process of action research is not practical for day-to-day instruction of a teacher with multiple courses and preparations, the implementation and strategies including cycles, data, and feedback from students, can lead to improvement in education.

Implications for Future Research

Through the use of action research, teachers are empowered with the ability to change as students change and adapt teaching to achieve the best results and highest levels of learning with research based strategies. Action research is a form of professional learning that empowers teachers to explore, modify, and create new instruction that best fits the ever changing curriculum and students. Through the process of action research, teachers can strengthen the content taught in their classrooms.

Lately, personalized learning has become a new term in education. Personalized learning is tailoring lessons to students of different ability levels and appealing concepts. This type of learning is becoming a part of education being used to help raise achievement scores and cater to students on different ability levels (Cavanagh, 2014). Action research could play a role in studies to help determine effective personalized learning methods by using the cycles to document changes in instruction and delivery of content. To effectively use personalized learning, teachers and schools will need to adjust the content and delivery to meet students' academic strengths and weaknesses, and what motivates them to succeed.

Online learning is also becoming a common method of delivery for content; however, the studies I researched showed mixed success with online courses without teacher interaction. Research and strategies on techniques to blend instructional methods both in the classroom and with online instruction could help improve the delivery and overall depth of knowledge gained by students. However, research in these areas is limited.

Action research could also be implemented to pilot new curriculum methods or units of instruction, such as LearnMate. Piloting curriculum in different schools and settings can ensure that the curriculum has a strong framework and a delivery method that appeals to the students and teachers. Curriculum of this design provides new teachers, both traditional, and non-traditional with a curriculum to teacher, but as an action researcher and teacher, modifications and changes are necessary in bettering our teaching and content.

The continued study of action research in schools could have an overall impact on a school's performance in teacher measurement, student learning, and school climate. As the generations of learners continue to change and technology takes a more prevalent role in education, the connections to the textbook and old methods of teaching are changing the face of the classroom and educational practices.

REFERENCES

Ashby, J., Sadera, W. A., & McNary, S. W. (2011). Comparing student success between developmental math courses offered online, blended, and face-to-face. *Journal of Interactive Online Learning, 10*(3), 128-140.

Barlow, M. (1967). *History of industrial arts in the United States.* Peoria, IL: Charles A. Bennett.

Bartow, S. M., Foster, P. N., & Kirkwood, J. J. (1994). Historical leaders in technology education philosophy. *Journal of Industrial Teacher Education, 32*(1). Retrieved from http://scholar.lib.vt.edu/ejournals/JITE/v32n1/Kirkwood

Bensen, M. J., & Bensen, T. (1993). Gaining support for the study of technology. *The Technology Teacher, 52*(6), 3-5.

Biggs, J. B. (1989). Approaches to the enhancement or tertiary teaching. *Higher Education Research Development, 8*, 7-15. doi:10.1080/0729436890080102

Biggs, J. B. (1999). *Teaching for quality learning at university*. Buckingham, UK: SRHE and Open University Press.

Bloom, P. (2002). *How children learn the meanings of words*. Cambridge, MA: MIT Press.

Bloom, B., Englehart, M. F. E., Hill, W., & Krathwohl, D. (1956). *Taxonomy of educational objectives: The classification of educational goals. Handbook I: Cognitive domain.* NewYork, NY: Longmans, Green.

Bonser, F. G., & Mossman, L. C. (1923). *Industrial arts for elementary schools*. New York, NY: Macmillan.

Brown, A. L., & Cocking, R. R. (2000). *How people learn*. Washington, DC: National Academy Press. Retrieved from http://www.csun.edu//~SB4310/How%20People%20Learn.pdf

Cantrell, P., Pekan, G., Itani, A., & Velazquez-Bryant, N. (2006). Effects of engineering modules on student learning in middle school science classrooms. *Journal of Engineering Education 95*(4), 301-309. doi:10.1002/j.2168-9830.2006.tb00905

Carmean, C., & Haefner, J. (2002). Mind over matter. *Educause Review*, *37*(6), 26-28.

Carnegie Mellon University Robotics Academy. (2008). *Robot algebra.* Robotics Academy Research. Retrieved from www.education.rec.ri.cmu.edu/content/educators/research/ robot_algebra/index.htm

Carr, W., & Kemmis, S. (2003). *Becoming critical: Educational knowledge and action research*, Routledge.

Chickering, A. W., & Ehrmann, S. C. (1996). Implementing the seven principles: Technology as lever. *AAHE Bulletin*, *49*, 3-6.

