Development of Leadership Through Hands-On Learning Activities in a Flipped Microprocessors Classroom

Dr. Ricky T. Castles, East Carolina University

Dr. Ricky Castles is an assistant professor in the Department of Engineering at East Carolina University. He is primarily affiliated with the ECU Electrical Engineering concentration. His research work focuses on the use of wireless sensor networks, microcontrollers, and physiological data collection for a variety of applications. His primary interest is in the area of adaptive tutorial systems, but he has ongoing projects in the area of hospital patient health monitoring. He is actively engaged in K-12 outreach through several venues including Summer Ventures, high school STEM day, the N.C. Science Olympiad, a Math Science Partnership grant, volunteer work with a local literacy camp, Boy Scouts Robotics Merit Badge counseling, and teaching the science portion of VBS and children's Sunday School at his local church.

Development of Leadership Through Hands-On Learning Activities in a Flipped Microprocessors Classroom

Electrical engineering students often find microprocessors to be a challenging course since it involves learning to read lengthy datasheets and learning to program at the device level. For two semesters, the Microprocessors course at East Carolina University (ECU) has been taught in a flipped classroom format allowing students to watch online lectures before attending each lecture period and to allow students more opportunities to ask questions and complete learning activities in class. During the scheduled lecture period students are encouraged to work with each other to complete hands-on in-class exercises allowing them to evaluate their understanding of the material presented in the online lecture and the assigned reading. Such in-class exercises may involve answering conceptual questions, writing code, or building circuits. It was observed by the instructor in previous semesters that some students who had a good grasp of course concepts became volunteer student leaders and helped others on their journey to learning course concepts by sharing approaches to solving problems and explaining difficult course concepts to others. It was also observed that some students did not exhibit leadership and relied on lab partners to do much of the work while they were not engaged. Leadership can also go beyond simply helping others, but taking initiative and seeking out assistance, coming prepared for class, learning to delegate responsibilities in a team project, and following through in completing the work expected. Leadership is also demonstrating by recognizing the assets of those in one's team and finding ways to work with others effectively to complete assigned tasks.

In the Fall 2016 semester, course leadership was formalized in the Microprocessors course at ECU. Students were encouraged to engage in leadership through coming to class prepared, helping other students learn, and asking questions when they struggled to understand course concepts. Leadership outside of the class was encouraged through the formation of study groups. The instructor also created a Piazza site for the students to use an online forum allowing them to ask questions and to answer each other's questions. Students were surveyed at the midpoint and end of the semester in order to reflect on their own participation in the course and to evaluate the leadership of their lab partner. Students were encouraged to provide constructive feedback in order to help their lab partner improve and to develop a plan for their own leadership development.

As part of a funded leadership grant, the instructor kept an online journal of each day's activities and the opportunities students had to engage in leadership through each of these activities. One lab session was also videoed to formalize the observation of student leadership. This video was reviewed and coded to assess the types of interactions the students had with their lab partners, other peers, and the instructor. Various leadership qualities were noted including asking questions when having difficulty, seeking help from other students, seeking help from the instructor, and collaboration in teams.

Introduction

The development of engineering students into engineering professionals requires a balance in the development of technical competency along with the ability to clearly communicate ideas, work

well with others, understand one's own strengths and weaknesses, delegate responsibilities to team members appropriately, and exhibit empathy and understanding for the other members of one's team. In many courses, students have opportunities to develop both technical, or "hard skills," and professional or "soft skills."

For several decades, traditional electrical engineering curricula has included courses emphasizing learning to programming microcontrollers. These courses tend to be technically rigorous and often involve working in teams to achieve a common goal. Engineering students easily learn that their technical competency is vitally important to their success in such courses, but when projects are particularly rigorous, students' ability to work well in teams becomes even more critical as the common goals are often more challenging than one student may be able to achieve alone. Being able to communicate well with a teammate or project partner, delegating responsibility, and various shared leadership traits are often key to student success. Despite the importance of the development of these leadership traits, students rarely undergo formal self-reflection on their leadership or their leadership growth while taking such a course.

The work presented herein is an attempt to begin a formalization of the assessment of leadership development in a microprocessors course. Pre and post data on students' self-assessment of their collaborative behaviors, ability to work with others to achieve a common purpose, ability to maintain positive working relationships while respectfully disagreeing, ability to divide labor, fostering of a positive work environment, self-efficacy and reflection, approaching work with honesty and integrity, commitment to task completion, empathy and understanding of others, along with self-assessment of their work to achieve technical competency are presented. Observations from a recorded hands-on lab period are also presented to categorize the behaviors observed by students

The following sections survey the literature on leadership skills necessary for success in engineering, discuss approaches to incorporating leadership development in engineering education curriculum, describe the hands-on activities incorporated in this course, and analyze the student survey data.

