The Influence of Teaching Assistants in an Undergraduate Engineering Laboratory Course

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***Abstract*— At large universities, it is common for a teaching assistant (TA) to have a prominent role in an undergraduate laboratory course. Therefore, they have a direct impact on the experience of the students in the laboratory. The training, background, and motivation of these TAs vary. The motivation of the students in the course also varies. This study sought to answer this question: how do TAs influence the students' learning experience in a required laboratory course? In the fall semester of 2014, at a large public university in the Midwest, TAs were observed in the laboratory sections of a required, junior-level course in general engineering. Additional data were obtained from student reflections in each laboratory report and an end of semester survey. Reflections were also collected from students enrolled in the same course in the spring semester of 2015. Finally, at the end of the spring semester, students from both semesters participated in a focus group about the course. The data were analyzed using values coding, which identified values, beliefs, and attitudes expressed by students about the course or the TA. Due to the TAs' prominent role in the laboratory setting, they had a direct impact on the students' experience in the laboratory. However, the impact was different among students who had the same TA. Some of the negative impacts reported were unclear expectations for success, inconsistent grading, and being unavailable or unhelpful. Some positive impacts were also reported, including being helpful and patient. Since data were only collected from the students, the motivations of the TAs were not clear. In this study, there was evidence that the TAs had a negative impact on the learning experience for some students, but not all. To reduce the negative impact in future courses, systems of training, assessment, and accountability for TAs could be improved.**

Keywords—instructional laboratories, graduate teaching assistants, undergraduate students

I. Introduction

Instructional laboratories are a common experience for all undergraduate students majoring in engineering, because laboratory experiences help link theory to practice [1]. Traditional on-campus laboratories require engineering departments to address challenges such as such as budget constraints, space limitations, class size, and limited teaching resources [2-5]. One common way to add teaching resources to laboratories is to use teaching assistants (TAs). The role of these TAs varies greatly between courses, departments, and universities. In some cases, the teaching assistants provide additional instructional support answering questions as they arise. At the other extreme, TAs are responsible for the entire laboratory experience and are the only instructional support during schedule laboratory sessions. The latter case describes the laboratories analyzed in this study. For this laboratory, the laboratory manager (university staff) provided experiment instructions and trained the TAs the week before each scheduled laboratory session. The TAs were also responsible for holding office hours and grading all of the laboratory assignments. Because of this high-level of interaction and control over the laboratory sections, the TAs had a direct impact on the students' experience in their laboratory.

II. Background

Instructional laboratories are included in undergraduate curriculum for undergraduate engineering majors. The learning outcomes and format vary between courses, departments, and universities. Instructional staff, including faculty, teaching assistants, and/or laboratory managers are responsible for developing and maintaining the instructional laboratories that students use in each course. This paper focuses on the laboratory experience of the students and the role of TAs in that experience.

A. Laboratory Experiences

Laboratory experiences are central to many undergraduate engineering programs. Instructional laboratories are a common way for programs to meet ABET Outcome 3b (ability to design and conduct experiments, analyze and interpret data) [6]. Traditionally, students are provided a set of instructions to conduct a prescribed experiment, collect the specified data, complete an analysis, and write a report. Feisel and Rosa [1] further define 13 objectives for engineering instructional laboratories. These objectives include models, data analysis, teamwork, safety, and learning from failure. Based on these objectives and working with real equipment, students are introduced to problems that prepare them for industry [7].

Previous studies have also shown that the laboratory environment should be conducive to learning. Specifically, when students are frustrated, their learning can be impeded [8]. Instead, the laboratory should be a place for students to be supported in their learning and understand the value of what they are learning [9].

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B. *Teaching Assistants*

Teaching assistants have become common in many undergraduate courses and laboratories [10]. The training that teaching assistants receive varies greatly between institutions and even departments [10-28].

Previous studies have shown that there are specific qualities that students' would like to see in their TAs: being available and approachable, the ability to explain, and feeling like the TA is invested in the students' success [29]. From the TAs' perspective, having autonomy and the ability to make decisions in their course increases their motivation [30]. Faculty support and training can also have a positive impact on the TAs' experience [15]. Additional factors that influence TAs' motivation include training, previous experience, appointment structure, students, and teaching colleagues [31]. Many factors have been shown to influence TAs' interactions with students.

III. Purpose

This paper explores an emergent theme from a previous study conducted to compare two types of laboratory equipment. During the analysis of the initial study it was observed that there were many unprompted comments about the TAs who taught the laboratory sections. From these comments, additional questions about the impact of TAs in the laboratory were asked.

