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Increasing Student Self-Efficacy through Undergraduate Research Experiences: A Qualitative Study

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Abstract

This research paper reports on a study that assessed the self-efficacy of undergraduate and graduate students relating to success in the field of engineering. The key selection criteria for participants in this study was engagement in research experiences at their academic institution. The study also investigated the self-efficacy development of graduate student mentors relating to mentoring undergraduates. Interview data was collected, transcribed, and coded. Results of the coding process are analyzed and shared.

The authors define self-efficacy as a psychological measure of the confidence an individual has toward their abilities in a specific activity. It is a generative ability that can be developed in an individual through experiences such as mastery experiences and vicarious experiences. Mastery experiences pertain to activities or tasks in which the individual is personally engaged that can help them develop expertise in a particular field, whereas vicarious experiences are experiences the individual has witnessed that can provide insight. These experiences can have either positive or negative effects on the self-efficacy of an individual. A high level of self-efficacy can then be a driving force within the individual to persevere through challenges, while a low level of self-efficacy may hinder them instead.

One form of engineering mastery experience that students can engage in is a research project. This type of experience is considered a mastery experience due to the very personal and hands-on nature of research. These experiences provide opportunities for students to engage in multiple stages of a project and to apply knowledge they have gained in a realistic setting and provide an authentic mechanism where they may observe the direct outcomes of their efforts. Research experiences also require students to search out new knowledge in order to solve and understand the problems they are given. This provides a hands-on approach to learning material, and therefore presents a very powerful mastery experience for students in which they can develop self-efficacy.

This paper presents a qualitative analysis of the experience of student researchers with regard to self-efficacy development. Specifically, we look at a construct of self-efficacy based around student research experiences and their impacts on confidence to work as an engineering professional. A phenomenological methodology guides the selection of participants and the interview process. The participants of this study are undergraduate and graduate engineering students at a Utah State University. To track self-efficacy development, the research team conducted semi-structured interviews with ten engineering students involved in authentic research projects. Interviews were transcribed and coded in order to augment a code map developed and presented by the authors in a previous publication [1]. This paper will discuss the themes and important ideas determined from the coding and analysis process. These themes will be interpreted to identify key self-efficacy constructs in experiential engineering education. Future research projects will look to develop these themes into a preliminary self-efficacy instrument to quantitatively assess self-efficacy development in the context of undergraduate research.

Introduction

Dr. Albert Bandura, who developed the concept of self-efficacy, said, “to succeed, people need a sense of self-efficacy, strung together with resilience to meet the inevitable obstacles and inequities of life [2].” Self-efficacy is one’s belief in one’s ability to succeed in a given area by reaching the desired outcome. This kind of belief can be manifest in an individual through how they perceive a given situation. Those with high self-efficacy will foresee themselves having positive outcomes while those with low self-efficacy will foresee failure.

Self-efficacy should not be confused with a person’s abilities, their overall confidence, or expected outcomes. Self-efficacy is similar to confidence in its effect on the individual to act but is more specific to a single field. As an example, a confident statement could be “I am confident in my writing ability,” whereas a self-efficacious statement could be “I am confident in my ability to write this conference paper.” Confidence refers only to one’s general abilities, while self-efficacy also takes into account a person’s specific attainments. Because of this specificity, those with high self-efficacy in one field may have very low self-efficacy in another.

According to Bandura, self-efficacy is a quality that influences an individual's personal motivations. He says, “efficacy involves a generative capability in which cognitive, social, and behavioral subskills must be organized into integrated courses of action to serve innumerable purposes [3].” He refers to self-efficacy as the driving force for human thought and action [4]. Those with low self-efficacy are less inclined to begin something new. People do not want to fail, and if they have no reason to believe they can succeed, then there is little reason to begin. Those with high self-efficacy have more courage and determination to begin new tasks and adventure, believing that they can prevail against the odds and succeed at their task.

Not only can high and low self-efficacy be manifested in an individual’s thoughts and perception, but also in their actions towards the field of interest. For example, if a group of students were asked to perform a series of complicated mathematics problems, some will have high self-efficacy because they feel confident they can complete the problems correctly. Other students with low self-efficacy are not confident in their ability to accomplish the task they are given. As the students work, some may encounter difficulties and may get the wrong answer. Those with a high self-efficacy are more likely to rework the problem and keep working even when it is hard or difficulties arise. Those with a low self-efficacy are more likely to give up and quit trying when they are struggling through similar hardships.