Background

What constitutes authentic leadership has been debated by scholars for decades. Based upon an extensive search of the literature Walumbwa et al. [1] developed a framework for leadership including several components: self-awareness, relational transparency, balanced processing, and internalized moral perspective. This framework is based upon the idea that leaders are aware of their own strengths and weaknesses and their own goals, that they can present their true self to others they have relationships with, that they can objectively analyze data and present their findings without bias, and that they have a moral compass that guides their decision making. This model has been validated through cross-cultural data collection in the US and China. Upon validation of their authentic leadership model, Walumbwa et al. expanded their model to include ethical leadership and transformational leadership including the ability of leaders to influence positive change and to act fairly.

Liden et al [2] describe a model of servant leadership with 9 dimensions: being sensitive to others' concerns, creating value for the community, possessing adequate skills to be able to help others, empowering others to succeed and encouraging others, helping subordinates to develop and grow, putting the needs of others above one's own, behaving ethically, making a genuine effort to get to know others and build relationships, and self-sacrifice/servanthood.

Summers et al. [3] identified several "soft skills" as being extremely important for engineers including: writing reports, team leadership, project and time management, and setting of project deadlines. There are many definitions of leadership and lists of skills, knowledge, and abilities expected of leaders. Bowman and Farr [4] describe a leader as "someone who can influence an organized group toward accomplishing its goals." They emphasize that the literature support four key leadership traits: communication, teamwork, cultural awareness, and ethics.

There are various leadership models and debates about what constitutes leadership. Similarly, there is much debate about how to adequately assess leadership development. Evaluation of leadership is also done in many different ways. Zafft et al. [5] applied a competing values framework (CVF) to assess leadership in self-managed teams. In their framework they use a dual-axis approach previously developed by Quinn et al. [6] where one axis has flexibility vs control and the other axis has external vs internal. This framework places an emphasis on producing results, leading change, managing processes and relating to people. Relating to people and leading change are on the more flexible end of the axis and producing results and managing processes are on the control end. Leading change and producing results are measured externally whereas relating to people and managing processes is internal.

Directly Instructing Students About Leadership

At the beginning of the semester when students were given the course syllabus they were pointed to the fact that leadership was 5% of their course grade and would be assessed through surveys and observed participation in the course. The students were told that leadership is important in teams and will be important throughout their careers as they will need to learn to work with a variety of people. Some past examples of good leadership practices in engineering courses were discussed such as helping others learn. Students were told that leadership is about more than just having all the right answers and helping others, but that it involves taking responsibility for their education and that asking good questions and seeking help when they needed it is taking leadership along with coming to office hours, starting assignments early, and following through on their delegated responsibilities by being an active participant in class activities. Other than some initial discussion, there were mentions of leadership throughout the semester when the professor felt that students were not following through on their responsibilities and when some groups were not keeping up with their assigned tasks and deadlines.

Development of Leadership Through Hands-On Laboratory Exercises in Self-Selected Teams

In many academic programs, leadership is not directly included in the curriculum. Students are often encouraged to pursue internships and programs put on by leadership centers. Many universities offer leadership classes and programs outside of the engineering curricula. With the heavy course loads most engineering students take in order to complete their degree, many

simply do not have time in their schedule to take additional courses in leadership and many engineering students are encouraged to pursue industry-based internships that may not focus on leadership development. It should be noted, however, that inside of the traditional engineering curriculum there are opportunities to develop leadership without taking additional coursework.

In this microprocessors class, leaders are not formally assigned and students are allowed to select their own lab partner. Within these organically formed pairings, the students must determine on their own how to work together to achieve team goals such as completing assignments and learning the course material. Evaluating the leadership of self-managed teams is an important topic for the leadership development of engineering students. Based upon the frameworks found in the literature [5,6], a survey was deployed on a pre and post basis to assess the development of leadership through working on laboratory exercises in self-selected pairs.

Laboratory exercises have long been used in engineering education to train students with the proper technical competencies to be successful in their career. Engineering is a profession that must blend theoretical concepts and practical application. The use of hands-on exercises in engineering education laboratories has evolved over the years with technology, but the laboratory remains one of the most important places where students learn not only technical skills, but also how to work with people, how to present data properly, and how to develop strategies to accomplish a shared goal. Feisel and Rosa [7] indicate that the objectives of laboratory exercises are not clearly defined in many cases, but they outline 13 broadly applicable objectives that may be applied to almost all engineering education laboratories. Their 11th objective is in the area of teamwork where they suggest that engineering laboratories should teach students to "work effectively in teams including structure individual and joint accountability, assign[ing] roles responsibilities, and tasks, monitor[ing] progress, meet[ing] deadlines, and interegrat[ing] individual contributions into a final deliverable"

Hands-on Activities

Felder et al. [8] suggest several teaching methods that work. One is the promote active learning in the classroom to involve students in the learning process and to take them off the sidelines as passive content receivers and to directly engage them by having them do calculations, draw flowcharts, complete solutions to problems, etc.