IV. Method

A. *Context of the course*

Control Systems (GE 320) was selected for the original study. It is the first of two required control systems courses for all general engineering majors at the University of Illinois at Urbana-Champaign. The GE 320 topics include Laplace transforms, linear mechanical and electrical system modeling, transfer functions, system stability, and feedback control design to specifications. The GE 320 prerequisites are Introductory Dynamics, Intro[duction] to Differential Equations, and either completion or concurrent enrollment in Analog Circuits and Systems. The majority of the students registered for GE 320 are general engineering majors, but students in other majors such as mechanical engineering and industrial engineering can also enroll in the course. Most students take GE 320 during their junior year or fall semester of their senior year. In the fall of 2014, 59 students enrolled in the lecture and one of six laboratory sections. Fifty-three of these students consented to participate in this study. In the spring of 2015, 33 students enrolled in the lecture and one of four laboratory sections. Twenty-one of these students consented to participate in this study. The author was not involved in teaching the course during the study.

During the 16-week semester, each student attended six two-hour laboratory sessions, each with a different experiment to complete. The first two experiments introduced the equipment, the next two experiments developed models of the DC motor, and the fifth experiment implemented three different position control algorithms. In the last experiment, the students developed a model and controller for a new system [32]. The learning objectives of the laboratory experiments were the same as previous semesters. The laboratory experiments were the same for both semesters. Students worked in groups of two (or three if necessary) to complete the experiments. However, they submitted individual answers to pre-lab and post-lab exercises and individual two-page laboratory reports.

B. *Procedure*

In the 2014-2015 academic year, with approval from the Institutional Review Board (IRB #15116), quantitative and qualitative data were collected to learn about the students' experiences in the laboratory for the GE 320 course.

The qualitative data included laboratory observations, reflections from students' individual laboratory reports, open-ended questions on the satisfaction survey, and focus groups. Data from the entire class were collected and data from students who had not consented to participate in the study were removed. All of the remaining qualitative data were transcribed from the original source. Then all names were replaced with pseudonyms.

During the analysis of this qualitative data recurring information about teaching assistants emerged. Therefore, an additional question was asked: how do TAs influence the students' learning experience in a required laboratory course? To answer this question, the qualitative data were coded using values coding to identify students' values, attitudes, and beliefs about the TAs in their laboratories [33]. The quantitative data collected in the original study did not provide any useful information to answer the follow-up question about TAs.

V. Results

Students in both semesters provided both positive and negative feedback about the teaching assistants (TAs) and logistics within the laboratory sessions. Based on the feedback, there is evidence that the TAs influenced the student's learning experience. However, the variation in responses from students indicates that the one TA can have a different impact on each student in the section.

The qualitative data about TAs are presented in two categories: (A) attitudes and (B) values and beliefs. In this study, an attitude is the way a student thinks and feels about themselves, another person, thing, or idea [33]. A value is the importance a student attributes to themselves, another person, thing or idea [33]. A belief is part of a system that includes the student's values and attitudes plus their personal knowledge, experiences, opinions, morals, and other perceptions of the world [33].

The TAs were responsible for running each laboratory section, grading, and office hours. At least three TAs were assigned to GE 320 in each semester. The TAs divided the required tasks as summarized in Table I. The TAs teaching laboratory sections received support throughout the semester from the laboratory manager and research team. During the week before each experiment, the TAs, laboratory manager, and researcher met as a team to complete a dry run of each experiment and discussed logistics for each laboratory. The

TABLE I. TEACHING ASSISTANT RESPONSIBILITIES FOR EACH SEMESTER.

	Fall 2014	Spring 2015
Lecture Responsibilities	Floyd held office hours related to lecture and graded homework	Office hours were split between the TAs
Laboratory Responsibilities	Frank was responsible for three sections. Felix was responsible for three sections.	George was responsible for one section. Greg was responsible for one section. Garrett was responsible for two sections.

laboratory logistics included a discussion of the objectives of each laboratory, common mistakes made by students in the past, and development of a rubric for grading the pre-labs, reports, and post-labs. Only one TA worked with the students during each laboratory section. Each TA was responsible for grading the laboratory reports of the students in their own section(s). Due to this prominent role in the laboratory setting, the TAs had a direct impact on the students' experience in the laboratory.