Christophel, D. M. (1990). The relationships among teacher immediacy behaviors, student motivation, and learning. *Communication Education, 37*, 323-340. doi:10.1080/03634529009378813

Cochran, L. H. (1970). *Innovative programs in industrial education*. Bloomington, IL: McKnight.

Coghlan, D., & Brannick, T. (2010). *Doing action research in your own organization*. Thousand Oaks, CA: Sage.

Crick, R. D. (2011). *Learning emergence*. Retrieved from http://learningemergence.net/about/learning-futures-design-principles/

CTAE Resource Network. (2014). Retrieved from https://www.ctaern.org/

Dabbagh, N. (2005). Pedagogical models for E-Learning: A theory-based design framework. *International Journal of Technology in Teaching and Learning*, *1*(1), 25-44.

Daier, R. A. (1986). High school technology education. In R. E. Jones & J. R. Wright (Eds.), *Implementing technology education* (pp. 68-72). Bloomington, IL: McKnight.

Dave, R. (1970). Psychomotor levels. In R. J. Armstrong (Ed.) *Developing and writing behavioral objectives* (pp. 33-34). Tucson, AZ: Educational Innovators Press.

DeVore, P. W. (1980). *Technology, an introduction.* Worcester, MA: Davis.

Emenike, M. E., Danielson, N. D., & Bretz, S. L. (2011). Meaningful learning in a first-year chemistry laboratory course: Differences across classical, discovery, and instrumental experiments. *Journal of College Science Teaching*, *41*(2), 89-92.

Entwistle, N. (1988). Motivational factors in students' approaches to learning. Learning strategies and learning styles (pp. 21-51). 10.1007/978-1-4899-2118-5_2

Erikson, E. H. (1968). *Identity, youth and crisis*. New York, NY: W. W. Norton & Company, Inc.

Face, W. L., Flug, E. R., & Swanson, R. (1966). Conceptual approach to American industry. In G.S. Wall (Ed.), *Approaches and procedures in industrial arts* (pp.

60-72). Fourteen yearbook of the American Council on Industrial Arts Teacher Education, Bloomington, IL: McKnight.

Foster, P. (1995). The founders of industrial arts in the US. *Journal of Technology Education*, *7*(1), Retrieved from http://scholar.lib.vt.edu/ejournals/JTE/jte-v7n1/foster.jte-v7n1.html

Fullan, M., & Langworthy, M. (2014). *A rich seam: How new pedagogies find deep learning.* London: Pearson. Retrieved from http://www.michaelfullan.ca/wp-content/uploads/2014/01/3897.Rich_Seam_web.pdf

Georgia Department of Education. (2007). *Georgia's performance standards.* Retrieved from http://www.georgiastandards.org/career.aspx?PageReq=PhaseI

Georgia Department of Education. (2013). *Georgia's performance standards.* Retrieved from http://www.georgiastandards.org/

Gholson, B., & Craig, S. D. (2006). Promoting constructive activities that support vicarious learning during computer-based instruction. *Educational Psychology Review, 18*(2), 119-139. doi:10.1007/s10648-006-9006-3

Gloeckner, G. W., & Adamson, G. (1996). Modular technology education. A wild west point of view. *Technology Teacher, 56*(1), 16-21.

Graham, C. R. (2006). *The handbook of blended learning*. San Francisco, CA: Pfeiffer. Retrieved from http://www.academia.edu/563281/Blended_learning_systems_Definition_current_trends_and_future_directions

Hansen, M. J., & Borden, V. H. (2006). Using action research to support academic program improvement. *New Directions for Institutional Research, 2006*(130), 47-62. doi:10.1002/ir.179

Herschback, D. R. (1997). From industrial arts to technology education: The eclipse of purpose. *Journal of Technology Studies, 23*(20), 20-28. Retrieved from http://scholar.lib.vt.edu/ejournals/JOTS/

Hong, L. (2006). Blending online components into traditional instruction a case of using technologies to support good practices in pre-service teacher education. *International Journal for the Scholarship of Teaching and Learning, 2*(1), 7-16. Retrieved from http://digitalcommons.georgiasouthern.edu/ij-sotl/

Intelitek. (2008). LearnMate. Retrieved from http://www.intelitek.com/Products.asp?CategoryID

International Technology Education Association. (1996). *Technology for all Americans: A rationale and structure for the study of technology*. Reston, VA: Author.

International Technology Education Association. (2000). *Standards for technological literacy: Content for the study of technology*. Reston, VA: Author.

International Technology Education Association. (2003). *Advancing excellence in technological literacy: Student assessment, professional development, and program standards*. Reston, VA. Author.