When the microprocessors course at ECU was first developed in 2013 it was developed with laboratory exercises as the central component. Weekly lecture periods focused on theoretical preparation for the weekly laboratory exercise. It was discovered that in this format the students were not actively engaged and seemed ill prepared in many cases for the laboratory exercises. Students also had difficulties completing many laboratory exercises in the allotted time period. In Fall 2015, the microprocessors course at ECU was converted into a flipped classroom model in order to allow for more hands-on activities to be completed during the lecture period and to allow students to have more time to complete lab assignments with the instructor present since they could do some hands-on preparation for the lab exercise in the lecture period and they could be allotted time in the lecture period after the lab to complete unfinished lab assignments. Students worked in pairs throughout the semester to complete weekly lab assignments that

increased in complexity as the students become more technically competent. In the early parts of the semester students were given template code and asked to make small modifications. As the semester progressed students were given no sample code and were required to develop all code on their own. Each day in class the students were given an in-class exercise to complete that reinforced the information presented in online lectures. Some of these exercises involved writing subroutines, looking up information in datasheets, building circuits, or answering conceptual questions.

Assessment of Leadership

Various methods have been deployed to assess leadership and the development of leadership over time. Some studies have focused on particular aspects of leadership and other have taken a more general approach. In [9] a measure of self-awareness is described through an autobiographical assignment in which students have to reflect upon their own skills and abilities through interviews of people who know them well, analysis of the feedback received, and writing an autobiographical sketch synergizing the feedback and their own beliefs about their strengths and weaknesses.

Some mixed methods studies have combined self-reflection through surveys combined with external observation by faculty members or other leadership experts [10]. Some leadership programs have assessed their development of leadership by comparing the job offers their graduates have gotten including starting salary and position type [11]. A module-based approach to teaching leadership within the engineering curriculum has included modules assessed through writing samples and with discussion groups [12].

In this study the students took an online multiple choice assessment twice during the semester to measure growth over time and they also were asked to evaluate their own leadership through short answer questions. A video of one laboratory period was also taken to observe how students work together to accomplish a shared purpose with a lab partner. More details on the experimental design are described in the next section.

Study Design and Research Question

Based upon informal observation of leadership development in previous semesters and a survey of the literature on the definition of leadership and methods for assessing leadership, two surveys were developed to determine what leadership skills students developed based upon their experience working in teams and completing hands-on activities. It was expected that students who are successful in the course either already have the ability to work well with others prior to taking this course or learn how to work well with others as a result of taking this course. It is expected that students learn better communication skills, that they learn to delegate responsibility for completion of assignments, that they learn time management skills and how to meet deadlines, and that they learn ways to access the information they need to be successful in completing their assignments.

A survey early in the semester was given to determine students' prior leadership abilities and a post survey was given at the end of the semester to determine leadership gains. A second survey

was deployed at the same time as the pre and post surveys to allow students to assess their own leadership and to provide positive feedback and constructive criticism to their lab partner. Pre and post surveys are a typical method used to assess leadership development and have been used in several prior studies on leadership development [10].

Student Survey Results

Students were surveyed early on in the semester and then at the end regarding various behaviors and attitudes indicative of positive team building and leadership development. A total of 23 students took the pre survey and 26 took the post survey. Numbers in each of the following tables are percentages in order to account for the different sample sizes. This students in the course surveyed are typically third-year undergraduates and have already engaged in several hands-on classes and classes with team-based assignments prior to enrollment in this course, so it is understood that many of them have already learned how to work together as a team, established their own work ethic, and learned to use some of their technical competency to solve problems. The goal of this course and formalizing assessment of leadership was both to establish a baseline of leadership development going into the course and to determine growth in leadership during the semester. The following subsections break down survey questions into several categories to assess leadership development in different areas.

Collaboration

Feeling like your contributions are heard in a group helps students gain confidence. A leader should be a good listener who can understand the concerns and contributions from other team members. As can be seen in Table 1, at the beginning of the semester most students found it important to listen to their team members and a similar portion of students indicated that they either often or almost always listen to their group members at the end of the semester. Leaders are also encouraging of others and help to boost team morale when faced with difficult circumstances. In this course, many students found the work challenging and weaker teams would sometimes give up on a project whereas the stronger teams believed they could complete the assignment and encouraged each other to persevere. While most students found it important to encourage their team members throughout the semester, the number of students indicating that they often or almost always encouraged members of their group increased from 74% to 88% from the pre survey to the post survey; additionally the students emphasized promoting self-confidence more at the end of the semester than they did at the beginning with a rise from 78% indicating they often or almost always actively promote self-confidence at the beginning of the semester to 89% at the end of the semester indicating that they regularly promote self-confidence. This is possibly indicative of how the students grew together working with their team as the assignments became increasingly difficult over the course of the semester. Leaders are able to instill trust in others and at the end of the semester 96% of students indicated that they focused on building trust between group members compared with 74% at the beginning of the semester. Good leaders are also able to identify the strengths and weaknesses of team members and delegate tasks in such a way as to make best use of the strengths of each team member. At the end of the semester 85% of students indicated that they often or almost always strive to bring out the talents that are unique to each individual in the group, up from 60% at the beginning of