A. Attitudes

The student's attitudes toward the laboratory and their TA varied. In both semesters, students expressed both positive and negative feelings. For some TAs, there were both positive and negative attitudes expressed by their students.

In both semesters, some students expressed gratitude for their TA in reflections. For example,

> "Thank you, [Frank], for being a very helpful TA for this lab course. You were patient and helpful when we asked you questions, and my lab partner and I appreciate it." (Chad, Experiment 6 Reflection)

> "...the TA for the lab was extremely helpful and patient with us and that allowed us to complete the lab with less frustration." (Avery, Experiment 1 Reflection)

Students in both semesters found their TA to be helpful. The perception that the TAs were helpful contributed to the overall climate of the laboratory. However, these feelings of gratitude were not consistent across all students. Each TA also received criticisms from students. For example,

> "Very difficult. Didn't help me learn. Condescending and unhelpful TA. Bad experience." (Curt, Survey)

Curt commented on his perception of the TA's attitude toward students, which contradicts the helpful TA comment earlier from Chad, who had the same TA as Curt. The varying opinions in the helpfulness of their TA could be explained by the fact that they were in different sections on separate days of the week.

> "Personally I would have appreciated if there was more than one TA available during the lab section just so when groups had questions we didn't [sic] have sometimes up to half an hour just to ask a yes or no question to the TA so we could continue." (Belle, Focus Group)

Belle brought up an observation that the 10:1 student to TA ratio could have been high at times. There were several points in the instructions for both types of equipment that said, "Show this to your TA before proceeding." In some labs, it was difficult for one TA to keep up with progress checks and assist students with problems.

B. Values and Beliefs

Based on the data, students value supportive TAs who are knowledgeable and available to help. Students also value information about the experiments and feedback on assignments that will help them be successful.

Many students commented about a desire for the TAs to be more prepared for the laboratory. For example,

> "TA needs to be more informed about lab objectives and equipment" (Ariane, Survey)

Based on observations in the fall, both TAs the fall semester could have been more prepared to answer technical and theoretical questions about controls. Ariane's comment could also explain multiple requests for more detailed introductory talks by the TAs at the start of each laboratory session. For example,

> "I felt that I was able to use the equipment but was not really confident that what I was doing was correct or why I was doing it. I think it would be better if in the beginning there would be a demo or at least a little blurb about the lab that we are doing for that day. This would help create a little bit more structure in the class." (Abbot, Experiment 1 Reflection)

Introductory talks can serve many purposes in laboratory sections. In just a few minutes at the beginning of each laboratory section, several concepts could be cleared up for students. Introductory talks can help convey the objectives for the experiment, as suggested by Abbot. Introductory talks can help clear up confusion from pre-lab questions. Introductory talks can also help tie the laboratory experiments to lecture. Unfortunately, introductory talks were not consistent despite comments in reflections in both semesters.

TAs also affected students directly when they provided feedback through grading. Students reported confusion and inconsistencies in the grading in both semesters. A representative comment from the focus group is as follows:

> "A lot of these just feel like mechanics, like grading was maybe frustrating it didn't [sic] really feel uniform or you don't [sic] really know what it would take to get the grade you wanted." (Audra, Focus Group)

An average of laboratory scores usually counted for about 20% of the overall grade for the course so it is understandable that students would be frustrated if they did not understand the expectations to earn an A, as pointed out by Audra.

Office hours were another recurring topic related to the TAs. The two laboratory TAs in the fall did not hold office hours, but the spring TAs did hold office hours. Students in both semesters commented on office hours. For example,

> "In addition, there was no place for reference to get help on the pre/post labs [sic], and going to lecture TA's office hours was not always helpful because he is not really involved with the lab." (Crystal, Experiment 6 Reflection)

> "The prelab was very difficult for me and I need extra office hours to fully understand the questions." (Belle, Experiment 3 Reflection)

Crystal and several other students in the fall sections commented that they thought it would be helpful to have office hours. Belle's comment from the spring semester illustrated how beneficial office hours can be for students. The pre-lab and post-lab exercises did not vary much between the types of equipment, based on the students' comments it was helpful to have time outside of scheduled laboratory sessions to ask questions.

C. *Limitations*

As the questions in this study emerged from a previous study, the collected data were focused on the student experience in the laboratory. None of the questions asked in the focus groups or on the end of semester surveys explicitly asked about the TAs. Moreover, much of the qualitative data came from the laboratory reflections, which were included in the laboratory reports graded by the TAs. Therefore, the students may not have felt comfortable expressing their feelings about the teaching assistants in that format.