Jethro, O. O., Grace, A. M., & Thomas, A. K. (2012). E-learning and its effects on teaching and learning in a global age. *International Journal of Academic Research in Business and Social Sciences, 2*(1), 203-210.

Kapachtsi, V.& Kakana, D. (2012). Initiating collaborative action research after the implementation of school self-evaluation. *International Studies in Educational Administration, 40*(1), 35-45.

Kenny, J., & Newcombe, E. (2011). Adopting a blended learning approach challenges encountered and lessons learned in an action research study. *Journal of Asynchronous Learning Networks*, *15*(1), 47-59.

Kolberg, E., & Orlev, N. (2001). Robotics learning as a tool for integrating science technology curriculum in K-12 schools. In *Frontiers in Education Conference, 2001. 31st Annual* (Vol. 1, pp. T2E-12). IEEE.

Korkmaz, O., & Karakus, U. (2009). The impact of a blended learning model on student attitudes towards geography courses and their critical thinking dispositions and levels. *Turkish Online Journal of Educational Technology, 8*(4), 51-63.

Krathwohl, D. R., Bloom, B. S., & Masia, B. B. (1964). *Handbook II: Affective domain*. New York, NY: David McKay.

Lee, R.-A., & Dashew, B. (2011). Designed learner interactions in blended course delivery. *Journal of Asynchronous Learning Networks*, *15*(1), 68-76.

Lewin, K. (1953). Group decision and social change. *Readings in social psychology, 3*, 197-211.

Lewis, T., & Zuga, K. F. (2005). *A conceptual framework of ideas and issues in technology education.* Arlington, VA: Technology Teacher In-service Education and National Science Foundation.

Liao, Y.-W., & She, H.-C. (2009). Enhancing eight grade students' scientific conceptual change and scientific reasoning through a web-based learning program. *Educational Technology and Society*, *12*(4), 228-240.

Maley, D. (1973). *The Maryland plan*. Beverly Hills, CA: Bruce.

Massoud, A., Iqbal, U., Stockley, D., & Noureldin, A. (2011). Using blended learning to foster education in a contemporary classroom. *Transformative Dialogues: Teaching and Learning Journal*, *5*(2), 1-11.

McGee, C., & Hampton, P. (1996). The effects of modular curriculum delivery on a New Zealand secondary school. *School Organizations*, *16*(1), 7-16. doi:10.1080/0260136960160102

Mclntyre, M. (2002). In league with the robots. *Tech Directions*, *62*(2), 14-18.

McLean, J. E. (1995). *Improving education through action research: A guide for administrators and teachers. The practicing administrator's leadership series roadmaps to success.* Thousand Oaks, CA: Corwin.

McLoughlin, C., & Oliver, R. (1999). Pedagogic roles and dynamics in telematics environments. In M. Selinger and J. Pearson (Eds.), *Telematics in Education: Trends and Issues* (pp. 32-50). Kidlington, Oxford: Pergamon.

Mertler, C. A. (2012). *Action research: Improving schools and empowering educators* (3rd ed.). Los Angeles, CA: Sage.

Mottet, T. P., & Beebe, S. A. (2006). Foundations of instructional communication. In T. P. Mottet, V. P. Richmond, & J. C. McCroskey (Eds.), *Handbook of instructional communication: Rhetorical and relational perspectives* (pp. 3-32). Boston, MA: Allyn and Bacon.

Montgomery, B., Larsen, K., & Hale, G. (2011). Deep learning and elearning. Retrieved from http://www.google.com/url?sa=t&rct=j&q=&esrc=s&source=web&cd=3&cad=rja&uact=8&ved=0CDkQFjAC&url=http%3A%2F%2Fwww.hewlett.org%2Fuploads%2Fdocuments%2FDeeper_Learning_and_e-Learning.pdf&ei=wph6U7zMJ6izsQT8k4GoBg&usg=AFQjCNFmhISzTwD8EBxl6CVjjXN-SMv6Ug&sig2=neuUZ0ZXhKZki8qCgxHnjg&bvm=bv.67229260,d.b2k

Mossman, L. C. (1929). *Principles of Teaching and Learning in the Elementary School*. New York: Houghton Mifflin Company.

Napier, N. P., Dekhane, S., & Smith, S. (2011). Transitioning to blended learning: understanding student and faculty perceptions. *Journal of Asynchronous Learning Networks*, *15*(1), 20-32.

Nourbakhsh, I. R., Crowley, K., Bhave, A., Hamner, E., Hsiu, T., Perez-Bergquist, A., Richards, S., & Wilkinson, K. (2005). The robotic autonomy mobile robotics course: Robot design, curriculum design and educational assessment. *Autonomous Robots, 18,* 103-127.