the semester. This is indicative that students have learned how to get the most from each other's strengths. Of concern at the end of the semester is that the number of students indicating that they fully commit to and deliver what is expected dropped slightly with 8% of students on the post survey being neutral on this question while all students indicated that they often or almost always commit and deliver on the pre survey. This may be because many students toward the end of the semester had a hard time keeping up with deadlines and in some cases failed to deliver what they were expected to complete in a timely manner. More students are also focused on bringing out the talents unique to each individual and encouraging the expression of differing viewpoints at the end of the course than did earlier which likely points to improved group dynamics over time and better understanding of each other's strengths.

Table 1 Survey results from a pre and post survey of microprocessors students regarding their collaboration with other students in their lab groups. Results are indicative of the percentage of students responding to each answer option.

	Rarely		Sometimes		Neutral		Often		Almost Always	
	pre	post	pre	post	pre	post	pre	post	pre	post
I actively listen to members in the group	0	0	0	0	4	8	30	38	65	54
I actively encourage members in the group	4	0	4	0	17	12	35	50	39	38
I actively promote self-confidence in others	0	0	4	0	17	12	39	35	39	54
I focus on building trust between all the group members	0	0	4	4	22	0	22	46	52	50
I strive to bring out the talents that are unique to each individual in the group	9	0	9	0	22	15	30	31	30	54
I actively encourage the expression of differing viewpoints in the group.	0	0	4	0	9	4	48	42	39	54

Shared Purpose

As can be seen in Table 2, students indicated early on in the semester that they regularly work toegether to establish a shared vision for projects and work well with group members to make decisions. All students indicated at the end of the semester, a significant increase from the beginning of the semester (100% vs 74%), that they often or almost always work with group members before starting a project to establish common ground. This is indicative that students are learning better how to plan out their time when projects become more difficult later in the semester. A similar number of students at the beginning and end of the semester indicated that they effectively work with group members in decision making and inspiring others to commit to achieving a shared purpose.

Table 2 Survey results from a pre and post survey of microprocessors students regarding their ability to work with others students to accomplish a shared purpose. Results are indicative of the percentage of students responding to each answer option.

	Rarely		Sometimes		Neutral		Often		Almost Always	
	pre	post	pre	post	pre	post	pre	post	pre	post
I do my part to facilitate the development of a shared project vision that is influenced by the views of all group members	0	0	0	0	9	0	61	58	30	42
I use group decision-making (consensus) to identify group roles and priorities	*0*	*0*	*0*	*0*	*4*	*8*	*48*	*38*	*48*	*54*
I work with other group members to establish common ground (similarities) before beginning a project	*0*	*0*	*4*	*0*	*22*	*0*	*35*	*62*	*39*	*38*
I effectively work with other group members in decision making	*0*	*0*	*0*	*0*	*0*	*4*	*43*	*46*	*57*	*50*
I inspire my group members to commit to achieving the shared purpose of the group	*0*	*0*	*4*	*0*	*9*	*15*	*48*	*38*	*39*	*46*

Disagreement with Respect

Over the course of the semester as team assignments became more challenging and there were multiple ways to solve the same problem it became clear that students had differences of opinions about how to approach solving the assignment problems. In some cases this led to disagreements between project partners and frustration. Good leaders are able to handle conflict constructively and use differences of opinion to strengthen the project outcomes by incorporating other people's ideas rather than letting conflict derail the project. As can be seen in Table 3, survey results indicate that students recognized and tried to understand and respect others' viewpoints before the class and taking this class did not change that.

Table 3 Survey Results from a pre and post survey of microprocessors students regarding how to respectfully disagree. Results are indicative of the percentage of students responding to each answer option.

	Rarely		*Sometimes*		*Neutral*		*Often*		*Almost Always*	
	pre	post	pre	post	pre	post	pre	post	pre	post
I recognize that group members have different viewpoints	*0*	*0*	*0*	*0*	*0*	*0*	*30*	*42*	*70*	*58*
I strive to understand the viewpoints of others in my group	*0*	*0*	*0*	*0*	*4*	*8*	*39*	*48*	*57*	*44*
I respect the viewpoints of others in my group	*0*	*0*	*0*	*0*	*9*	*4*	*35*	*46*	*57*	*50*
I strive to help create an environment where everyone feels safe to share his/her viewpoints	*0*	*0*	*0*	*0*	*9*	*4*	*35*	*38*	*57*	*58*
When I express a difference of opinion with other students, I assert my position without putting them down or putting down their ideas.	*0*	*0*	*0*	*0*	*5*	*8*	*41*	*46*	*55*	*46*
I treat others with dignity	*0*	*0*	*0*	*0*	*0*	*0*	*35*	*27*	*65*	*73*