Self-efficacy should not be confused with the successful achievement of all student outcomes. Some students may still come to the wrong conclusions at the end of their work, but they will continue to work, thus demonstrating high self-efficacy. An outcome is inherent in action, but the outcome is not defined by a person’s self-efficacy. Action takes courage, and that courage is the manifestation of self-efficacy.

Self-efficacy is not only shaped by previous personal experiences and accomplishments, also called mastery experiences, but also by vicarious experience, social persuasion, and physiological states. Mastery experiences are activities in which the individual engages within

the field of interest. When such an experience has positive outcomes, the self-efficacy of the individual improves; however, when the experience is negative, the individual will often have a decrease in self-efficacy, although not necessarily a major decrease. If an individual has already attained some level of success, then the effect of setbacks is less detrimental to their self-efficacy. On the other hand, to those who are already hesitant to engage in an activity, failures will be much more detrimental to their self-efficacy. [3]

Social persuasion includes anything said or done by a person which directly or indirectly influence another. This social persuasion can often be used to help someone else accomplish, or even just begin a task. For example, a student with low self-efficacy in a field who receives continued encouragement from a mentor or advisor may be able to develop high self-efficacy regardless of setbacks. This type of influence over self-efficacy is one that can be used by teachers and/or mentors to positively or negatively affect the self-efficacy of students. Social persuasions also include public or societal biases such as the statement "girls are bad at math", and can negatively influence people and thus prevent them from engaging in those types of activities. Influences from friends and family also play a role in the social shaping of an individual's personal self-efficacy. Each of these things can have positive or negative impacts on an individual's self-efficacy and either encourage the individual to try and persevere, or discourage and hinder their self-efficacy.

Vicarious experiences are another source for the development of self-efficacy. Vicarious experiences occur when a person sees or visualizes another person attempting the same task. When an individual sees another complete a task successfully, especially someone they perceive as having a similar status to them, they gain confidence in their ability to accomplish that task. Mentors can use this to support students by demonstrating how to do the task. By stepping through a task with their students and showing an example, they help the individual gain a higher confidence in their own abilities to succeed. However, observing others failing at a similar task could also have negative effects on self-efficacy.

Another major impact on a person's self-efficacy towards a task is their physiological state. An individual who experiences negative emotions and physical traits, such as sweaty palms or faintness before an action, may often interpret them as an omen of failure. Coupled with subsequent failure, this can lead to a crushing blow to an individual's self-efficacy. On the other hand, those with a high general self-efficacy are less likely to negatively interpret their physiological responses to certain situations. They may recognize them as physiological manifestations of nervousness or discomfort in the required task, but still confidently engage in the activity to build the necessary experience required to master the task. These successes will then serve as mastery experiences to further enhance their self-efficacy in the specific area.

These four influences affect self-efficacy and can be applied to help students or individuals be more confident entering a field. It is important for students to have high self-efficacy towards their studies. High self-efficacy in a student's field will lead to them having more self-motivation to work hard and be confident in their field. Students' self-efficacy toward being an engineering professional outside of academic institutions may be separate from their studies, and this study focuses on that applied facet of self-efficacy in engineering.

Hutchison notes in her study of self-efficacy in first-year engineering students that many students have a strong reaction to self-efficacy beliefs [5]. She found that students with high self-efficacy are likely to continue strong in their studies, while those with low self-efficacy are likely to struggle and many students, especially women, may leave STEM fields because of low self-efficacy [5]. Those students who do not have the confidence that they can succeed when they encounter difficulties are less inclined to continue when difficult curriculum or teaching is presented to them without a strong support system. Although this may be one cause of attrition from STEM fields, it is possible to help students gain the self-efficacy they need to continue in their program and enter the workforce.

Self-efficacy is best developed through mastery experiences where the individual is able to work through a related challenge [3]. These challenges include anything where a person is challenged to think and act outside of what they may normally do. When students are mentored and supported through the difficult areas of a subject and towards a positive result, they are likely to develop strong self-efficacy in the subject. With improved self-efficacy, the student is more likely to push themselves towards more successful outcomes in the field and eventually begins to develop lifelong learning skills in learning on their own. By providing students with mastery experiences, they are more likely to succeed.