Nugent, G., Barker, B., Grandgenett, N., & Adamchuk, V. (2010). Impact of robotics and geospatial technology interventions on youth STEM learning and attitudes. *Journal of Research on Technology in Education*, *42*(4), 391-408. doi:10.1080/15391523.2010.10782557

Olgun, Ö. S. (2009). Engaging elementary preservice teachers with active learning teaching methodologies. *The Teacher Educator*, *44*(2), 113-125. doi:10.1080/08878730902721772

Parsons, R. D.& Brown, K. S. (2002) *Teacher as a reflective practitioner and action researcher*. Belmont, CA: Wadsworth/Thompson Learning.

Pearson, G., & Young, A. T. (Eds.). (2002). *Technically speaking: Why all Americans need to know more about technology*. Washington DC: National Academy Press.

Petrina, S. (1993). Under the corporate thumb troubles with our MATE. *Journal of Technology Education, 5*(1), 72-80.

Piaget, J., & Beth, E. W. (1966). *Mathematical epistemology and psychology*. New York, NY: Gordon and Breach.

Picciano, A.G. (2006). Blended learning: Implications for growth and access. *Journal of Asynchronous Learning Networks, 10*(3), 95-102.

Prosser, M., & Millar, R. (1989). The "how" and "what" of learning physics. *European Journal of Psychology of Education, 4*(4), 513-528. Retrieved from http://www.ejpes.org/

Pullias, D. (1997). The future is...beyond modular. *The Technology Teacher, 56*(7), 28-29.

Ramsden, P. (1981). *A study of the relationship between student learning and its academic context* (Doctoral dissertation, University of Lancaster).

Ramsden, P. (1992). *Learning to teach in higher education*. London, UK: Routledge.

Ramsden, P., (2003). *Learning to teach in higher education 2nd edition* (pp. 45-52). New York, NY: Routledge.

Riel, M. (2010). Understanding action research. *Research Methods in the Social Sciences*, *17*(1), 89-96.

Richmond, V. P., Lane, D. R., & McCroskey, J. C. (2006). Teacher immediacy and the teacher-student relationship. *Handbook of instructional communication: Rhetorical and relational perspectives*, 167-193.

Robinson, M. (2005). Robotics-driven activities: Can they improve middle school science learning. *Bulletin of Science, Technology and Society*, *25*(1), 73-84. doi:10.1177/0270467604271244

Rogers, M. E. (2004). A comparison of the effectiveness of modular drafting instruction versus contemporary drafting instruction on collegiate technology education students. *Journal of Industrial Teacher Education, 41*(2).

Romiszowski, A. (1999). The development of physical skills: Instruction in the psychomotor domain. In C-M. Reigeluth (Ed.), *Instructional-design: Theories and models* (Vol. II, pp. 457–481). Mahwah, NJ: Erlbaum.

Ross, B. *&* Gage, K. (2006). Global perspectives on blended learning: Insight from WebCT and our customers in higher education. In C. J. Bonk & C. R. Graham (Eds.) *The handbook of blended learning: Global perspectives, local designs* (pp. 155-168). San Francisco, CA: Pfeiffer/Wiley

Russell, A. (1909). Proceedings of the Royal Society A: Mathematical, physical and engineering sciences. *Proc R Soc A*, *82*, 524-531.

Schoen, S. (2007). Action research: A developmental model of professional socialization. *Clearing House*, *80*(5), 211-216. doi:10.3200/tchs.80.5.211-216

Shea, P. (2007). Towards a conceptual framework for learning in blended environments. In: Picciano, A., and Dziuban, C. (Eds.), *Blended Learning: Research Perspectives*, Needham, MA: Sloan Center for Online Education, 19-35.

Sigler, E. (2009). Action research in public schools: Is it research? Should it be reviewed? *Journal of Empirical Research On Human Research Ethics*, *4*(2), 17-25. doi:10.1525/jer.2009.4.2.17

Singh, H. (2003). Building effective blended learning programs. *Educational Technology*, *43*(6), 51-54.

Sklar, E., Johnson, J., & Lund, H. (2000). *Children learning from team robotics*. Research Report 1, RoboFesta Edutainment and Robotics Education Research Centre, Faculty of Technology, The Open University, Milton Keynes, UK.

Smith, D. F. (1981). Industrial arts founded. In R. V. Barella & R. T. Wright (Eds.), *An interpretive history of industrial arts*, pp 36-42. Bloomington, IL: McKnight.