Division of Labor and Dedication to Project Completion

On extensive projects it is impossible for one person to do all of the work and be successful. The best leaders are able to delegate responsibilities to other and can recognize the strengths each team member brings to the table in order to delegate responsibilities appropriately. In Table 4 it can be seen that students realize the importance of division of labor in group assignments and are able to clearly communicate the expectations they have for the roles they and their lab partner will play in an assignment. In most teams it was observed that this was the case and partners were both equal contributors to attaining the group goals while learning to divide labor in such a way as to maximize the use of each other's strengths. Perhaps more important that appropriately dividing up labor amongst team members is following through on the tasks that are assigned. At the end of the semester, some students indicated that they do what they say that will do slightly less often that at the beginning of the term while more students indicated that they almost always follow through. Most students indicate that they almost always put in enough time and effort to complete team projects and that they take their work seriously.

Table 4 Survey results from a pre and post survey of microprocessors students regarding how they divide up labor on a project. Results are indicative of the percentage of students responding to each answer option.

	Rarely		*Sometimes*		*Neutral*		*Often*		*Almost Always*	
	pre	post	pre	post	pre	post	pre	post	pre	post
I work with the group to make sure that individual group member roles and responsibilities are identified before starting a project	*0*	*0*	*0*	*4*	*9*	*0*	*48*	*42*	*43*	*54*
I work with the members of the group to make sure that members are clear about their own roles and the roles of others in the group	*0*	*0*	*0*	*0*	*4*	*0*	*43*	*54*	*52*	*46*
I work with members of the group to identify our individual strengths and how we can each contribute to the group effort	*4*	*0*	*0*	*0*	*4*	*4*	*52*	*50*	*39*	*46*
I do what I say I will do	*0*	*0*	*0*	*0*	*4*	*12*	*48*	*35*	*48*	*54*
I put out enough effort to complete my assigned group tasks	*0*	*0*	*0*	*0*	*9*	*8*	*39*	*42*	*52*	*50*
I do my fair share of work in group projects	*0*	*0*	*0*	*0*	*4*	*4*	*39*	*38*	*57*	*58*
I take seriously my responsibility to complete my individual tasks that contribute to the completion of a project	*0*	*0*	*0*	*0*	*0*	*4*	*39*	*35*	*61*	*62*
I invest adequate amounts of time needed to complete my assigned tasks	*0*	*0*	*4*	*0*	*4*	*0*	*57*	*50*	*35*	*50*
I complete the individual tasks assigned to me in a group project	*0*	*0*	*0*	*0*	*4*	*4*	*39*	*38*	*57*	*58*
I invest the effort with other team members to put the pieces of the project together	*0*	*0*	*4*	*0*	*4*	*4*	*35*	*42*	*57*	*54*
I fully commit to and deliver what is expected of me in a group project	0	0	0	0	0	8	57	50	43	42

Learning Environment

Effective leaders establish a good working relationship for the team to be productive. They get to know the members of their team and work to establish an effective way to communicate with the team. The find common ground on team projects and build trust relationships so that every team member can count on others to contribute to the team positively based upon their unique set of skills and abilities. Showcased in *Table 5* are the results of pre and post survey questions regarding the establishment of a cohesive learning environment where team members know each other, value each other's strengths, and establish positive communication. Students have similar responses about getting to know each other at the beginning and end of class. Growth was shown in establishing trust in other members and building an effective communication process with 96% of students at the end of the semester indicating that they often or almost always work to build a communication process that makes it safe for members in the group to say what is on their mind (compared with 83% at the beginning of the semester). Once the projects became more difficult, students were not able to complete all work by their own effort and had to trust that their partner would make good contributions and that when conflict arose they could communicate effectively to resolve it and indicate their thoughts about how to approach each problem. At the end of the semester more students indicated that building trust was important to them and the importance of this grew from the beginning of the semester

Table 5 Survey results from a pre and post survey of microprocessors students regarding how they establish a positive learning environment to work together

	Rarely		*Sometimes*		*Neutral*		*Often*		*Almost Always*	
	pre	post	pre	post	pre	post	pre	post	pre	post
I work with members of the group to get to know each other	*0*	*0*	*0*	*0*	*9*	*12*	*57*	*46*	*35*	*42*
I strive to build with group members a communication process that makes it safe for members in the group to say what is on their minds	*0*	*0*	*0*	*0*	*17*	*4*	*26*	*46*	*57*	*50*
I work with group members to establish common ground among all group members before beginning a group project	*0*	*0*	*4*	*4*	*9*	*4*	*39*	*42*	*48*	*50*
I approach collaboration by relying heavily on building trust among group members	*4*	*0*	*4*	*0*	*13*	*16*	*43*	*48*	*35*	*36*
I demonstrate to the group members that I believe that trust is the foundation for successful collaboration and	*4*	*0*	*9*	*0*	*13*	*12*	*35*	*46*	*39*	*42*