At many universities there are opportunities for students to engage in research projects with members of the faculty. These opportunities provide those students with personal experiences that may become positive mastery experiences. This is also an opportunity to receive encouragement from a mentor and/or advisor, which may build self-efficacy through social persuasion. Mentoring which is well received by an individual has potential monumental impact on the individual's self-efficacy.

Mentored undergraduate research is defined by Seymour as, "undergraduate student engagement in authentic research conducted under the direct supervision of faculty researchers [6]." Mentoring has the potential to shape and influence the self-efficacy of a student. Many students who have engaged in undergraduate or graduate research have commented on the importance of their relationship with their mentor, and its impact on their research [7]. These students have given voice to the importance of mentorship in the development of their self-efficacy, which provides evidence of the power of social persuasion in the shaping of self-efficacy.

Mentoring has an impact not only the mentee, but also on the mentor. Graduate student mentors are presented the opportunity to teach and guide other students which may be a new or uncomfortable position for many. These mentors often have a mentor or advisor of their own that pushes them and encourages them to engage in this activity. Thus, they too receive social influence on their self-efficacy towards mentorship and teaching, while they also engage in an authentic mastery experience of teaching in which they are able to shape their own self-efficacy. Due to this, mentorship is an important aspect of the development of self-efficacy in research students, and one which has not been significantly investigated in the literature of engineering education.

Methodology

Self-efficacy is a psychological construct that can be assessed through people's responses to questions about an activity. This assessment can be performed in one of two ways, depending on the desired research methodology. The first way utilizes a quantitative instrument, while the second involves qualitatively questioning participants. The development of an instrument for the former is typically dependent on experience with the latter. The broader study aims to use an exploratory mixed method design, and this paper reports on the qualitative findings. It is anticipated that these qualitative results will be used in order to develop a self-efficacy instrument for undergraduate engineering students regarding future professional employment. Since self-efficacy is specific to a certain task, and since there is no instrument currently developed to look at this construct of self-efficacy, foundational qualitative work, such as this, needs to be conducted to build a solid foundation for the instrument's development. While some research has been done in STEM fields pertaining to self-efficacy and engineering [5,8,9], we seek to situate an instrument focused on undergraduate research's impacts on self-efficacy as a professional.

In order to do this, the authors have investigated the phenomenon of students engaging in research experiences at a western undergraduate research university. We rely on a phenomenological research methodology to develop our qualitative understanding of undergraduate research and its impact on self-efficacy. Phenomenology consists of studying an event or phenomenon to understand its impact on those engaged in the phenomenon. The phenomenon investigated in this study was the experience of participating in engineering research as either an undergraduate student researcher or graduate student mentor. Both graduate and undergraduate students were interviewed during this study to understand the effect of the phenomenon of research on the participants. These interviews were conducted in a semi-structured manner such that the interviewer was free to ask the participant to expand on points that might hint to their feeling of efficacy toward engineering practice. The interview questions focused on the student's feelings toward engineering research and how they personally felt their abilities were influenced by their experience.

During the initial phase of this study, four interviews were conducted and coded [1]. Coding was conducted using a phenomenological approach, as mentioned above. As coding was done, researchers looked for experiences and feelings that were common across multiple participants. These themes were then organized into a code map, shown in Figure 1. With the initial code map complete, six more interviews were conducted. The semi-structured interview process was continued and refined to ask more direct questions concerning the trends seen during the first rounds of interviews. Some of the questions that were most frequently asked to the participants are found in Appendix 1.

During the course of the ten interviews conducted, multiple graduate student mentors and undergraduates were interviewed. The breakdown of the population can be seen in Table 1. Between these two groups consisting of four graduate students and six undergraduate students, there was a sufficient sample for a phenomenological study according to Creswell, Duke, and Riemen [10, 11, 12].

Table 1. Demographics of the participants in this survey

Demographic	Number of participants
Male	7
Female	3
Civil Engineering Students	6
Mechanical Engineering students	4
Undergraduate Students	6
Graduate Students	4
New to Research	4
Experienced researchers	6

Methods

This paper focuses on the development of efficacy in students engaged in graduate and undergraduate engineering research as well as in mentoring experiences. The self-efficacy of an individual can be examined by reviewing their words and thoughts delivered in an interview process on a subject. During the course of the interviews conducted with participants, the participants shared many of their thoughts on research and on self-efficacy, both generally speaking and toward their own experience.