Data about the TAs were only collected in field notes during the observations in the fall semester, and not the spring semester. Additionally, data were not collected from the TAs directly during the study, so their values, attitudes, and beliefs about the laboratory were not captured.

VI. Discussion

Since the data collected was from the student's perspective, the values, attitudes, and beliefs of the students were used to gain understanding of their motivation in the laboratory. A student's motivation shapes their experience in a course and laboratory. Ambrose et al. [9] synthesize key concepts of student motivation from several theories developed by Atkinson [34, 35], Wigfield & Eccles [36, 37], and Ford [38]. According to Ambrose et al. [9], motivation is comprised of value, expectancy, environment. Value and expectancy drive learning goals each student has for the course and laboratory. The value defines what a student will gain from achieving their learning goal. The expectancy drives the student's belief that they can achieve their learning goal. Environment refers to the overall classroom climate that can range from supportive to unsupportive. Based on the qualitative data, value, expectancy, and environment contributed to the student experience in the GE 320 laboratory.

A. *Value*

Students place their own value for a course and laboratory experience. Value is comprised of three components: attainment value, intrinsic value, and instrumental value [9]. The variation of value between students is evident throughout the qualitative data.

Students derive attainment value from the satisfaction of completing a task or goal [9]. Attainment value was evident in the reflections when students had positive feelings about successfully completing an experiment. Students indicated a possible decrease in value with negative comments about the amount of time spent in order to complete an experiment or pre-lab. In order to increase attainment value in the laboratory, students should be able to meet the goals of each experiment within the allotted time.

Students gain intrinsic value from the satisfaction of simply working on a task, but not the outcome of the task [9]. Students indicated intrinsic value with positive comments about learning. Students mentioned sticking through the course and laboratory because their major concentration was control systems, which is another example of intrinsic value. Not all students derive intrinsic value from a laboratory on their own. However, a TA can encourage intrinsic value by showing their own excitement and enthusiasm for the concepts and experiments.

Instrumental value extends from the extrinsic rewards of completing a task or goal [9]. Students derive instrumental value from good grades and other external rewards. In contrast, students loose instrumental value when they receive an unexpected low grade. Students also demonstrated instrumental value when they found connections between the laboratory and the course or their future careers. One way to increase instrumental value is for the TA to provide a real world example that relates to the experiment for the day or an example of how a still learned in the laboratory could be useful in a future career. Additionally, the TA and professor should emphasize the connections between the laboratory and lecture components of a course.

B. *Expectancy*

Both value and positive expectancy drive motivation. Positive expectancy builds from the belief that a desired outcome is possible. In addition to having value in a goal, each student also needs to believe he can achieve the goal [9]. Comments from students about "losing pointless points" or not knowing what it takes to earn an A on the laboratory reports are clear indications that they did not believe they could succeed. While not all students expressed frustration with unclear expectations, there is still room for improvement. One way to improve expectancy would be to make sure each TA states the expectations for all laboratory assignments during the first day and provides detailed feedback and timely feedback on all assignments. Perhaps allowing students to peer review each other's work or submit a revised report would also help reduce confusion about expectations.

C. *Environment*

A supportive environment also contributes to motivation. Students perceive the environment of a course in a range from supportive to unsupportive [9]. This range was evident in the qualitative data for GE 320. One student commented that one TA was condescending and unhelpful. Several students mentioned that the fall TAs were not available enough to answer questions. Both of these situations contributed to an unsupportive environment. However, not all students agreed on the level of support provided by each TA. One way to improve the environment is to assure the laboratory TAs hold office hours each week that there is a pre-lab or laboratory report due. Another improvement would be to have the TAs give short introductory talks at the beginning of each laboratory session and be prepared to answer questions that arise during the experiments.

VII. Conclusions and Future Work

TAs, like other instructional staff, have a direct impact on the students' experience in instructional laboratories. Based on the student responses, in this laboratory, the TAs had a direct impact on the students' values, attitudes, and beliefs about the laboratory for GE 320. Since TAs have such an influence over the laboratory experience, their training and preparation for each laboratory experiment is important. The course and TAs in this study had limited training and preparation. In addition, they only received feedback on their teaching if they collected it. More extensive training for TAs and requiring TAs to gather feedback about their teaching might improve the overall experience for both TAs and students in the laboratory.

In future studies, it would be helpful to gather data about the values, attitudes, and beliefs of the TAs as well. A longitudinal study of TAs in multiple semesters with integrated feedback and training would also provide insight into ways to improve laboratory experiences for students.