practice that belief in my interactions										

Self-knowledge

One of the most important skills in being a productive team member is recognizing one's own priorities, strengths, and weaknesses. As can be seen in *Table 6*, students have increased the frequency at which they reflect on their own beliefs, values, and attitudes with 62% indicating that they almost always do this compared with 39% who stated they almost always do this at the beginning of the term. Perhaps simply being required to take this survey caused them to do more reflection than they may have otherwise. Students also are more often aware of and honest with themselves about their own knowledge and strengths. At the end of the semester 65% indicated that they are almost always honest with themselves about what they do and do not know compared with 48% at the beginning of the semester. More students also indicated that they were aware of their own talents, strengths, limitations, and weaknesses even though a few were less willing to admit when they did not know or understand something.

Table 6 Pre and post survey results for students in a microprocessors course regarding their self-reflection and knowledge of their own abilities and strengths

	Rarely		*Sometimes*		*Neutral*		*Often*		*Almost Always*	
	pre	post	pre	post	pre	post	pre	post	pre	post
I examine and reflect on my own beliefs, values, and attitudes	*0*	*0*	*0*	*0*	*4*	*8*	*57*	*31*	*39*	*62*
I am honest with myself about what I know and don't know	*0*	*0*	*4*	*0*	*4*	*4*	*43*	*31*	*48*	*65*
I deeply understand my own talents/strengths and limitations/weaknesses	*0*	*0*	*0*	*0*	*17*	*8*	*48*	*44*	*35*	*48*
I recognize when my interactions with others are not respectful	*0*	*0*	*9*	*4*	*17*	*16*	*39*	*40*	*35*	*40*
I am willing to admit when I don't know something or don't understand	*0*	*0*	*4*	*0*	*0*	*8*	*39*	*27*	*57*	*65*

Empathy/Understanding of Others

Effective leaders have empathy for those who see things from a perspective different from their own and put themselves in another person's place. They are also able to be patient with those who may be slower to learn new things than they are and genuinely listen to the concerns of others. Based upon the survey results presented in Table 7, most students realize the importance of empathy. Students in some cases have difficulty showing patience with those who are slow to learn or catch on, but in all other cases both before and after the class students are indicating that

they exhibit empathy for others. Survey results indicate that students have made improvements in listening to others and are more likely to genuinely listen to others and embrace alternate viewpoints.

Table 7 Pre and post survey results indicating student's empathy and understanding of others

	Rarely		*Sometimes*		*Neutral*		*Often*		*Almost Always*	
	pre	post	pre	post	pre	post	pre	post	pre	post
I look at a perceived problem from different angles before moving forward	*0*	*0*	*4*	*4*	*13*	*4*	*35*	*54*	*48*	*38*
I am patient with team members and others who are slow to learn/catch on	*0*	*0*	*4*	*0*	*9*	*12*	*39*	*35*	*48*	*54*
I genuinely listen to others in the group	*0*	*0*	*0*	*0*	*4*	*8*	*43*	*31*	*52*	*62*
I demonstrate the capacity to put myself in another person's place	*0*	*0*	*9*	*4*	*4*	*4*	*52*	*54*	*35*	*38*
I strive to understand other group members' frame of reference.	*0*	*0*	*0*	*4*	*4*	*8*	*52*	*42*	*43*	*46*

Competence

Leaders in engineering must be technically-competent and must be able to apply their knowledge to solve problems. Since this is a class based upon programming and circuit design in a digital environment, logic and brainstorming were critical to student success and will be for engineers throughout their careers. Each lab and hands-on exercise required students to apply new knowledge gained through lectures and reading assignments to an activity or assignment. From these assignments it was hoped that students would see how such knowledge could be applied to a variety of scenarios beyond the scope of the course. A commitment to lifelong learning is important for engineers to remain competent in their field. The results depicted in Table 8 indicate that students believe that they are often or almost always using appropriate logical methods to solve problems. Students are investing in their own knowledge and are doing more reflection on how to apply what they have learned after having taken this course.

Table 8 Pre and post survey results regarding students ability to apply their knowledge competently and to understand where the knowledge gained in this course can be applied more broadly

	Rarely		*Sometimes*		*Neutral*		*Often*		*Almost Always*	
	pre	post	pre	post	pre	post	pre	post	pre	post
I use brainstorming and logic to strategically solve problems/issues	*0*	*0*	*0*	*0*	*0*	*0*	*43*	*46*	*57*	*54*
I apply my background knowledge to the content of this course	*0*	*0*	*0*	*0*	*4*	*4*	*39*	*31*	*57*	*65*
I seek to be a deep learner-interest in learning rather than studying for a particular grade	*0*	*0*	*0*	*0*	*17*	*15*	*26*	*23*	*57*	*62*
I invest in learning new knowledge and skills to better myself personally and professionally	*0*	*0*	*0*	*0*	*9*	*12*	*43*	*31*	*48*	*58*
I reflect on ways to apply what I am learning beyond this setting	*0*	*0*	*0*	*0*	*14*	*4*	*45*	*46*	*41*	*50*

Open-ended Responses

In addition to multiple-choice questions, students were also asked a series of open-ended questions regarding what they learned over the semester. Several of their responses are indicated below. There is a consistent theme in the students remarks that many of them learned more about how to properly communicate with their lab partner throughout the course in terms of communicating expectations, discussing ideas, delegating responsibility, and following through on assignments. Students also improved their work ethic and preparation for each class.