Snyder, J. F., & Hales, J. F. (1981). *Jackson's Mill industrial arts curriculum theory*. Charleston, WV: West Virginia Department of Education.

Stanford Center for Opportunity Policy in Education, Stanford University. (2013). Criteria for high quality assessment. Retrieved from http://216.78.200.159/RandD/Other/Criteria%20for%20Higher-Quality%20Assessment%20-%20SCOPE.pdf

Sterry, L.& Savage, E. (1990). *A conceptual framework for technology education.* Reston, VA: International Technology Education Association.

Svensson, L. (1977). On qualitative differences in learning: III. Study skill and learning. *British Journal of Educational Psychology*, *47*(3), 233-243. doi:10.1111/j.2044 8279.1977.tb02352.x

Towers, E. R., Lux, D. G., & Ray, W. E. (1966). *A rationale and structure for industrial arts subject matter*. Columbus, OH: The Ohio State University.

VEX Robotics. (2010). *VEX education overview.* Retrieved from www.vexrobotics.com/education/

Volk, K. S. (2010). Action research as a sustainable endeavor for teachers. *Action Research, 8*(3), 315-332. doi:10.1177/1476750309351358

Webb, N.L. (2002). *Depth-of-knowledge levels for four content areas*. Retrieved from http://facstaff.wcer.wisc.edu/normw/All%20content%20areas%20%20DOK%20levels%2032802.doc

Weigel, V. (2002). *Deep learning for a digital age: Technology's untapped potential to enrich higher education*. New York, NY: Jossey-Bass.

Weymer, R. A. (2002). Factors affecting students' performance in sixth grade modular technology education. *Journal of Technology Education, 13*(2), 34-46.

Wicklein, R. C. (2006). Five good reasons for engineering design as the focus for technology. *The Technology Teacher, 65*(1), 10-12. Retrieved from https://www.questia.com/library/p5246/the-technology-teacher

Wilber, G. (1948). *Industrial arts in general education.* Scranton, PA: International Textbook.

Wright, T. (1992). Building a defensible curriculum base. *Journal of Technology Education, 3*(2), 62-67. Retrieved from scholar.lib.vt.edu/ejournals/JTE/

Zollman, A. (2012). Learning for STEM Literacy: STEM Literacy for Learning. *School Science and Mathematics*, *112*(1), 12-19. doi: 8594.2012.00101

Zollman, A., Smith, M. C., & ReiSDorf, P. (2011). Identity development: Critical components for learning in mathematics. *Motivation and disposition: Pathways to learning mathematics. Seventy-third National Council of Teachers of Mathematics Yearbook*, 43-53.

APPENDICES

Appendix A

Daily reflection journal to be completed by the researcher at the end of each class period.

Date: ________________ AR Cycle #: ________________

Description of activity in class today: ________________

What activities did students like? ________________

Where did students struggle? ________________

Other notes/observations from the day: ________________

Appendix B

Assignment completion to be completed by the researcher to record the amount of time it takes each student to complete the assigned task.

Date(s): ______________________ AR Cycle #: ________________________________

Assignment being completed: ____

Student's school id #	Gifted	Male/female	Completion time	Accuracy/Notes

Appendix C

Questions to be asked by the researcher/teacher to the student(s) to clarify any of the other data collected.

Student id # ______________________________

Date: ________________ AR Cycle #: ________________

Description of the activities:

What did you like about the lesson?

What items were confusing during the lesson?

Do you think the content would be easier to understand by having a teacher lead a demonstration or did the LearnMate content explain the content with enough clarity?

Appendix D

Dear Parent/Guardian,

A research study is being conducted during a portion of your son/daughter's Engineering Applications course. This letter is intended to give you information about the study and seek permission for your student to participate.

Purpose of the Study

We are doing a research study to determine what instructional method leads to deeper learning when using the LearnMate VEX Robotics curriculum. We are asking you to be in the study because you are currently enrolled in the Engineering Applications course where the LearnMate VEX Robotics content is part of the curriculum taught. If you agree to be in the study, you will perform tasks just as you would in a regular class. Notes will be collected and analyzed each day based on your reaction to the content and speed of doing and understanding assigned tasks. You student may be asked questions to help clarify observations and data in an informal interview.

Study Procedures

The study will take place during our VEX Robotics Unit 2 LearnMate lesson and will use student scores, daily observations made by myself, and informal interviews with the students. The study will take three weeks to complete. The data collected will be used to determine how to best change lesson delivery for the benefit of the students.
The following data and information will be collected:

- Scores on quizzes
- Performance on hands-on tasks and the time to complete the task
- Questions for follow-up will consist of the following items:
    - What did you like about the activity?
    - What did you have difficult with during the activity?