Acknowledgment

The author would like to thank Michael C. Loui, R. S. Sreenivas, and Dan Block for their support of this project. This work was supported by the Academy for Excellence in Engineering Education at the University of Illinois.

References

[1] L. D. Feisel and A. J. Rosa, "The Role of the Laboratory in Undergraduate Engineering Education," *Journal of Engineering Education,* vol. 94, no. 1, pp. 121--130, 2005.

[2] P. H. Borgstrom *et al.*, "Science and engineering active learning (SEAL) system: A novel approach to controls laboratories," presented at the 119th ASEE Annual Conference and Exposition, San Antonio, Texas, June 10, 2012, 2012. Available: https://peer.asee.org/21900

[3] W. E. Dixon, D. M. Dawson, and B. T. a. Costic, "A MATLAB-based control systems laboratory experience for undergraduate students: toward standardization and shared resources," *IEEE Transactions on Education,* vol. 45, no. 3, pp. 218--226, 2002.

[4] C. M. Ionescu, E. Fabregas, S. M. Cristescu, and S. a. Dormido, "A Remote Laboratory as an Innovative Educational Tool for Practicing Control Engineering Concepts," *IEEE Transactions on Education,* vol. 56, no. 4, pp. 436--442, 2013.

[5] F. Khan, N. Birchfield, and K. V. Singh, "REvitalizing the engineering curriculum through studio based instruction," vol. 5, pp. 131--138, 2012.

[6] R. M. Felder and R. Brent, "Designing and Teaching Courses to Satisfy the ABET Engineering Criteria," *Journal of Engineering Education,* vol. 92, no. 1, pp. 7--25, 2003.

[7] J. Marshall and W. Marshall, "A laboratory based, problem solving pedagogy prepares students to hit the job market running!," 2012.

[8] E. Tomas and A. A. Sara, "Factors that Affect Student Frustration Level in Introductory Laboratory Experiences," San Antonio, Texas, 2012/06/10, 2012. Available: https://peer.asee.org/21386

[9] S. A. Ambrose, M. W. Bridges, M. DiPietro, M. C. Lovett, and M. K. Norman, *How Learning Works: Seven Research-Based Principles for Smart Teaching* (no. l). 2010, p. 336.

[10] M. Shashi, H. Frances, N. John, and C. Lizette, "Benefits And Challenges Of Training Teaching Assistants," Chicago, Illinois, 2006/06/18, Available: https://peer.asee.org/798

[11] K. Faizal, "The Development of a Teaching Assistant Training Program in Applied Science: Design and Implementation," Vancouver, BC, 2011/06/26, Available: https://peer.asee.org/18915

[12] J. J. Heeg *et al.*, "Effective Educational Methods for Teaching Assistants in a First-Year Engineering MATLAB® Course," Indianapolis, Indiana, 2014/06/15, Available: https://peer.asee.org/20346

[13] K. Faizal, M. Saloome, and F. Deborah Esther, "Engineering Teaching Assistant Training: Increased Engagement Using Varied Delivery Methods," San Antonio, Texas, 2012/06/10, Available: https://peer.asee.org/21317

[14] Z. Jiabin, H. Jonathan, C. Monica, C. Osman, and G. Rocio Chavela, "Experiences Of Graduate Teaching Assistants In Engineering Laboratories: Content Analysis Using The "How People Learn" Framework," Louisville, Kentucky, 2010/06/20, Available: https://peer.asee.org/16167

[15] M. Farshid, R. Kelsey Joy, J. Hyunyi, M. Alena, and A. D.-D. Heidi, "Factors That Help and Hinder Teaching Assistants' Ability to Execute Their Responsibilities," Atlanta, Georgia, 2013/06/23, Available: https://peer.asee.org/19602

[16] J. C. Thomas, "Graduate Teaching Assistant Certification as a Requirement for First-Time TAs in the Cockrell School of Engineering at The University of Texas," New Orleans, Louisiana, 2016/06/26, Available: https://peer.asee.org/25422

[17] R. Kevin Andrew, V. Juan Diego, and B. P. Lindsey, "The Influence of a College Teaching Workshop Series on Teaching Assistant Perceptions of Preparedness and Self-efficacy," San Antonio, Texas, 2012/06/10, Available: https://peer.asee.org/22072