Students were asked about how they adjusted from the middle of the semester to the end with the following questions

Since the midterm survey, do you feel that you have improved your preparation for lectures and labs? What have you improved about how you prepare for class?

Out of 18 completed end of semester surveys, 12 students (67%) reported some change they had made in their study habits over the course of the semester indicative that they were developing more responsibility for their education and developing positive habits. Three students reported watching the online video lectures more often and two of those students reported taking notes while watching the online videos instead of passively watching without taking notes. Three students reported spending more time on homework and lab assignments. One student reported that he started the assignments earlier so he would have more time to ask questions. One student

reported getting a tutor for the class and going to tutoring twice per week; this student's grade improved tremendously over the course of the semester with a 30 percentage point improvement from the first test to the second test. Students reported learning how to get more organized with course material and asking the professor more questions in class and during office hours. One student who had a major issue with skipping class reported that he was missing fewer class meetings toward the end of the semester.

Students were asked the following question about how they learned to become a good lab partner.

What have you learned this semester about how to be a good lab partner?

Out of the 18 respondents completing the post survey, 15 students reported learning something about how to be a better lab partner. Two of the students who did not report learning anything about being a better lab partner were already in a very productive team and had good leadership skills since they were both military veterans and non-traditional students. Six students emphasized the importance of communication. Students also talked about the importance of developing a strategy for completing assignments including delegating responsibility, working together on all tasks, and engaging in assignments often. Four students mentioned the importance of following through with individual responsibilities on assignments. One student mentioned the importance of building a relationship with his lab partner and approached this by spending time getting to know his lab partner outside of class. One student commented on how being a good lab partner means in some instances allowing the other person's ideas to prevail and not just pushing your own way to solve a problem. Some direct quotes from the students follow:

> "I would say that this semester taught me that being a good lab partner doesn't always mean that you have to contribute things in your own way. Sometimes the best approach may be the other person's approach, and learning to help with that instead of making it about your solution is something that I learned this semester. "
>
> "Communication and responsibility are always important in group settings. Being able to talk with your partner about what is going on and following through with it is important to succeed."
>
> "I have learned that being a "good" lab partner is all about communication with each other. With better communication comes better understanding of the material. It also allows for delegation of the work needing to be done for each project."
>
> "I learned that working on assignments together instead of splitting the assignment into parts and assuming responsibility of my part is better for both mine and my partner's understanding of the material. I also learned that spending time with your partner outside of class working on the class was important for our relationship as lab partners. We became more comfortable with each other and it became easier for us to communicate."

What leadership skills do you feel you have developed as a result of taking this course?

When asked about the leadership skills students developed as part of this class, many different items were mentioned. Five students indicated they learned the most about communication with their lab partner, the instructor, and other students. One student specifically mentioned learning how to be more respectful in communication with his lab partner. Four students indicated that they learned how to ask for help better and sought help from the instructor and their peers. One student mentioned being more honest about his own abilities and identifying when he did not understand something. Two students reported developing the ability and desire to help other students be successful. One student mentioned developing confidence in his own abilities. Two students indicated improved ability to understand problems and to solve them. One student mentioned improving on procrastination on starting or completing assignments. Some quotes from students follow:

> "I feel that I learned how to keep a positive mentality throughout any problems we would have in writing code for an assignment. If we were ever frustrated about something we did not understand, I would make sure to instill confidence in both of our abilities and encourage asking for help. I believe that this helped keep our group together and positive. I also learned that being honest about not understanding something and asking for help was better than trying to figure it out on my own."
>
> "Delegating tasks and not doing everything myself"
>
> "In the beginning of the year, <the instructor> said that leadership is not always having the answer but knowing when to ask questions when fuzzy on material. That is a large aspect of my leadership skills I learned this semester because prior to this class I assumed that it only meant having the answers and taking charge but it makes sense because it takes a real leader to know when he/she needs help."

Video-based Analysis

A video was recorded of one of the hands-on laboratory sessions in the course. This lab session lasted for 2 hours. The task assigned to students during that week's laboratory exercise centered on using a three-axis accelerometer and using analog-to-digital conversion and an LCD panel to display the digital representation of the voltage coming from each access and to display the voltage level that represents. Students were to implement some simple mathematics in their program to convert the digital value to a voltage. They were to then complete a worksheet recording the voltages from the accelerometer with the accelerometer in different positions.