The authors of this paper began this research with four interviews, in order to gain a precursory grasp of self-efficacy development in students. The interviews were transcribed and then coded for common themes that highlight or describe the self-efficacy of the participants. These themes were then mapped into the code map shown in Figure 1. The coding showed that there were definitely connections between students' confidence and their involvement in research. All of the initial participants noted an increase in confidence toward engineering themes. More detailed findings from these initial interviews were provided in a previous paper [1].

Each of these common threads became one of the codes that is included in an updated code map below. The codes found during the previous interviews were combined with findings from the additional interviews to provide the results found in this paper. New findings may be added to form a new code map as research into this fact of self-efficacy continues, which can be used to guide future interviews and research and be used in the development of an instrument.

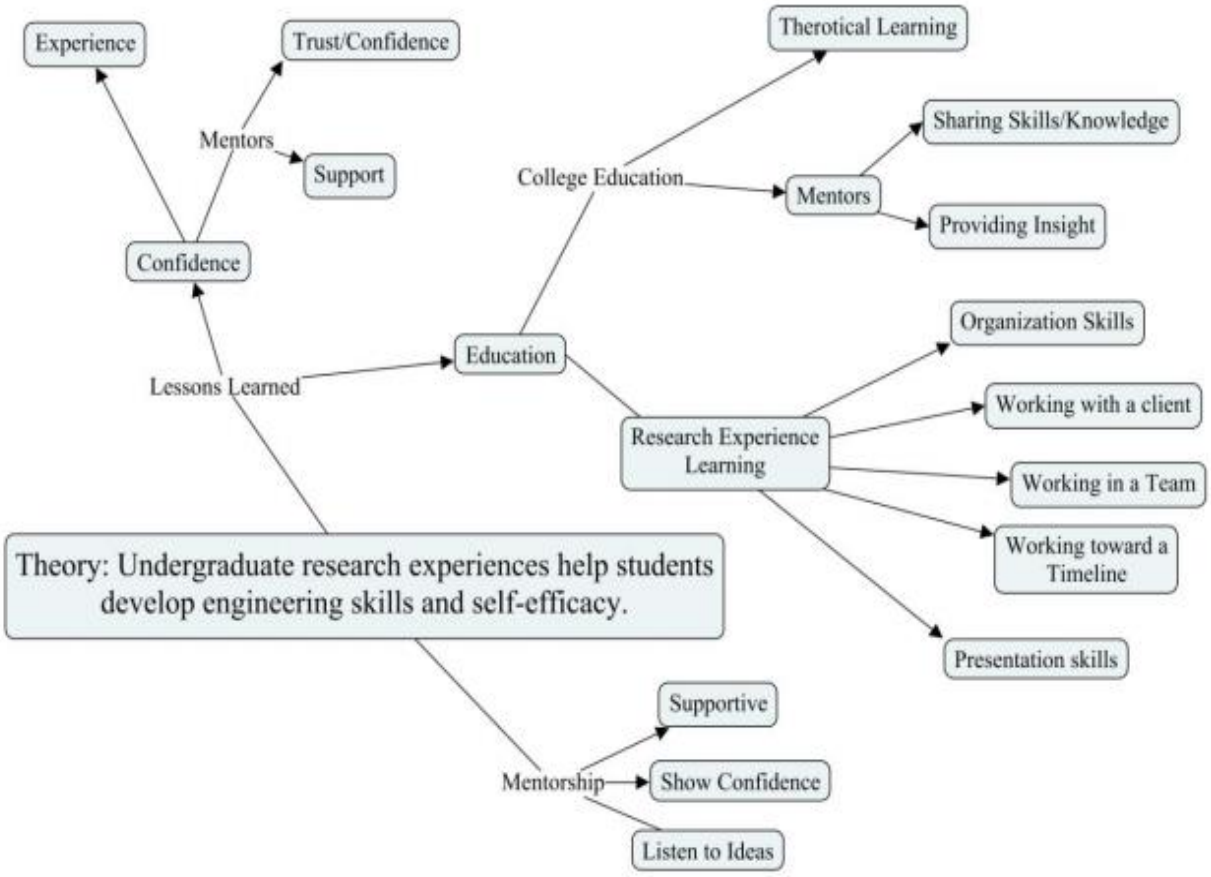

Figure 1: Initial code map developed by the authors. [1]