[18] B. Robert, S. Tony, R. Hossein, T. Fernando, and A. Amithraj, "Innovative Training Strategy (ITS) For Teaching Assistants," Louisville, Kentucky, 2010/06/20, Available: https://peer.asee.org/15813

[19] K. Ronald, G.-L. Clarisa, K. Michael, P. Jerome, B. Janet, and R. Ronald, "An Integrated Approach To Teaching Assistant Training And Orientation," Honolulu, Hawaii, 2007/06/24, Available: https://peer.asee.org/1678

[20] B. Mary Lynn and Z. Sarah, "Preparing Graduate Students To Teach: A Seminar On Teaching For Graduate Assistants In Engineering," Austin, Texas, 2009/06/14, Available: https://peer.asee.org/4897

[21] A. H. Kathleen, Z. Hannah Christine, W. Kevin Robert, K. Rachel Louis, and M. K. Krista, "Teaching Assistant Professional Development Through Design: Why They Participate and How They Benefit," Seattle, Washington, 2015/06/14, Available: https://peer.asee.org/24806

[22] W. P. William and C. Peck, "A Teaching Assistant Training Program With A Focus On Teaching Improvement And Graduate Student Development," Washington, District of Columbia, 1996/06/23, Available: https://peer.asee.org/6311

[23] A. V. Matthew and A. D.-D. Heidi, "A Teaching Assistant Training Protocol for Improving Feedback on Open-Ended Engineering Problems in Large Classes," Atlanta, Georgia, 2013/06/23, Available: https://peer.asee.org/19135

[24] C. Shannon, C. Colin, and S. W. Marjorie, "Teaching with Graduate Teaching Assistants: Tips for Promoting High Performance Instructional Teams," New Orleans, Louisiana, 2016/06/26, Available: https://peer.asee.org/26057

[25] G. Alexander, B. Inger, and W. Britton, "Using A Website And Wiki As A Support Tool For Teaching Assistants," Louisville, Kentucky, 2010/06/20, Available: https://peer.asee.org/16856

[26] B. Mary Lynn, "Using Peer Teaching Observations to Give Feedback to Graduate Teaching Instructors," San Antonio, Texas, 2012/06/10, Available: https://peer.asee.org/22193

[27] E. G. Martha and G. Ryan Christopher Reuer, "What's Stopping Them? Perspectives of Teaching Assistants on Incorporating Diverse Teaching Methods," Indianapolis, Indiana, 2014/06/15, Available: https://peer.asee.org/23305

[28] G. Edward, "Working Effectively With Teaching Assistants," Austin, Texas, 2009/06/14, Available: https://peer.asee.org/5515

[29] C. Dylan, B. Daniel, B. Maeghan Marie, M. Paula Ann, A. N. Kevin, and N. M. Audra, "Student and Teaching Assistant Perspectives on Characteristics of an Effective Teaching Assistant," Seattle, Washington, 2015/06/14, Available: https://peer.asee.org/24748

[30] E. W. Katherine and M. M. Holly, "Graduate Teaching Assistants' Decision Making and Perceptions of Autonomy," Vancouver, BC, 2011/06/26, Available: https://peer.asee.org/18038

[31] R. L. Kajfez and H. M. Matusovich, "Competence, Autonomy, and Relatedness as Motivators of Graduate Teaching Assistants," *Journal of Engineering Education,* vol. 106, no. 2, pp. 245-272, 2017.

[32] R. M. Reck, "BYOE: Affordable and portable laboratory kit for controls courses," presented at the 122nd ASEE Annual Conference and Exposition, Indianapolis, IN, June 17, 2015, 2015. Available: https://peer.asee.org/23653

[33] J. Saldana, *The Coding Manual for Qualitative Researchers*. SAGE Publications Ltd, 2013.

[34] J. W. Atkinson, "Motivational determinants of risk-taking behavior.," *Psychological Review,* vol. 64, no. 6, Pt.1, pp. 359--372, 1957.

[35] J. W. Atkinson, *An introduction to motivation,* . Van Nostrand, 1964.

[36] A. Wigfield and J. S. Eccles, "Expectancy-Value Theory of Achievement Motivation.," *Contemporary educational psychology,* vol. 25, no. 1, pp. 68--81, 2000.

[37] A. Wigfield and J. S. Eccles, "The development of achievement task values: A theoretical analysis," *Developmental Review,* vol. 12, no. 3, pp. 265--310, 1992.

[38] M. E. Ford, *Motivating humans : goals, emotions, and personal agency beliefs*. Sage Publications, 1992.