Risk and Discomfort

No risk or discomfort is anticipated as a result of participation in this study. This study will be used to help better classroom instruction and involves content already being taught in the Engineering Applications course at Ola High School. The study can also be used by other teachers to help better classroom instruction in a blended instructional model that uses both online teaching resources and teacher-led instruction.

Benefits

This research help determine how to use the LearnMate curriculum to better reach students and increase the students' understanding and deeper learning of the content. This study will allow your student influence the method in which the content is taught based on their experiences with the lessons.

Privacy/Confidentiality

The data collected about your student will be connected to their Henry County Schools issued student ID number and will not be shared externally. Interviews will be recorded on paper only with the student ID number. All identifiable data will only be accessed by the researcher during the course of the study and any documents with the student's ID number will be destroyed following the Henry County Schools procedures at the completion of the study. The project's research may also be reviewed by a committee of professors at the University of Georgia (UGA). Identifiable results of this study will not be released to anyone other than the researcher and the UGA review committee without your written consent unless required by law.

Taking Part is Voluntary

Your student's involvement in this study is voluntary and you may choose to not allow him/her to participate or have your student stop at any time without penalty or loss of benefits to which they are otherwise entitled. If you decide to withdraw your student from the study, the information that can be identified as your student's will be kept as part of the study and may continue to be analyzed, unless you make a written request to remove, return, or destroy the information. Your child's participation in this study will not affect their grades or class standing.

If you have Questions

The main researcher conducting this study is Christie Schmitt, a doctoral student at the University of Georgia. If you have questions about the study, you may contact her at schmitc@uga.edu or at 404-326-0332. If you have any questions or concerns regarding your student's rights as a research participant in this study, you may contact the Institutional Review Board (IRB) Chairperson at 706-542-3199 or at irb@uga.edu.

Research Subject's Consent to Participate in Research:

To voluntarily allow your student to take part in this study, you must sign on the line below. Your signature below indicates that you have read or had read to you this entire Parental Permission Form, and have had all of your questions answered.

Your Student's Name: ____

Your Signature: ____ Date _____________

Your Printed Name: ____

Signature of Researcher: ___________________________________ Date _____________

Printed Name of Researcher: _______________________________

Please sign both copies, keep one and return one to the researcher.

Appendix E

Assent Script/Form for Participation in Research
Effects of eLearning and Blended Instruction on Student Learning

We are doing a research study to determine what instructional method leads to deeper learning when using the LearnMate VEX Robotics curriculum. We are asking you to be in the study because you are currently enrolled in the Engineering Applications course where the LearnMate VEX Robotics content is part of the curriculum taught. If you agree to be in the study, you will perform tasks just as you would in a regular class. Notes will be collected and analyzed each day based on your reaction to the content and speed of doing and understanding assigned tasks. You may be asked questions to help clarify observations and data in an informal interview.

The following data and information will be collected:

- Scores on quizzes
- Performance on hands-on tasks and the time to complete the task
- Questions for follow-up will consist of the following items:
    - What did you like about the activity?
    - What did you have difficult with during the activity?

You do not have to say "yes" if you don't want to. No one, including your parents, will be mad at you if you say "no" now or if you change your mind later. We have also asked your parent's permission to do this. Even if your parent says "yes," you can still say "no." Remember, you can ask us to stop at any time. Your grades in school will not be affected whether you say "yes" or "no."

Data gathered will be used to determine the most effective way to teach the LearnMate VEX Robotics curriculum for depth of knowledge. This study will be part of a dissertation for the University of Georgia and will be published. We will not use your name on any papers that we write about this project. We will only use a number so other people cannot tell who you are.

You can ask any questions that you have about this study. If you have a question later that you didn't think of now, you can contact Christie Schmitt at schmitc@uga.edu.

Name of Child: ______________________________

Parental Permission on File: ☐ Yes ☐ No**
***(If "No," do not proceed with assent or research procedures.)*

(For Written Assent) **Signing here means that you have read this paper or had it read to you and that you are willing to be in this study. If you don't want to be in the study, don't sign.**

Signature of Child: ___________________________ **Date:** __________________

(For Verbal Assent) **Indicate Child's Voluntary Response to Participation:** ☐ Yes ☐ No

Signature of Researcher: ___________________________ **Date:** __________________

Appendix F

UNIVERSITY OF GEORGIA
CONSENT FORM
EFFECTS OF ELEARNING AND BLENDED INSTRUCTION ON STUDENT LEARNING

Researcher's Statement
I am asking you to take part in a research study. Before you decide to participate in this study, it is important that you understand why the research is being done and what it will involve. This form is designed to give you the information about the study so you can decide whether to be in the study or not. Please take the time to read the following information carefully. Please ask the researcher if there is anything that is not clear or if you need more information. When all your questions have been answered, you can decide if you want to be in the study or not. This process is called "informed consent." A copy of this form will be given to you.