Results

Having participants who were experienced with research, as well as those who were new to the process, allowed the research team to identify differences in the confidence of experienced researchers and new researchers. When asked how confident they felt in their abilities to accomplish what they had set out to do, many new researchers seemed to have not developed this confidence. While these individuals were excited to be doing research, they were generally not confident that they could figure out what they were attempting to learn. These new researchers were also asked how they felt their classroom education had prepared them for this type of work. One male student responded saying, “I’d say that for the most part, I mean, I understand what’s going on and how to find the things we need. So, I wouldn’t say it’s been exemplary, but I would say it’s been sufficient.” One of the female participants responded by saying, “As far as material, no, this is all new to us. But as far as working in a team, … we’ve been working together for a long time.” They had learned some teamwork skills, but had never written a proposal or a technical document. It was also interesting to note the difference in the confidence between the male and female participants. The female students were less confident when asked whether or not they could succeed. One female student said, “I think we can’t do it on our own, but I think we can probably do it with our mentor’s help.”

This is an instance of when mentoring came up in the interviews. All of the new research participants mentioned how their mentor helped them write a grant -proposal and helped them get everything started. There were many aspects to their research that they were unsure of and nervous about, yet they still were doing their best. The students worked often with their advisor in order to gain direction and know what to do. They mentioned that it was their advisor that approached them originally to work on this project. It was their advisor who helped them write a proposal that was accepted, and get equipment set up. It was another advisor who would help them run tests and analyze their data. While they did not feel supremely confident in their abilities, they felt like they could move on with the support of their advisor.

These students exhibited some self-efficacy, otherwise they would not be engaging in such a difficult task. As they mentioned, they had the support of mentors and they felt more confident in their own abilities and in the abilities of their mentors. This confidence is an example of the effect of social persuasion on an individual's self-efficacy. This idea of social persuasion is visible in the interviews with these students who had only just begun research, but it is also seen in those who have been doing research for a while.

By conducting this research, the primary author of this paper has personally been engaging in undergraduate research. He has found that it is the support and encouragement of his mentors that provide him the often-needed push to keep going and keep working. Often when researchers get to a roadblock it is important that they have a mentor that can push them toward the end goal. This idea of mentoring was one of the major themes that was identified in all of the interviews conducted.

Many of the other participants in this study spoke highly of their advisors. The effect that mentors have on individuals is powerful and driving. One participant noted that she felt like she could not do what she had been asked to do, but her mentor believed in her and coached her through to success. She said, "…I had a meeting with my advisor and they told me how to do it." In this instance the coaching she received was very direct. In other instances, this mentoring may be less specific. In some instances, the mentoring that a student receives plays a larger role than just the direction of a project.

Each of the students in this study were engaging in research of their own, their own mastery experience. Along with the source of social persuasion, mentoring, many students noted that they felt empowered through their research. Students were asked how they felt about themselves as an engineer after participating in research. One participant, who also works as an engineering intern, noted that working in this research environment was more similar to their experience as an engineer than any of their classes.

Another student noted that after his participation in research he felt more confident in his classes. He was more willing to participate and felt better able to learn the material. While some of the participants in this study where new to research, some had been doing research for a period before this study. All of the participants that had been engaged in research for a while noted how research had given them hands-on learning experience that made them feel more prepared to work in the field. Some of the participants who were close to graduation noted that they felt more confident in their engineering abilities because of the research they had been involved in.

Another source of self-efficacy that affects an individual is vicarious experiences. Some of the participants in this study acted in mentorship roles with other students. These students made many positive comments about the effect the experience had on others, but also on how mentoring affected them.

Mentors are participating in a mastery experience for mentoring but they are also vicariously participating in the research that others are doing. This provides a very powerful self-efficacy developing experience. One graduate student participant who was a mentor noted that they changed the course of his studies in order to include more opportunities to mentor. Another felt they were better prepared to work in a team when going into the field as an engineer because they had been able to not only be mentored but be a mentor, and see many sides of engineering projects. This theme of mentoring, along with other prevalent themes from the interviews, were combined to update the original code map that the authors had made. This updated map can be seen in Figure 2. The biggest themes from participants were learning, mentoring, confidence, and mentors. Each of these themes highlight the development of self-efficacy in the participants.