On the day of the lab, a video recording was made to observe the leadership skills the students demonstrated and to document some issues that indicate a lack of leadership. Several key areas of leadership were documented:

1. Punctuality- Which students were on time to class
2. Task Engagement- Which students were actively writing code and testing it on their trainer kits

3. Discussion-Which students were working with their lab partners and discussing approaches to code
4. Seeking assistance-Which students asked the instructor questions during the lab period or sought help from a non-lab partner neighbor
5. Tracking course material-Which groups were on task and which were still working on an old lab assignment

It was observed on the video that out of a class of 20 students, four students were tardy to lab and one student was absent. This indicates students who are not taking the responsibility to commit to the class with their punctuality.

Throughout the period many teams were actively engaged in working on the task. Out of the 10 student teams, most students were talking with their lab partner and working to develop a coded solution. Unfortunately, by this point in the semester several groups were behind and several groups were working on the previous week's laboratory assignment instead of the current week's assignment. It was observed that in one group neither of the lab partners were discussing their work with each other. In a few cases students were talking between teams to help each other achieve goals. Most all groups asked the instructor a question at least once during the lab exercise.

The leadership behaviors exhibited by students in the online video correlated with students' overall course performance. Students who scored highly on the written exams and who earned the highest grades were actively engaged with the current assignment, worked efficiently during the lab period, and in some cases completed their lab assignment early and were able to leave the lab before the end of the period. Students who were less engaged in the laboratory and who were working on older assignments were often students who scored lower on exams.

Conclusions

By formally assessing leadership development in a hands-on microprocessors course, it was determined which leadership skills students were able to develop over the course of the semester. Students learned about communication, delegation of task responsibility, and respect for each other. Students developed better self-efficacy and were able to identify their own strengths and to recognize the strengths of their lab partner and other students in the class. Students learned the importance of following through on tasks and completing the work delegated to them in a timely manner. Although some students did not report gains in leadership, most students learned about how to work in teams to complete assignments. This study shows one technique for analyzing student leadership development within the context of a hands-on course and shows that dividing students into teams and allowing them to work on technically rigorous hands-on tasks allows leadership skills to emerge as students work toward a common purpose.

References

1. Walumbwa, F. O., Avolio, B. J., Gardner, W. L., Wernsing, T. S., & Peterson, S. J. (2008). Authentic leadership: Development and validation of a theory-based measure. *Journal of Management*, 34(1), 89-126.
2. Liden, R. C., Wayne, S. J., Zhao, H., & Henderson, D. (2008). Servant leadership: Development of a multidimensional measure and multi-level assessment. *The leadership quarterly*, *19*(2), 161-177.

3. Summers, Michele, Beverly Davis, and Cynthia Tomovic. "When engineering and technology skills are not enough: Engineering leaders out of their element." *Proceedings of the CIEC Conference*. 2004.
4. Bowman, Bruce A., and John V. Farr. "Embedding leadership in civil engineering education." *Journal of professional issues in engineering education and practice* 126.1 (2000): 16-20.
5. Zafft, Carmen R., Stephanie G. Adams, and Gina S. Matkin. "Measuring Leadership in Self-Managed Teams Using the Competing Values Framework." *Journal of Engineering Education* 98.3 (2009): 273-282.
6. Quinn, Robert E., and John Rohrbaugh. "A spatial model of effectiveness criteria: Towards a competing values approach to organizational analysis." *Management science* 29.3 (1983): 363-377.
7. Feisel, Lyle D., and Albert J. Rosa. "The role of the laboratory in undergraduate engineering education." *Journal of Engineering Education* 94.1 (2005): 121-130.
8. Felder, Richard M., et al. "The future of engineering education II. Teaching methods that work." *Chemical Engineering Education* 34.1 (2000): 26-39.
9. Nino, D. (2016) Developing Engineering Leaders Using a Reflective Autobiographical Exercise *Proceedings of the 2016 ASEE Annual Conference and Exhibition* New Orleans, LA. June 2016
10. Mendoza, Luisa R., Orea-Amador, L., & Kendal, M. (2016) Mixed Method Study of the Evolution of Leadership Traits during a Leadership Experience. *Proceedings of the 2016 ASEE Annual Conference and Exhibition* New Orleans, LA. June 2016
11. Schuhmann, Richard. J. et al. (2015) Engineering Leadership Education-The Path Forward *Proceedings of the 2015 ASEE Annual Conference and Exhibition* Seattle, WA. June 14-17, 2015
12. Stephens, Clinton & Friesen, Katherine (2015) Building Piece by Piece: Teaching Engineering Leadership Through Integrated Modules *Proceedings of the 2015 ASEE Annual Conference and Exhibition* Seattle, WA. June 14-17, 2015.