Principal Investigator: *Christie Schmitt*
Workforce Education
schmitc@uga.edu

Purpose of the Study
I am doing a research study to determine what instructional method leads to deeper learning when using the LearnMate VEX Robotics curriculum. We are asking you to be in the study because you are currently enrolled in the Engineering Applications course where the LearnMate VEX Robotics content is part of the curriculum taught. If you agree to be in the study, you will perform tasks just as you would in a regular class. Notes will be collected and analyzed each day based on your reaction to the content and speed of doing and understanding assigned tasks. You may be asked questions to help clarify observations and data in an informal interview.

Study Procedures
If you agree to participate, you will be asked to continue to do our VEX Robotics Unit 2 LearnMate lesson as normally done in the Engineering Applications course. I will use student scores, daily observations made by myself, and informal interviews to help gather data to better instruction as we learn about each section in the unit. The study will take three weeks to complete. The data collected will be used to determine how to best change lesson delivery for the benefit of the students.
The following data and information will be collected:

- Scores on quizzes
- Performance on hands-on tasks and the time to complete the task
- Questions for follow-up will consist of the following items:
    - What did you like about the activity?
    - What did you have difficult with during the activity?

Risks and discomforts
No risk or discomfort is anticipated as a result of participation in this study. This study will be used to help better classroom instruction and involves content already being taught in the Engineering Applications course at Ola High School. The study can also be used by other teachers to help better classroom instruction in a blended instructional model that uses both online teaching resources and teacher-led instruction.

Benefits
This research help determine how to use the LearnMate curriculum to better reach students and increase the students' understanding and deeper learning of the content. This study will allow your student influence the method in which the content is taught based on their experiences with the lessons.

Incentives for participation
Your involvement in this study is voluntary and you may choose to not participate or stop at any time without penalty or loss of benefits to which they are otherwise entitled. If you decide to withdraw from the study, the information that can be identified as yours will be kept as part of the study and may continue to be analyzed, unless you make a written request to remove, return, or destroy the information. Your participation in this study will not affect your grades or class standing.

Privacy/Confidentiality
The data collected about your student will be connected to their Henry County Schools issued student ID number and will not be shared externally. Interviews will be recorded on paper only with the student ID number. All identifiable data will only be accessed by the researcher during the course of the study and any documents with the student's ID number will be destroyed following the Henry County Schools procedures at the completion of the study. The project's research may also be reviewed by a committee of professors at the University of Georgia (UGA). Identifiable results of this study will not be released to anyone other than the researcher and the UGA review committee without your written consent unless required by law.

Taking part is voluntary
Your involvement in this study is voluntary and you may choose to not participate or stop at any time without penalty or loss of benefits to which they are otherwise entitled. If you decide to withdraw from the study, the information that can be identified as yours will be kept as part of the study and may continue to be analyzed, unless you make a written request to remove, return, or destroy the information. Your participation in this study will not affect your grades or class standing.

If you have questions
The main researcher conducting this study is Christie Schmitt, a doctoral student at the University of Georgia. If you have questions about the study, you may contact her at schmitc@uga.edu or at 404-326-0332. If you have any questions or concerns regarding your student's rights as a research participant in this study, you may contact the Institutional Review Board (IRB) Chairperson at 706-542-3199 or at irb@uga.edu.

Research Subject's Consent to Participate in Research:
To voluntarily agree to take part in this study, you must sign on the line below. Your signature below indicates that you have read or had read to you this entire consent form, and have had all of your questions answered.

________________________	______________________	______
Name of Researcher	Signature	Date
________________________	______________________	______
Name of Participant	Signature	Date

Please sign both copies, keep one and return one to the researcher.

UNIVERSITY OF GEORGIA
CONSENT FORM
EFFECTS OF ELEARNING AND BLENDED INSTRUCTION ON STUDENT LEARNING

Researcher's Statement
I am asking you to take part in a research study. Before you decide to participate in this study, it is important that you understand why the research is being done and what it will involve. This form is designed to give you the information about the study so you can decide whether to be in the study or not. Please take the time to read the following information carefully. Please ask the researcher if there is anything that is not clear or if you need more information. When all your questions have been answered, you can decide if you want to be in the study or not. This process is called "informed consent." A copy of this form will be given to you.