The map starts with the authors theory statement. The authors then categorized the main lessons learned by the participants into three categories: mentoring, education, and confidence. Mentoring pertained primarily to the graduate students that had opportunity to mentor other students. The education category contained some of the things that the participants mentioned that they had learned during the course of their research experience up until the interview. There were to main divisions that happened in education. The first was the lessons learned during their coursework that prepared them for this research. The other was things that they learned during their research that they did not learn during the course of their education. The last major theme that was identified in the interviews was the student's confidence. The students all mentioned how their self-efficacy and confidence in their own abilities was shaped by the experience that they were engaging in. Most of them also noted the significance of their mentors on their development of confidence.

Some participants were asked if they thought research experiences would be good for everyone. Some responded that there is difficulty in such a goal due to time constraints, but most agreed that all students would benefit from research opportunities. Some inclusion of research work for students would help them to understand better what they are learning and tie things together. Most importantly it would provide them with powerful mastery experiences through which they could gain higher self-efficacy.

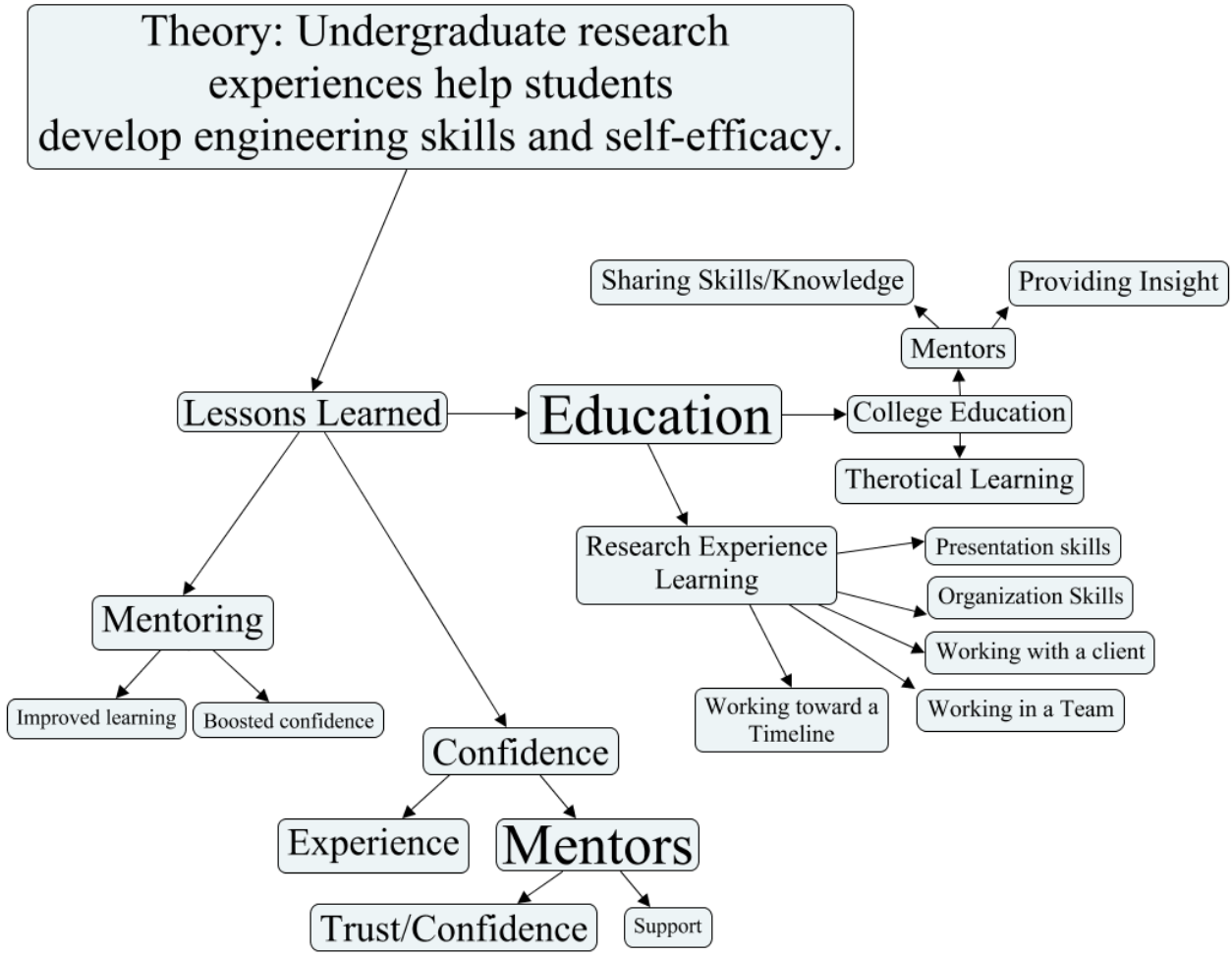

Figure 2: Code Map developed by the authors.

Future Efforts

With a better understanding of self-efficacy and its effects on students the authors seek to continue to map student self-efficacy on a broader scale. In order to do this, they plan to construct an instrument to quantify the self-efficacy of undergraduate engineering students toward their future employment in engineering. This research will then be used to improve mentoring and undergraduate research opportunities to aid more students in the development of self-efficacy. Findings from this and previous work will enable us to find relevant and pertinent constructs to target with a self-efficacy instrument for engineering professional practice. Since according to Bandura, “there is no all-purpose measure of self-efficacy [13],” it is important that the instrument be tailored specifically to one area of self-efficacy, so that accurate results can be attained. A directed self-efficacy instrument can then be utilized with large participant numbers to learn more about this key area in undergraduate research.

Conclusions

Through the course of these interviews the authors found many themes that pertained to the growth of self-efficacy in students. Students that engage in research opportunities have the chance to see, do, and experience things that most students never do. This, combined with the supporting effort of advisors and mentors, provides powerful sources for the development of self-efficacy.