Principal Investigator: *Christie Schmitt*
Workforce Education
schmitc@uga.edu

Purpose of the Study
I am doing a research study to determine what instructional method leads to deeper learning when using the LearnMate VEX Robotics curriculum. Participants involved in the study are enrolled in the Engineering Applications course where the LearnMate VEX Robotics content is part of the curriculum taught.

If you agree to be in the study, you will be a member of the action research team and will meet at the end of each cycle to review notes and data to ensure that the plan for the next cycle has no bias and is based on data collected.

Study Procedures
Students will be do our VEX Robotics Unit 2 LearnMate lesson as normally done in the Engineering Applications course. I will use student scores, daily observations made by myself, and informal interviews to help gather data to better instruction as we learn about each section in the unit. The study will take three weeks to complete. The data collected will be used to determine how to best change lesson delivery for the benefit of the students.
The following data and information will be collected:

- Scores on quizzes
- Performance on hands-on tasks and the time to complete the task
- Questions for follow-up will consist of the following items:
    - What did you like about the activity?
    - What did you have difficult with during the activity?

If you agree to be in the study, as a team will meet at the end of each cycle (3 times) to review notes and data to ensure that the plan for the next cycle has no bias and is based on data collected.

Risks and discomforts

No risk or discomfort is anticipated as a result of participation in this study. This study will be used to help better classroom instruction and involves content already being taught in the Engineering Applications course at Ola High School. The study can also be used by other teachers to help better classroom instruction in a blended instructional model that uses both online teaching resources and teacher-led instruction.

Benefits

This research help determine how to use the LearnMate curriculum to better reach students and increase the students' understanding and deeper learning of the content. This study will allow the students to influence the method in which the content is taught based on their experiences with the lessons.

Incentives for participation

Your involvement in this study is voluntary and you may choose to not participate or stop at any time without penalty or loss of benefits to which they are otherwise entitled. If you decide to withdraw from the study, the information that can be identified as yours will be kept as part of the study and may continue to be analyzed, unless you make a written request to remove, return, or destroy the information.

Privacy/Confidentiality

The data collected about will be connected to students Henry County Schools issued student ID number and will not be shared externally. Interviews will be recorded on paper only with the student ID number. All identifiable data will only be accessed by the researcher during the course of the study and any documents with the student's ID number will be destroyed following the Henry County Schools procedures at the completion of the study.

All meeting information and feedback from you as the Action Research Team will be kept confidential and individual identifying information will not be shared. All information will be destroyed with the student data.

The project's research may also be reviewed by a committee of professors at the University of Georgia (UGA). Identifiable results of this study will not be released to anyone other than the researcher and the UGA review committee without your written consent unless required by law.

Taking part is voluntary

Your involvement in this study is voluntary and you may choose to not participate or stop at any time without penalty or loss of benefits to which they are otherwise entitled. If you decide to withdraw from the study, the information that can be identified as yours will be kept as part of the study and may continue to be analyzed, unless you make a written request to remove, return, or destroy the information.

If you have questions

The main researcher conducting this study is Christie Schmitt, a doctoral student at the University of Georgia. If you have questions about the study, you may contact her at schmitc@uga.edu or at 404-326-0332. If you have any questions or concerns regarding your student's rights as a research participant in this study, you may contact the Institutional Review Board (IRB) Chairperson at 706-542-3199 or at irb@uga.edu.

Research Subject's Consent to Participate in Research:

To voluntarily agree to take part in this study, you must sign on the line below. Your signature below indicates that you have read or had read to you this entire consent form, and have had all of your questions answered.

_________________________	_________________________	__________
Name of Researcher	Signature	Date
_________________________	_________________________	__________
Name of Participant	Signature	Date

Please sign both copies, keep one and return one to the researcher.

Appendix G

The University of Georgia

Phone 706-542-3199

Fax 706-542-3660

Office of the Vice President for Research
Institutional Review Board

APPROVAL OF PROTOCOL

September 22, 2015

Dear Jay Rojewski:

On 9/22/2015, the IRB reviewed the following submission:

Type of Review:	Initial Study
Title of Study:	Effects of eLearning and Blended Instruction on Student Learning
Investigator:	Jay Rojewski
IRB ID:	STUDY00002468
Funding:	None
Grant ID:	None

The IRB approved the protocol from 9/22/2015.

In conducting this study, you are required to follow the requirements listed in the Investigator Manual (HRP-103).

Sincerely,

Adam Goodie, Ph.D.
University of Georgia
Institutional Review Board Chairperson

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