Self-efficacy plays an important role in the development and success of students. Self-efficacy is a motivating factor in the life of every individual. With low self-efficacy in the task at hand, individuals are less likely to engage in the task. Individuals with high self-efficacy in an area are more likely to engage in that area, and when things go wrong are less likely to give up.

Growth in self-efficacy is something that was noticed in our participants. Those who had been involved in research for longer were more confident that they could not only complete their degrees, but be successful engineers after graduation. They had confidence in their abilities to complete the tasks they were given and confident that they could successfully complete their research. Those who had not been involved for a long period of time in research were less confident and sure of themselves.

As evidenced by the participants in this study, mastery experiences combined with good mentoring, social persuasion, create a powerful tool to build confidence and self-efficacy. High self-efficacy in students will lead to more students being engaged in classes, less students dropping out, and better success in schools. This higher self-efficacy can be developed in students through research experiences, or similar programs implemented into curriculum. As self-efficacy with regard to preparation for engineering professional employment is better understood, it will become possible to use our knowledge of it to help shape and encourage students.

Having a better understanding of self-efficacy in students will allow teachers and mentors to help those who struggle. Students who have high self-efficacy will continue to progress normally, but those with low self-efficacy can receive targeted intervention (via social persuasion, vicarious experiences, and/or master experiences) in order to improve their self-efficacy. It is possible such enhancement will lead to more efficacious students and lower dropout rates. Such work could also be beneficial in recruiting and retaining minorities in STEM fields.

Self-efficacy research is important in the continuation of education. Bandura states that efficacy plays a major role in our education systems in that students need to be confident in their ability to manage their time and learning [14]. By studying self-efficacy and its development in students, it is possible to do more than just teach, but it becomes possible to motivate and educate.

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Appendix 1

Table 2. Most common questions asked to participants. Additional questions can be found in the authors' prior paper [1].

Question Number	Question
1	How do you feel that this research experience has impacted your confidence to work as a professional engineer after graduation?
4	Was there anything that contributed to your confidence that was learned during this project?
5	Was there anything that altered or confirmed your idea of what an engineer does resultant to your work on this project?
6	Do you feel this project was a worthwhile experience to help you on a career trajectory as an engineer?
7	What is your view of undergraduate research in the undergraduate engineering education process?
12	What were the most valuable things that you learned from the principal investigator?
15	What were the most valuable things that you learned from the graduate student [mentor]?